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Dissertation

Navigating Collaborative Pathways to a Just Energy Transition:

Implications for Governing Coal Transitions in Germany and India

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Abstract

The phase-out of coal plays a crucial role in addressing climate change and a shift to 100% renewable energy. To manage this phase-out equitably, the concept of a just transition has attracted attention from both researchers and practitioners. It is a multifaceted concept that implies that justice and equity are an integral part of energy transitions and highlights the need for a broadened understanding beyond a techno-economic focus. The dissertation engages in the just transition debate on the navigation of just transitions in coal phase-outs by enriching the debate on the following thematic foci: (i) public participation in governing a just transition, (ii) understanding perspectives of coal communities in the Global South, and (iii) integrating social aspects in energy models. The dissertation is based on qualitative research and data collection methods. It is rooted in the Sustainability Transition Research (STR), while also drawing from the field of political science and energy models.

The role of participation in just transition governance is analysed in Chapters 1 and 2. The first chapter analyses the political instrument of expert commissions in overcoming stalemate situations in phase-out processes by evaluating the Coal Commission in Germany. While the setup did not leverage the full potential of collaborative governance, the Commission contributed to overcoming the contested stalemate situation by facilitating a space for trust-building and mutual understanding. The second chapter analyses the power relations within the participatory approach to the distribution of transition funding in the Lusatian mining region in eastern Germany. The analysis reveals that while most actors consider the participation of public actors important for the transition, its implementation is reduced to mere consultation, missing the opportunity for capacity building and knowledge sharing. Together, the chapters emphasise the role of participatory approaches and provide recommendations to strengthen the design of such processes in transitions. To understand the perspectives of communities in coal mining regions, Chapter 3 looks at the intensifying just transition discourse in India by analysing regional just transition imaginaries in the heavily coal-dependent state of Jharkhand. This highlights the tensions between, on the one hand, sustaining structures through technological innovation and green growth and, on the other hand, focusing on the inclusion of marginalised voices in local contexts and facilitating transformative change. The final chapter analyses the potential for integrating social aspects into traditionally focused techno-economic modelling. The analysis highlights that the integration of social aspects into energy models remains infrequent, although existing methods demonstrate how socio-political factors can be incorporated. Based on this, the chapter proposes recommendations for enhancing interdisciplinary work.

The main insights of the dissertation for the navigation of just transitions are: (1) It is crucial to address structural injustices and vulnerabilities to guide a just transition, as these can otherwise become entrenched in transition planning. (2) Despite the recognised importance of participation, its actual implementation often falls short of embodying a meaningful engagement, highlighting the significance of addressing power imbalances, fostering leadership, and creating spaces for trust-building and mutual understanding. (3) The development of collaborative and shared visions stands out as a mechanism to guide just transitions as they can illuminate diverse interpretations of what constitutes a just transition and explain the existing tensions among the aspirations of various actors. Finally, (4) the recognition of transitions as a socio-political endeavour underscores the significant potential of integrating just transition elements into energy modelling and, thus, revealing pathways to steer transitions in just ways.

Keywords: energy transition, coal transition, structural change, just transition, Germany, India, expert commissions, public participation, imaginaries, social energy modelling, sustainability transitions research

Zusammenfassung

Der Ausstieg aus der Kohle spielt eine entscheidende Rolle bei der Bekämpfung des Klimawandels und dem Übergang zu 100% erneuerbaren Energien. Um diesen Ausstieg gerecht zu gestalten, hat das Konzept *just transition* Aufmerksamkeit sowohl in der Forschung als auch in der praktischen Anwendung erlangt. Es handelt sich um ein facettenreiches Konzept, das impliziert, dass Gerechtigkeit ein integraler Bestandteil der Energiewende ist und die Notwendigkeit eines erweiterten Verständnisses über einen techno-ökonomischen Fokus hinaus betont. Die Dissertation beschäftigt sich mit der Debatte um eine *just transition*, indem sie die Diskussion um die folgenden thematischen Schwerpunkte bereichert: (i) Partizipation an der Gestaltung einer *just transition*, (ii) Verständnis der Perspektiven von Gemeinden in Kohleabbaugebieten im Globalen Süden und (iii) Integration sozialer Aspekte in Energiemodelle. Die Dissertation basiert auf qualitativen Forschungs- und Datenerhebungsmethoden. Sie ist in der Sustainability Transition Research (STR) angesiedelt und stützt sich zudem auf die Bereiche der Politikwissenschaft und der Energiemodellen.

Die Rolle von Partizipation bei der Gestaltung einer *just transition* wird in den Kapiteln 1 und 2 analysiert. Das erste Kapitel untersucht das politische Instrument der Expertenkommissionen zur Überwindung von Pattsituationen in Ausstiegsprozessen, indem es die Kohlekommission in Deutschland analysiert. Obwohl die Kommission nicht das volle Potenzial von kooperativen Governance Ansätzen ausschöpfte, trug sie doch zur Überwindung der umstrittenen Pattsituation bei, indem sie einen Raum für Vertrauensbildung und gegenseitiges Verständnis ermöglichte. Das zweite Kapitel analysiert die Machtverhältnisse innerhalb des partizipativen Ansatzes zur Verteilung der Strukturwandelgelder in der Kohleabbauregion Lausitz im Osten Deutschlands. Die Analyse zeigt, dass die Beteiligung öffentlicher Akteure zwar als wichtig angesehen wird, die Umsetzung jedoch auf bloße Konsultationen reduziert wird, wodurch die Möglichkeit des Kapazitätsaufbaus und des Wissensaustauschs verpasst wird. Die Kapitel heben die Rolle partizipativer Ansätze hervor und geben Empfehlungen zur Verbesserung der Gestaltung dieser Prozesse. Um die Perspektiven von Gemeinden in Kohleabbauregionen zu verstehen, befasst sich Kapitel 3 mit dem sich intensivierenden Diskurs über eine *just transition* in Indien und untersucht regionale Visionen einer *just transition* im stark kohleabhängigen Bundesstaat Jharkhand. Dies verdeutlicht die Spannungen zwischen der Erhaltung von Strukturen durch technologische Innovationen und grünem Wachstum einerseits und der Konzentration auf die Einbeziehung marginalisierter Stimmen in lokalen Kontexten und die Ermöglichung eines transformativen Wandels andererseits. Das letzte Kapitel analysiert das Potenzial der Integration sozialer Aspekte in die traditionell fokussierte techno-ökonomische Modellierung. Die Analyse zeigt, dass die Integration sozialer Aspekte in Energiemodelle nach wie vor selten ist, obwohl bestehende Methoden aufzeigen, wie soziopolitische Faktoren einbezogen werden können. Aufbauend darauf nennt das Kapitel Empfehlungen zur Förderung der interdisziplinären Arbeit.

Die wichtigsten Erkenntnisse der Dissertation für die Gestaltung von *just transitions* sind: (1) Es ist von entscheidender Bedeutung, sich mit strukturellen Ungerechtigkeiten und Vulnerabilitäten auseinanderzusetzen, um eine *just transition* zu steuern, da sich diese sonst in der Planung verfestigen können. (2) Trotz der erkannten Bedeutung von Partizipation bleibt die tatsächliche Umsetzung oft hinter einem bedeutsamen Engagement zurück, was die Bedeutung der Behebung von

Machtungleichgewichten, der Förderung von Führungsqualitäten und der Schaffung von Räumen für Vertrauensbildung und gegenseitiges Verständnis unterstreicht. (3) Die Entwicklung kollaborativer und gemeinsamer Visionen bietet einen Ansatz zur Ausgestaltung von *just transitions*, wodurch unterschiedliche Interpretationen beleuchtet und bestehende Spannungen zwischen den Bestrebungen verschiedener Akteure erklärt werden können. (4) Die Berücksichtigung der Energiewende als gesellschaftliches Vorhaben unterstreicht das bedeutende Potenzial der Integration von *just transition* Elementen in die Energiemodellierung, um gerechte Wege für die Energiewende aufzuzeigen.

Schlüsselwörter: Energiewende, Kohleausstieg, Strukturwandel, Just Transition, Deutschland, Indien, Expertenkommission, Partizipation, Visionen, Soziale Energiemodellierung, Nachhaltigkeitsforschung

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Directories

Overview

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List of Abbreviations

ABM ..... Agent-based models

AfD ..... Alternative für Deutschland

BCCL ..... Bharat Coking Coal

CCL ..... Central Coalfields

CG ..... Collaborative governance

CGE ..... Computable general equilibrium models

CGR ..... Collaborative Governance Regime

CIL ..... Coal India Limited

COP ..... United Nations Climate Change Conferences, Conference of Parties

CSR ..... Corporate Social Responsibility

DMF ..... District Mineral Fund

ECL ..... Eastern Coalfield Limited

EEG ..... Erneuerbare-Energien-Gesetz

EnWG ..... Energiewirtschaftsgesetz

ESM ..... Energy System Model

EU ..... European Union

FG ..... Focus Group

FoC ..... Friends of Chair

GDR ..... German Democratic Republic

GHG ..... Greenhouse gas emissions

IAM ..... Integrated Assessment models

ICGF ..... Integrative framework for collaborative governance

IMAG ..... Inter-Ministerial Working Group

JTM ..... Just Transition Mechanism

MLP ..... Multi-Level-Perspective

POINT ..... POwer-IN-Transition

RBA ..... Regionaler Begleitausschuss

RE ..... Renewable energy

RLS ..... Reiner Lemoine Stiftung

SAS ..... Sächsische Agentur für Strukturentwicklung

SC ..... Scheduled Castes

ST ..... Scheduled Tribes

STR ..... Sustainability Transition Research

UNFCCC ..... United Nations Framework Convention on Climate Change

WRL ..... Wirtschaftsregion Lausitz

Chapter 1

Introduction:

Navigating a just and timely energy transition in Germany and India

1 Introduction

1.1 Motivation and research questions

1.1.1 The need for a just and timely energy transition

There is a global consensus on the urgency to combat climate change and reduce greenhouse gas emissions (GHG), demanding a transition to 100% renewable energy (RE) to mitigate the impacts of climate change (Kemfert, Breyer, and Oei 2019; IPCC 2022). Despite the growth in RE deployment, fossil fuel consumption and production are not declining to the same extent (IEA 2021a). Coal accounts for 41% of overall fossil fuel CO_2 emissions in 2022 (Friedlingstein et al. 2022, 4826). Accordingly, to meet the 1.5° target set out in the 2015 Paris Agreement at the United Nations Climate Change Conferences (Conference of Parties (COP)) in the framework of the United Nations Framework Convention on Climate Change (UNFCCC), a steep decrease in coal production is required, which is fuelling discussions on how to phase-out coal in a timely manner (Diluiso et al. 2021; Yanguas Parra et al. 2019; IPCC 2022). Traditionally perceived as a techno-economic project, the energy transition is increasingly recognised to encompass socio-economic and cultural factors, advocating for a socio-political framework that extends beyond mere technological shifts (Alarcón et al. 2023). In this context, the concept of a just transition has gained prominence, highlighted by its inclusion in the 2015 Paris Agreement and subsequent focus in COPs, alongside regional, national, and subnational initiatives and programs like the Just Transition Mechanism (JTM) by the European Union (EU) (Majekolagbe 2023; Schuster et al. 2023; Stevis and Felli 2020). Navigating and managing coal phase-out processes in the sense of a just and timely transition can be considered one of the paramount challenges of the 21st century.

Just transition is a dynamic and multifaceted concept without a uniform definition that implies that justice and equity are an integral part of the energy transition (Wang and Lo 2021; Just Transition Research Collaborative 2018). There are varied interpretations regarding the inclusion of actors, scope, scale, and governance mechanisms (Majekolagbe 2023; Healy and Barry 2017; Wilgosh, Sorman, and Barcena 2022; Stevis and Felli 2020). Initially rooted in fossil fuel labour movements, the concept of just transition has expanded to include a vision of transformative change. This broader perspective emphasises providing support for vulnerable groups, reducing inequalities, and addressing the extensive socio-economic and cultural impacts caused by both reliance on fossil fuels and the transition away from them. This includes considering the effects on local communities and addressing issues related to race, class, gender, age, and health while challenging existing power structures and enabling community participation in the transition (Wilgosh, Sorman, and Barcena 2022; Stevis and Felli 2020; Walk 2024). As discussions on just transition increase across various political, scientific, and industry realms, debates intensify on the nature of justice, extending beyond fossil fuel worker and industry rights to prioritise diverse and often marginalised concerns (Wang and Lo 2021; Wilgosh, Sorman, and Barcena 2022).

Considering the depth of the transition in the energy system and society, the energy transition offers an opportunity for restructuring processes, allowing for the reinvention of societal and energy system structures (Sovacool et al. 2020). However, the prevailing centralised power structure within the fossil

fuel industry and energy sector, dominated by state and corporate entities, underlines existing asymmetrical power relations and often overshadows issues of dependency and vulnerability (B. Ghosh et al. 2021; Sovacool et al. 2020; Jasanoff and Kim 2015). The potential of a just transition to achieve radical change remains uncertain, with risks of co-optation by dominant actors who may prioritise specific strategies, social groups, and industries (Wang and Lo 2021; Alarcón et al. 2023). The discourse on just transition is evolving, highlighting the need to broaden its scope beyond technological solutions and to contextualise it within specific local settings, considering unique and complex dependencies, governance structures, and cultural factors (Wang and Lo 2021; Heffron and McCauley 2018; Roberts et al. 2018). This requires imagining new ways to build a 100% RE future and recognising the structural injustices, or in other words, finding ways to collaboratively navigate pathways for a just transition.

Germany and India are chosen as empirical case studies for this dissertation. These countries represent distinct scenarios in their transition pathways and socio-historical contexts but are also united in their significant contributions to combat climate change and play a crucial role in international climate negotiations (Dubash et al. 2018; Goodman 2016; Minx et al. 2024; Kemfert, Oei, and von Hirschhausen 2018). The countries are in different transition stages: Germany, having established a coal phase-out date in 2020, is on a declining trajectory in terms of coal mining and consumption. Conversely, India, while setting ambitious renewable energy goals, has not yet pinpointed a coal phase-out timeline, maintaining coal as a significant component of its energy portfolio (Diluiso et al. 2021; Minx et al. 2024). The analysis of the coal transition in these countries offers insights into coal transitions in different stages and perspectives of the Global North and Global South, which provide insights into various transition processes in different countries.

This dissertation aims to engage in the just transition debate by shedding light on central aspects and challenges in navigating just transitions to enrich the understanding of just transitions in coal phase-outs. Particularly, the dissertation draws on the following debates and thematic foci of the just transition literature: the role of participation, understanding the perspectives of coal communities, and the integration of social aspects in energy models.

First, public participation is seen as a central point in governing just transitions, offering benefits such as enhanced transparency, legitimacy, increased knowledge sharing, capacity building, and potential reduction of inequalities (Walter and Hammerschmid 2017; Musch and von Streit 2020; Arnstein 1969; Brisbois and de Loë 2016a; Newig et al. 2018; Purdy 2012; Stober et al. 2021). However, participation does not automatically guarantee “just” outcomes as it can reinforce existing inequalities and power relations, thereby marginalising actors (Wilgosh, Sorman, and Barcena 2022; Coy et al. 2021). Current literature underscores the need for meaningful engagement, cautioning against the reduction to a buzzword and co-optation by decision-makers to a mere symbolic involvement (Wilgosh, Sorman, and Barcena 2022; Majekolagbe 2023). Therefore, despite its potential benefits, challenges remain in designing participatory processes and their role in achieving just transitions as it can enhance or limit the pace of transitions, and whose voices are included (Avelino 2021; Brisbois and de Loë 2016a; Wang and Lo 2021). This dissertation, particularly in Chapters 2 and 3, analyses participatory processes in the context of Germany's coal transition. Chapter 2 assesses the "Commission on Growth, Structural

Change and Employment" (hereafter referred to as the Coal Commission) as a political tool in transition governance. The Coal Commission was acknowledged as a significant milestone in consensus-building on the coal phase-out and the Chapter examines its role in overcoming the stalemate situation and integrating the perspectives of diverse actors. Chapter 3 delves into the participatory mechanisms on a regional level in the distribution of transition funds in the coal region Lusatia as determined by the Coal Commission, with a specific focus on power dynamics in the processes.

Second, the literature highlights the need to understand communities' perspectives, their daily challenges, and real-life experiences to inform policy discussion about the nature of just transitions in a particular context (B. Ghosh et al. 2021; Furnaro and Yanguas Parra 2022; Vargas Guevara et al. 2022). There is a particular prominence on analysing cases from the Global South, where diverse inequalities and injustices, such as informality and land possession rights, are prevalent and that are often absent in the just transition literature focused on the Global North (Alarcón et al. 2023; B. Ghosh et al. 2021; S. Pai, Harrison, and Zerriffi 2020). In this regard, the exploration of imaginaries and visions of just transitions facilitates a deeper understanding of local cultural contexts to uncover alternative and marginalised perspectives (Jasanoff and Kim 2015; B. Ghosh et al. 2021; Sovacool et al. 2020). Against this background, Chapter 4 explores regional just transition imaginaries in the coal mining region of Jharkhand in India, including the temporal and spatial dimension of just transition and emphasising the aspect of land dispossession and self-determination rights of communities. Thereby, the chapter offers nuanced insights into the just transition discourse in the Global South.

Third, given that socio-political factors serve as both drivers and barriers, influencing energy transitions in many ways, there is an emerging demand for better reflecting these aspects in energy modelling (Trutnevyte et al. 2019; Turnheim et al. 2015; Holtz et al. 2015). Energy models inform policy-makers, facilitate discussions with various actors, and shape policy formulations, underscoring their role in projecting the future trajectories of energy systems (Süsser et al. 2021; Midttun and Baumgartner 1986; Silvast et al. 2020; Hofbauer, McDowall, and Pye 2022; Royston and Foulds 2021). Nevertheless, energy models predominantly rely on techno-economic assumptions, often omitting the socio-political dimensions crucial to energy transitions. Chapter 5 addresses this by providing an overview of how social factors are currently incorporated into energy models and, based on the analysis, proposes recommendations for enhancing interdisciplinary work. This integration is vital for navigating just transition pathways, facilitating interdisciplinary dialogue and learning, and improving the overall understanding of socio-technical dynamics in energy transitions.

This dissertation contributes to the understanding of just transitions beyond a techno-economic focus, influenced by my academic career, which began as an industrial engineer trained in techno-economic aspects of the energy transition. During my master's studies and student working activities, I got the chance to broaden my perspective to include the socio-political implications of energy transitions. This resulted in a master's thesis using an energy system model (ESM) and including calculations on employment numbers in South Africa, Colombia, and India (published as Hanto et al. (2021) and Löffler and Krumm (2022)). This stimulated my interest and motivation to address socio-political aspects and injustices happening in the course of the energy transition and the potential to build a just transition in my dissertation. I was able to pursue this motivation through my work in the FossilExit research group and by receiving a scholarship from the Reiner Lemoine Stiftung (RLS). Being part of the FossilExit

research group and RLS PhD-group provided me with the tools, inspirational influence, and peer group to work on the topics that I address in this dissertation in an inter- and transdisciplinary way. It also enabled me to explore aspects outside of the scope of this dissertation which contributed to, influenced or supplemented the dissertation in different ways. This involvement enabled research through interdisciplinary collaborations that complemented the dissertation. Notably, the work with Pelz et al. (2024) on the socio-economic impacts of the coal industry in Jharkhand prepared the analysis in Chapter 4. Additionally, the analysis of Arnz and Krumm (2023) applies participatory modelling and social science theories in transport modelling, which complements Chapter 5. Furthermore, a field research stay in India enriched Chapter 4, offering direct engagement with actors and deepening my insights into the transition challenges in the Global South. Additionally, a research stay at the University of Pittsburgh broadened my expertise in quantitative social science methods and United States just transition policies. Furthermore, beyond the scope of this dissertation, I collaborated with the RLS PhD-group to analyse the implications of the German energy transition (Reiner Lemoine Stiftung 2020), supplemented by a study on public acceptance with Agora Energiewende (Zuber and Krumm 2020). The book chapter on the development of RE in Germany with Weibezahn et al. further complements this (Weibezahn et al. 2022).

In sum, the dissertation enriches the growing literature on just transitions through three contributions: (1) The dissertation adds to the literature on the role of participation and power relations in just phase-out processes through in-depth case studies exploring critical yet often neglected power relations. (2) The dissertation enhances the discourse on just transitions in the Global South by examining the lived experience of coal communities in the coal mining region of Jharkhand in India, specifically focusing on land dispossession and the influences of spatial and temporal factors. (3) The dissertation contributes to the growing literature on social energy modelling by providing an overview of the status quo and, importantly, by proposing a framework to illustrate the potential entry points for integrating social aspects in energy models.

The remainder of this introduction provides further details on the research objects, questions and methodological and theoretical background of this dissertation. It is structured as follows: Section 1.1.2 provides an overview of the energy transition in Germany and India and Section 1.1.3 outlines the research objectives and questions. Section 1.2 gives an overview of the literature on just transition and identifies the research gaps addressed in the dissertation. Furthermore, it delivers a brief overview of the situation in Germany and India. Section 1.3 states the concepts, theories, and methods used in this dissertation and Section 1.4 outlines the chapters. This is followed by the limitations and research outlook in Section 1.5. The introduction concludes with implications for a just transition in Section 1.6.

1.1.2 Coal and energy transition in Germany and India

The dissertation investigates the just transition process in Germany by analysing the role of participation in just transition governance and just transition imaginaries in India. Figure 1 provides an overview of the energy transition in Germany and India including key facts of the coal regions Lusatia and Jharkhand that are investigated in the dissertation. Subsequent sections will delve into these contexts to inform the analysis in Chapters 2 to 4.

Coal phase-out process in Germany and the coal region of Lusatia

The political process of the energy transition in Germany, commonly referred to as the *Energiewende*, is widely considered a success, especially in terms of the increased deployment of RE (Hirschhausen et al. 2018; Weibezahn et al. 2022). In this context, the enactment of the 'Renewable Energy Act' (*Erneuerbare-Energien-Gesetz* (EEG)[1]) alongside amendments to the 'Enery Industry Act' (*Energiewirtschaftsgesetz* (EnWG)[2]) in the early 2000s enabled a significant change in the regulatory framework towards an increase in RE (Reiner Lemoine Stiftung 2019; Weibezahn et al. 2022; Hirschhausen et al. 2018). The share of RE in electricity generation climbed from 6% in 2000 to 45% in 2022 (BMWK 2023). Initially centred on the electricity sector, the decarbonisation efforts have since broadened to encompass the overall energy system, including the heating, transport, and industry sectors (Weibezahn et al. 2022; Kemfert, Oei, and von Hirschhausen 2018; Reiner Lemoine Stiftung 2019). The German *Energiewende* has not only achieved significant domestic milestones but has also garnered international acclaim, demonstrating Germany's commitment to energy transition and its potential to drive economic, technical, and political change (Kemfert, Oei, and von Hirschhausen 2018). That said, the integration of RE into the energy system must proceed alongside a strategic phase-out of fossil fuels, particularly coal, to meet the climate targets.

Coal has a long tradition in Germany, and after the Second World War coal was instrumental in the nation's economic, social, and political reconstruction: In 1985, it accounted for 53% of the electricity mix in Western Germany (and 82% in the German Democratic Republic (GDR)) (Statistik der Kohlenwirtschaft e.V. 1999; Oei, Brauers, and Herpich 2019). After a continuous decline in Western Germany of over 60 years, the last hard coal mines were closed in 2018 due to EU-led subsidy reductions and economic shifts favouring cheaper import alternatives (Oei, Brauers, and Herpich 2019). However, lignite coal remains a significant energy source for electricity accounting for 17% in 2023 (Statistisches Bundesamt 2023), underlining its historical economic and social importance, particularly in mining regions (Stognief et al. 2019; Gürtler and Herberg 2021). The decision to phase out coal by 2038 in Germany was informed by an expert commission established in 2018, culminating in the 'Coal Phase-Out Law' (*Kohleausstiegsgesetz*[3]) in 2020. Previous political attempts had failed due to resistance from incumbent actors, including energy-intensive utilities, mining-related unions, and regional governing parties (Furnaro 2022; Hermwille and Kiyar 2022). The Coal Commission, comprising 28 voting members and three non-voting parliamentarians from various sectors, was tasked with outlining a coal phase-out pathway, regional support measures, and worker transition plans (Agora Energiewende and Aurora Energy Research 2019; BMWi 2019). Before the Commission's formation, discussions were marked by intense conflict and divergent interests, leading to a hurting stalemate, with the awareness that the continuation of the status quo was very unlikely. This was accompanied by the

[1] Bundesregierung. 2023. Gesetz für den Ausbau erneuerbarer Energien (Erneuerbare-Energien-Gesetz - EEG 2023). https://www.gesetze-im-internet.de/eeg_2014/EEG_2023.pdf.

[2] Bundesregierung. 2024. Gesetz über die Elektrizitäts- und Gasversorgung (Energiewirtschaftsgesetz - EnWG). https://www.gesetze-im-internet.de/enwg_2005/EnWG.pdf.

[3] Bundesregierung. 2020. Gesetz zur Reduzierung und zur Beendigung der Kohleverstromung und zur Änderung weiterer Gesetze (Kohleausstiegsgesetz). https://www.gesetze-im-internet.de/kohleausg/Kohleausstiegsgesetz.pdf.

economic difficulties faced by old and inefficient power plants, a rising share of renewable energy, and growing societal calls for a coal phase-out (Furnaro 2022; Leipprand and Flachsland 2018; Hermwille and Kiyar 2022). The Commission's consensus on a phase-out deadline and its recommendations for addressing the economic and social impacts of this transition resulted in €40 billion allocated for the next 20 years to support Germany's coal regions. The Coal Commission paved the way for the current discussions on phasing out coal already by 2030 as proposed by the new government coalition elected in September 2021.

The Lusatia region (Lausitzer Revier) in Eastern Germany, situated near the Polish border within the federal states of Brandenburg and Saxony, has been allocated €17.2 billion of the transition funds. With a history of lignite mining spanning over a century, lignite coal served as a crucial energy source during the GDR period (Hermann, Greiner, & Matthes, 2017). The phase-out of coal represents a significant structural change, making it another major transformation since the post-reunification period in 1990, which led to large-scale deindustrialisation and social dislocations (Gürtler, Luh, and Staemmler 2020). The lignite industry was particularly impacted and Lusatia experienced high unemployment rates and outmigration, with over 20% unemployment in the early 2000s and an out-migration of 18% of the population between 1995 to 2015 (Walk and Stognief 2021). Despite the industry's decline, its economic and cultural significance persists. The post-reunification years have made a lasting impact on the region, setting less favourable conditions for adaptation compared to the Rhenish lignite region in Western Germany. Lusatia is confronted with unique challenges, such as the region’s remote location within Germany and rural settlement structure, demographic trends, and untapped economic potential and emigration of young, well-educated people (Stognief et al. 2019). Therefore, the distribution of the transition funds in Lusatia can be viewed as an effort to avoid repeating past mistakes and to provide the coal regions with opportunities for lasting socioeconomic development (Gürtler, Luh, and Staemmler 2020). The transition funds are partly administered by the federal level (around 11 billion) and partly by the affected federal states (around 6 billion). The law declared the aim to involve the people of Lusatia and let them actively participate in shaping their region**.**

The role of coal in India and the coal region of Jharkhand

In contrast to Germany, projections for India indicate an increase in coal production and consumption in the coming years (IEA 2023b). Despite being the world's third-largest CO_2 emitter, with coal consumption peaked in 2021, India's per capita emissions remain low but rising (IEA 2021a; 2023a). As the second-largest coal importer, coal is a significant component of India's energy consumption, supporting approximately 15 million jobs directly and indirectly (Spencer, Pachouri, et al. 2018). The coal sector is integral to India's energy sector and regional development (Mohan and Topp 2018; Montrone, Ohlendorf, and Chandra 2021). Simultaneously, India has set ambitious RE targets, with a notable increase in RE capacity after 2015, following the declared aim of 175 GW by 2022 and an increase to 500 GW by 2030 to supply 50% of energy needs as announced at the COP21 (The Economic Times India 2021). Prime Minister Modi's announcement of achieving net-zero emissions by 2070 underscores India's commitment to climate goals (Ministry of External Affairs 2022). Key challenges in the energy transition in India are meeting rising energy demand while ensuring energy security and

reducing energy poverty (Gupta et al. 2019; Spencer, Colombier, et al. 2018; Vishwanathan et al. 2018). Moreover, a just transition is indispensable, given the socio-economic dependency on coal in regions marked by vulnerabilities, conflicts, and socio-economic disruptions (S. Pai and Zerriffi 2021).

Jharkhand, alongside Chhattisgarh, Odisha, West Bengal, Madhya Pradesh, Telangana, Andhra Pradesh, and Maharashtra**,** is one of the top coal mining states in India, accounting for 26% of India´s coal reserves, as well as significant forest and mineral resources (NITI Aayog 2023). With 114 operational mines spread across twelve of its 24 districts (Singhal, Gupta, and Faraz 2022), coal is a vital source of livelihood for millions and a significant contributor to state royalties (Spencer, Pachouri, et al. 2018; Dsouza and Singhal 2021). The necessity for a just transition in Jharkhand is underlined by its status as the second most multidimensionally poor state in India, facing challenges in health, education, and living standards (Bhushan, Banerjee, and Agarwal 2020). The state was formed in 2000, following a series of tribal movements and political struggles, among others centred on identity and land rights (Jewitt 2008; Ranjan and Prasad 2012). The state has undergone severe changes, transitioning from forests to mines and from agricultural to mining-based livelihoods (Lahiri-Dutt 2016). Legislative frameworks like the Mines and Minerals (Development and Regulation) Act 1957[4] and the subsequent Coal Mines (Nationalisation) Act 1973[5], which granted the government authority to seize land for coal mining, have intensified issues of land dispossession and displacement among marginalised communities. This is further intensified by protracted and opaque compensation and job placement processes arising from land acquisitions (Lahiri-Dutt 2016; Oskarsson, Lahiri-Dutt, and Wennström 2019), highlighting the complex interplay between coal mining policies and just transition in Jharkhand.

[4] Government of India, Ministry of Mines. 2012. Mines and Minerals (Development and Regulation) Act, 1957. https://ibm.gov.in/writereaddata/files/07102014115602MMDR%20Act%201957_10052012.pdf.

[5] Government of India, Ministry of Mines. 1973. The Coal Mines (Nationalisation) Act, 1973. https://lddashboard.legislative.gov.in/sites/default/files/A1973-26.pdf.

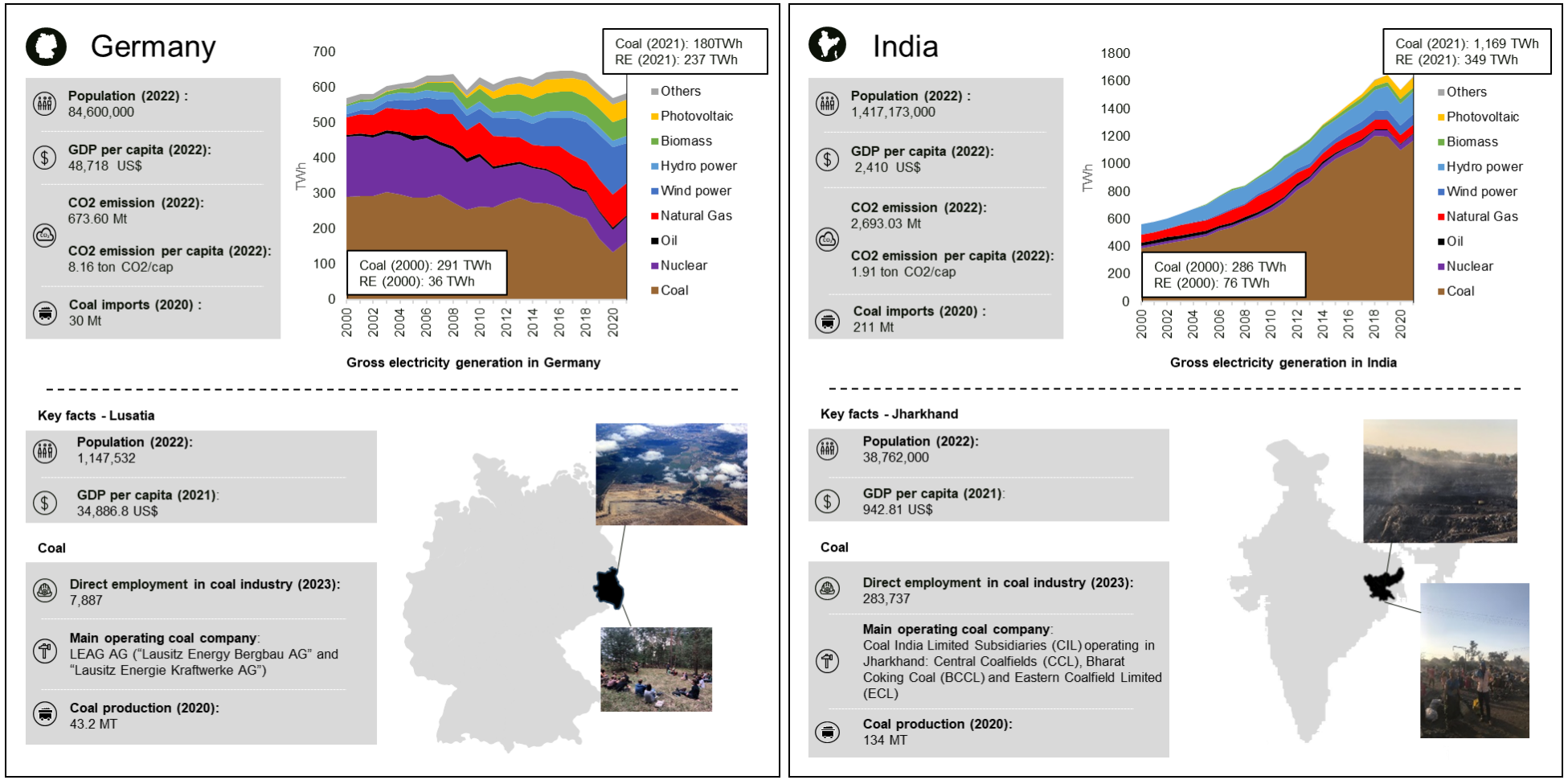

Figure 1: Overview of energy and coal transition in Germany and India.

Sources: Bhushan, Banerjee, and Agarwal (2020); BMWK (2023); CEIC (2024); IEA (IEA 2024a; 2024c; 2024d; 2024b); MoSPI (2023); NITI Aayog (2023); S. Pai and Zerriffi (2021); Singhal, Gupta, and Faraz (2022); Spencer et al. (2018); Statistik der Kohlenwirtschaft e.V. (2024a; 2024b); Statistische Ämter des Bundes und der Länder (2022); The World Bank (2024); own pictures (2023), Nyča (2017; CC-BY-SA-3.0).

1.1.3 Research aim and questions

The research aim of this dissertation is to give insights on how to collaboratively navigate a just transition, particularly focusing on the transitions in Germany and India. This dissertation attends a dual perspective: it is context-specific, with detailed case studies from Germany and India, while simultaneously contributing to the discourse on just transition by offering recommendations and insights also applicable to other contexts, thus serving as a valuable resource for understanding and implementing just transitions in diverse contexts. Additionally, at a methodological and theoretical level, the dissertation augments the just transition literature by further conceptualising what just transition signifies for different actors in different contexts, developing a framework for incorporating interdisciplinary approaches to energy modelling, and employing transdisciplinary methodologies for data gathering, aimed at collecting insights from various actors involved in the transition process. The dissertation is structured around three foci: the role of participation, understanding the perspectives of coal communities, and the integration of social aspects in energy models (see Figure 2).

The first focus, discussed in Chapters 2 and 3, explores the role of public participation in the governance of just transitions, exemplified through case analysis in Germany. The dissertation first studies the national level in Germany in Chapter 2 by analysing the role of the Coal Commission as a political tool in governing the coal phase-out and overcoming the stalemate situation by analysing two research questions: *(1) How did the "Commission on Growth, Structural Change and Employment" achieve to breach the previous stalemate? (2) How were the final recommendations for a coal phase-out in Germany formed?*

Next, Chapter 3 dives into the regional governance process of a just transition in Lusatia. It analyses the power relations in the participatory approaches of the distribution of the transition funds provided based on the Coal Commission's recommendations and the role in the transition process. Specifically, the chapter investigates the following two research questions *(1) What power dynamics can be observed in the participation processes and what factors enable or hinder the capacity of local actors to affect outcomes? (2) Are there deficits in the participation processes that hinder the support of just transition processes?*

The second focus is on the understanding of the perspectives of coal communities. Considering the increased attention on the energy transition in India, Chapter 4 moves to India and looks at the just transition discourse by analysing regional and emerging just transition imaginaries in the heavily coal-dependent state of Jharkhand. Besides dominant visions on just transition, this chapter covers on-the-ground perspectives of coal communities and their lived experiences by analysing the following research questions: *(1) What are just transition imaginaries in Jharkhand? (2) What tensions exist between them?*

The third focus is on embedding just transition elements in energy models by improving the integration of the social dimension in energy modelling. Chapter 5 analyses the potential for integrating social aspects into traditionally focused techno-economic modelling by addressing the following research questions: *(1) Which model types are particularly good at integrating social aspects? (2) What social aspects are represented in energy models? (3) How are these social aspects integrated?*

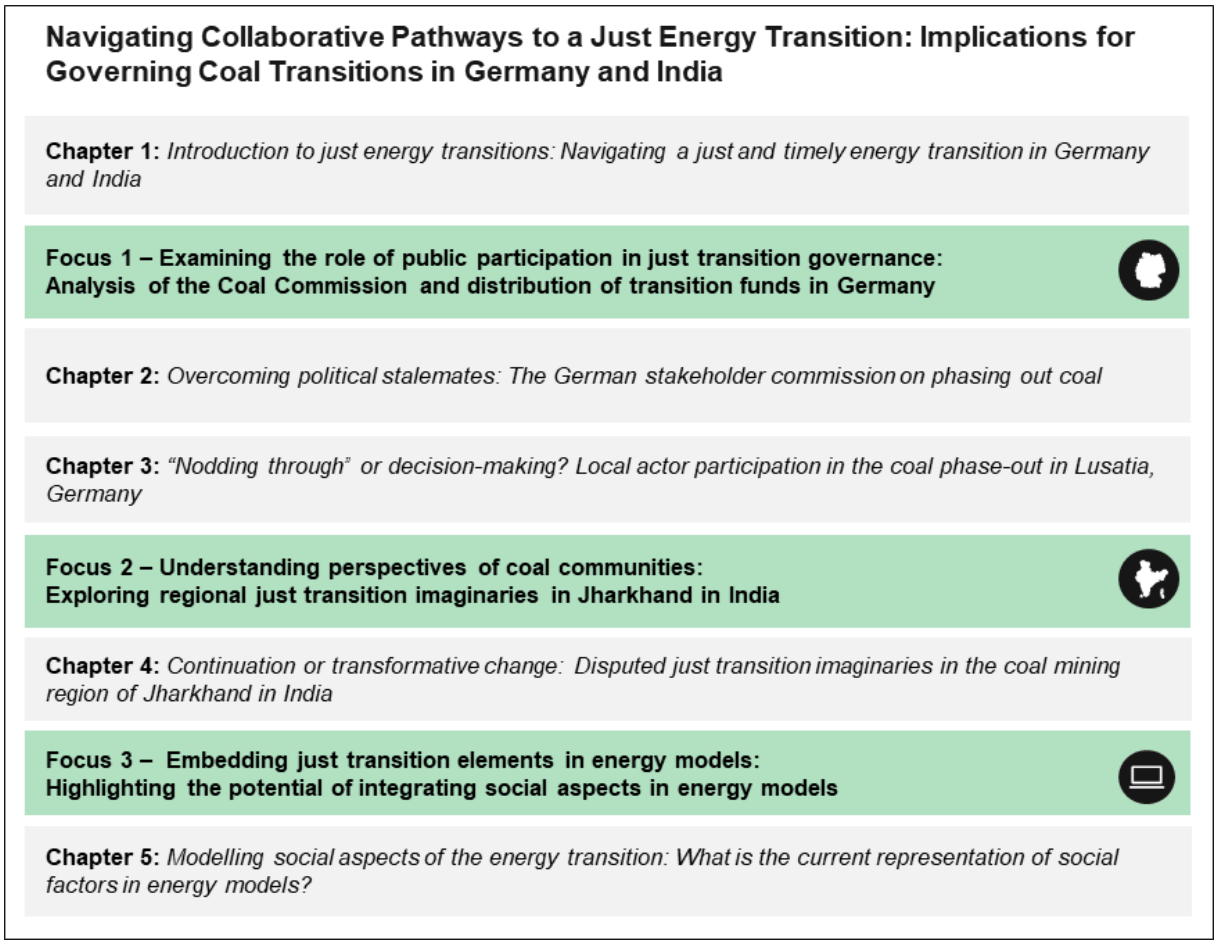

Figure 2: Overview of chapters.

Source: Own depiction.

1.2 Navigation of a just and timely energy transition

This section presents the literature on just transition facets that this dissertation focuses on. While this aims to provide context for the chapters, its structure goes beyond merely aligning with each chapter. Instead, it offers background information on the general context and foci within which the dissertation is situated. Each subsection concludes by outlining the situation in Germany and India, highlighting the specific research gaps, and linking these to the corresponding chapters where they are addressed.

1.2.1 The evolution of the just transition concept

Just transition is a concept that was developed in the 1980s and initially rooted in labour movements. Since then, the concept has developed and been adopted by a variety of actors with different perspectives and purposes. The evolution of the concept can be conceptualised into three phases: the period from the 1980s to 2001 classifies the emergence of the concept, 2011 to 2013 can be described as the labour and globalisation phase, and from 2013 the concept diffused beyond unions (Stevis, Morena, and Krause 2020). This highlights the contested and dynamic nature of the concept in the present day, as it is shaped by actors with diverse aims and backgrounds. The expansion from its

original focus on cushioning the effects on fossil fuel workers against the adverse effects of decarbonisation has grown to encompass a wide array of justice elements including distributional, restorative, procedural, and recognition justice. This broadening reflects a shift towards both theoretical and political concepts that encompasses a range of issues from justice and equity to participation and power dynamics, underscoring the complexity of moving towards just energy systems (Hess, McKane, and Belletto 2021; Wang and Lo 2021; Wilgosh, Sorman, and Barcena 2022; Velicu and Barca 2020).

The ongoing discourse illustrates that achieving a just transition is not solely about navigating economic challenges but also about confronting entrenched social inequalities and power structures. The evolution of the concept has sparked criticism of just transitions, which primarily emphasise fossil fuel workers, potentially neglecting community revitalisation and socio-cultural aspects, such as social cohesion and identity (Majekolagbe 2023; Velicu and Barca 2020; Wilgosh, Sorman, and Barcena 2022; Ciplet and Harrison 2020). Velicu and Barca (2020) argue that while transitions towards green jobs have gained traction, the processes and meanings of justice in transitions remain largely theoretical. Majekolagbe (2023) highlights that the initial framing of a transition significantly influences its outcomes. This suggests that with a narrow starting point, e.g. focusing on green jobs, it is likely that the transition focus will be on that aspect and other aspects overlook other crucial aspects in just transition policies. In this context, scholars are delving into the integration and linkage of the just transition concept with other theoretical groundworks. This includes aligning just transition with intersectionality and decolonising theories, as well as integrating concepts of well-being and capabilities (Majekolagbe 2023; Walk 2024). Additionally, there is an ongoing investigation of the application of just transition across various contexts, such as socio-technical transitions and environmental justice, broadening the scope and depth of the just transition discourse (Wang and Lo 2021).

The just transition concept's evolution and its contested nature are mirrored in the diverse terminologies and justice concepts embedded in its discourse, influenced by factors like political reforms, and the scale, scope, and thematic areas of implementation (Stevis and Felli 2020; Wilgosh, Sorman, and Barcena 2022; Just Transition Research Collaborative 2018; Wang and Lo 2021). Wilgosh et al. (2022) define two approaches: a limited (affirmative) approach focusing on market-based solutions, green growth, and traditional (fossil fuel) employment structures, and an expansive (transformative) approach advocating for inclusivity and systemic reform. These approaches differ significantly in their perspectives on identity, inclusivity, and power dynamics, with the expansive approach emphasising the inclusion of marginalised groups, participatory governance, and a restructuring of power and ownership relations, challenging entrenched socioeconomic paradigms and addressing policies that impact disadvantaged communities (Wilgosh, Sorman, and Barcena 2022). Expansive approaches thereby address often neglected policies that target poor, rural, peasant, and indigenous communities, while the relevance and opportunities of fossil fuel workers are equally addressed (Majekolagbe 2023; Alarcón et al. 2023). While concerns exist that just transition initiatives may perpetuate existing inequalities and power structures or create new injustices (Wilgosh, Sorman, and Barcena 2022; Sovacool et al. 2019), scholars position the aim of just transition to redefine power dynamics and address various injustices (Stevis and Felli 2020; Sovacool et al. 2019; Abram et al. 2022; Wilgosh, Sorman, and Barcena 2022; Majekolagbe 2023; Velicu and Barca 2020). Additionally, Wilgosh, Sorman, and Barcena (2022) contend that the transformative, emancipatory potential of just transitions is constrained when the process is dominated

by powerful actors who maintain the status quo. This highlights the need to delve into factors that shape what justice means, including spatial, temporal, and socio-cultural factors (Majekolagbe 2023).

The just transition concept is rooted in the environmental, climate, and energy justice literature, and employs justice pillars to address the *why, what, who, and how*, articulated as distributive, procedural, recognition, and restorative justice[6] (Majekolagbe 2023; Newell and Mulvaney 2013; Heffron and McCauley 2018; Hess, McKane, and Belletto 2021). In short, distributive justice focuses on the fair distribution of burdens and benefits of energy-related decisions. Procedural justice emphasises the inclusion of affected actors in decision-making processes, among others by providing capacities to ensure meaningful participation. Recognition justice acknowledges the diversity and complexity of transitions across various social groups and locations. Furthermore, considering the impacts of coal mining on the environment and social structure, restorative justice aims at redressing past harms to both people and the environment, also beyond financial losses like culture, identity, and sense of place (S. Pai, Harrison, and Zerriffi 2020; Heffron and McCauley 2018; Abram et al. 2022; Schuster et al. 2023). These justice pillars strive to confront structural inequalities and oppression, underscoring the nexus between social justice and energy policy (Abram et al. 2022). It is to say that there is rarely a one-size-fits-all, universal solution. Rather, the emphasis on justice pillars allows for the contextual tailoring of approaches in just transitions (Schuster et al. 2023; Abram et al. 2022; Majekolagbe 2023). In Section 1.2.2, I outline justice discussions about governance and participation in just transition processes.

Another element in shaping just transitions is the spatial and temporal dimensions and their implications (Heffron and McCauley 2018). Space is often used in different contexts to describe the socio-economic dependency and identity struggles in coal regions and communities. The extractive industry significantly impacts the spatial dynamics of a region, influencing its social and cultural fabric, not just economically (Bridge et al. 2013; Oskarsson, Lahiri-Dutt, and Wennström 2019). Mining physically alters landscapes, embodying historical developments and is linked to socio-spatial inequalities. These spatial aspects are crucial in shaping the energy transitions, highlighting marginalised perspectives and promoting a more nuanced understanding of how socio-technical projects influence socio-spatial relations, and practices, emphasising the importance of space in environmental and energy discourse (Feola et al. 2023; Chateau, Devine-Wright, and Wills 2021; Garvey et al. 2022). The temporality aspect of just transitions impacts how transitions are perceived and experienced. It involves examining the timing, pace, and patterns of transitions, and reflecting on how these factors influence expectations, decisions, and power dynamics in mining communities (Malakar, Herington, and Sharma 2019; Jenkins, McCauley, and Forman 2017). By focusing on temporality, researchers can better understand the nuanced interactions between past, present, and future in the context of environmental and economic changes, highlighting the significance of transition timing on societal and individual outcomes (D'Angelo and Pijpers 2018; Luning 2018). Additionally, the expansion of coal mining frequently involves land acquisition and dispossession, which significantly impact livelihoods, generational wealth, and land rights for vulnerable

[6] These are the main pillars of justice referred to in the literature, but there are also references to cosmopolitan and intergenerational justice, as well as calls for the inclusion of non-Western theories (Heffron and McCauley 2018; Schuster et al. 2023; Suboticki et al. 2023).

groups that are linked to the spatial and temporal dimensions (Oskarsson, Lahiri-Dutt, and Wennström 2019; Luning 2018).

Recently, the scientific discourse has increasingly acknowledged the need for nuanced analysis within the Global South, recognising the unique context-dependent factors relevant to just transitions. While the last decade has seen a rise in studies focused on these regions, there persists a dominant Western-centric approach in theories, frameworks, and research practices—an *epistemological power* that may not fully align with the Global South's distinct historical and socio-economic landscapes (Alarcón et al. 2023; B. Ghosh et al. 2021; S. Pai, Harrison, and Zerriffi 2020). As a result, frameworks designed for contexts in the Global North may fail to accommodate the diverse forms of inequality issues prevalent in the Global South (Alarcón et al. 2023). Notably, the informal sector, integral to the livelihoods of coal communities, includes marginalised groups like indigenous communities that are frequently overlooked in policy-making (Mirzania et al. 2023; Lahiri-Dutt 2007). Highlighting the evolution of just transitions in Africa, Otlhogile and Shirley (2023) emphasise the significance of local and regional initiatives and programs for just transitions. Scholars and practitioners advocate for moving towards decolonising research and practices to address structural injustices as well as past, present, and future injustices (Alarcón et al. 2023; B. Ghosh et al. 2021; L. T. Smith 2012). In this context, B. Ghosh et al. (2021) propose three ways towards decolonising transition research: (1) addressing and acknowledging everyday struggles and resistance in the Global South, (2) addressing nuances of local dynamics including power dynamics, informal institutions as well as inequality and injustices, and (3) integrating meaningful and empowering participatory research methods to embrace transformative activities and communities of practices and value the research participants. Such approaches promise to reveal alternative and marginalised perspectives to move towards a just future (B. Ghosh et al. 2021).

In this context, imaginaries and visions aid in understanding the historical context, cultural meaning, social construction of systems and their governance, the interplay of technology, social innovations, and prevailing values and norms (Jasanoff and Kim 2015; Sovacool et al. 2020; Marquardt and Delina 2019). The influence of the fossil fuel sector on shaping imaginaries is significant, affecting public perceptions and mentalities (Schmelzer and Büttner 2024). Imaginaries provide an angle to analyse how actors perceive phenomena, construct reality, and communicate perceptions. Essentially, imaginaries provide a lens in the mechanism of how changes in transition can happen, the cultural meaning behind it, how visions are strategically deployed, and unveiling contestations and power dynamics underlying them[7] (Hoffman et al. 2021; Jasanoff and Kim 2015; Hess and Sovacool 2020). They represent collective assumptions and visions of the future, enabling an analysis of how individual and shared visions interrelate, and propose alternate realities (Hess and Sovacool 2020; Taylor 2004). The analysis of imaginaries has moved from imaginaries produced and focused on state actors and nations to non-state actors like social movements and corporations (Hess and Sovacool 2020; Jasanoff and Kim 2015). In this context, alternative emerging imaginaries provide insights into visions from “below the seats of power” (Jasanoff and Kim 2015, 20), such as marginalised or grassroots positions (Marquardt and

[7] The concepts of discourse, framing, storylines, and imaginaries are distinct but also interrelated, providing different angles to analyse how actors understand phenomena, construct or interpret a reality and communicate perceptions. In contrast to imaginaries, storylines and frames tend to focus more on specify policy arenas and competing coalitions. They do not necessarily involve symbolic constructions of futures (Sovacool et al. 2020).

Delina 2019; J. M. Smith and Tidwell 2016). This facilitates the investigation into contested and competing visions that diverge from official state narratives. Furthermore, this opens up spaces for dialogue and explores the potential of exceeding established structures by engaging with communities and social movements (Hess and Sovacool 2020; Christiansen and Carton 2021; Longhurst and Chilvers 2019). In the context of coal transitions, this entails conceptualising futures without coal, which has historically shaped identities and social capital (Newell and Mulvaney 2013; Velicu and Kaika 2017). The exploration of imaginaries can aid collectives in understanding their lived experience and fostering agency in shaping their futures. Despite its importance, much analysis remains at the national level, with a need for deeper exploration of regional and community roles in constructing alternative energy futures (see for example (Marquardt and Delina 2019)).

Just transition background in Germany and India

The discourse on the future after coal in Germany and India is shaped by the distinct transition and development stages and local contexts in each country. In Germany, scholars have emphasised the contentious debates preceding the coal phase-out decision, focusing on the objectives crucial for a just transition. In India, research has illuminated the perception of coal and the narratives associated with it, while also examining the multifaceted dependencies in coal regions pivotal for a just transition. In the following, I present exemplary literature to provide context to the analysis in the chapters.

In light of the contentious setting preceding Germany's coal phase-out decision, analyses have been conducted to decipher the dynamics of coalitions either supporting or opposing the phase-out and to understand the political economy, shaped by context-specific factors in Germany. The contentious nature of the phase-out is particularly evident against the backdrop of coal's historical significance, its intertwining with regional identities, contributions to regional development, and political constitutions (Furnaro 2022; Oei, Brau

ers, and Herpich 2019). Employment concerns have notably complicated an earlier phase-out, with the confrontation of climate and job narratives creating friction (Gürtler, Löw Beer, and Herberg 2021; Oei, Brauers, and Herpich 2019; Kalt 2021). Leipprand and Flachsland (2018) show that actors' risk-centric framing complicated the advocacy for a coal phase-out before the phase-out decision. Markard, Rinscheid, and Widdel (2021) argue that the eventual phase-out reflects the anti-coal coalition's success, attributed to its stability and the strategic use of climate change rhetoric to delegitimise coal. They state that the pro-coal coalition achieved to emphasise in the discourse the need for a cheap electricity supply and underlined that coal is a cheap form of electricity. Hermwille and Kiyar (2022) criticise the German coal phase-out as too late and expensive as it is misaligned with the Paris Agreement and includes high compensation payments towards the fossil fuel industry. They highlight the emphasis on structural change adjustments as a regional economic objective, particularly in Eastern Germany, to mitigate the scepticism rooted in past restructuring experiences decisions (Hermwille and Kiyar 2022). This highlights the importance of the integration of coal phase-out with regional development strategies, encompassing employment and enhancing soft location factors like education and culture (Hermwille et al. 2023; Oei, Brauers, and Herpich 2019). Hermwille et al. (2023) describe the coal phase-out as a “watershed moment”, catalysing adaptation, motivation, and innovation, while

stressing the need for a shared vision and self-ownership in regional futures, alongside financial support for structural transformation as a means to redefine coal regions and address injustices that the industry has created (economic, social, and environmental).

In India, coal has a long tradition seen as the backbone for development, energy security, and meeting the rising energy demand (Mohan and Topp 2018; Montrone, Ohlendorf, and Chandra 2021; Shukla and Swarnakar 2022a). In this context, scholars analyse the narratives and perceptions surrounding coal and energy within the Indian context. Mohan and Topp (2018) identify two predominant narratives: "energy for development," emphasising energy's role in economic growth and strategic planning, and "energy for all," focusing on energy access for poverty alleviation and basic development. These narratives emphasise the social and political dimensions of India's energy transition and contrast with the economic and industrial focus on national development. Further analysis by Montrone, Ohlendorf, and Chandra (2021) on the political economy of coal in India suggests that coal expansion and the challenges to transitioning to RE are influenced by coal-related employment in Eastern India, vested interests, and political resistance to pollution regulations. Malakar, Herington, and Sharma (2019) discuss the temporal dichotomy in energy justice, highlighting the conflict between short-term policy measures to alleviate energy poverty and the long-term commitment to a low-carbon transition. All this is encompassed in the uncertainty of the trajectories of coal and policies that still favour coal (Mohan and Topp 2018; Shukla and Swarnakar 2022a).

The just transition discourse in India is nascent, with scholars and practitioners emphasising critical aspects that warrant attention. A pivotal focus is understanding the multifaceted dependencies on coal at state and district levels, revealing injustices and pinpointing policy interventions. S. Pai (2021) reveals the socio-economic impact and contribution of the coal sector at the district level, encompassing employment and pensions (direct, indirect, induced, informal jobs and pensioners), district revenues, welfare expenditures, and coal's role as an industrial and domestic fuel source. S. Pai and Zerriffi (2021) further delve into sub-national socio-economic developments within the Indian coal industry and provide data on the socio-economic dependency on coal. In my collaborative research with Pelz et al. (2024), we leveraged this dataset to analyse the complex picture of inter-linked livelihoods and economic dependencies, employing a spatial analysis to assess household reliance on coal-related activities through a telephone survey of 2000 households in Jharkhand. Our findings indicate a noticeable concentration of coal-dependent livelihoods within close proximity to active mines, predominantly characterised by informal, casual labour. This underscores the relevance of addressing informality, given its substantial share in the workforce, lack of social security, and the role in supporting rural, impoverished populations (Lahiri-Dutt 2007; Ahmad and Lahiri-Dutt 2006). Moreover, the discourse encompasses the contentious issues of land acquisition and pending compensations in coal mining regions, alongside community rights, impacts on tribal populations, and gender-specific challenges (Oskarsson, Lahiri-Dutt, and Wennström 2019). These dimensions highlight the transition of traditional livelihoods by coal mining that results in enduring social disruptions, thereby underlining the nuanced challenges in conceptualising and implementing a just transition in India (Reddy and Mishra 2016; Sahoo and Senapati 2021). As shown above, these are important aspects in the just transition discourse in the Global South

Research gaps addressed in the dissertation

This dissertation aims to enhance the understanding of what constitutes a *just* transition, aiming to mitigate existing injustices and prevent the emergence of new ones within transition processes (Wilgosh, Sorman, and Barcena 2022; Majekolagbe 2023; Alarcón et al. 2023). There is a need for more in-depth case studies that examine the unique contexts of specific regions, defining pathways to achieve just transitions (Healy and Barry 2017; Wang and Lo 2021; Heffron and McCauley 2018). Germany has already decided to phase-out coal and by international comparison, Germany has allocated significant financial resources towards the coal phase-out and structural change measures. I analyse how the coal phase-out is now being shaped in terms of a just transition. Chapters 2 and 3 focus on the participation processes in the coal phase-out in Germany. Thereby, I analyse justice pillars as well as power dynamics and their impact on the participation processes and contribute to understanding the role of participation in the just transition debate (see Section 1.2.2).

Moreover, there is a call for increased research focus on the Global South to understand distinct regional contexts and highlight lived experiences, potentially revealing alternative imaginaries conducive to just transitions (B. Ghosh et al. 2021; Wang and Lo 2021). Additionally, there is an emphasis on exploring the temporal and spatial dimensions of transitions to understand cultural ties and the materiality of coal, thereby informing future decision-making processes (Wang and Lo 2021; Heffron and McCauley 2018). Chapter 4 applies the concept of sociotechnical imaginaries, as defined by Jasanoff and Kim (2015), to investigate just transition imaginaries in the coal mining region of Jharkhand in India, illuminating the contested nature of imaginaries and the significance of alternative, emerging visions. Furthermore, the analysis draws from the just transition approaches by Wilgosh et al. (2022) and literature on the spatial and temporal dimensions of just transitions, especially on land dispossession. This analysis emphasises bottom-up perspectives and the daily experiences of individuals in the Global South. With this, the chapter contributes to the discussion of what signifies a just transition in the Global South.

In Chapter 5, the dissertation integrates insights on just transitions into energy modelling, proposing directions for advancement in understanding and facilitating just transitions (see Section 1.2.3).

1.2.2 The role of public participation in governing a just transition

The governance of just transitions has an “increasingly important role in steering the worlds towards climate compatible development” (Newell and Mulvaney 2013, 132) and requires accounting for institutional challenges, managing uncertainties, and public and political resistance (Newell and Mulvaney 2013; Köhler et al. 2019). Just transition governance addresses the substantial socio-economic and cultural impacts of the energy transition, which affects livelihoods, local economies, communities, and cultures. Additionally, there is an opportunity to reimagine structures and institutions during this transition, which necessitates deep restructuring, renegotiation, reconfiguration, and a thorough understanding of transitions (Cha and Pastor 2022; Harrahill and Douglas 2019; Oei, Hermann, et al. 2020; Walk et al. 2021; Braunger and Walk 2022). Furthermore, the complexity of phasing out fossil fuels is influenced by various factors, including the influence of incumbent fossil fuel entities and societal pressures, which range from environmental concerns to the impact on employment

(Diluiso et al. 2021). It is not guaranteed that governance processes result in just and timely outcomes (Wang and Lo 2021; Suboticki et al. 2023), especially in light of the limited progress in reducing fossil fuel consumption and production (Jewell et al. 2019).

Academic discourse emphasises that governance in the context of a just transition should not be solely top-down but should instead cultivate support from a wide array of actors and follow principles of procedural justice (Wang and Lo 2021; Köhler et al. 2019; Hess, McKane, and Belletto 2021; Oei, Brauers, and Herpich 2019). This highlights the role of participation[8] and at the same time addresses the tension between the urgent need to phase-out fossil fuels and the potentially slower process of inclusive decision-making involving diverse actors (Wang and Lo 2021; Stirling 2015). Therefore, the focus of governance in the energy transition is to balance the imperative of timely action with the commitment to justice and inclusivity (Ciplet and Harrison 2020; Sovacool et al. 2020; Ciplet and Harrison 2020; Skjølsvold and Coenen 2021).

Participation can be studied through economic and procedural lenses, with notable intersections between the two. Economic participation, exemplified by initiatives like citizen energy and prosumer movements, involves engagement in energy production and consumption (Suboticki et al. 2023). This dissertation concentrates on procedural participation, which relates to the involvement of the public in shaping decision-making processes. The spectrum of public participation objectives ranges from information exchange to consensus building and community empowerment (Suboticki et al. 2023; Arnstein 1969; Coy et al. 2021; Majekolagbe 2023). Arnstein's "ladder of citizen participation" categorises eight levels of participation, from nonparticipation (manipulation and therapy) through tokenism (informing, consultation, placation) to forms of citizen control (partnership, delegated power, citizen control) (Arnstein 1969). Similarly, Coy et al. (2021) explore the range of empowerment outcomes in participation, conceptualising a progression from influence on decision-making, through agency to develop capacities and organise autonomous action, to a power shift to have ownership of issues. This underscores the complexity of participatory processes in ensuring just and timely transitions.

While there is not a *one-size-fits-all* approach, understanding what participation should aim for is an essential part of a just transition (Majekolagbe 2023; Wilgosh, Sorman, and Barcena 2022). Majekolagbe (2023) posits that participation functions as a multifaceted tool encompassing information sharing, consensus building, and consent gathering. However, a predominant critique is the limitation of participation to top-down methods, primarily focused on consultation or information exchange, which may not substantially influence outcomes, aiming more to educate than to foster a shared vision (Galende-Sánchez and Sorman 2021; Sovacool et al. 2020). Newell and Mulvaney (2013) highlight the concern that participation is employed to legitimise pre-determined decisions rather than to engage actors in shaping outcomes, often relying on technical models and forecasts. Wilgosh, Sorman, and Barcena (2022) describe the level of participation as an element of just transition approaches. In the limited approach, participation is characterised by symbolic, top-down consultation lacking co-creation, whereas the expansive approach advocates for collective ownership and bottom-up processes. The latter aims to enable diverse visions to impact the transition's outcomes, aligning with the notion of

[8] Also referred to as public engagement in the just transition literature.

meaningful participation (Wilgosh, Sorman, and Barcena 2022). For participation to be meaningful there are certain conditions stated in the literature: the acknowledgement of all actors, especially the most vulnerable; genuine engagement throughout the decision-making process; the empowerment of citizens to influence planning; and the availability of choices that promote welfare beyond mere safety or security, with an emphasis on balancing power dynamics (Cattino and Reckien 2021; Doelle and Majekolagbe 2023; Ryder et al. 2023).

In the discourse on just transitions, the significance of the key justice pillars, distributive, recognition, procedural and restorative, is paramount in ensuring that participation processes contribute to a just outcome and process. While all pillars are critical during the design, implementation, and evaluation of participatory processes, procedural justice is often at the forefront and linked primarily to participation (Huang and Chen 2021; Suboticki et al. 2023). However, against the background of the complex, sometimes messy, process of transitions and concerns that participation may lead to unjust outcomes, all justice pillars have an influence on the processes and should be paid attention to (Majekolagbe 2023; Suboticki et al. 2023). Procedural justice emphasises the involvement of diverse actors and the transparency of decision-making processes, advocating for local knowledge mobilisation, information disclosure, and inclusive representation in institutional processes (Huang and Chen 2021; Suboticki et al. 2023; Jenkins et al. 2016). Concerning distributive justice, an examination of the distribution of burdens and benefits helps identify actors who should be engaged in participatory processes and challenges the assumption that participatory procedures automatically lead to just outcomes (Newell and Mulvaney 2013; Suboticki et al. 2023; Gürtler and Herberg 2021). As Hermwille et al. (2023) highlight in their analysis of narratives in carbon-intensive regions, quality governance processes require that actors possess not only the financial means but also the authority to contribute to developing common visions for regional futures, as opposed to top-down decisions imposed by national governments.

Particularly concerning recognition justice, this displays the questions of who are the *right* participants (Majekolagbe 2023). Suboticki et al. (2023) critique the vague definition of *the public* in participation processes, advocating for careful consideration of why particular actor groups need attention and emphasising the need to address marginalisation and inequities explicitly. Identifying relevant groups is a critical step that influences the thematic focus of participatory engagements (Suboticki et al. 2023; Majekolagbe 2023). The socio-cultural and socio-economic dimensions of just transitions highlight the importance of considering a range of vulnerabilities, including race, class, gender, and other factors that may lead to social marginalisation, and that participation processes reflect the inclusive and responsive needs and perspectives (Majekolagbe 2023; Braunger and Walk 2022).

In addition to the discussions on the pillars of justice, the study of power dynamics serves as a lens through which the potential reinforcement or disruption of existing inequalities and power structures can be examined as many of the drawbacks of participation processes, such as a lack of transparency and resource imbalances, can be traced back to power dynamics (Avelino 2017; Birnbaum 2016; Brisbois and de Loë 2016a; Coy et al. 2021; Fung and Wright 2003; Lukasiewicz and Baldwin 2017; Ross et al. 2021; Purdy 2012). Power aspects influence factors such as representation, whose voices are

prioritised, and the overarching design of participatory processes (Purdy 2012). Various frameworks have been developed to analyse power in participation, linking process design to outcomes and highlighting the influence of power on decision-making, including for example inclusion and exclusion of actors and agenda-setting (Emerson and Nabatchi 2015; Ansell and Gash 2007; Arnstein 1969; Ran and Qi 2018; Purdy 2012; Scott and Thomas 2017; Cook 2015). Participation can either reinforce or challenge prevailing power relations, with powerful actors potentially dominating outcomes if imbalances are not addressed (Brisbois 2020; Turnhout et al. 2020; Wilgosh, Sorman, and Barcena 2022; Musch and von Streit 2020). Scholars emphasise the link between participation processes and the potential for emancipation, suggesting that meaningful participation for less powerful actors hinges on the redistribution of power (Coy et al. 2021; Arnstein 1969; Avelino 2021). Thus, examining whether participants can influence decision-making reveals insights into representation and emancipation within participatory processes (Avelino 2017; Birnbaum 2016; Brisbois and de Loë 2016a; Coy et al. 2021; Fung and Wright 2003; Lukasiewicz and Baldwin 2017; Ross et al. 2021). The call for greater power analysis in these processes is emphasised by its implications for the pace and nature of just transitions, influencing the distribution of benefits and burdens, and determining which voices are heard and how actors are represented (Avelino 2021; Wang and Lo 2021).

Public participation in just transition governance in Germany and India

The outline of literature on public participation in the German context centres on studies assessing the Coal Commission's role and outcomes, which underpins the analysis presented in Chapter 2. Additionally, regional governance processes are presented to provide contextual background for Chapter 3. For the Indian case, the focus shifts to research that explores the inclusion of diverse voices within the transition process, informing Chapter 4.

In Germany, social dialogues in the energy sector have a long tradition and predominantly occur between employers' associations, trade unions, and industry actors, often in informal settings (Reitzenstein, Schulz, and Heilmann 2020; Abraham 2017). The Coal Commission accompanied this tradition by facilitating dialogue among a wide array of actors, including unions, environmental NGOs, and representatives from affected regions (Gürtler, Löw Beer, and Herberg 2021). While the Coal Commission has been widely praised, especially by the media and observers, for having breached the stalemate in the coal phase-out, it also faced criticism, for example, that the phase-out is too late to stay in line with the Paris Agreement and too expensive considering the large compensation payments (Gürtler, Löw Beer, and Herberg 2021; Hermwille and Kiyar 2022). Section 1.2.1 discusses how financial support for structural change was crucial in gathering backing for the coal phase-out. Yet, the recommendations of the Coal Commission were not directly translated into legislation, with altered decisions being incorporated into the coal phase-out law a year later, in July 2020 (Hermwille and Kiyar 2022; Agora Energiewende and Aurora Energy Research 2019). A comparative analysis with the Canadian Commission reveals differences in legitimisation strategies: Germany's approach emphasised substantial government expenditure to support industries, workers, and affected regions, alongside broad interest representation. In contrast, the Canadian model was more focused on including insights from coal communities and reflecting these to the federal government (Gürtler, Löw Beer, and Herberg 2021). In a similar vein, Grothus and Setton (2020) highlight the task of civil society in commissions to highlight protests and opinions from the streets. However, there is a potential risk of participants from

civil society being instrumentalised as legitimising bodies, especially if the commission's outcomes fail to meet the expectations and demands of the actors.

Academic discourse points to the role of public participation in regional governance processes in Germany, particularly against the backdrop of economic restructuring and changing regional identities (Harrahill and Douglas 2019; Schuster et al. 2023; Oei, Brauers, and Herpich 2019; Matern et al. 2023). In Lusatia, despite the establishment of participatory processes for distributing transition funds, Schuster et al. (2023) show a lack of transparency and high levels of bureaucracy, leading to a perception among locals that they do not directly benefit from the transition, which fuels resentment. Furthermore, they note that women and young people are underrepresented in decision-making processes and that decisions are predominantly made at national and regional government levels with limited civil society engagement (Schuster et al. 2023). In their analysis of justice claims in Lusatia, Gürtler and Herberg (2021) observe that while financial support is crucial, it must be administered with an awareness of potential recognition and procedural injustices. Thus, participation processes need to account for the societal struggles accompanying transitions and the sensitive negotiations that this requires.

In the context of India's deep-rooted structural inequalities related to caste, class, and gender, ensuring the participation of marginalised individuals is subject to increased discussions for just transition governance. For example, Grover, Swami, and Suresh (2023) advocate for empowering local governments, highlighting their role in democracy in rural areas. Local governments are the third tier of the Indian government, which includes *panchayats* and *gram sabhas*. These are local assemblies in rural areas, including coal regions that make decisions on various village matters. J. Pai, Jha, and Gopal (2023) delve into panchayat members' perspectives on energy transitions, emphasising the role of grassroots voices in the transition discourse, especially those adversely affected by coal mining. They stress the importance of empowering local governance to tailor policies that resonate with local needs rather than imposing unfitting top-down policies. In a similar vein, Mohan and Topp (2018) underscore the conflict between centralised policymaking and the social realities of coal mining. The establishment of the Just Transition Task Force in Jharkhand in November 2022, aimed at advising on transition strategies, primarily involves state departments and institutions and assesses communities' socio-economic dependencies through surveys and discussions (Kumar and Tandon 2023). Pandey and Sharma (2021) examine public engagement in RE initiatives in India, findings that are also interesting for participation in coal phase-out. They show that communities resist predefined roles in RE projects, demanding recognition justice and mobilising their agency by outlining needs and priorities and formulating their social, political, and ecological identities.

Research gaps addressed in the dissertation

In sum, participation plays a role in just transition governance by bringing together various actors and empowering them to shape their future. Yet, the design and outcomes of participatory approaches remain subjects of debate, underscoring the need for case studies on (successful) transition governance (Wang and Lo 2021). Stakeholder commissions are emerging as a political tool to discuss and govern phase-out strategies in the energy sector, enabling the involvement of actors in transition plans (Brauers et al. 2022). Coal phase-outs are often contested due to economic dependencies on coal, potential job

losses, and incumbent actors favouring the status quo (Diluiso et al. 2021; Jewell et al. 2019; Ohlendorf, Jakob, and Steckel 2022). Against this backdrop, Chapter 2 examines the role of the Coal Commission in Germany in overcoming the stalemate situation on the phase-out of coal. The chapter investigates the setup and the formation of its recommendations to understand the Commission's dynamics. In this way, the dissertation engages in the debate on suitable political instruments and processes to overcome stalemate situations and facilitate change and actor engagement in transitions by analysing the expert commission as a governance strategy.

Chapter 3 delves into the distribution of the transition funds in Lusatia, assessing the role of these processes in the just transition, which are shaped by the regional context and historical scepticism towards structural changes. As regional participation processes increasingly feature in sustainability transitions, many are simply consultations or suffer from design and implementation flaws, which might limit their ability to strengthen a just transition. The chapter explores in-depth the participation processes which are still in progress and an important part of the regional transition strategy in Lusatia. The analysis puts a focus on the important aspect of power dynamics in such processes by exploring how power dynamics influence local actor engagement. Both Chapters can inform other transition processes on the role of public participation in supporting just transitions.

In Chapter 4, the focus shifts to Jharkhand in India exploring the role of public participation in securing community rights and land ownership. The chapter connects participation to issues of temporality and spatiality and the justice pillars in just transition visions in the region. The chapter addresses the research gap in exploring the role of public participation in the Global South.

1.2.3 Including just transition elements within energy modelling

Energy models play a pivotal role in navigating the energy transition, serving not only to represent the current status quo but also to project future trajectories (Lopion et al. 2018). The famous adapted words of George Box *"All models are wrong, but some are useful"* (Box 1979, 202) highlight their role in providing insights and trajectories that shape and inform policy-making processes (and vice versa), influencing political debates and strategic decisions, and legitimate or justify political decisions and targets (Süsser et al. 2021; Midttun and Baumgartner 1986; Silvast et al. 2020; Hofbauer, McDowall, and Pye 2022). Energy models can be mobilised to depoliticise policymaking, excluding non-expert voices from debates (Aykut, Demortain, and Benboudiz 2019). Moreover, according to Midttun and Baumgartner (1986), forecasting is evolving into a form of negotiation modelling that addresses questions of whose interests are fulfilled by the forecasting exercise. Royston et al. (2023) call the navigation of economic energy models a complex political game, "mastering the machinery" (Royston et al. 2023, 9), where established actors' voices are amplified, potentially marginalising others. This underlines the significance of framing in models, where assumptions and results are political, influencing sustainable transition strategies. The interaction between policymakers and models is bidirectional; policymakers influence modelling by affecting data assumptions, study scopes, and the usage of model results (Süsser et al. 2021), while models facilitate actor collaboration (between different scientific groups, policymakers, and other actors), foster communication and co-operation, and explore options for policy interventions (Silvast et al. 2020; Silvast and Foulds 2022). Recognising these complex dynamics calls for reflexivity, inclusivity of unheard voices, transparency, and open access in modelling

practices (Süsser et al. 2021; Royston et al. 2023; Silvast et al. 2020; Hofbauer, McDowall, and Pye 2022).

Energy models, predominantly characterised by their techno-economic foundations, are increasingly confronted with their limitations in capturing the multifaceted nature of energy transitions. These models, while grounded in technical and economic parameters, often do not assess socio-political elements such as public acceptance, employment trends, participation and attitudes, societal norms, incentives, and the overarching political landscape (Pregger et al. 2019; Stern, Sovacool, and Dietz 2016; Trutnevyte et al. 2019; Holtz et al. 2015; Overland and Sovacool 2020). The critical role of energy models in informing policy underscores the inevitability of an interdisciplinary approach to exploring just futures (McGookin, Ó Gallachóir, and Byrne 2021; Holtz et al. 2015; Royston and Foulds 2021). The integration of qualitative social science insights into quantitative models presents challenges, such as the qualitative character, which are often hard to specify in numbers and stay in conflict with the "clearer and more concrete" (Overland and Sovacool 2020, 4) nature of natural and technical science (Overland and Sovacool 2020; Turnheim et al. 2015; Geels, Berkhout, and van Vuuren 2016). Despite the intrinsic strengths and weaknesses of qualitative and quantitative approaches, incorporating social dimensions into energy models to help develop the accuracy of models, enhance forecasting outcomes, and understand socio-technical dynamics (Bolwig et al. 2019; Turnheim et al. 2015). This integration not only enriches the models but also resonates with a larger spectrum of policymakers, addressing diverse policy criteria such as acceptance, legitimacy, and cost-effectiveness (Geels, Berkhout, and van Vuuren 2016). Furthermore, fostering dialogue between disciplines is crucial for analysing common challenges, developing shared concepts, and aligning problem frames, particularly in governance and policy decisions. Such interdisciplinary dialogues facilitate the improvement of energy models, ensuring they are more reflective of the complexities integral to transition pathways (Turnheim et al. 2015).

In this context, scholars are increasingly examining how to incorporate public concerns and preferences into energy models to ensure that the results are just and reflective of a range of perspectives (McGookin et al. 2024). Participatory modelling is a method that involves the integration of actors at different levels throughout the modelling process, and, thus, being able to account for "the fundamental and often unspoken assumptions of actors" through the involvement (Holtz et al. 2015, 53). McGookin, Ó Gallachóir, and Byrne (2021) identify two key drivers for the increasing interest in participatory modelling approaches: understanding the energy transition within its socio-political context and democratising of decision-making processes. They distinguish between shallow and meaningful integration, while the former assesses acceptance of the modelling outcomes and the latter involves actors throughout the process (McGookin, Ó Gallachóir, and Byrne 2021). Such participatory approaches can enhance the legitimacy and robustness of models, foster mutual understanding and trust, and facilitate social learning. They are linked to procedural and recognition justice, enabling capacity building, consensus formation, and shared ownership of results. Participatory modelling also promotes collaborative knowledge co-production, aiding in the creation of a shared language that supports effective communication and ensures the practical applicability and impact of outcomes (McGookin et al. 2024; Vågerö and Zeyringer 2023; Holtz et al. 2015; Quimby and Beresford 2023). However, reviews indicate that current participatory practices often remain limited to single, isolated interactions predominantly

involving academic actors, resolving more on information extraction, thus restricting the empowerment potential (Holtz et al. 2015; McGookin, Ó Gallachóir, and Byrne 2021). Challenges in participatory modelling include managing complexity and ensuring transparency, as models do not fully represent reality, and addressing the resource-intensive nature of participatory methods (McGookin, Ó Gallachóir, and Byrne 2021; Vågerö and Zeyringer 2023). In this regard, McGookin, Ó Gallachóir, and Byrne (2021) developed a framework to show opportunities for co-creation, such as discussing model results and co-defining model input assumptions, and co-developing storylines and narratives.

In Arnz and Krumm (2023), we delve into sufficiency futures within the German passenger transport sector to examine demand reduction potentials. We construct three sufficiency storylines by adopting an interdisciplinary and participatory methodology. The work is divided into two phases: (1) the qualitative storyline development, followed by (2) scenario modelling using the transport model quetzal_germany (Marlin Arnz 2022). The approach incorporates expert engagement at two entry points: during storyline development and in the scenario modelling phase. Initially, in an expert workshop 15 transport and sufficiency experts identified key change drivers for avoid and shift strategies. These insights were then articulated into storylines, using the Multi-Level-Perspective (MLP) logic to dissect transition dynamics across outcome, process, and actor dimensions. Subsequently, in the scenario modelling phase, these drivers were translated into model input parameters, with a subsequent expert survey (23 responses) quantifying these parameters for scenario input. The final step involves transport modelling with quetzal_germany. This approach, integrating expert insights and a qualitative framework, offers an investigation of sufficiency in passenger transport, extending beyond the conventional scope of transport modelling (M Arnz and Krumm 2023).

Energy modelling of a just transition in Germany and India

Overall, socio-political aspects are increasingly being discussed and applied in energy models. While we see a trend towards the integration of these aspects in applications in the Global South (Fuchs et al. 2023), the review by Vågerö and Zeyringer (2023) on the inclusion of energy justice in ESMs shows that it is still less addressed in comparison to applications on Global North countries and regions. The analysis by Fuchs et al. (2023) on modelling in policy-making in the Global South shows that many standard modelling approaches overlook the political economy influences and developmental challenges unique to the Global South, affecting the processes and results of modelling. They emphasise the necessity of recognising the roles of various actors in shaping modelling processes and the need for in-country capacities to ensure local ownership and contextual relevance of modelling projects for effective policymaking.

There are modelling approaches endeavouring the integration of socio-political aspects in energy modelling exercises in Germany. For example, Pregger et al. (2019) include statements from societal and energy experts to develop context-based scenarios that identify consistent societal scenarios using energy models to account for energy demand and supply structures. McKenna et al. (2018) develop feasible energy concepts for small communities by combining actor workshops to assess the values of the community towards local potential RE employing a multi-criteria decision analysis and energy system modelling. This illuminates three core community values: sustainability, environmental sustainability, and local energy autonomy. Furthering this discourse, Flachsbarth, Wingenbach, and

Koch (2021) investigate the impact of social acceptance by examining wind energy distribution scenarios in Germany and their implications for future transmission line expansion. Their findings suggest that socially and ecologically favoured wind power distribution does not necessarily reduce the need for grid expansion when compared to economically driven distribution strategies (Flachsbarth, Wingenbach, and Koch 2021). Drechsler et al. (2017) address the question of the efficient and equitable allocation of RE by combining legal analyses, economic and energy modelling with monetary valuation, and numerical optimisation. They define equity as the even distribution of the burdens of RE production on all individuals in society and include them in the scenarios. Complementing this, Weinand et al. (2022) explore the trilemma of cost-efficiency, landscape impact, and regional equality in onshore wind expansion planning, employing a multi-criteria planning approach to develop a cost-effective, visually unobtrusive, and evenly distributed method for wind capacity planning.

In the examination of India's low-carbon transition, Löffler and Krumm (2022) employ the ESM GENeSYS-MOD to explore a sector-coupled energy system across power, heating, transportation, and industry at the state level and examine two scenarios to analyse the effects of an energy system that stays within 2°C against a baseline scenario. Subsequently, we conduct an employment analysis using the employment factor approach based on Rutovitz, Dominish, and Downes (2015), revealing that while jobs in the fossil fuel sector decline, RE deployment, which is characterised by higher labour intensity, could generate up to four million jobs, cushioning employment impacts of transitions. This study also briefly addresses just transition measures. We applied a similar method to South Africa which also shows a high dependency on coal and where the question of a just transition is pressing (Hanto et al. 2021). In a similar vein, S. Pai et al. (2020) evaluate job creation and loss during decarbonisation in India, emphasising the need for increased solar and wind capacity to offset coal sector job losses. David Jacobs et al. (2019) investigate the co-benefits of power sector decarbonisation in India, focusing on skill requirements for renewable energy jobs. Sharma and Banerjee (2021) assess the distributional employment impacts, noting regional discrepancies in RE sector job gains versus fossil fuel job losses. In another example, Singh, Upadhyay, and Powar (2022) explore the impacts of hydropower site development in India using a multi-criteria decision-making model, highlighting the importance of considering social, economic, environmental, and technical factors to support sustainable policy-making. Bardhan et al. (2020) propose a framework for meeting residential cooling demands in India, advocating for solar photovoltaics and peer-to-peer trading to alleviate energy stress in buildings, thereby contributing to distributional justice.

Research gap addressed in the dissertation

In this section, I outlined the role of modelling in navigating a just transition, highlighting the need to analyse the politics of modelling and improve the integration of the socio-political dimension in energy models. The integration of just transition elements is a key theme for model advancements (Trutnevyte et al. 2019; Pfenninger, Hawkes, and Keirstead 2014). In Chapter 5, I address this research gap by systematically exploring the potential of integrating social aspects into energy models. This provides a starting point for further dialogue and model improvements to capture the socio-political dimension and better understand and analyse just transition pathways.

1.3 Concepts, frameworks, and methods

This section provides an overview of concepts, frameworks, and methods applied in the dissertation. Positioned within the domain of Sustainability Transition Research (STR), the dissertation also incorporates theories and frameworks from other disciplines, reflecting the interdisciplinary essence of transitions. The dissertation is informed by the current state of literature and the research gaps identified and thus contributes to the literature by enhancing the perspective on just transitions which I highlight in the sections. The organisation of this section follows the structure of the dissertation. A detailed explanation of the used concepts, along with insights into the research design, data collection, and analytical methods can be found in the respective chapters.

1.3.1 Sustainability transition research

STR understands climate change and other environmental problems as a composite of grand societal challenges rooted in the production and consumption patterns of socio-technical systems (Köhler et al. 2019; Loorbach, Frantzeskaki, and Avelino 2017). In that sense, *sustainability transitions* refer to the radical shifts to new kinds of socio-technical systems, recognising that these challenges extend beyond the realm of mere technological solutions or incremental changes (Markard, Raven, and Truffer 2012; Köhler et al. 2019). An inquiry within STR is the mechanisms and governance strategies that can facilitate these profound shifts (Köhler et al. 2019; Markard, Raven, and Truffer 2012). This gains particular significance in the context of fossil fuel decarbonisation, where path dependencies and lock-in effects pose substantial barriers, highlighting the critical role of governance in transitioning towards more sustainable systems (Markard, Raven, and Truffer 2012; Köhler et al. 2019).

Understanding the barriers to transitions, the mechanisms through which transitions unfold, and how transformative change can be facilitated is pivotal, with the concepts of niches and regimes being central to this understanding (Markard, Raven, and Truffer 2012; Loorbach, Frantzeskaki, and Avelino 2017). Socio-technical regimes establish a logic that guides incremental changes, offering orientation and coordination while potentially constraining alternative developments. These regimes encompass institutions, infrastructure, technologies, rules, and cultural meanings (Geels 2002; Markard, Raven, and Truffer 2012; Rip 1995). In contrast, niches represent protected spaces fostering radical innovations through learning, experimentation, and networking. Under certain conditions, niche innovations can challenge and potentially replace established systems (Markard, Raven, and Truffer 2012; Geels 2002). The MLP elaborates on this by examining the interactions between regimes, niches, and the socio-technical landscape, explaining the dynamics of lock-ins, path dependencies, and the emergence of radical innovations (Markard, Raven, and Truffer 2012; Loorbach, Frantzeskaki, and Avelino 2017; Geels 2002). For example, Geels (2012) applies this framework to analyse the automobile regime, while Upham, Eberhardt, and Klapper (2020) investigate the psychological dimensions of the Fukushima nuclear accident's impact as a landscape shock. Avelino (2017) incorporates power dynamics in the MLP in the POwer-IN-Transition (POINT) framework, distinguishing between the reinforcing power of regimes, the innovative power of niches, and the transformative power that emerges at the intersection of niches and regimes, where new institutional and structural innovations can occur. She also proposes the distinction between global reinforcive and transformative power at the landscape level to account for the different potential developments at the landscape level (Avelino 2017).

The dissertation engages with key research themes prominent in STR, including the governance of transitions (Chapters 2 and 3), the role of power in transitions (Chapters 2-4), ethical and justice aspects (Chapters 2-5), and methodological reflections (Chapter 5) (Köhler et al. 2019). The initial focus is on the governance of a timely and just phase-out of fossil fuels, considering the limited progress in reducing fossil fuel consumption and the imperative to guide these transitions (Köhler et al. 2019; Jewell et al. 2019). The dissertation delves into power dynamics within transitions, aiming to understand power relations in empirical cases on participation processes, especially regarding class, race, gender, and geographical location (Köhler et al. 2019; Avelino 2021). Ethical and justice aspects of transitions are analysed, exploring distributive, participatory, recognition, and restorative issues within decision-making processes and addressing inequalities via the lens of just transitions (Jenkins et al. 2016; Newell and Mulvaney 2013). Furthermore, I highlight the perspective of actors, especially communities, in the Global South by analysing what a just transition means for actors in Jharkhand (Chapter 4), which is seen as an important research need in STR (Köhler et al. 2019; B. Ghosh et al. 2021). Given STR's interdisciplinary nature, the dissertation also contributes to the emerging field of social energy modelling, integrating insights from social science to enhance the understanding of the complex nature of transitions (Köhler et al. 2018; Hirt et al. 2020; Turnheim et al. 2015). The next section describes the applied concepts and frameworks and how these have contributed to the field.

1.3.2 Concepts and frameworks

1.3.2.1 Collaborative governance

There are different paths to major policy change as required in the phase-out of coal. Sabatier and Weible (2007) state that besides policy-oriented learning, external shocks, and internal shocks, negotiated agreements are alternative pathways to political change. In this context, collaborative governance (CG) emerges as a prominent theme, suggested as a mechanism to achieve consensus-oriented decisions that surpass mere lowest compromises, especially in contentious fields (Ansell and Gash 2007; Emerson and Nabatchi 2015; Innes and Booher 1999). Scholars develop and apply different frameworks to analyse CG focusing on different aspects. Ansell and Gash (2007) developed a contingency model of CG to analyse if it will produce successful collaborations. Furthermore, Newig et al. (2018) analyse the environmental performance of CG by identifying clusters of causal mechanisms that describe the relationship between the governance approach and environmental outcomes. Innes and Booher (1999) account for the complex and self-organising system of CG by offering a framework that evaluates the consensus-building process. In Chapter 2, my co-authors and I explore how the Coal Commission was able to overcome the stalemate situation surrounding the coal phase-out in Germany and the formation of the recommendations using the integrative framework for collaborative governance (ICGF) by Emerson et al. (2012). The framework offers a structured approach to analyse the set-up of the Coal Commission and allows for the inclusion of contextual factors which both are important to answer the research questions. With this, we adopt a political science framework to STR to account for the political process of phase-out processes that have received little attention so far (Kern and Rogge 2016; Markard, Suter, and Ingold 2016). This approach enriches the understanding of the workings and

dynamics of phase-out processes and contributes to the discourse with an exploration of the political processes

Emerson et al. (2012) define CG as *"the processes and structures of public policy decision making and management that engage people constructively across the boundaries of public agencies, levels of government, and/or the public, private and civic spheres in order to carry out a public purpose that could not otherwise be accomplished."* (Emerson, Nabatchi, and Balogh 2012, 2). Based on this, the ICGF was developed as a tool for the systematic and empirical evaluation of CG processes to "understand when, where, why, how, and to what effect collaborative governance […] can be used" (Emerson and Nabatchi 2015, 26). The ICGF consists of interconnected dimensions that illustrate the system context, the *Collaborative Governance Regime* (CGR) (the regime in which decisions are taking place), and the collaboration dynamics. The system context encompasses political, legal, socioeconomic, and environmental factors that both influence and are influenced by the CGR. From the system context, various drivers such as uncertainty, interdependence, consequential incentives, and initiating leadership direct the early collaborative efforts. This leads to a cycle of collaboration dynamics: *principled engagement* of stakeholders, which fosters *shared motivation* and eventually builds the *capacity for joint action* (Emerson, Nabatchi, & Balogh, 2012). However, as described, the stalemate situation at the beginning of the Coal Commission's work is relevant to the inner workings of the Commission. Therefore, we added an additional point on the actor networks within and outside of the Commission to understand how these networks influence the Commission's dynamics and outcomes, particularly regarding the representation of interests and the impact on the Commission's outputs.

1.3.2.2 Power analysis in participation processes

Chapter 3 delves into the participatory processes of the distribution of the transition funds in Lusatia provided by the German government, following the Coal Commission's recommendations. The focus is on analysing the power dynamics inherent in the processes and placing them within the context of Lusatia's regional just transition. Besides the prominent "ladder of participation" by Arnstein (1969) (see Section 1.2.2), there are several conceptualisations of power in participation. For example, Purdy (2012) provides a framework that combines arenas for power use (formal authority, resources and discursive legitimacy), with the process elements (participants, process design, and content). As mentioned in Section 1.3.1, Avelino (2017) develops the POINT framework to analyse power and (dis)empowerment. She shows the connection between empowerment and the possibility of unintended disempowerment effects in transition, e.g. through a highly complex discourse that fails to engage some people, resulting in a loss of impact and expertise. Chapter 3 aims to understand the implications of the power dynamics on the participation process and on the transition process itself. With this, the analysis extends the analyses of power relations within transitions, examining how power structures are established, evolved, and either sustained or challenged within the context of transitions. This seeks to contribute to the understanding of power dynamics in participation, offering insights into their implications for the governance and outcomes of such processes (Köhler et al. 2019; Avelino 2021; Partzsch 2017; Wang and Lo 2021).

My co-authors and I build upon the work by Brisbois et al. that offers a framework for analysing power dynamics in transition and participatory processes (Brisbois, Morris, and de Loë 2019; Brisbois 2019;

Brisbois and de Loë 2016a), which is grounded in Lukes' three dimensions of power (Lukes 2004). The first dimension, *instrumental power*, is defined as the capacity to influence decisions despite opposition, observable through the lens of "who wins" in decision-making scenarios (Brisbois, Morris, and de Loë 2019, 4). It underlines the significance of actor-specific resources (financial, technical, social, institutional, and knowledge) and the imbalances therein. Actors leverage these resources to impact the behaviour of others and shape policy outcomes, with typical displays of lobbying and coercion. *Structural power*, which can be overt or visible, reveals the social, political, and economic structures and institutions in which the process is situated. It illustrates how these structures influence and mould the process, affecting the inclusion or exclusion of issues, shaping policy agendas, and creating conditions that either enable or hinder the ability of actors to promote or articulate their interests. *Discursive power* focuses on the social institutions, norms, and values and accounts for how these elements are constructed, challenged, and manipulated. It influences the political and socio-economic conditions of a process, determining the extent to which participation is constrained or enabled. Understanding these dimensions is vital for realising the full potential of participation in transitions, highlighting the need for shared structural power and acknowledging the impact of beliefs and ideas on actor behaviours and discourse. The interconnection of these dimensions reveals the relationship between participation outcomes and the role in the transition process (Brisbois, Morris, and de Loë 2019; Brisbois 2019; Brisbois and de Loë 2016a).

1.3.2.3 Imaginaries about just transition futures

In Chapter 4, my co-author and I analyse just transition imaginaries in the coal mining region of Jharkhand in India. There are various types of imaginaries that make sense of how societies and individuals imagine the future (Hess and Sovacool 2020). For example, spatial imaginaries are representations of a certain place or space (Chateau, Devine-Wright, and Wills 2021) and energy imaginaries are concerned with ideas and visions around forms of energy including the form of energy governance (Movik and Allouche 2020; Genus et al. 2021). Social imaginaries encompass how people understand society and the social structure, including values and institutions (Schmelzer and Büttner 2024; Taylor 2004). Sociotechnical imaginaries bridge the social and technical realms by analysing shared visions of the future through the interplay of technology, science, and social reality (Jasanoff and Kim 2015; 2009). This chapter applies the concept of sociotechnical imaginaries and connects it with the temporal and spatial dimensions as well as the justice pillars of just transition. The analysis emphasises the significance of community-focused and emerging imaginaries, offering insights into the lived experiences of communities, particularly in the Global South. Our work delves into the local contexts, exploring regional structures and the aspirations of various actors regarding their future. With this, we contribute to the direction of studying sociotechnical imaginaries, from a national-level to a local-level approach to understand the dynamics that shape just transitions in specific locales.

Jasanoff and Kim (2015) define sociotechnical imaginaries as *"collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology"* (Jasanoff and Kim 2015, 19). The performative dimension and explanatory power of imaginaries link it

to present-day action and future decision-making by understanding and analysing the politics and power relations attached to established processes, structures, and policy subjects as well as norms and visions leading to these structures (Marquardt and Delina 2019; Ballo 2015; Jasanoff and Kim 2015; Fahimi, Upham, and Münch 2022). The emphasis on emerging imaginaries seeks to question and potentially disrupt established norms, in contrast to institutionalised imaginaries that became stable through cultural, institutional, and material practices. These alternative imaginaries spotlight the dynamics of progress and change, underscoring the significance of investigating sociotechnical imaginaries within just transition contexts, particularly in regions like Jharkhand where such discourse is emerging (Hirt, Sahakian, and Trutnevyte 2022; Christiansen and Carton 2021; Tidwell and Tidwell 2018; Marquardt and Delina 2019; Rabiej-Sienicka, Rudek, and Wagner 2022). The research is based on the limited and expansive distinction made by Wilgosh et. al (2022) and analyses the representation of the justice pillars by examining the characteristics of the approaches in the material and imaginaries identified. Moreover, examining spatial dimensions within sociotechnical imaginaries can bring to light marginalised perspectives and tackle energy and environmental challenges by recognising socio-spatial inequalities and the interplay between collective memories and future visions (Müller 2019; Chateau, Devine-Wright, and Wills 2021; Feola et al. 2023). Temporality in coal transitions illuminates actors' perceptions and power dynamics, affecting decisions on the pace of transition and the implications of waiting on future expectations and control over actions (D'Angelo and Pijpers 2018; Luning 2018). Especially, the impacts of the spatial-temporal dimension in land dispossession are highlighted.

1.3.2.4 Social energy modelling

Chapter 5 explores the integration of social aspects into energy models. This involves an initial separate examination of energy models and the STR literature to identify relevant aspects for integration. Based on this, my co-authors and I developed a framework to assess the potential of integrating social aspects (see Section 1.4.4 for a description of the developed framework). With this, we contribute to the literature on social modelling by providing an overview of the current integration of social aspects into energy models and by offering a tool to foster interdisciplinary dialogue to enhance the inclusion of social aspects in energy models.

First, there is a diverse array of energy models to address specific energy challenges. Scholars employ different model categorisations depending on the objectives of the research (Lopion et al. 2018; Köhler et al. 2018; Nikas, Doukas, and Papandreou 2019). To systematically address the diversity of energy models, my co-authors and I categorise them into four types based on their characteristics and functionalities, following mainly Hirt et al. (2020) and Pfenninger, Hawkes, and Keristead (2014). The four model types are ESMs, integrated assessment models (IAM), agent-based models (ABM), and computable general equilibrium models (CGE). Each category is evaluated for its strengths and limitations in representing energy transitions. Second, my co-authors and I draw upon the STR literature to categorise social and behavioural aspects of the energy transition, focusing on the elements identified by researchers as critical for the socio-technical transition: (1) Behaviour and lifestyle, (2) Heterogeneity of actors, (3) Public acceptance and opposition, (4) Public participation and ownership, and (5) Transformation dynamics (e.g. (Hirt et al. 2020; Trutnevyte et al. 2019; Köhler et al. 2018)). Third, the chapter builds on existing strategies on how to link energy models with insights from social science (Hirt et al. 2020; Trutnevyte et al. 2019; Turnheim et al. 2015; Köhler et al. 2018; Geels, Berkhout, and van

Vuuren 2016; Li and Strachan 2019). Particularly, Trutnevyte et al. (2019) propose three approaches for linking models and social sciences: bridging, iterating, and merging. Each strategy reflects a different degree of connection between models and social science insights. In the bridging approach, models and social science research progress alongside, occasionally creating connections to facilitate exchanges, particularly about shared concepts and theories. The iterating approach follows a story-and-simulation method, where narratives established by social sciences are converted into quantitative assumptions for model inputs, and model outputs may be used to refine these narratives. Merging involves a deep integration where societal factors are incorporated into models, either modifying existing models significantly or leading to the development of entirely new models.

1.3.3 Methods

1.3.3.1 Research design

The energy transition is highly context-specific and shaped by regional conditions and dynamics. Therefore, **case studies** offer insights into a specific context – a case – and help to understand and expose the context as well as the connections and dynamics relevant, thereby structuring knowledge in a manageable manner (Lund 2014; Sovacool, Axsen, and Sorrell 2018). They provide an in-depth analysis of one or multiple cases, such as regions or policy processes and, thus, provide a “systematic production of exemplars” (Flyvbjerg 2006, 242). Through such detailed analysis, case studies seek not only to illuminate individual cases but also to contribute to theoretical frameworks and the generalisation of findings to enrich the knowledge of specific phenomena (Sovacool, Axsen, and Sorrell 2018; Flyvbjerg 2006; Yin 2018). In this dissertation, I employ case studies to shed light on policy processes (Chapters 2 and 3) and specific regional contexts (Chapters 2, 3, and 4), aiming to offer theoretical contributions and transfer knowledge to other cases. In Chapter 2, my co-authors and I demonstrate how the Coal Commission's process to navigate the coal phase-out stalemate can offer valuable lessons for other sustainability transitions, integrating political science perspectives into transition research. Chapter 3 derives implications for participation processes in transitions by delving into the process of the distribution of the transition funds in Lusatia. In Chapter 4, my co-author and I explore the complexities of phase-outs and just transitions in Jharkhand, providing policy implications for other cases in and beyond the Global South and contributing to the literature on spatial and temporal dimensions of just transitions.

In contrast, a **systematic literature search or review** provides an overview of existing publications on the current state of knowledge (Petticrew and Roberts 2012; Sovacool, Axsen, and Sorrell 2018). This provides “a comprehensive, unbiased and replicable summary of the state of knowledge” by accounting for multiple factors (Sovacool, Axsen, and Sorrell 2018, 22). The approach complements case studies by aggregating findings from multiple studies to construct a picture and make sense of a large scale of information without producing new data. Thereby, it points out uncertainties, knowledge gaps, and further research (Petticrew and Roberts 2012). Chapter 5 employs a systematic literature search of publications on energy models from two EU-funded projects to examine the current integration of social aspects in energy models. The chapter points out existing approaches and provides recommendations for further research, thereby contributing to the advancement of the field.

1.3.3.2 Data collection

The dissertation uses a series of different data collection methods. Chapters 2 to 4 use semi-structured interviews and policy documents as data sources. In Chapter 4, my co-author and I complement this by conducting focus groups and background interviews. Chapter 5 relies on academic publications. The following section gives an overview of the data collection technique employed in the dissertation. Further elaboration on the procedure of the interviews and focus groups as well as the sampling of the documents can be found in the respective chapters.

First, **semi-structured expert interviews** are a tool to access and understand people's understanding, beliefs, and experiences about a certain issue (Sovacool, Axsen, and Sorrell 2018). Interviews facilitate the reconstruction of situations or processes through the expertise of the interviewees (Gläser and Laudel 2010). The term 'expert' denotes the interviewees' specialised knowledge related to the research topic, enabling researchers to access and reconstruct detailed knowledge about the subject matter (Gläser and Laudel 2010), while the researchers should consider the interviewees' affiliations or organisational backgrounds when analysing their perspectives (Sovacool, Axsen, and Sorrell 2018). In semi-structured interviews, the guideline comprises a series of questions related to the research topic, with flexibility for adjustments or additional questions as the conversation unfolds, structured along main questions with possible follow-up questions if needed. This structure allows the interviewer to delve deeper into topics significant to the interviewee or explore new topics that emerge during the discussion. This contrasts with unstructured interviews, which lack predetermined questions, and structured interviews, characterised by close-ended questions often utilised in surveys (Bryman 2012). Additionally, Chapter 4 incorporates **background interviews**, which serve to refine the interview guideline, confirm the data sampling strategy, and provide specific background information, thereby enhancing the research's validity.

Second, **focus groups** are interviews with typically at least four participants (Bryman 2012) aiming at "constructing a social context in which participants can collectively generate, negotiate and express perceptions and meanings" (Sovacool, Axsen, and Sorrell 2018, 29). A strength of focus groups is their ability to facilitate interaction among participants, allowing for the exchange and challenge of viewpoints, which can lead to the revision of opinions and foster a rich environment for argumentation and discussion. This dynamic can provide the researcher with more nuanced insights than might be possible in one-on-one interviews, where participants are less likely to modify their views (Bryman 2012). Furthermore, the interactions can shed light on controversies and dynamics between the participants, presenting a variety of arguments. Focus groups are appreciated for their participatory nature, enabling researchers to recede into the background, thus promoting a more balanced power dynamic between the participants and the researcher. However, it is important to acknowledge that researchers still exert influence by initiating the focus group, selecting participants, and determining the discussion topics. While focus groups can be resource-intensive in terms of time and costs, conducting a minimum of three focus groups is recommended to ensure the consistency and reliability of the findings related to the research subject (Gailing and Naumann 2018).

Sovacool, Axsen, and Sorrell (2018) describe how interviews and focus groups create empirical novelty by creating new data from actor groups such as elites, experts, small populations (e.g. early adopters), and vulnerable populations, that are typically challenging to access. In the context of the dissertation,

the emphasis is on elites and vulnerable populations. Elites are defined as individuals in positions of power influencing decision-making, whereas vulnerable populations may include the elderly, youth, economically disadvantaged individuals, and indigenous communities. Understanding these groups is vital for unravelling complex processes or situations, requiring culturally sensitive research strategies (Sovacool, Axsen, and Sorrell 2018). In Chapter 2 my co-authors and I use semi-structured interviews to delve into the Coal Commission's internal dynamics, while Chapter 3 focuses on understanding the perspectives of participants and affected actors in the distribution of the transition funds. In both cases, elites, people in a position of power, were important interview partners as they set the agenda of the processes and their motivation and action shaped the processes. Chapter 4 uses this approach in Jharkhand in India, where interviews with elite figures from the coal industry, union leaders, representatives of international organisations, local NGOs, media personnel, and social workers are conducted to explore just transition imaginaries. To engage with marginalised and vulnerable groups, my co-author and I organised focus groups to capture the lived experiences of coal community members and foster discussions about visions for the future. The focus groups were able to reach communities including people with poor education, low income, the elderly, and indigenous people. The focus groups not only facilitated data collection from these groups but also stimulated discussions about future ambitions, encouraging participants to articulate and reflect on their visions for the future despite potential constraints rooted in their present circumstances.

Third, **documents** serve as a source of background or context information on a topic and offer insights into how actors frame a topic, drawing from the language and terminology used (Sovacool, Axsen, and Sorrell 2018; Bowen 2009; Creswell 2014). Documents may include personal records like diaries, official documents from government or private organisations, digital content, or media outputs (Sovacool, Axsen, and Sorrell 2018; Bryman 2012). Additionally, **scientific publications** are utilised in systematic literature searches or reviews to assess the current landscape of a research field. In Chapters 2 to 4, documents complement the data from semi-structured interviews and focus groups by enriching the background and contextual understanding. Specifically, Chapter 4 employs policy documents to explore the just transition visions among actors in India. In Chapter 5, academic publications constitute the primary data sources, facilitating an assessment of how social aspects are integrated in energy models.

1.3.3.3 Data analysis

The chapters employ **qualitative content analysis** to systematically analyse data sources, primarily employing a codebook (Bryman 2012; Sovacool, Axsen, and Sorrell 2018). A codebook contains codes – labels or tags – that facilitate capturing the essence of data segments (Saldaña 2009). The coding process involves assigning these codes to raw data pieces, simplifying and preparing them for later interpretation, thus enabling the transformation of data into units for analysis (DeCuir-Gunby, Marshall, and McCulloch 2011). This process assists in contextualising the data and aligning it with the research objectives (Bryman 2012). Codes within the codebook may be developed inductively, from the data itself, or deductively, based on pre-existing theory or research objectives (Kuckartz 2018). The coding procedure is often iterative, with feedback loops allowing for the refinement and clarification of codes (DeCuir-Gunby, Marshall, and McCulloch 2011; Kuckartz 2018). To ensure the reliability and quality of

the analysis, especially when multiple coders are involved, inter-coder reliability measures were implemented. My co-authors and I ensured a consistent understanding and application of codes across the dataset, cross-verified our coding outcomes, and made necessary adjustments to enhance precision and consensus (Mayring 2014).

In each chapter, we built a code system rooted in analytical categories derived from the theoretical framework employed in the research, serving as the basis for the data analysis and interpretation. This allows for flexibility to open up new categories that emerge from the data itself (Bryman 2012; Kuckartz 2018). Explicitly, Chapter 2 follows the approach by Gläser and Laudel (2010) as a method for evaluating expert interviews as a reconstructing analysis and a mechanism-oriented explanatory strategy to analyse the workings of the Coal Commission. In Chapter 4, my co-author and I use thematic analysis as a specific method of qualitative content analysis (Nowell et al. 2017). This method proved useful for managing a large dataset, as this approach mandates a structured approach to data handling, ensuring systematic examination and interpretation of the data. It enables the identification and summarisation of key themes by accentuating similarities and differences among the actors studied (Nowell et al., 2017).

1.4 Outline and findings

Table 1: Overview of chapters, research questions, theory and methodology, scientific contribution, own contributions and pre-publication.

	Chapter 2: Overcoming political stalemates: The German stakeholder commission on phasing out coal	**Chapter 3: "Nodding through" or decision-making? Local actor participation in the coal phase-out in Lusatia, Germany**	**Chapter 4: Continuation or transformative change: Disputed just transition imaginaries in the coal mining region of Jharkhand in India**	**Chapter 5: Modelling social aspects of the energy transition: What is the current representation of social factors in energy models?**
Research questions	• How did the "Commission on Growth, Structural Change and Employment" achieved to breach the previous stalemate? • How were the final recommendations for a coal phase-out in Germany formed?	• What power dynamics can be observed in the participation processes and what factors enable or hinder the capacity of local actors to affect outcomes? • Are there deficits in the participation processes that hinder the support of just transition processes?	• What are just transition imaginaries in Jharkhand? • What tensions exist between them?	• Which model types are particularly good at integrating social aspects? • What social aspects are represented in energy models? • How are these social aspects integrated?
Applied theory and methods	• Framework: Integrative framework for collaborative governance (IFCG) • Research design: Case study • Data collection: Semi-structured expert interviews, documents • Data analysis: Qualitative content analysis	• Concept and framework: Power in participation and just transition • Research design: Case study • Data collection: Semi-structured expert interviews, documents • Data analysis: Qualitative content analysis	• Concept and framework: Sociotechnical imaginaries and just transition • Research design: Case study • Data collection: Semi-structured expert interviews, focus groups, policy documents, background interviews • Data analysis: Qualitative content analysis (thematic analysis)	• Concepts: Interdisciplinary approach combining STR literature and literature one energy models • Research design: Systematic literature search • Data collection: Scientific publications • Data analysis: Qualitative content analysis

Empirical and scientific contributions	• In-depth analysis of the German Coal Commission and their role in overcoming the stalemate situation • Transfer of a political science framework to transition research • Policy recommendations for collaborative governance in sustainability transitions	• In-depth analysis of two participation processes of the distribution of the transition funds in Lusatia, Germany • Analysis of power relations in participation processes in a just transition process • Policy recommendations for participation processes in sustainability transitions	• Identification of regional just transition imaginaries in Jharkhand, India • Highlighting the needs and wishes of communities in the coal region and capturing the lived experience • Providing insights into the spatial and temporal dimensions of just transitions • Implications for the just transition design in Jharkhand and other cases, especially in the Global South	• Overview of state-of-the-art approaches for integrating social aspects in energy models • Combining insights from socio-technical transition and energy models • Development of a framework to integrate social aspects into energy models • Demonstrate research gaps and ways to advance the integration of social aspects in energy models
Publication	Published as: Hauenstein, Christian; Isabell Braunger; Alexandra Krumm; Pao-Yu Oei. **2023**. 'Overcoming Political Stalemates: The German Stakeholder Commission on Phasing out Coal'. *Energy Research & Social Science* 103 (September): 103203. https://doi.org/10.1016/j.erss.2023.103203.	Submitted and under review to the special issue 'The Politics and Governance of Phase-Out' in *Environmental Politics*	Submitted to *Energy Research & Social Science*	Published as: Krumm, Alexandra, Diana Süsser, and Philipp Blechinger. 2022. 'Modelling Social Aspects of the Energy Transition: What Is the Current Representation of Social Factors in Energy Models?' *Energy* 239 (January): 121706. https://doi.org/10.1016/j.energy.2021.121706.
Co-author statement and own contribution	Joint work with Christian Hauenstein, Isabell Braunger, and Pao-Yu Oei. The authors contributed equally to this work: Conceptualisation, methodology, interviews, formal analysis and writing of the manuscript. Christian Hauenstein provided the project administration.	Joint work with Nora Stognief and Maren Krätzschmar. Conceptualisation and methodology were conducted jointly. Interviews were carried out jointly. Formal analysis and writing were conducted by Alexandra Krumm and Nora Stognief. Alexandra Krumm and Nora Stognief provided the project administration.	Joint work with Rajeev Ranjan. Conceptualisation and methodology were conducted by Alexandra Krumm. Interviews were carried out jointly. Focus groups were organised by Rajeev Ranjan and carried out jointly. Formal analysis was conducted by Alexandra Krumm. Writing was conducted by Alexandra Krumm and Rajeev Ranjan. Alexandra Krumm had the lead role in the coordination.	Joint work with Diana Süsser and Philipp Blechinger. Conceptualisation and methodology were conducted jointly with Diana Süsser. Data analysis was conducted by Alexandra Krumm. Formal analysis was conducted by Alexandra Krumm and Diana Süsser. Writing, review and editing were conducted by Alexandra Krumm, Diana Süsser, and Philipp Blechinger. Alexandra Krumm had the lead role in the coordination.

Source: Own depiction.

1.4.1 Chapter 2: Overcoming political stalemates: The German stakeholder commission on phasing out coal

Chapter 2 delves into the role of the Coal Commission in Germany as a governance instrument in finding recommendations on the coal phase-out, particularly focusing on how it navigated the stalemate in the coal phase-out discussions. Through 18 semi-structured expert interviews with Coal Commission members (overall 28 members), supplemented by document analysis, the chapter evaluates the Coal Commission's process using the ICGF - examining system context, drivers, collaborative regime formation, and collaboration dynamics. The analysis reveals that the Coal Commission's collaborative setting facilitated trust and understanding, creating an encouraging environment for dialogue and negotiation, effectively addressing and overcoming existing contestations. The motivation of members to reach a consensus was influenced by a unique context, characterised by political and economic pressures and the absence of viable alternatives. Financial incentives also played a crucial role in aligning economic interests towards coal phase-out, a strategy made viable by Germany's economic strength. Despite the Coal Commission's broad actor representation, criticisms regarding gender imbalance and the underrepresentation of youth were noted. The recommendations emerged from tough negotiations, reflecting a compromise that tended to favour more powerful stakeholders, with no specific measures to address resource imbalances like negotiating experience, thereby allowing the discourse dominated by influential actors.

The chapter highlights that CG can facilitate progress in transition processes by fostering a consensus-building platform that helps overcome political stalemates. While this approach enhances the acceptability of transitions, it is not a panacea and should complement rather than replace necessary political decisions and actions when there is a clear political mandate. Establishing a CG requires experienced, neutral facilitation, adequate time for transparent processes, and the creation of spaces for open dialogue, with particular attention to empowering less powerful or underrepresented groups to mitigate potential power imbalances. The Coal Commission's success in breaking the stalemate and setting a phase-out timeline by 2038, with the potential for an earlier deadline, offers valuable insights into the utility of CG in transition contexts, especially where there is slow progress in phasing out fossil fuels.

1.4.2 Chapter 3: “Nodding through” or decision-making? Local actor participation in the coal phase-out in Lusatia, Germany

In Chapter 3, my co-authors and I investigate the participation processes in the distribution of the transition funds in Lusatia by analysing what power aspects can be observed in the processes and how these enable or hinder the capacity of local actors to affect outcomes. Furthermore, we place the processes in the transition to analyse if it hinders the support of just transition processes. Based on 15 semi-structured interviews with actors involved in the processes in Lusatia and a document analysis of meeting notes, websites, and other relevant information, we reconstruct the phases of the participation processes. The effort in establishing participation processes illustrates the perceived importance of a locally rooted transition and bottom-up decision processes. However, my co-authors and I note a significant gap between the public actors' declared participation aims and their execution. The findings

indicate that key decision-making often occurs either before or after involving public actors, highlighting power imbalances in agenda-setting, participant selection, and process design that undermine meaningful participation. Public actors retain significant decision-making authority, which can overshadow the input from civil society and local communities, potentially reinforcing existing power structures rather than facilitating transformative change and presenting a missed opportunity for capacity-building. The emphasis on economic and infrastructural priorities over environmental and social sustainability aspects reflects existing discursive power relations in the region. This analysis emphasises the role of participatory approaches, the different perspectives of actors, and the critical role of public actors in shaping processes to promote just and transformative change for a just transition.

The chapter concludes with recommendations to strengthen public participation in Lusatia and other local transition processes. Collective decision-making demands settings that encourage open dialogue, empower individuals, and prevent a few from dominating decisions, emphasising the importance of involving local actors. Public actors need more resources and knowledgeable staff, including experts in participation, to ensure everyone's voices are heard and represented. It is vital to focus on building the skills and capacities of local participants, allowing them to influence the processes to ensure diverse perspectives in the just transition planning. Lastly, incorporating a strong focus on sustainability and social justice from the start is vital to achieving just outcomes in the transition process.

1.4.3 Chapter 4: Continuation or transformative change: Disputed just transition imaginaries in the coal mining region of Jharkhand in India

Chapter 4 analyses just transition imaginaries and the tensions between them in the coal mining region of Jharkhand in India. Utilising twelve semi-structured expert interviews, four focus groups, 36 documents and four background interviews, my co-author and I identified two main imaginaries: *green growth and reskilling strategy, and self-determination and land ownership*. The former aligns with the limited approach of just transition, focusing on technology advancement and renewable energy as future pathways for Jharkhand, while the latter, embodying elements of an expansive approach, emphasises emancipatory actions, particularly around self-determination and local governance through *panchayats* and *gram sabhas*. These imaginaries offer contrasting perspectives on the justice pillars, with notable differences in how they address compensation for land acquisition, procedural justice regarding decision-making processes, recognition of vulnerable groups, and restorative justice concerning land rights. The first imaginary envisions Jharkhand as an energy hub, prioritising technology and renewable energy, whereas the second imaginary draws on historical contexts and traditional livelihoods, underscoring the significance of land, particularly for tribal communities.

The chapter contributes to the burgeoning discourse on just transition policy within the Global South context. Particularly, the chapter illuminates the issue of land dispossession and ownership through the lens of community experiences. By delving into these lived experiences, the chapter aims to reveal the tensions between various actors' visions and how these could potentially influence the pathways of a just transition in the region. Additionally, this chapter participates in the discussions about the definition and constituents of justice in transition processes. This analysis not only outlines the different just transition pathways envisioned in Jharkhand but also highlights the critical interplay between local aspirations, governance structures, and justice considerations in shaping these transitions. The insights

gained from the Jharkhand case study are posited to be of value also for informing just transition strategies in other regions and contexts.

1.4.4 Chapter 5: Modelling social aspects of the energy transition: What is the current representation of social factors in energy models?

This chapter explores the current status of the integration of social aspects within energy models, aiming at fostering interdisciplinary collaboration and illustrating the potential for such integration through insights from STR and modelling approaches. My co-authors and I performed a systematic literature search focusing on scientific publications on energy models from the openENTRANCE and SENTINEL[9] projects. The developed framework breaks down the modelling process into three main steps: (i) storyline, scenario, and input parameter, (ii) optimisation and simulation process, and (iii) discussion of model outcomes. The initial step encompasses integrating social aspects through exogenous storylines or scenarios and their translation into model parameters. The second step delves into the model's mathematical framework, influencing its structure, such as the objective function. The final step involves contextualising model outputs with social aspects, providing a nuanced interpretation of results and, potentially, informing iterative adjustments to storylines, scenarios, or inputs. This framework offers two contributions: Firstly, it provides a systematic approach to address questions concerning what model types integrate social aspects and how. Secondly, it serves as a tool to facilitate interdisciplinary dialogue between modellers and social scientists, promoting a collaborative approach to enhance energy modelling in just transitions.

The integration of social aspects into energy models remains infrequent, although existing methods demonstrate how behavioural and social factors can be incorporated. This often involves expanding modelling exercises with qualitative storylines, scenarios, and input parameters, thereby relying on exogenous assumptions and predominantly integrating easily quantifiable aspects, such as employment figures. A significant challenge identified is the quantification of social aspects and the translation of qualitative narratives into model parameters, often troubled by methodological uncertainties and a lack of empirical data. To advance the integration of social aspects in energy modelling, we propose three strategies: First, modelling should surpass the representation of social factors as mere exogenous variables, necessitating a comprehensive approach to embedding social dimensions and openness to alternative ways of modelling. Second, the worlds of modellers and social scientists should move closer together within interdisciplinary or transdisciplinary projects, with each field open to adapting its methods to facilitate integration. And third, linking different models and model types offers promise in overcoming the limitations of individual models. This could leverage the unique strengths of each model, potentially requiring further modifications to harness the full spectrum of capabilities.

[9] https://openentrance.eu/ and https://sentinel.energy/

1.5 Limitations and research outlook

This section outlines the limitations of the dissertation, offering directions for future research. The limitations are categorised according to the three research foci. While distinct, the foci exhibit overlaps, which are addressed in the relevant passages.

In the first research focus (Chapters 2 and 3), the dissertation primarily examines the design and functioning of participation processes, emphasising power dynamics and their impact on the ability of actors to voice their perspectives and influence outcomes. Nonetheless, the dissertation falls short when it comes to analysing the impact of the outcomes of participation processes on just transitions. While Chapter 3 places the participation process in Lusatia in the just transition context, it lacks a detailed examination of the actual impacts on the region's future. An analysis could involve investigating the funded projects, the rationales behind their selection, and their implications for Lusatia's economic, socio-economic, and socio-cultural landscape. Linking these outcomes to the justice pillars of just transition and regional vulnerabilities would offer deeper insights into how these processes guide the transition. Furthermore, the analysis in the chapters is primarily based on interviews, providing significant insights but potentially missing the nuanced dynamics observable in live participation sessions. Originally, there was an intent to attend workshop sessions in Brandenburg in Lusatia, as part of the analysis. However, due to repeated postponements of the workshop session, an observation was not possible. Future research could benefit from such observational involvement to capture the details of participation dynamics and reconcile them with interview data, offering a more extensive understanding of the participation processes in just transition governance[10].

In Chapter 3, the second focus, my co-author and I delved into the perspectives of actors in communities in coal regions. As pointed out by B. Ghosh (2021), meaningful and empowering participatory research methods are especially important in the context of decolonising transitions and conducting research in the Global South. Our research design aimed to capture the visions of communities and account for the agency, capabilities, and knowledge they possess. However, the research faced limitations. One notable challenge was the difficulty for the participants to imagine a future beyond coal, highlighting the omnipresence of and structural dependency on coal within these regions. Furthermore, we only conducted one focus group with each set of participants. Here, we missed the chance to establish long-term, sustainable collaboration with the communities to both empower them and account for the nuanced local cultural, and socio-political conditions, as well as sensitivities. D. Ghosh (2018) underscores that fieldwork is often bounded by the researcher's capabilities and positionalities, bringing attention to the ethical and emotional complexities of fieldwork and its inherent limitations. In her book, L. T. Smith (2012) offers insights into decolonising research methods and the role of indigenous knowledge, suggesting that these approaches could facilitate a deeper engagement with marginalised communities. Future research could benefit from integrating these methodologies to establish a more

[10] Related work did the research groups of Research Institute for Sustainability (RIFS) in the project “Social Transformation and Policy Advice in Lusatia" (https://www.rifs-potsdam.de/en/blog/2022/06/research-accompany-transform-our-research-project-structural-change-lusatia) and Leibniz-Institut für ökologische Raumentwicklung e.V. Dresden in the project “Scientific monitoring of the transformation in Lusatia" (http://transformation-lausitz.ioer.eu/).

sustained collaboration with actors in communities, thereby enriching the understanding of their perspectives on just transitions.

This goes hand in hand with the limited focus on theoretical and philosophical examinations of justice theories and the use of non-Western theories in the dissertation as I focused on applying existing theories and frameworks. Yet, this approach has its limitations, particularly in the context of non-Western settings like India, where the exploration and integration of non-Western theories could offer valuable insights (see e.g. (Malakar, Herington, and Sharma 2019)). Furthermore, the research illuminated how examining spatial and temporal dimensions can uncover components of a just transition. However, the potential to explore underutilised concepts within just transition scholarship, such as the capability approach or restorative justice, was not fully exploited. Such explorations could enrich our understanding of just transitions, providing nuanced perspectives and contributing to the theoretical evolution of the concept.

The third focus is on embedding elements of just transition in energy models by reviewing the literature to identify how social aspects are integrated into energy models. The logical progression would involve engaging in modelling exercises that apply, refine, and innovate upon existing approaches for integration, such as exploring alternatives to linear optimisation and enhancing model linkages. Studies that I contributed to, which are not part of the dissertation, examine the direct employment impacts of energy transitions in India and South Africa (Löffler and Krumm 2022; Hanto et al. 2021) and sufficiency narratives in Germany (M Arnz and Krumm 2023). They underline the potential for further research in inter- and transdisciplinary modelling approaches. Firstly, advancing methods to quantify qualitative aspects of just transitions is essential, requiring a combination of qualitative insights and quantitative metrics. Secondly, conducting participatory modelling case studies involving local communities and policymakers could fulfil three objectives: making the modelling process more inclusive, improving the embedding of results in the socio-political context, and fostering shared visions for the future. This approach echoes the methodology employed by Gookin et al. (2022), who demonstrate the worth of participatory modelling in bridging community concerns and ESM in rural Ireland. By linking this focus with the previous two, such a methodology not only promotes the visibility of communities in transition processes but also provides policymakers with data-driven, collaboratively developed visions to guide their decisions. Ideally, this would involve an iterative, long-term engagement with actors, allowing for continuous validation of results and adaptability to evolving local circumstances.

Comparative studies serve as a valuable methodological tool in both social science and energy modelling, offering insights into patterns, trends, and the effects of local contexts on just transition processes (Sovacool, Axsen, and Sorrell 2018). Although there are several options for comparative studies, I would like to point out two options that I think are promising for advancing just transitions. First, comparative analyses of just transition imaginaries in coal-mining regions could provide profound insights into the distinct interpretations and expectations of what constitutes a just transition across different regions and among diverse actors. A comparative framework incorporating both South-South and North-South perspectives can reveal a spectrum of transition imaginaries, ranging from socio-economic development to emissions reduction, social justice, and economic growth. This comparative

lens could enhance our comprehension of actors' perceptions in coal-mining regions regarding just transitions, identifying potential strategic and policy avenues to facilitate these transitions. Second, comparing just transition policies, including participatory mechanisms, across various national and contextual landscapes can help understand how they address community vulnerabilities and can offer critical guidance for developing just policies. This comparative endeavour could also extend to analysing financial mechanisms that facilitate phase-out processes and foster just transitions at the regional level.

1.6 Conclusion

This dissertation explores the navigation of collaborative pathways in the coal phase-out process through a just transition lens, concentrating on three foci: the role of public participation in governance, the perspectives of coal-dependent communities, and the modelling of social aspects. This dissertation aims to show aspects of how to navigate collaborative pathways for a just transition by focusing on the mitigation of inequality, the inclusion of diverse voices in the process, and just transition strategies that are sensitive to the nuances of affected communities and the socio-economic landscape. Based on this, I draw the following conclusions.

First, addressing structural injustices and vulnerabilities is crucial for guiding a just transition, as these can become entrenched in transition planning if not properly addressed. Importantly, a just transition should neither perpetuate existing injustices nor create new ones. The just transition needs to navigate the complexity of transitioning economies beyond coal while addressing social and environmental impacts. The just transition concept holds the potential to encompass a wide array of interest groups and perspectives, spotlighting the complex, often neglected socio-economic and cultural impacts on communities in transition regions. This includes considerations of environmental remediation, cultural traditions, and the self-determination and ownership rights of local populations concerning their future. This dissertation demonstrates that engaging directly with people in the regions is pivotal to understanding their needs, desires, and perceptions of a just transition. Such engagement can inform policies rooted in the lived experiences and daily challenges of those affected, ensuring that the transition is not only environmentally sustainable but also socially equitable and culturally sensitive.

Second, despite the recognised importance of participation in just transitions, its actual implementation often falls short of embodying just transition principles, with meaningful and equitable engagement frequently lacking. This dissertation, through the analysis of two case studies, underscores the significance of addressing power imbalances, fostering leadership, and creating spaces for trust-building and mutual understanding for creating an environment for meaningful participation. Participation should transcend mere "ticking a box" or superficial engagement. The insights from Chapters 2 to 4 suggest that participatory processes can enhance capabilities and emancipatory outcomes, aiding in the development of a collective vision for the future of regions. Effective participation involves integrating individuals from coal regions throughout the transition process, rather than relegating them to passive recipients of externally made decisions. Moreover, the dissertation reveals that participatory approaches can harness local knowledge, which helps tailor transitions that are attuned to specific local needs and conditions. In the German context, although there are identified shortcomings in the approaches, participatory mechanisms have been instrumental in determining a coal phase-out timeline and

implementing just transition strategies at the regional level. These insights from the German experience could be valuable for enhancing participatory processes in the Indian context and beyond.

Third, the development of collaborative and shared visions stands out as an instrument for guiding just transitions. Such visions can illuminate diverse interpretations of what constitutes a just transition and explain the existing tensions among the aspirations of various actors. Recognising and exploring these visions can provide crucial insights into the essential attributes of just transitions, including the recognition of cultural dimensions and the integration of often-neglected aspects like informality and the role of women. In a transformative context, a just transition encompasses the creation of unified visions among all relevant actors, necessitating engagement with a wide array of voices. This inclusive approach can enhance the justice pillars by influencing the distribution of benefits and burdens, shaping decision-making processes, ensuring recognition, and addressing environmental and social harms. Importantly, such a process includes generating bottom-up visions, thereby empowering communities to actively participate and shape their futures. Creating these shared visions requires providing the necessary tools, capacities, and platforms for communities and local actors to collaboratively envision and articulate their aspirations. This also involves establishing channels for dialogue with influential actors and policymakers to reconcile divergent perspectives and embed these collective visions into policy frameworks. Advocating for collaborative navigation of just transitions underscores the importance of fostering spaces for cooperation, mutual understanding, and the co-creation of shared futures.

Finally, recognising the just transition as a socio-political endeavour underscores the significant potential of integrating just transition principles into energy modelling. Such integration can reveal pathways that are equitable and just. Given the influential role of models in shaping policy, incorporating just transition elements can guide policymakers toward more just solutions, particularly as models communicate transition pathways to a broad audience. Current energy modelling practices reflect a narrow view of transitions, focusing mainly on technical and economic aspects. This approach underscores the necessity of embedding socio-political factors into the modelling process, moving beyond ad-hoc considerations to a more integrated approach. By incorporating socio-political dimensions directly into energy models, there is a greater opportunity to steer transitions toward outcomes that are not only technologically and economically viable but also socially just.

Overall, as a concluding remark, navigating a just and timely transition collaboratively is far from automatic or self-evident and requires determined efforts from a myriad of actors across different levels. This involves creating a common vision that encompasses a wide array of perspectives, enabling energy models to integrate socio-political dimensions, and steering the governance towards a just transition. Although this dissertation primarily concentrates on coal transitions, the insights derived hold relevance to a bigger spectrum, extending applicability to other fossil fuel phase-outs and the overarching energy transition. The findings highlight the complexity of just transitions, advocating for an inclusive, multi-faceted approach that exceeds mere technical or economic considerations to embrace the socio-political landscape shaping these transformative processes.

Chapter 2:

Overcoming political stalemates: The German stakeholder commission on phasing out coal[*]

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2 Overcoming political stalemates: The German stakeholder commission on phasing out coal

2.1 Introduction

To meet the international 1.5°C (or well-below 2°C) climate target, a substantial decline in global coal consumption is needed by 2030 (IPCC 2018; 2022). However, despite the reduction of coal consumption in some countries, global consumption has remained relatively flat over the last decade (IEA 2020). At the UN Climate Change Conference in Glasgow (2021) the international community has agreed to phase down global coal (UNFCCC 2021), renewing impetus to address a timely transition away from coal. In individual countries, societal and political pressure to deliver on climate mitigation and to phase out coal is growing (Blondeel, Van de Graaf, and Haesebrouck 2020; Rinscheid and Wüstenhagen 2019). However, in other countries, the future of coal remains highly contested, due to economic dependencies on coal, fear of job losses, and incumbent actors profiting from the status quo (Jakob et al. 2020; Newell 2018; Ohlendorf, Jakob, and Steckel 2022; Diluiso et al. 2021; Jewell et al. 2019). This can lead to stalemate situations between opposing stakeholders, with the incumbent system increasingly becoming under pressure, however, still able to prevent or delay a transition away from fossil fuels, such as coal (M. Leach, Scoones, and Stirling 2010; Seto et al. 2016; Brisbois and de Loë 2016a; Sabatier and Weible 2007).[11] A few countries, such as Canada, Chile, and several European countries, have announced a coal phase-out in recent years (Europe Beyond Coal 2022; Ritchie 2021). However, in most of these countries, coal only played a subordinate role in the energy system and in terms of employment at the time of the decision (Blondeel, Van de Graaf, and Haesebrouck 2020; IEA 2019; Jewell et al. 2019).

A notable difference is Germany, the world's largest lignite producer and consumer, with high economic and social dependence on coal in some of its coal mining regions (Jewell et al. 2019; Oei, Brauers, and Herpich 2019). Based on the recommendations of a stakeholder commission, the "Commission on Growth, Structural Change and Employment", hereinafter referred to as the (Coal) Commission, Germany determined to phase out coal consumption and production the latest by 2038, and to implement structural change measures for affected regions (Gürtler, Löw Beer, and Herberg 2021). The agreement of the Coal Commission received wide attention and was celebrated by many as a milestone to phase out coal, after several political attempts to reduce Germany's use of coal in previous years had failed due to overwhelming resistance by supporters of a continued use of coal, within and outside of governing parties (Furnaro 2022; Hermwille and Kiyar 2022). Particularly, the coal industry and related unions, energy-intensive industries, as well as politicians in coal mining regions tried to stall any policy to reduce coal use in Germany (Bang, Rosendahl, and Böhringer 2022; Kalt 2021; Hermwille and Kiyar 2022; Leipprand and Flachsland 2018).

[11] According to Sabatier and Weible (Sabatier and Weible 2007, 206) a "policy stalemate" describes "a situation in which all parties to the dispute view a continuation of the status quo as unacceptable". They consider a stalemate situation to be a prerequisite to successful negotiations because "individuals satisfied with the status quo have little incentive to give up anything in negotiations (…)."

Collaborative governance (CG) approaches, such as the Coal Commission, are considered to offer possibilities to overcome stalemate situations and promote consensus-oriented decisions that exceed lowest common denominator compromises in previously highly contested issues (Sabatier and Weible 2007; Emerson and Nabatchi 2015). However, lack of win-win scenarios, strong belief heterogeneity, or power imbalances among participants can limit the success of CG (Dutterer and Margerum 2015; Brisbois and de Loë 2016a). Considering conflicts over the future of coal, scholars argue that just transition objectives and stakeholder involvement could contribute to achieve timely and equitable coal phase-outs (Jakob et al. 2020; Muttitt and Kartha 2020; Diluiso et al. 2021).

In the Coal Commission, representatives of different interest groups were supposed to develop recommendations for a phase-out pathway and closing date for coal, and measures to support structural change in affected regions (BMWi 2019). Due to a history of intensive conflicts and highly diverging objectives among stakeholders, many questioned beforehand if the Coal Commission could resolve the issues at hand, while others criticized it for being not ambitious enough in its climate objectives (Gürtler, Löw Beer, and Herberg 2021; Hermwille and Kiyar 2022; Grothus and Setton 2020). However, in the end the Commission achieved to develop and pass recommendations supported by all influential actors in the related German context, achieving a high level of legitimacy for these recommendations and overcoming the previous stalemate situation (Praetorius et al. 2019; Gürtler, Löw Beer, and Herberg 2021).

In this paper, we assess how the stalemate situation in the German conflict over the future of coal was overcome, enabling the agreement on a coal phase-out in Germany. We focus on the process of the "Commission on Growth, Structural Change and Employment" and the question, how this Commission achieved to breach the previous stalemate situation and how the final recommendations were formed.

To assess this stakeholder commission process and the formation of its final recommendations, we apply the integrative framework for collaborative governance, introduced by Emerson et al. (2012). This framework enables the systematic and empirical assessment of CG processes. For the empirical analysis, we use semi-structured interviews conducted with 18 participants of the Coal Commission and qualitative content analysis (Gläser and Laudel 2010). Our findings may help to further the debate on politics of phasing out coal and achieving just transitions, and contested sustainability transitions in general. In particular, our findings may inform similar stakeholder commission processes in other countries or of other unresolved issues, such as the future of fossil fuel consuming industries.

This paper is structured as follows: Section 2.2 presents the integrative framework for collaborative governance and methods applied. Section 2.3 presents the analysis of the Commission's system context, drivers, and regime formation. In Section 2.4, we present the findings on the dynamics of the Commission. We discuss our findings in Section 2.5 and in Section 2.6 follows our conclusion.

2.2 Theoretical approach and methodology

Participatory governance approaches are receiving increased attention as a means to address resource and environmental conflicts (Newig et al. 2018; Emerson, Nabatchi, and Balogh 2012; Ansell and Gash 2007). Arnstein (1969) emphasizes the different levels of involvement and decision-making power of

citizens and non-state actors naming it “ladder of participation”. The rungs range from nonparticipation, such as manipulation, to some degrees of tokenism, e.g. consultation, to degrees of citizen power with the highest rung being citizen control. Based on this analysis, different forms of participatory governance approaches are defined, which among them include collaborative governance (CG). According to Emerson et al. (2012, 2) one can speak of CG if “people [are being engaged] constructively across the boundaries of public agencies, levels of government, and/or the public, private and civic spheres in order to carry out a public purpose that could not otherwise be accomplished.”

CG can promote consensus-oriented decisions that exceed lowest common denominator compromises in previously highly contested issues (Krick 2015; 2013; Innes and Booher 1999; Sabatier and Weible 2007; Emerson and Nabatchi 2015), and it can help to “neutralize veto positions” (Krick 2013, 28). By including expert knowledge, public interests, and consensus-building in decision-making, CG can increase public acceptance and support for certain policies (Krick 2013; Boswell 2009; Siefken 2016). However, collaboration can also be limited by a lack of win-win scenarios, strong belief heterogeneity, and the high complexity of debated issues. Other potential limitations include power imbalances among participants and stakeholder networks, as well as external pressures (Dutterer and Margerum 2015; Brisbois and Loë 2017; Krick 2013; Brisbois and de Loë 2016a). A highly critical issue for CG processes is furthermore the question of who has access to the process and who not, as well as the inclusion and exclusion of issues addressed in the CG process (W. D. Leach 2006; Newig et al. 2018; Ansell and Gash 2007; Brisbois and de Loë 2016a). Some also criticize CG processes as means to dilute accountability and political responsibility by governments, and the desire to avoid having to make critical decisions (Hanemann and Dyckman 2009; Kallis, Kiparsky, and Norgaard 2009; Krick 2015; Siefken 2016). Evidence that collaborative and other participatory governance processes could improve environmental standards of derived policy outcomes remains scarce (Jager et al. 2020).

The integrative framework for collaborative governance by Emerson et al. (2012) builds on a wide range of literature for the analysis of different forms of collaboration and collaborative processes (e.g. Ansell and Gash 2007; Innes and Booher 1999), and has been widely used to assess collaborative (governance) processes (Emerson and Nabatchi 2015). We use the framework to structure our analysis of the Coal Commission and the decision-making process of its members. This framework has its focus on collaboration dynamics, as laid out in the following section. We complement this with an additional focus on actor networks within and outside of the Commission, influences from outside of the Commission on its work, as well as interests represented in the Commission. These issues can impact the dynamics, as well as the output of such a CG process (Dutterer and Margerum 2015; Krick 2013; W. D. Leach 2006; Brisbois and Loë 2017; Ansell and Gash 2007; Brisbois and de Loë 2016a), and were stressed also in many of the conducted interviews.

2.2.1 Integrative framework for collaborative governance

Figure 3 depicts the integrative framework for collaborative governance as three nested layers comprising the outer *system context* and the *collaborative governance regime* (CGR, which contains the *collaboration dynamics* and *actions*.

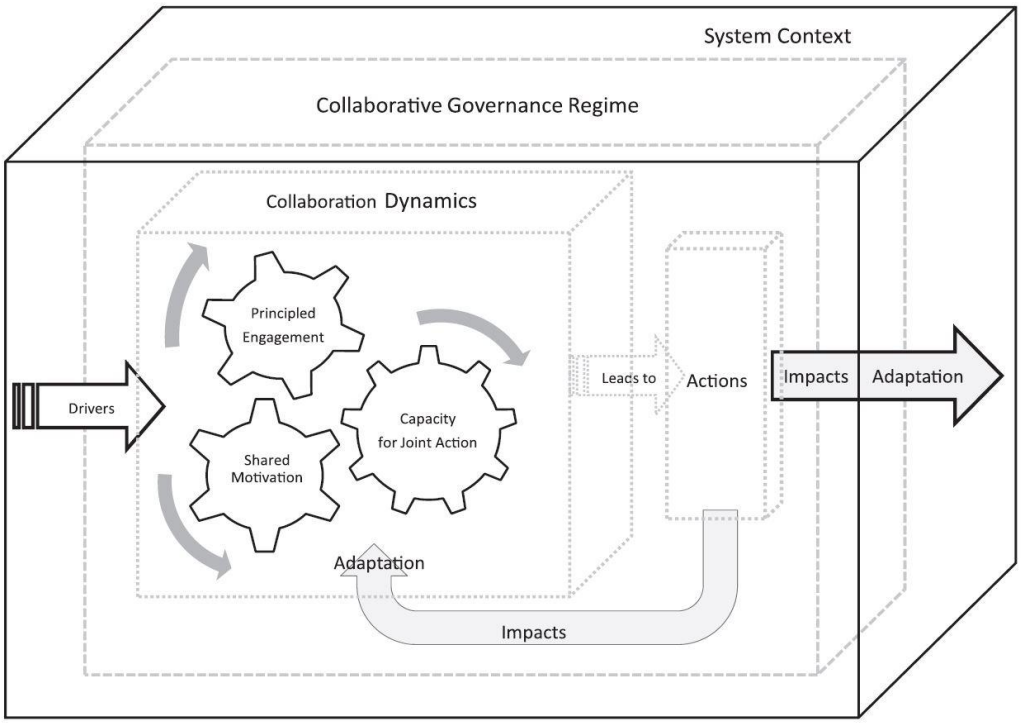


Figure 3: The integrative framework for collaborative governance.

Source: Emerson et al. (2012, 9).

The *system context* includes the "political, legal, socioeconomic, environmental and other influences that affect and are affected by the CGR" (Emerson, Nabatchi, and Balogh 2012, 5). *Drivers* from the system context form and influence the direction of a CGR. This can include, in the case of externally directed CGRs (Emerson and Nabatchi 2015, chap. 8), the formulation of a mandate and the selection of participants. Emerson and Nabatchi (2015, 44) posit that the following four drivers are necessary to initiate a CGR and motivate relevant stakeholders to engage: "(1) uncertainty, (2) interdependence, (3) consequential incentives, and (4) initiating leadership". The studied CGR need to be seen in the historical and surrounding system context, and depend on drivers enabling and forming the CGR. We lay out the system context, drivers, and regime formation of the Coal Commission in Section 2.3.

The CGR encompasses the process of collaboration among the participants, as well as possible actions resulting from this collaboration, which can influence both, the ongoing collaboration, or the outer system. At the heart of the CGR are the collaboration dynamics, which can lead to collaborative actions or outputs, such as a piece of policy advice. They consist of ***principled engagement***, ***shared motivation***, and ***capacity for joint action***, which are in iterative interaction with each other (as depicted in Figure 1). Each collaboration dynamic comprises further elements:

- *Principled engagement* comprises the elements ***discovery***, ***definition***, ***deliberation***, and ***determination***. The process of *discovery* aims to exchange information among participants, to gather new information, and to understand other participants' interests better. *Definition* is about aspects such as agreeing on the boundaries of the problem at hand. The *deliberation* process focuses on the problem-solving-oriented engagement of participants, and exchange among them, in contrast to a "mere bargaining or negotiation" situation (Newig et al. 2018, 283).

Determination includes the joint definition of binding rules and outputs. Many *determinations* are needed to structure the actual collaborative process and to agree on joint outputs (Emerson and Nabatchi 2015).

- S*hared motivation* comprises the elements ***trust***, ***mutual understanding***, ***internal legitimacy***, and ***commitment***. The development of *trust* among participants is essential, enabling open exchange and providing the basis for *mutual understanding*, which "refers to the ability to comprehend and respect others' positions and interests, even when one might not agree with them" (Emerson and Nabatchi 2015, 66). Both of these elements are necessary to achieve *internal legitimacy*, which results in participants trusting in the process and its efficacy. Based on these elements, bonds evolve between the participants of shared *commitment*, "which enable participants to cross the organizational, sectoral, and/or jurisdictional boundaries that previously separated them and commit to a shared path" (Emerson, Nabatchi, and Balogh 2012, 14).
- *Capacity for joint action* comprises the elements ***procedural and institutional arrangements***, ***leadership***, ***knowledge***, and ***resources***. *Procedural and institutional arrangements* comprise "formal and informal rules and protocols, institutional design, and other structural dimensions … [that] manage the repeated interactions of multiple participants over time" (Emerson and Nabatchi 2015, 69). This includes the precondition that the participants have the capacity to make decisions on behalf of the actor group they represent. *Leadership* can be essential in multiple forms, such as to facilitate the deliberation process, to resolve conflicts, or to reach joint decisions. Chairs should therefore be "neutral and skilled mediators" whose main tasks are to implement professional and working norms, to settle disputes between members, and to facilitate an equal say in discussions and decisions for all stakeholders (Sabatier and Weible 2007, 206). Shared *knowledge* about the issues at hand is one of the bases for collaboration. In this context, it can be understood as "social capital of shared information that has been weighed, processed, and integrated with the values and judgments of CGR participants" (Emerson and Nabatchi 2015, 72). *Resources*, such as time, institutional support, or personal connections, are rarely distributed equally among participants. To enable the fair and equal participation of all participants, it is necessary to address differences in resource endowments (Newig et al. 2018; Emerson and Nabatchi 2015).

This framework provides a systematic way to analyze the process and formation of the Commission and its output. To explicitly account for the potential influence of power imbalances among actors within and outside of the Commission, as raised in the literature, as well as conducted interviews, we inductively complement the elements of this framework in the analysis with the categories "stakeholder networks within the Commission", "external influences on the Commission's work", and "represented interests". This enables us to assess how the Commission managed to overcome the stalemate situation and how its final recommendations were formed.

2.2.2 Data collection and analysis

We conducted 18 semi-structured expert interviews with members of the Coal Commission (eleven interviews) or their personal assistants (so called 'sherpas', six interviews), and the administrative office

between November 2020 and March 2021 (chairs and administrative office (4); affected regions and communities (3); environmental associations (4); science (1); trade unions (2); business/industry (3); other (1)). Interviews with participants of the Commission process served to provide information on the inner working procedures, events, and interactions among participants. The sherpas were instrumental in the work of the Commission. They conducted many of the background discussions and coordination, and prepared drafts for later decisions. The interviews lasted between approx. 60 and 90 minutes and were conducted in German. Due to the COVID-19 pandemic, only one interview was conducted in person, all others via the video-conference tool Zoom.[12] The interviews were recorded and transcribed, resulting in 469 pages of interview data.

The semi-structured interview guide was developed based on the integrative framework for collaborative governance and information about the German coal phase-out process collected in advance to the interviews. We used a qualitative content analysis approach (Gläser and Laudel 2010) to process the interview data. We coded for 16 categories using the coding tool provided by Gläser and Laudel (2010). Twelve categories were deducted from the twelve elements of collaboration dynamics (see Section 2.2.1). The categories from the framework were supplemented with the component "covered topics", to provide information on the priorities set in the work of the commission. We added inductively three categories on: 1) stakeholder networks within the Commission; 2) external influences on the Commission's work; 3) represented interests.

Additional information which we use in particular to describe the system context, the drivers and the formation of the Coal Commission is knowledge that was acquired during a research project from 2017-2022 on the German coal phase-out process, including numerous visits to all coal regions and regular meetings with all involved stakeholders, as well as through the insights of published reports, research articles, and documents from the Commission process.

2.3 The Coal Commission: System context, drivers, and regime formation

In Germany, so-called *expert commissions*[13] have a long tradition in the political system, providing advice on a specific topic on an ad hoc basis, or as institutionalized permanent councils (Krick 2013; Siefken 2016). The German Coal Commission is a typical example of such an expert commission with its mandate for policy formulation and its participants fulfilling the dual role of representatives or stakeholders, and at the same time of experts to their specific fields (Krick 2015). In the literature on CG this corresponds to an externally directed CGR (Emerson and Nabatchi 2015, chap. 8). As the integrative framework for collaborative governance describes, processes and developments within the studied CGR need to be seen in the historical and surrounding system context, and depend on drivers

[12] To ensure data protection, a university version of the software was used.

[13] Siefken (2016) defines expert commissions in the German political system as „temporary appointed bodies (…) [whose members] for the most part come from the science community and interest groups – but not predominantly come from the parliament, government, and administration. They are tasked with providing subject-specific sound advice for policy plans, programs and measures" (own translation). Krick (2015) speaks of *hybrid advisory committees*, yet addressing the same bodies.

enabling and forming the CGR. In this section, we describe the historical developments and situation in Germany that led to the initiation of the Coal Commission and composes the system context in which the Commission was situated. This is followed by the drivers and incentives for participation, and the initial formation of the Commission.

Germany began to manage the reduction of hard coal (Oei, Brauers, and Herpich 2019) and lignite mining (Stognief et al. 2019) back in the 1960s. Reasons for the decline in mining were globalization (as imported coal was cheaper) and the later unification of Germany (since industries in the East were less cost effective than those in the West). Overall employment in the coal sector decreased from approximately 600,000 in the 1950s to less than 20,000 direct jobs in 2020. About 40% of German power production in 2017 was based on coal, down from more than 50% up to 2002.[14] In the late 2000s, however, incumbent utilities were still planning to expand coal-fired power generation capacities, and expecting only a slow growth of renewables (Kungl and Geels 2018). Even in the early 2010s, a phase-out of coal power in Germany, parallel to the phase-out of nuclear power, was barely considered in the political debate (Müller-Hansen et al. 2021; Selje 2022; Furnaro 2022).

Towards the mid-2010s, pressure on the coal sector increased. Germany was expected to fall short of its 2020 climate targets, and, furthermore, the Paris Agreement made it seem inevitable that coal use would have to be reduced (Leipprand and Flachsland 2018). Several attempts to regulate the phase-out of coal failed due to resistance by the utilities and mining companies, which saw their business model threatened, and industry actors, which were worried about rising energy prices (Furnaro 2022). In 2016 the so-called 'safety standby' was implemented, which compensates a few selected lignite power plants for shutting down, but failed to initiate the complete phase-out of coal (DIW Berlin, Wuppertal Institut, and Ecologic Institut 2019). Decisions on the future of coal by the governing coalition of CDU/CSU and SPD was further complicated because "(…) the conflict lines did not seem to fall between but within the major political parties, at least the SPD and CDU" (Hermwille and Kiyar 2022, 29). Within the Federal Government, the Ministry for Economic Affairs had tended to argue in favor of the continued use of coal prior to the establishment of the Coal Commission, while the Ministry for the Environment had continuously argued in favor of a phase-out (Markard, Rinscheid, and Widdel 2021). In general, however, the government had been in favor of moderate rather than radical change (Leipprand and Flachsland 2018).

After being strictly against any measures for an early phase-out, a number of unions including ver.di[15] started to consider options for a policy-induced coal phase-out. However, other trade unions, such as the IGBCE[16], continued to lobby for continued coal mining (Kalt 2021). Mining regions feared that they would face negative economic and social consequences due to job and tax revenue losses, and demanded financial support to manage the upcoming transition (Oei, Hermann, et al. 2020). On the

[14] Energy-Charts: Annual net electricity generation in Germany. Available online: https://www.energy-charts.info, accessed on November 19, 2021.

[15] ver.di is the second largest trade union in Germany and represents mostly workers in the service sector, including also workers in coal-fired power plants. However, coal employees are only a small group of the union members. With increasing public support to end the use of coal, also debates within ver.di started in 2016 and its position shifted towards supporting a coal phase-out (Kalt 2021).

[16] Industriegewerkschaft Bergbau, Chemie, Energie – Trade union for mining, chemicals and energy industries.

other hand, local residents feared losing their homes due to the destruction of villages in the event of continued coal mining, and environmental NGOs called for a coal phase-out between 2025 and 2035 (Löw Beer et al. 2021).

Overall, this created a situation of high uncertainty over the future of coal in Germany, with none of the interest groups powerful enough to enforce a decision (Leipprand and Flachsland 2018; Hermwille and Kiyar 2022). The positions around the debate of coal were so divergent that a top-down decision from the government would have been very vulnerable to criticism from all sides, offering little to gain for political parties (Liersch and Stegmaier 2022; Löw Beer et al. 2021). As early as 2016, the Federal Government announced the establishment of some kind of commission in their Climate Protection Plan 2050.

In 2018, the then newly appointed Federal Government implemented the Coal Commission (Grothus and Setton 2020). The appointment resolution, or mandate, of the Commission set out the task to develop an "action program" by the end of 2018 (BMWi 2019, 109). This action program was to ensure the achievement of the Climate Action Plan 2030 target for the energy sector (-61 to -62% emission reduction compared with 1990 levels), while supporting structural change and economic development in affected regions, including the establishment of a fund from primarily federal resources for structural change. Furthermore, it was to include a pathway and a final date for the phase-out of coal-fired power generation. All these aspects were to be combined in a manner to achieve social acceptability and social cohesion (BMWi 2019, 109).

The literature highlights the importance of incentives for cooperation and as a starting point for participation, which played a crucial role in relation to the Commission (Emerson and Nabatchi 2015). Prior to the Commission, the debate on the future of coal in Germany between the involved actors was irreconcilable and its outcome highly uncertain (Hermwille and Kiyar 2022; Leipprand and Flachsland 2018). The participation in the Commission presented the opportunity for actors to actively have a voice opportunity and influence over the future of coal in Germany, as well as over the distribution of funds for structural change. Furthermore, the Commission provided a starting point for cooperation between the different interest groups, allowing to overcome the highly contentious environment (Gürtler, Löw Beer, and Herberg 2021; Hermwille and Kiyar 2022).

The selection of members and the initial formation of the Commission also played a role in stakeholders deciding to join the Commission (Gürtler, Löw Beer, and Herberg 2021; Emerson and Nabatchi 2015). The Commission comprised four chairs and 24 stakeholder representatives with voting rights (hereinafter referred to as (Commission) members). In the run-up to the Commission, established actors were asked for advice, as well as lobbied for the inclusion of certain stakeholder groups (Grothus and Setton 2020). In the end, the Commission represented the major interest groups involved in discourse on coal in Germany at that time (Markard, Rinscheid, and Widdel 2021; Leipprand and Flachsland 2018).[17] Figure 4 shows the different general stakeholder groups represented by the Commission

[17] Some people, however, criticized that no young persons and limited female representation was present in the commission (Löw Beer et al. 2021).

members (Table A 1 in the Appendix provides a detailed overview of all Commission members). However, interests within those stakeholder groups were anything but homogeneous. For example, out of the seven regional representatives, two were against continued mining, representing communities at risk of destruction, while four were in favor of continued mining, for example, due to the impact on jobs. Considering the members' general positions regarding an early coal phase-out, around one third each of the 28 members were considered as being inclined towards an early coal phase-out, against it, or undecided, based on their institutional affiliations (Bang, Rosendahl, and Böhringer 2022; Agora Energiewende and Aurora Energy Research 2019; Löw Beer et al. 2021).

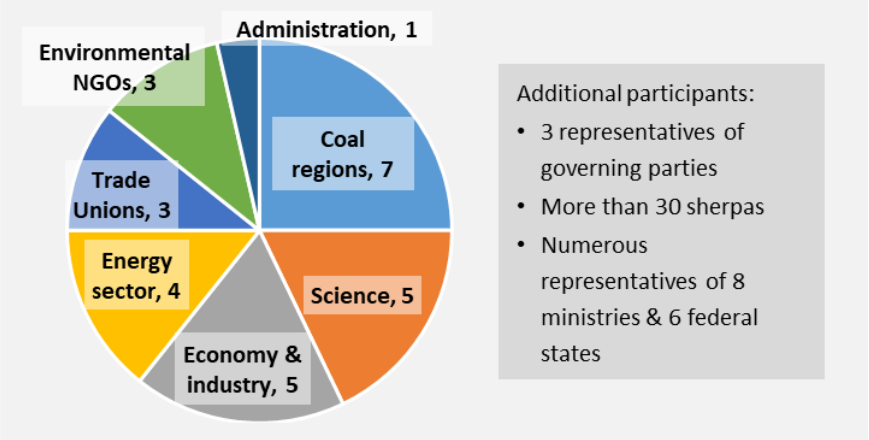


Figure 4: Affiliations of the 28 members with voting rights and additional participants.

Source: Authors' depiction based on BMWi (2019).

All 28 members were allowed to bring along with them personal assistants without voting rights, who were referred to as 'sherpas'. In addition, three members of the German parliament (from all governing parties), eight representatives from related ministries and six members from federal states were appointed as participants without voting right – resulting in plenary sessions being held with around 100 participants. An administrative office was formed to support the Commission's work.

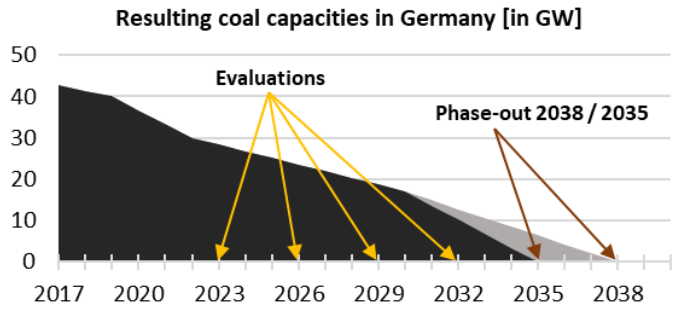
The Commission convened for the first time on June 26, 2018. Nine further plenary meetings and visits to the three lignite regions of Germany were held over the next few months, culminating in a final report agreed upon by 27 (out of 28) members on January 25, 2019.[18] During its process, 67 additional external experts were invited to provide input so as to pave the way for a sufficiently fact-based decision-making process.

Figure 5 shows the Commission's central recommendations, which include a phase-out pathway for German coal-fired power generation, measures to support structural change in the affected regions, and financial support and compensation.

[18] One person representing the Lusatian coal region voted against the outcome as her demands to guarantee the safeguarding of villages in Lusatia from potential destruction was not included in the final report.

Financial aspects

- ✓ €40bn in transition measures in coal regions: €1.3bn annually for 20 years for specific measures (controlled by federal legislation), €0.7bn annually for 20 years at the disposal of the federal states. Only some funds will represent additional funding (mainly a re-distribution of existing funding mechanisms)
- ✓ Costs and conditions for compensating utilities subject to negotiations with government at a later stage (~€4.2bn as of 2021)
- ✓ Early retirement/adaptation allowance mechanisms (labor market policies following the blueprint of German hard coal mining phase-out)



Energy & Climate

- ✓ 12.5 GW of coal capacity will go offline by 2022, only 17GW remain by 2030 (~40 GW in 2019)
- ✓ Phase-out date 2038 with the option of an early phase-out by 2035
- ✓ Confirmed target of 65% renewable electricity production by 2030

Program on structural change

- ✓ Infrastructure & investment support (e.g. transport, digitalization)
- ✓ Innovation (set-up and funding of research institutions in the mining regions, demonstration projects, innovation zones)
- ✓ Establishment of government agencies
- ✓ Civil society and community support programs

Figure 5: Recommendations of the German Coal Commission.

Source: Authors' depiction based on BMWi (2019).

2.4 Coal Commission CGR: Developing joint recommendations for the German coal phase-out

In this section, we present our findings for the collaborative governance regime of the German Coal Commission. Based on the information collected in the interviews and documents, we have assessed to what extent the process in the Coal Commission has taken into account the various elements of CGR. Furthermore, we have identified in which way these individual elements contributed to the members achieving to breach the previous stalemate situation and to find a common compromise, as well as issues that negatively influenced the Commission's work. In the Appendix we present the results for the full list of elements of the CGR. In the following, we briefly describe the main results. In the subsequent analysis, we focus on the central findings and describe them in detail.

2.4.1 Establishing basics for collaboration and working structures

The challenge facing the Coal Commission was to find compromises between the conflicting goals of the numerous interest groups involved. Furthermore, many of the Commission's members and participants had been involved personally in the long-lasting conflict over the future of coal production and power generation in Germany, and animosities among different members existed at the start [int_5; int_11]. However, as detailed in Section 2.3 above, the mandate offered a strong incentive for stakeholders to engage in the process of the Commission and thereby potentially be able to influence German energy and structural change policies.

The expert hearings during the first meetings in the Coal Commission, the site visits, and one joint dinner offered the opportunity to get to know the other participants without having to engage in (public) fierce discussions and bargaining [int_1; int_5; int_6; int_11; int_13]. Furthermore, these exchanges, as well as the later work in small and confidential rounds, contributed to improve the mutual understanding of positions and objectives, and to build up trust between members [int_1; int_5; int_8; int_10; int_13; int_16]. Confidence in the process and its effectiveness to find common solutions and recommendations was high among most members [int_1; int_8; int_10; int_16]. Over time, the majority of members became seriously engaged and were motivated to contribute to a successful outcome of the Commission [int_1; int_8; int_10; int_15]. Several interviewees pointed out that this built up mutual trust and understanding among members across divides of interest groups, and their shared commitment to the process were key enabling factors for constructive and enduring negotiations [int_5; int_11; int_16].

> *"[…] it was also a very important point in this Commission's work that Commission members from different camps trusted each other, trusted each other's professionalism, trusted each other's values, trusted each other to get through things."* Interview_11.

Several interviewees mentioned that arranging more meetings of an informal nature, such as the one joint dinner, and earlier during the Commission's working period, would have been means of increasing trust and understanding among members even further [int_1; int_3; int_5; int_11]. In contrast, leaks of information from plenary assembly meetings to the press challenged the trust in others and the process itself [int_2; int_5; int_7; int_8; int_17], yet, other experienced negotiators were not surprised by leaks in such a political process [int_6; int_9].

The leaks, and the large size of the plenary assembly meetings, often with 100 or more participants, did not allow for a constructive working atmosphere in these meetings [int_10]. Members therefore rarely departed from their initial positions and little progress was made in these meetings, and the large size made it impracticable for drafting texts [int_5; int_12; int_14; int_16].

> *" […]it became clear that a lot of time could pass in such a large group, but in the end, there would be no coal compromise. And then there were considerations to convene a group of people who had been in the Coal Commission, who more or less represented all groups and were accepted by all. The group was then supposed to try to discuss and negotiate all the central issues in some form in as protected a space as possible."* Interview_9.

Figure 6 provides an overview of our findings on positive and negative influences and aspects of the collaborative governance dynamics in the German Coal Commission.

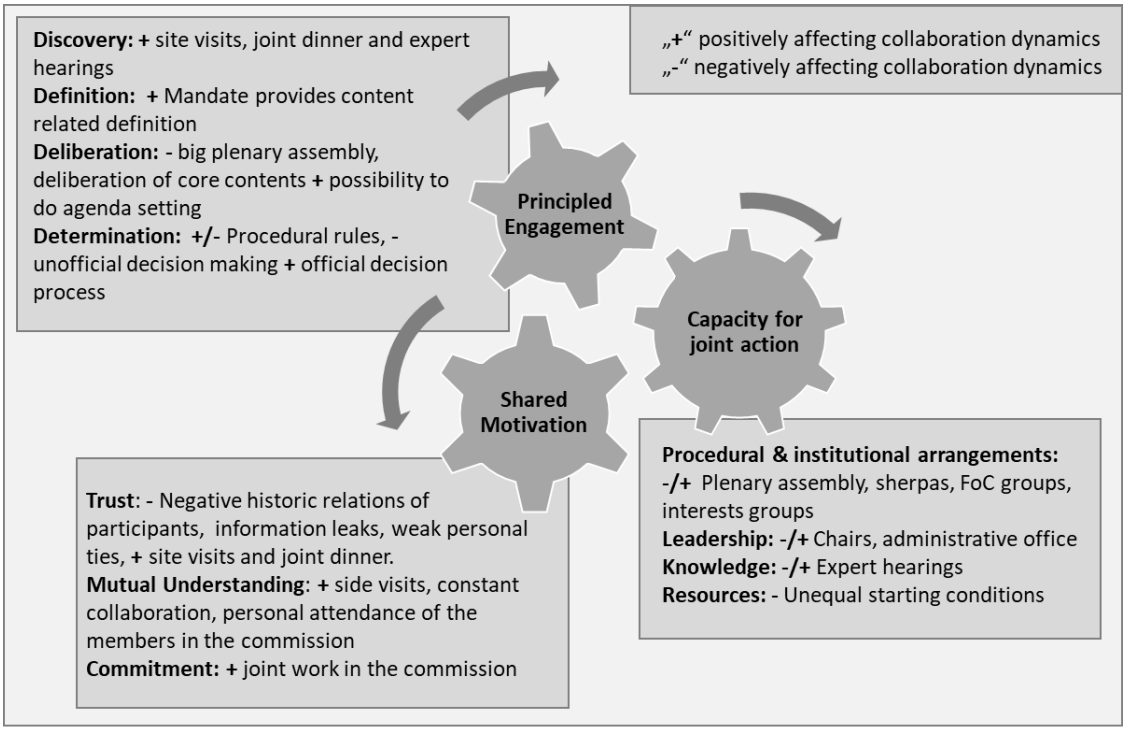


Figure 6: Overview of main findings on principled engagement, shared motivation and capacity for joint action in the German Coal Commission

Source: Author's depiction. For an exhaustive list and further details see Appendix Table A 2.

2.4.2 Topical split: energy vs. structural change

The commission in one of their first meetings decided to split the group in two working groups, one for "Energy Industry and Climate Targets", and one for "Economic Development and Jobs in the Regions" (BMWi 2019, 111) to separate and ease the discussions and deliberations [int_8]. However, commission members did not want to be absent in either of the groups as the topics were closely linked and interest groups needed cohesion funds as well as phase-out dates as bargaining power. Besides agreeing on such funds, the environmental interest group had little to bargain within the discussions, except the threat of leaving the Commission [int_3; int_8]. Thus, after having met in these subgroups only once, it was decided to convene instead in the plenary assembly only [int_7].

The writing of the draft for a first report of the Commission in October 2018 was delegated to the administrative office. However, several members perceived this draft as politically influenced[19] and requested changes in the organizational and working structures of the Commission [int_5; int_11; int_14]. As a result, one of the chairs set up the first so-called *Friends of Chair* (FoC) group and selected six Commission members for it [int_11].

[19] The administrative office of the Coal Commission, tasked with providing administrative assistance in the form of organizing expert hearings and site visits, or drafting texts, was criticized for not working transparently, as well as for reaching politically influenced decisions [int_5; int_8; int_10; int_12]. This criticism was nourished by the staffing of the administrative office, which was thought to be politically motivated. For example, some staff had been posted from administrations of affected federal states [int_5; int_8].

2.4.3 The Friends of Chair groups

In this first FoC group on “energy and climate”, two out of six members represented environmental interests, while the others represented the energy sector, industry, and unions (see Table A 1 for an overview of members of the FoC). Members representing locally affected people were not part of this FoC [int_5; int_6; int_9]. The second FoC group on “structural development and employment” was only implemented in November, after several federal state prime ministers had intervened and demanded greater support for affected coal regions. This second FoC group mainly included members that represented local and regional economic interests, as well as employees’ and employers’ interests. Several interviewees stressed that the adequate choice of the FoC members was an important factor for the successful work of the FoC groups [int_5; int_9; int_11; int_13]. In particular, the FoC members needed to represent sufficiently all interest groups, be accepted by their constituency to negotiate in their name, and be willing to engage in finding compromises.

These FoC groups, although not provided with an official mandate by the Commission’s plenary assembly, became central institutions of the further deliberation process on the way to the joint recommendations. In these groups, the critical details were discussed and texts for the interim and final reports prepared [int_5; int_6; int_8; int_9]. Their intimate and high-level character contributed to foster trust and shared commitment among the involved members, and a goal-oriented working atmosphere [int_5; int_9; int_11; int_13]. The confidential nature of the FoC groups allowed their members to depart from their public demands, or temporarily surpass their constituency’s “red lines” (which would not have been possible in public or in the plenary), to explore possible compromises [int_5; int_9]. From their initiation on until mid of December, the FoC groups convened very frequently, often multiple times per week [int_5]. In this process, the sherpas of the FoC members played an important role, meeting in FoC sherpa rounds, and preparing text drafts that then were further discussed and refined by the FoC members to be then introduced in the plenary assembly [int_5; int_10; int_11]. The plenary assembly remained the institution, where decisions had to be passed by a two-thirds majority to be included in the Commission’s recommendations.[20]

2.4.4 The night of the final negotiations

The general parts of the final report were prepared by the FoC groups and the administrative office, and decided upon in the plenary assembly. However, key issues, like the concrete phase-out pathway and end date, and the size of the structural change fund, remained open questions and were not talked about in the plenary until the last day of the Commission [int_5; int_7; int_10]. After convening in the plenary assembly during the last day without resolving these issues, members of the FoC and the chairpersons met separately to negotiate compromises for these points [int_5; int_11].

[20] While the mandate for the Coal Commission included the objectives and the list of appointed chairs and members, it did not specify the working procedures of the Commission. Thus, one of the first tasks of the Commission was to agree on and pass procedural rules for its work, which happened during the first plenary assembly meeting of the Commission [int_3; int_10]. It was determined that decisions would have to be passed by the members with a two-thirds majority in the plenary assembly, which should guarantee that no decision could be passed without the consent of one of the major interest groups [int_3].

First, a decision on the part on structural change was made, before starting the final negotiations on the coal phase-out pathway and date. Thus, compromises concerning the latter issues had to be reached within this same field, excluding compromises including structural change questions [int_3]. Furthermore, members of the environmental group generally supported demands for a just transition for workers and structural change in the affected regions, while the trade union representatives, on the contrary, did not support the demand by the environmental group for a timely coal phase-out to the same extent. This eventually weakened the negotiating position of the environmental side towards the unions regarding an early phase-out [int_1].

These negotiations were led rigorously among the participants. This also included uncollaborative behavior, such as taking advantage of the short-term absence of individual members to change previously mutually agreed wording in the draft of the recommendations [int_11]. The members participating in these discussions then met during several pauses with the other members of their interest groups to consider possible compromises and red lines, and continue the negotiations based on these interest group positions [int_5; int_11]. Despite continuously large conflicts of interest and the tough style of the negotiations, members finally reached compromises for all remaining issues [int_11]. This was also driven by the fear of an overall failure of the Commission, if no solution would have been found during that night; the continuation of talks on the next day was no option due to the risk of leaks and resulting external pressure in case of any interruption of the negotiation talks [int_6; int_11].

2.4.5 The Commission's chairs

The role of the chairpersons was described as very ambiguously. Many of the interviewees perceived the chairs as advocates for certain interests,[21] and counterpart for the associated interest groups only, rather than as neutral moderators [int_3; int_9, int_12]. Several interviewees also criticized missing concepts and moderation by the chairs to facilitate more inclusive exchange and communication within the Commission, and effective problem-solving approaches [int_5; int_11; int_13]. In the beginning, it remained unclear how the Commission would arrive at joint decisions or who would write the Commission's reports [int_3; int_7].

> *"[…] I don't think anyone [of the chairpersons] really had a concept of how a Commission has to go through different phases and then also come to results, which to some extent sees the different interests and then creates a balance of interests instead of the smallest common compromise."* Interview_3.

On the other hand, several interviewees mentioned that the leadership by the chairs, and particularly by one of the chairs, who was perceived by many as the unofficial leader of the Commission (due to being most partisan and well connected to the government), was very important for the successful deliberations and decision-making in difficult situations [int_6; int_7; int_13; int_15; int_16]. It was also

[21] Two chairs were associated with the structural and economic interests of coal regions, one was perceived as also representing Federal Government interests and one was associated with environmental interests.

this chair who had chosen the members of the first FoC group, which was perceived as an important decision for the successful deliberations in this group [int_5; int_9; int_11; int_13].

2.4.6 Role of federal state representatives and national government

The federal states had representatives in the Commission in the form of two former federal states prime ministers, serving as chairs. In addition, each affected federal state could send additional representatives without voting rights to the Commission. Often, the active federal (prime) ministers from these states made use of this opportunity personally and engaged very directly in the work of the Commission [int_3; int_5; int_11].

> *"[…] the prime ministers […] not unskillfully maneuvered in such a way that the federal states had the right to intervene and speak in the Commission at any time. They made extensive use of this […] so that the federal states were very, very strongly represented in the Commission with their statements."* Interview_16.

It was considered important to address the interests of the federal states, as it was clear to the Commission members that they could potentially block the implementation of measures at a later stage [int_5; int_8; int_11]. The federal state governments involved had been strong supporters of continued coal mining in the past (Hermwille and Kiyar 2022). Furthermore, the (former) prime ministers of Eastern federal states continuously expressed the fear of an early coal phase-out driving voters into the arms of the party of the extreme right, the *Alternative für Deutschland* (AfD), at the then upcoming federal elections [int_1; int_7]. In November 2018, the Commission was about to agree on the first part of the final report on measures for structural change. However, the prime ministers considered the foreseen funds for affected regions as too low. Subsequently, Chancellor Merkel ordered the Commission to resume its work and revise its recommendations, effectively delaying the Commission and potentially increasing total funds for the coal regions [int_5; int_6; int_14].

The possibility to make relatively unrestricted recommendations for the size of the fund for structural change, the establishment of which was provided for in the mandate, comprising primarily federal resources (BMWi 2019), provided an important leverage for compromises. Federal state governments were willing to give up their opposition to the coal phase-out to some extent in turn for financial compensation [int_5; int_6; int_12; int_15].

> *"[...] because whether they get another billion or not for structural measures - that's decisive for a prime minister when he says I'm also getting the railway line. For the environmental side, which is fighting for the climate, it doesn't matter."* Interview_16.

The Federal Government was furthermore indirectly involved in the Commission's work through its close contact to one of the chairs [int_9; int_14]. The ministries' representatives were not publicly active within the plenary sessions, but in the background, had continuous close consultations to check whether the discussed proposals could actually be implemented [int_11; int_16].

2.4.7 Members' participation possibilities and influence

Most interviewees stressed the different roles and participation possibilities of the individual Commission members. Depending on their negotiation experience, connectedness, expertise, and available

resources (e.g., time, staff), members had higher or lower chances to influence the Commission's work [int_7; int_9; int_11] (also see Table A 3 in the Appendix). As described above, key deliberation processes took place outside of the plenary assembly, for example, in the FoC groups or bilateral talks in between sessions. Even though several interviewees stated that, the composition of FoC groups represented all interest groups [int_5; int_6; int_9; int_13], access to these groups remained exclusive [int_11]. This limited the possibility for many members to participate in deliberating the core contents, because they were constrained to introduce their opinion into these groups via other members of their interest groups [int_3; int_4; int_13; int_15]. For the coordination and consultation within interest groups, these met separately from the other Commission meetings throughout the process of the Commission [int_5; int_11]. Many decisions, like who would belong to the FoC groups, were not discussed nor decided by the plenary assembly, but by the chairs after consulting with individual members [int_3; int_5; int_11; int_12]. Members without experience in such processes found it hard to know how to introduce and enforce their demands in the right way, at the right place and the right time [int_4; int_12]. For example, while all members were able to make demands and suggest topics for debate in the plenary assembly, topics usually had to be supported by other influential members or FoC groups to be considered for debate within the FoC groups where the first drafts of documents were written [int_16].

2.5 Discussion

In the above analysis, we show how the German Coal Commission reached an agreement on the future of coal supported by all major interest groups (Hermwille and Kiyar 2022). Stakeholder commissions as such offer the possibility of breaking stalemates and triggering a ratcheting-up of climate policies down the road. In Germany, the next government (from 2021 on) started discussions and planning for advancing the coal phase-out from 2038 to 2030 (Bang, Rosendahl, and Böhringer 2022). Yet, the Commission was also criticized for delivering a late and expensive coal phase-out within their recommendations. In the following, we discuss our findings on how the Commission breached the stalemate situation and how its final recommendations were formed.

The Commission created and fostered a collaborative environment, enabling the cooperative work on finding joint solutions. It provided a space for individuals representing the various interest groups to get to know each other on a personal level and engage in a direct exchange. This contributed to increase the level of mutual understanding and trust, and the willingness to find an agreement. This can be considered a major achievement of the Commission compared to the previous situation, in which pro- and contra-coal interest groups formed "enemy camps" (Grothus and Setton 2020, 283). Despite some drawbacks (e.g., limited opportunities for informal exchange among participants; insufficient confidentiality of Commission meetings), the Commission's members developed a shared commitment to engage intensively to achieve the Commission's objectives, a precondition for successful collaborative policy formulation processes (Ansell and Gash 2007; Emerson, Nabatchi, and Balogh 2012).

However, the willingness of the different interest groups to participate and engage in such a collaborative approach, working on compromise-based policy recommendations, depends on the lack of alternatives to enforce a unilateral policy formulation (Emerson and Nabatchi 2015; Sabatier and Weible 2007). The

context of the German Coal Commission was characterized by the highly contested and uncertain future of coal, the lack of sufficient power for one interest group or coalition to enforce their interests (Hermwille and Kiyar 2022), and political parties with more to lose than to gain from taking the responsibility for a decision (Löw Beer et al. 2021). In this situation, leaving the decision to a stakeholder commission offered policymakers the possibility to dilute responsibility and gain legitimacy for a derived policy (Gürtler, Löw Beer, and Herberg 2021), and interest groups the possibility to actively shape a possible policy formulation. On the other hand, the participants knew that it would be very difficult to enforce their interests outside of the Commission, and leaving the Commission would have born the risk of leaving the decision up to others.

Yet, aligning the objective of an early coal phase-out with (local) economic and political interests remained challenging. In the Coal Commission, this dilemma was eased by public funds at hand of the Commission to distribute among affected stakeholders – substantially burdening the taxpayers, without having them explicitly represented. This was possible to do so in Germany, given its economic capacities, and may not be possible in countries with less economic capacities or in times of crisis. In historic comparison, costs implied by these recommendations amount to only about one-fifth to one-third of the sum of subsidies paid to hard coal production in Germany between 1950 and 2008 (Hermwille and Kiyar 2022), and further subsidies had been paid to hard coal production until the end of hard coal mining in Germany in 2018. Nevertheless, high costs and payments to individual stakeholders, if perceived as not serving the common good, bear the risk of reducing an agreement's legitimacy (Gürtler, Löw Beer, and Herberg 2021). The commission's composition was perceived as relatively balanced and comprehensive, including representatives from locally affected people, industry, unions, environmental associations, science, and regional and national politics. Thus representing the major coalitions involved in discourses on coal in Germany during that time (Markard, Rinscheid, and Widdel 2021). Regarding gender aspects the Commission was less balanced, with only ten female members out of 28. Although jobs in the affected regions are likely to be created in the service sector, in which women make up the majority of employees (Walk et al. 2021), discussions focused heavily on male dominated industrial jobs. However, to achieve just transitions in coal regions for all, it is key to actively consider gender aspects throughout the entire process (Braunger and Walk 2022).

Gürtler et al. (2021) find that the German Coal Commission partly derived its legitimacy from its bottom-up rhetoric of including regional stakeholders' interests, yet ultimately led to recommendations for top-down policies. One reason for the limited bottom-up character of the recommendations might have been, apart from the comprehensive mandate (Gürtler, Löw Beer, and Herberg 2021), the difficulties of stakeholders representing local interests to participate effectively in the Commission process, due to limited negotiation experience and other resources. Few influential members of the Commission drafted and decided largely upon key contents of the final recommendations, a regular issue of such collaborative processes (Brisbois and de Loë 2016a). A leadership more sensitive to such power imbalances as well as additional resources to level the playing field might be able to remove some of these barriers (Newig et al. 2018). In addition, younger generations and perspectives from countries most affected by the climate crisis were barely represented.

Overall, the Commission facilitated the members to decide on joint recommendations and with this overcoming the stalemate in the contentious environment. While the collaborative setting contributed to

reconciling previously heated and emotional debates, it was also the very specific contextual situation at that moment in time in Germany that all veto players considered participating in the Commission and passing a joint agreement as best option to pursue their political interests. Not considered here due to the scope of the study, but relevant for further considerations are the later differences in the law that was passed to implement the coal phase-out ("Kohleausstiegsgesetz", eng. coal phase-out law) compared to the Commission's recommendations. Key members of the Coal Commission criticized among other things that the implemented phase-out was slower than agreed upon in the Commission and publicly withdrew their support.[22] Furthermore, the relatively costly approach with large public funds for structural change and other measures raises the question to what extent the German Coal Commission case could be an example for other phase-out decisions

(Hermwille and Kiyar 2022). Considering economic possibilities and functioning of government, similar processes to promote a just and timely coal phase-out might also be an option for some other major coal producing and consuming countries like Australia or the USA (Jewell et al. 2019). Due to the regional concentration of the coal sector in both countries, and the decentralized federal system, processes in these countries could focus on a state level, such as already started in Colorado, USA.[23]

Limits to our study include, that it cannot be determined for sure whether a counterfactual policy formulation process, for example, a citizen forum, or simply a decision by the Federal Government would also have achieved a coal phase-out agreed upon by the diverse interest groups. Furthermore, our study is based on a single case in a wealthy country. Another advantage for the German coal commission was the existence of numerous studies that had investigated potential techno- and socio-economic effects of different coal phase-out scenarios in Germany. Since energy transitions in general are very context-specific processes, it is rather difficult to generalize our results. A comparative study, possibly including other forms of collaborative institutions such as citizen assemblies, could nevertheless help to improve our understanding of the possibilities of collaborative governance approaches to manage phase-out processes in line with ambitious climate targets.

2.6 Conclusion

The recommendations of the German "Commission on Growth, Structural Change and Employment" on a coal phase-out pathway and structural change measures were a important step to ending the use of coal in one of the world's major coal consuming countries, easing the following decision by Europe to target climate neutrality by 2050. Prior to the Commission, the situation was "highly contentious" with counteracting objectives and heated debates between different interest groups leading to a stalemate situation in the debate about the necessary coal phase-out.

[22] Deutscher Naturschutzring (January 21, 2020): Mitglieder der Kohlekommission zur Aufkündigung des Kohle-Kompromisses durch die Bundesregierung. https://www.dnr.de/presse/pressemitteilungen/mitglieder-der-kohlekommission-zur-aufkuendigung-des-kohle-kompromisses?L=928, last accessed March 31, 2022.

[23] World Resources Institute (April 1, 2021): Colorado, United States: State-Level Planning for a Just Transition from Coal. https://www.wri.org/update/colorado-united-states-state-level-planning-just-transition-coal, last accessed May 11, 2023.

This paper explores the role of the Coal Commission to reach joint recommendations in the debate on the coal phase-out in Germany and how they were formed. We find that the Commission helped to find joint recommendations and overcome long standing stalemate situation by providing a safe space to build up trust and understanding which was important considering the highly contentious situation. The broadly defined mandate and the provision of public funds by the Federal Government largely defined the possible solution space for the Commission. It significantly influenced the willingness of incumbent actors to participate and agree on a phase-out by offering high compensation payments to affected regions and companies. Furthermore, the political and economic pressure and absence of other alternatives contributed to actors' willingness to engage in the Commission and find joint recommendations. Having shifted discussions in Germany from if to how to do a coal phase-out, enabled the next government to raise ambitions and start planning for a coal phase-out by 2030 instead of 2038.

Critical aspects concerning the work within the Commission are the fact that although the Commission provided a general CG setting, yet inclusive and win-win-oriented collaboration only played a limited role in the process. Instead, the final recommendations were rather the result of tough negotiations. Existing power imbalances influenced the way members could participate resulting in a domination of the decision-making process by certain members. Nevertheless, the Commission managed to overcome a decade-long stalemate that several other attempts by the government had failed to resolve.

While the findings of this study are context specific, some general conclusions regarding the potential role of CG in future sustainability transitions can be drawn:

- A CG process can not replace the political decision-making process to initiate a transition. Only if the political objective to achieve a transition is credibly stated, potential veto players will start engage in the discussion of how to design this transition.
- The establishment of a CGR at national level and the inclusion of regionally affected actors at the same time can lead to strong power imbalances due to the different experiences of the members in negotiation processes. Research on CG points to a number of strategies that can be used to empower less-powerful or underrepresented groups (see e.g. R. Lasker and Weiss 2003; Mitchell 2005).
- The facilitator should be experienced in CG processes and be considered neutral. Facilitation experience is more important than expert knowledge on the CGRs topic. There are comprehensive findings on this from CG research (see e.g. Ryan 2001; R. D. Lasker, Weiss, and Miller 2001).
- Time must be allowed for a transparent process, for finding a common way of working, and for periods of reflection on the working process. Needs for changes in the working process may arise over time. Changes to working procedures should be made transparently to avoid losing internal legitimacy.
- Spaces must be created for open and trustful exchange and discussion among members to allow for exploration of practical compromises beyond publicly stated red lines.

The setting up of a commission or another form of collaborative governance can, under certain conditions, contribute to advancing a transition process. It can help to bring opposing parties together, enabling them to find compromises and overcome political stalemate. The more the structures of the

GGR are designed to develop collaborative dynamics, the more participatory and thus legitimate is the process. A CG process can help to increase the acceptability of the intended changes. However, it is in no way a panacea and does not replace the political process and the political decision to undertake a transition, but only can support the design and implementation of the transition process.

Chapter 3

"Nodding through" or decision-making? Local actor participation in the coal phase-out in Lusatia, Germany*

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3 "Nodding through" or decision-making? Local actor participation in the coal phase-out in Lusatia, Germany

3.1 Introduction

The German decision to phase-out coal is accompanied by an unprecedented amount of €40 billion in regional transition funds to support affected regions as stated in the coal phase-out law (*Kohleausstiegsgesetz),*[24] creating a unique situation where the question of how – and for what – this money is spent is not only of interest to the people in the regions but can also inform other regions with similar transitions ahead. The lignite mining region of Lusatia (*Lausitz*) in eastern Germany receives a share of €17.2 billion. Lusatia is located at the border of two federal states, Brandenburg and Saxony, each of which has its own procedure for allocating its respective share of the funds. Both include local actors in the process of selecting project proposals to receive funding but differ in the authority and involvement of local non-state actors.

Lusatia provides an insightful case study not only because it is one coal region with two parallel institutional frameworks for managing the transition, but also due to its history. The coal phase-out is already the second major transition process after the sudden structural break following the German reunification led to large-scale deindustrialisation and social dislocations, this first transition process having been handled in a very top-down manner and resulted in widespread feelings of powerlessness and being left behind (Stognief et al. 2019; Walk and Stognief 2021; Morton and Müller 2016). A declared aim of today's regional transition policy is to include and strengthen regional participation, i.e. in the formal process of selecting projects to receive funding.

The distribution of transition funds is interesting as this money has been a deciding factor in the negotiation of the phase-out decision and a means to increase acceptance. Now that the German coal phase-out is in its implementation phase, questions of justice in the distribution of these funds become highly relevant, as voices from the region describe the participation processes of the distribution of the transition funds as not satisfactory. We are interested in whether the participation processes in Lusatia keep their promise of anchoring the transition in the local population and avoiding a repetition of the top-down management of the 1990s.

Considering the urgency of fossil fuel phase-outs globally, the question of how mining regions and communities can cope with the transformation is receiving increasing scientific interest (cf. Johnstone and Hielscher 2017; Campbell and Coenen 2017; Stognief et al. 2019; Wirth, Černič Mali, and Fischer 2012; Reitzenstein et al. 2022). The concept and policy agenda of just transitions acknowledge the need to handle phase-out processes in an inclusive and participatory way (Newell and Mulvaney 2013). The coal industry is often a pillar of regional identity and has a strong socio-economic and socio-cultural influence on local communities (Cha and Pastor 2022; Harrahill and Douglas 2019; Oei, Hermann, et al. 2020; Walk et al. 2021; Braunger and Walk 2022). Participation, if well implemented, can increase

[24] Bundesregierung. 2020. Gesetz zur Reduzierung und zur Beendigung der Kohleverstromung und zur Änderung weiterer Gesetze (Kohleausstiegsgesetz). https://www.gesetze-im-internet.de/kohleausg/Kohleausstiegsgesetz.pdf. (For background information on the legal and institutional framework of the transition, see Appendix 0.)

representation, social acceptance and trust, being a key aspect of procedural justice in transitions (Stober et al. 2021; Newig et al. 2018).

While participation processes are becoming more and more common in sustainability transitions, many are mere consultations or have other design or implementation flaws that limit their potential to strengthen a just transition (Lelieveldt and Schram 2023; Galende-Sánchez and Sorman 2021; Purdy 2012). Within transition and participation processes, it is important to study power dynamics in attempts to politically steer sustainability transitions (Partzsch 2017). This includes, for example, studying what parties are included or excluded, who sets the agenda and (unduly) influences other actors, and what outcomes result from participatory forms of governance (Huxham et al. 2000; Newig et al. 2018; Sovacool and Brisbois 2019; Purdy 2012; Cook 2015; Huang and Chen 2021).

We take a closer look at Lusatia to analyse the distribution process of transition funds in the two federal states, focusing on local actors. We are interested in the role these participation processes play in the transition process of phasing out coal and whether they support a just transition, addressing the following research questions: (1) What power dynamics can be observed in the participation processes and what factors enable or hinder the capacity of local actors to affect outcomes? (2) Are there deficits in the participation processes that hinder the support of just transition processes?

We compare two distribution processes in a similar socioeconomic context, in Brandenburg and Saxony. We describe the overarching conditions and relevant actors to account for the specific regional context of Lusatia, reconstruct the processes by dividing them into four phases and identify when and by whom decisions are made, and place the processes in the context of transition planning. Our research is based on 15 semi-structured interviews with actors from regional transition agencies, CSOs, and policy circles.

We find that when and by whom important decisions are made is crucial for participation processes. In Lusatia, much actual decision-making power remains with a small number of public actors[25] and is largely exerted outside the phases of non-state actor involvement. These deficits in participation also affect the just transition as they hinder capacity building, frustrate participants, and weaken the sustainability of outcomes.

Our empirical case study contributes to the literature on the role of participation in just transitions on a local level by shedding light on power dynamics in participation processes in transition planning (Wang and Lo 2021; Huang and Chen 2021; Köhler et al. 2019). We contribute to the discussion of how participation can be used in transition governance, empower communities and local actors, and help achieve just and sustainable outcomes. With the ongoing debate on the global fossil fuel phase-out and energy transition in general, this paper's findings are relevant for other regions with similar transitions ahead.

[25] We use the term "public actors" to denote actors from government and administration, including publicly owned companies relevant to the processes, but excluding nonexecutive actors (such as public universities).

3.2 Theoretical background

The concept of a just transition, initially coined in the 1980s in the context of labour movements, has become one of the key concepts in the study of the social and economic impacts of moving away from fossil fuels (Wang and Lo 2021; Braunger and Walk 2022; Cha and Pastor 2022; Wilgosh, Sorman, and Barcena 2022; Stevis and Felli 2020; Harrahill and Douglas 2019). Key pillars of the just transition concept are distributional, restorative, procedural and recognition justice (Heffron and McCauley 2018). Procedural and recognition justice are closely related to each other and to participation processes, as they are both concerned with structural sources of inequality and oppression. Procedural justice is about mobilising local knowledge, representation of various voices in institutions, information disclosure (transparency), sharing of knowledge, and developing an understanding of the situation. Recognition justice addresses the (non)recognition or misrecognition of social groups (or areas) and is concerned with respecting vulnerable groups and deals with inclusivity and identity in transition processes. Distributive justice deals with how burdens and benefits are distributed in the energy transition, e.g. through participatory approaches. Restorative justice puts a focus on the remediation of past harms to people and the environment (Wang and Lo 2021; Wilgosh, Sorman, and Barcena 2022; McCauley and Heffron 2018; Jenkins et al. 2016; Huang and Chen 2021).

There is a growing body of literature on just transition and its definitions, resulting in different terminologies and classifications (Stevis and Felli 2020; Wang and Lo 2021; Just Transition Research Collaborative 2018). Wilgosh, Sorman, and Barcena (2022) synthesize different understandings of just transition into two major streams: (1) the limited approach, which is status-quo, market-based-solutions, and employment-oriented, and (2) the transformative approach, which is inclusive and structurally transformative oriented. Participation in a limited approach is represented by a top-down, symbolic structure and consultation without co-creation and equal partnership, while the transformative approach is marked by collective ownership and bottom-up transition processes. Thus, in a transformative sense, the purpose of participation is to give the collective (and alternative) visions of actors influence on the actual outcome of participation processes and the transition in general. This is often referred to as “meaningful” participation (Wilgosh, Sorman, and Barcena 2022). Cattino and Reckien (2021) map out conditions for meaningful participation: full decision-making power of the involved public and clear and meaningful engagement in all decision-making stages to be able to steer the process, recognition of all actors, and providing processes that support a logic of welfare and social security. Arnstein (1969) has developed the “ladder of participation” whose rungs represent different levels of giving and taking power in decision-making, ranging from information exchange and consultation to the highest rung of citizen control.

Positive outcomes of participation highlighted in the literature include transparency, consensus-building, increased acceptance, knowledge-sharing, emancipation and capacity-building of actors (Walter and Hammerschmid 2017; Musch and von Streit 2020; Arnstein 1969; Brisbois and de Loë 2016a; Newig et al. 2018; Purdy 2012). However, problematic aspects of participation have been identified, such as lack of representation, top-down management, transparency, and legitimacy. Poorly planned and executed participation processes risk reinforcing existing imbalances in whose voices are heard (Alcántara et al. 2016; Delli Carpini, Cook, and Jacobs 2004; Renn 2008).

Many of the drawbacks can be drawn back, as Purdy states, to "power disparities among participating organizations and how power affects such issues as representation, participation, and voice" (Purdy 2012, 1). Power plays both a key role in analysing participation processes and is an emerging field in sustainability transition studies (Avelino 2021; Köhler et al. 2019). As Partzsch (2015) states, there is "no change without power" (48, own translation) and the study of power analyses how processes (re)produce existing or new power relations (Avelino 2021). Power is an "essentially contested concept" (Lukes 2004, 30) with varying nuances and analytical approaches to capture power relations and sources based on a long tradition in political science research, most notably the works of Weber, Foucault, Mann, and Arendt (Sovacool and Brisbois 2019). However, as Avelino (2021, 2) puts it, "rather than trying to capture the essence of power in one, all-encompassing definition, the challenge is to construct a local language in a specific context".

Participation can both reinforce or dismantle existing power relations (Brisbois 2020; Turnhout et al. 2020; Wilgosh, Sorman, and Barcena 2022). Outcomes, such as environmental policies, are influenced by the process and thus also power imbalances (Brisbois, Morris, and de Loë 2019; Musch and von Streit 2020). In the words of Arnstein (1969, 2), "participation without redistribution of power is an empty and frustrating process for the powerless". In local actor participation processes, studying power means asking the question of whether participants have a tangible influence on the decisions being made but it also helps to uncover representation and emancipatory aspects (Avelino 2017; Birnbaum 2016; Brisbois and de Loë 2016a; Coy et al. 2021; Fung and Wright 2003; Lukasiewicz and Baldwin 2017; Ross et al. 2021).

The work by Brisbois et al. (Brisbois 2019; Brisbois and de Loë 2016b; 2016a) analyses power in collaborative approaches based on the three dimensions of power by Lukes (2004). Power dynamics in transition processes can reveal changes in political power and the influence on transitions (Brisbois 2019). The three dimensions focus on "power over", or domination, in the sense of one actor making another actor do something that conflicts with that actor's interests (Lukes 2004) (see Table 2 for an overview).

The outcome and the role of participation in the transition process and the power dimensions are closely connected. The structural power dimension is important in terms of sharing power between state institutions and other actors: only if structural power is shared, the full potential of participation may be untapped. However, looking exclusively at structural power would unnecessarily restrict the analysis. For instance, instrumental power exertion in the sense of lobbying may point to limited access and as such to a lack of structural power transfers. The dimension of discursive power allows us to understand why actors act in specific ways, based on their beliefs and ideas, as well as how they narrow or broaden discourses.

Table 2: Overview of power dimensions.

Instrumental power	Structural power	Discursive power
• Instrumental power is "the ability to prevail in decisions, despite opposition" and is visible in terms of "who wins" (Brisbois, Morris, and de Loë 2019, 4). • This highlights the role of actor-specific resources (financial, technical, social, institutional, and knowledge) and related imbalances. • Actors make use of their instrumental resources to directly influence other actors' behaviour and shape policy outcomes. • Typical activities include lobbying or coercion.	• Structural power can be either hidden or visible • Reveals the social, political, and economic structures and institutions that the process is embedded in and how they influence and shape the process • Includes the inclusion or exclusion of issues, the ability to shape policy agendas, and constraining or enabling conditions for certain actors to enforce or voice their interests	• Discursive power accounts for the "broad social institutions, norms and values" that the process is embedded in and how they are "constructed, expressed, contested and manipulated" (Brisbois 2019, 3). • This shapes and defines a process's political and socioeconomic conditions and can limit or enable participation.

Source: based on Brisbois, Morris, and de Loë (2019), Brisbois (2019), and Brisbois and de Loë (2016a).

3.3 Methodology

Our research is based on an analysis of the actor participation processes in Lusatia. We conducted (1) a series of 15 semi-structured interviews with actors involved in the processes of allocating transition funds in Lusatia and (2) a document analysis of meeting notes, websites, and other relevant information to understand the processes (see Table A 4). We spoke to participants of actor committees and process organisers, including organised civil society actors such as NGOs and unions, mayors and municipal politicians, representatives of the regional transition agencies in both federal states and chairpersons of the actor committees. The interviews lasted between 60 and 90 minutes and were conducted between August 2022 and January 2023. The interviews were roughly divided into three sections: (1) definition and understanding of CSOs, (2) participation processes, and (3) discourse/outcome. For the full interview guideline see Table A 5.

Once data collection was complete, we developed a codebook based on our theoretical background and coded the interview transcripts and documents in MAXQDA. Where applicable, we verified the interviewees' statements through triangulation. Building upon existing scholarship, we analyse how the dimensions of power manifest in the processes and what this means for the impact in terms of our normative rationale view of participation. In the discursive dimension, our focus is on dominant themes and values that influence the process as well as different actors' views on participation. We then discuss these findings in the context of the scholarship on just transition.

3.4 Results

In this section, we show when decisions are being made and by whom and how the three power dimensions manifest in each phase, focusing on how this enables or hinders the capacity of local actors to affect outcomes (research question 1). For an overview of the process in both states, see Figure 7.

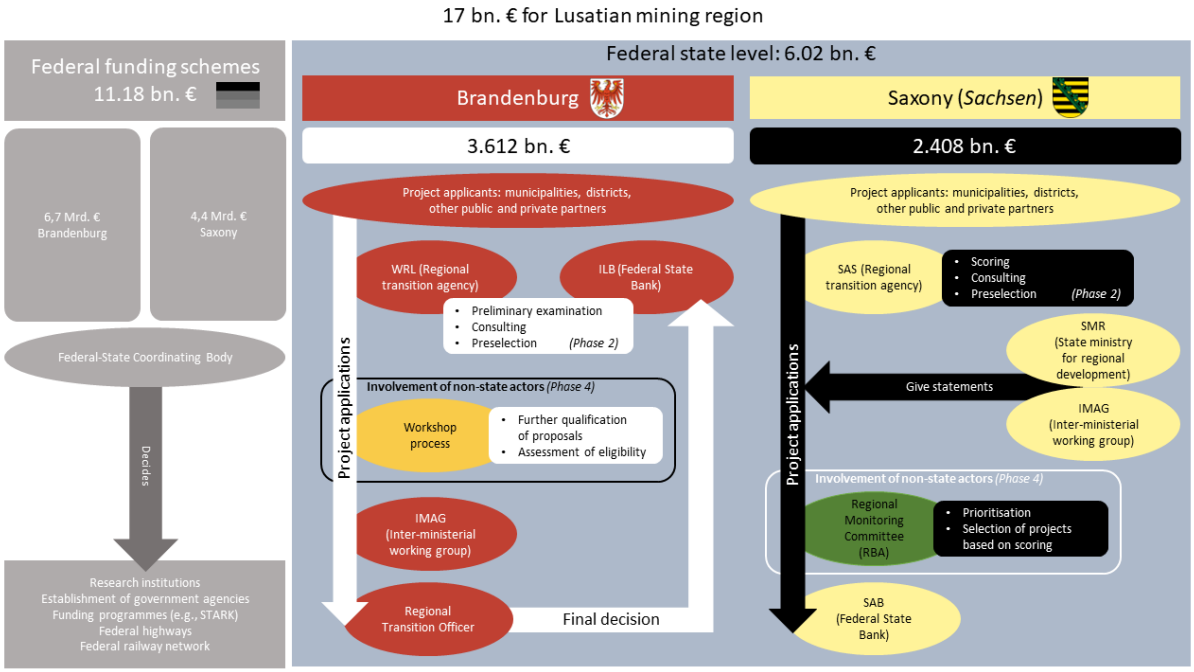

Figure 7: Overview of transition funds and their distribution.

Source: Own depiction based on Bundesregierung (2020), Wirtschaftsregion Lausitz (2023), Sächsisches Staatsministerium für Regionalentwicklung (2021).

3.4.1 Overarching conditions

The desire to avoid repeating past experiences when people a transition was imposed on people from the outside partly explains the increasing number of participation processes in Lusatia. The economic decline and the negative experiences of the 1990s are frequently mentioned [1, 2, 4, 5, 6, 12, 13, 15]. Many are worried about the loss of industry jobs and opportunities for value creation, as well as the loss of regional self-determination [1, 2, 10]. The region is viewed as unattractive by many interviewees due to deficits in opportunities for education, cultural offerings, support for civil society, and environmental quality [2, 3, 4, 8, 13]. Significant problems are demographic change and skills shortages [1, 3, 4, 6, 8, 13, 15] as well as right-wing populism [1, 2, 5, 13].

Due to their connections and economic, administrative, or political roles, some actors have access to resources and opportunities to influence political decision-making and exercise instrumental and structural power in the regional transition process. The prime ministers of the two federal states and their state chancelleries play a key role in the regional transition [2, 3]. Even though they were not formal members, the prime ministers exerted significant influence on the Commission for Growth, Structural Change, and Employment whose work set the federal framework for the coal phase-out as well as the amount of financial support for the affected federal states (Gürtler, Löw Beer, and Herberg 2021; Hauenstein et al. 2023). Structural power is exerted through legislation, e.g., through the Structural Support Law, stipulating the distribution of €40 billion with a focus on the promotion of economic development. The distribution of funds also has an instrumental power dimension as it provides actors with resources. Unions are frequently mentioned as being among the most influential non-state actors [2, 4], as are large corporations such as the lignite mining and generation company LEAG or the German

Railways (Deutsche Bahn) [2, 3, 8, 11]. Civil society organisations have a more precarious standing, tend to have fewer resources and access to institutions, and are not given political priority [2, 3, 4] (cf. Furnaro 2023).

3.4.2 Phase 1: Initiation of the process

Once the general amount of funding was established, in both federal states, the state chancelleries appointed regional transition officers for Lusatia. In addition, each federal state established a regional transition agency to manage the selection of projects: the Wirtschaftsregion Lausitz (WRL) in Brandenburg and the Sächsische Agentur für Strukturentwicklung (SAS) in Saxony [2, 3, 6, 7, 12, 14].[26] Their tasks include the set-up, coordination, and management of actor participation processes [9, 10]. The federal states provided guidelines for funding allocation, exercising structural power in shaping agendas and controlling structures and problem definition. Both states recognise the importance of involving diverse societal groups, but this does not always translate into strong commitment, as motivations for participation also include that strengthening civil society is "currently en vogue" [7].

In **Brandenburg**, so-called "workshops" are a key element of the project selection process. The workshop process aims to foster discussions about projects instead of scoring them according to pre-set criteria [1, 6, 11]. Five workshops were organised, each with a specific thematic focus and involving non-state actors, to avoid top-down decision-making by the WRL [1, 9]. As one interviewee put it, the goal was a "handover of power through the workshop process" to the members and spokesperson [1]. One public sector representative stated: "What we are doing in Brandenburg is, in my view, a very clever bottom-up process, but one that is backed up top-down." [9]. Others outside the public sector were more critical, opining that the workshop process was an attempt to avoid the impression of a top-down process [2]. The workshops have no official rules of procedure, and the process was not organised by professional participation experts, two aspects which are important for deliberation and empowerment (cf. Alcántara et al. 2016).

In **Saxony** representatives from the state, district, and municipal levels as well as interest groups from different parts of society are part of the Regional Monitoring Committee (Regionaler Begleitausschuss, RBA) as part of the project selection process [4, 7, 10, 14]. The former gives the final vote that decides what projects are to be funded; the latter merely has an advisory function [5, 7, 10, 12, 14]. The idea when establishing the RBA was to give civil society a role in the process of project selection and allocation of funds [7].

3.4.3 Phase 2: Pre-section of projects

In **both states**, funding schemes are only aimed at municipalities, not private applicants, as stipulated in the federal Structural Support Law. Project applications are screened, filtered, and qualified by the WRL or SAS before entering the actor committees for discussion and voting [2, 3, 4, 7, 9, 10, 11, 12, 15] (WRL 2023; SMR 2021). This highlights the influence of these agencies regarding what projects are discussed and subsequently funded.

[26] WRL and SAS are limited liability companies with 100% public shareholders and are thus referred to as public actors.

The WRL in **Brandenburg** has an "information monopoly" and "information advantage" [3, 10] as well as administrative and agenda-setting power: only they possess knowledge of all submitted projects and its pre-selection influences the direction of the transition and the topics discussed in the workshops. This lack of transparency is a concern for some workshop members since there is no record of projects that did not make it to the workshops, nor an open list of criteria or reasons for project dismissals or qualifications [3, 10]. This keeps members from getting the whole picture which might influence their decision on the project proposals. Before and during the application process, the WRL speaks to applicants together with representatives from the ministries [1, 2, 3] and the investment bank of the state (ILB) [9]. A project enters a workshop once the WRL finds that it meets the eligibility criteria and expects that workshop members will have no fundamental criticisms [9]. As some interviewees pointed out, this turned the state chancellery's regional transition officer into a "bottleneck", determining the order and timing of decisions [2, 3]. Some also criticise that there are no tangible criteria for project selection [10], suspecting that this is so that projects favoured for political reasons can more easily get approved [3]. Some projects got approved even though they had never been discussed in any workshop [10, 15].

In **Saxony**, the picture is similar, as the SAS is responsible for the qualification of the projects [4]. Unlike Brandenburg, Saxony does have a scoring process [5, 12, 14]. However, some interviewees criticised the scoring process as not being transparent [9, 14]. After pre-selection, project descriptions are submitted to the RBA (incl. funding sums) [4]. However, not all projects have to be approved by the RBA. Interviewees stated that 75% of the funds were reserved for the federal state, which merely informed about their spending in the RBA [13, 14].

3.4.4 Phase 3: Selection of participants

In **both states**, selecting participants was an informal and non-systematic process led by the agencies and ministries. They directly approached actors they considered suitable, and in turn, different actor groups lobbied to become part of the committees [2, 3, 5, 7, 9, 10, 11, 12, 14, 15]. There is a perceived lack of transparency regarding the selection of participants. Professional lobbyists were at an advantage; as one RBA member put it, "You have to know the rules of the game" [14]. Some actors, such as environmental CSOs are less represented in comparison to other actors such as unions [9, 10].

The WRL in **Brandenburg** had informal talks with different actors they knew, and personal connections were very important [1, 2, 9]. A spokesperson from outside politics and administration was chosen for each of the five thematic workshops and granted some agenda-setting power [1, 2, 3, 11]. Persons and organisations interested in participating also contacted the spokespersons and agencies directly [3, 9, 11, 15] or used their connections to the WRL and the governing parties [2]. These lobbying activities are an example of the exercise of instrumental power by non-state actors. Most workshop members are either close to the public sector or from the business or research sectors. CSOs are only represented in Workshop 5 (culture, creative economy, tourism, and marketing) [2, 3]. The WRL and spokespersons also exercised discursive power by admitting possible "querulous people" into the workshops, hoping that this would keep them from criticising from outside [9]. Full lists of members including individual names are not publicly available to limit lobbyism [9, 10].

In **Saxony**, the voting members of the RBA are comprised of actors from the state, district, and municipal levels in the coal districts. The other group of participants are the non-voting/advisory members, who were clustered into "interest groups" with one spokesperson plus a deputy each [4, 5, 7, 13, 14]. The SAS asked each state ministry to suggest suitable persons or organisations from the different interest groups based on informal talks [7]. The interest groups are expected to discuss and agree on a stance on the projects, which is then presented by the spokesperson in the RBA [4, 5, 7, 14]. Compared to the workshops in Brandenburg, Saxony included more CSO actors, and the list of all RBA members is publicly available.[27] However, there is no official record of interest group members as they are not officially part of the RBA. This is so that the process representatives only have to speak to a select few members who in turn discuss within their interest groups [7, 12]. Interviewees' statements suggest that public actors often view actor participation as arduous and resource-intensive [1, 3, 7, 9, 12, 13].

3.4.5 Phase 4: Workshop process and RBA

Phase 4 is the "heart" of the participation process, as this is where non-state actors participate in the actor committees.

We observe resource imbalances in **both states**. While the public sector, businesses, and large organisations usually have the resources to enable their representatives' participation within working hours and/or reimburse expenses, members of smaller organisations often participate in their free time with no compensation, including the time-intensive preparatory work of reading project proposals and formulating statements [4, 6, 7, 12, 14]. As a result, some actors have more financial resources than others but also personal connections, pointing to instrumental power. For this reason, the SAS is currently considering a small expense allowance for members with limited resources following pressure from some advisory members [7, 9, 12]. We find a discrepancy between the views of process representatives from politics and administration, who are mostly convinced of the high participatory quality of their processes [1, 9, 12], and the participants, many of whom have a more sobered view [3, 4, 5, 13, 14, 15].

In **Brandenburg**, workshop members are expected to make a consensual decision based on a discussion of the submitted projects [3, 10, 15]. Opinions on the process differ among the members that we have spoken to. One spokesperson felt that the process was very participatory and that the workshop made a vital contribution to improving the project proposals, stating that applicants could present ideas, receive advice, and refine projects in an iterative process [11]. In contrast, another spokesperson criticised that most project proposals entering the workshop had already been preselected to an extent where the workshop members' role was reduced to a mere "nodding through" of the projects: "You do shadow boxing. You occupy people in workshops who have nothing to say. And they raise their hands. Or they don't. And then, to the outside world, we have a good image." [3].

Interviewees also lamented a low discursive quality, lack of idea generation, and limited expertise on social aspects of the transition [2, 3, 6]. Participants do not formally vote on the proposals. Instead, they

[27] Sächsische Agentur für Strukturentwicklung GmbH. 2023. "Mitglieder des Regionalen Begleitausschusses für das Lausitzer Revier (Stand 16.02.2023)." https://sas-sachsen.de/wp-content/uploads/2023/08/Mitglieder_RBA_LR_NEU_AUGUST_23.pdf.

are expected to come to a consensual decision which, however, serves merely as a suggestion while the actual decision-making occurs outside the workshops: first during pre-selection and later after the workshop meetings, when the decision is communicated to the inter-ministerial working groups (IMAG) [3, 11, 14], whose task is to confirm eligibility for funding based on the WRL's pre-selection and recommendations from the workshops. While it usually decides in agreement with the workshop's recommendations [9], this is not a formal obligation. This is a clear top-down element underscoring that decision-making power remains with established public actors.

Unlike in Brandenburg, the IMAG in **Saxony** gives its input already before the RBA meetings. State representatives argue that the distinction between voting and non-voting/advisory members is because only representatives of the public sector are allowed to decide on public spending [7, 12, 14]. However, there is also the view that this restriction should not apply as the RBA does not make the legally binding final decision [7]. The RBA was designed to enable discussions at the meetings, with the opinion of the advisory members supposed to influence the final vote [7, 12]. However, in practice, this is absent, and their opinions do not have to be formally considered [13], leading to frustration, distancing, and less engagement among both the advisory members and the interest groups they represent [4, 5, 7, 14]. While a process representative stated that interest groups' votes were never disregarded [12], members of these groups report otherwise [4, 5]. Project content is rarely subject to substantive discussion; objections are acknowledged but seldom have consequences [4]. As the voting members are representatives of the municipalities and districts, they are part of the same target group eligible for project funding. As enough funds for all submitted projects were available in the first round, most voting members had no incentive to vote against any of the projects as each benefited from the others' vote in favour of their own administration's project proposals [7]. Even the voting members have limited agenda-setting power, as they merely receive the proposals, discuss them, and then vote in favour or against them.

3.4.6 Summary of results: Phases and power dimensions

Table 3: Phases, actors, and manifestation of instrumental, structural, and discursive power in each phase.

Phases		Brandenburg	Saxony
		Actors and manifestation of power dimensions	**Actors and manifestation of power dimensions**
Overarching conditions and relevant actors		• Influential actors: prime minister and their state chancelleries of the two states; Unions *(Instrumental, Structural)* • Dominant identity as energy and industrial region; dominant themes of employment and economic prosperity, observed in the thematic orientation of participation processes and selection of projects *(Discursive)* • Intention and high awareness to create a participatory process manner due to regional history but mostly resulting in information/consultation *(Discursive)*	
Participation process	**Phase 1: Initiation of the process**	• State actors: regional transition officer and agency (WRL): Creation of guidelines in a closed setting defines the control over the agenda-setting and problem definition *(Structural)*	• State actors: regional transition officer and agency (SAS): Creation of guidelines in a closed setting defines the control over the agenda-setting and problem definition *(Structural)*
	Phase 2: Pre-selection of projects	• WRL: preselection of projects without publicly known scoring system and no available overview of all projects (selected and not selected) *(Structural)*	• SAS: preselection of projects with publicly known scoring system • 75% of funds reserved for the federal state without consultation of the RBA *(Structural)*
	Phase 3: Selection of participants	• WRL: informal talks to select participants • Advantage through lobbying by established and well-connected actors *(Instrumental)* • Spokesperson: freedom and power to select participants *(Instrumental, Structural)*	• SAS: informal talks to select participants • Advantage through lobbying by established and well-connected actors *(Instrumental)* • Non-state actors are required to organise and represent "interest groups" of actors who are given no official involvement in the process *(Structural)*
	Phase 4: Workshop process and RBA	• Spokesperson: freedom and power to design their workshop sessions; restricted by what actually can be decided within the workshops *(Structural)* • Resource imbalances affecting less equipped actors the most *(Instrumental)* • "Nodding through" process in the workshops instead of discussions *(Structural)* • Final decision made by IMAG *(Structural)*	• IMAG gives input before RBA meetings *(Structural)* • Resource imbalances affecting less equipped actors the most *(Instrumental)* • Clear distinction between voting members (state actors) and non-voting/advisory members (non-state actors) → opinions of advisory members do not have to be formally considered *(Instrumental, Structural)*

Source: Own depiction.

3.5 Discussion

Based on our findings from the results section on what power dynamics can be observed in the processes, especially in what ways they enable or hinder the capacity of local actors to affect outcomes (research question 1), we now turn to research question 2 and point out deficits in the participation processes that hinder the support of just transition processes. Looking at the life cycle of coal phase-outs, the distribution of the transition funds, which were a key legitimising factor for the phase-out pathway, is crucial to increase public acceptance (Hauenstein et al. 2023; Gürtler, Löw Beer, and Herberg 2021; Furnaro 2022). As transition planning affects an entire region and the everyday life of the people living in the region, it is important to be aware of the implications of participation and power dynamics for the just transition.

We observe an uneven distribution of power with public actors holding significant decision-making power in both processes, often equating participation to information or consultation. They influence structural power aspects such as agenda setting and problem definition, process design including participant selection, and institutional setting, but also instrumental and discursive aspects. These aspects are also emphasised in the literature on power (e.g., Cook 2015; Purdy 2012; Brisbois 2019). Despite both states involving different non-state actors, they are excluded from key decision-making stages, notably Phase 1 (agenda-setting) and Phase 2 (pre-selection). In Phase 4, public actors and the IMAG have the final say in Brandenburg and Saxony, the RBA decides, however, only public actors are allowed to vote while the interest groups merely advise. Regional transition officers and associated public actors initiate and define the process, shaping participants' influence and capacity across all phases. Consequently, workshops and RBAs are reduced to a mere "nodding through" of pre-selected project proposals. As for the instrumental dimension, addressing resource imbalances is vital for meaningful participation, especially as many non-state actors participate voluntarily without financial compensation.

Looking at discursive power, we find that participation is unequivocally considered to be important to the transformation process, and considerable effort has been made to set up the processes in the WRL and SAS. For the initiating actors (public actors, representatives from politics and administration), the focus is on anchoring the transition in the region by involving local actors. In contrast, CSO members tend to have different priorities, emphasising aspects such as capacity and coalition building. These diverging ideas on participation can lead to dissatisfaction with the process (Ryder et al. 2023; Musch and von Streit 2020; C. Walker et al. 2023; Newell and Mulvaney 2013). Additionally, the unrealistic expectations that were raised in the communication of the processes led to frustration among participants, especially in Brandenburg (but, in extension, also in Saxony due to the comparative outlook towards Brandenburg's process). Particularly in Brandenburg, the use of terms like "workshops" and the ways public actors advertise the process suggests a more inclusive approach, but the process falls short of these expectations. At the same time, statements from administrative staff suggest that participation is not viewed beyond information or consultation and that the implementation of consultation already proves difficult. This connects to the often used role of participation as a legitimising tool for already made decisions or already defined paths (Newell and Mulvaney 2013).

In this context, the idea of participation in a limited vs. transformative just transition approach is of interest. As we see in the statements of non-state actors, emancipatory elements and capacity-building are important features in participation processes and a transformative just transition (Wilgosh, Sorman, and Barcena 2022). Ryder et al. (2023) show that people join participation processes to have influence, get information, and feel that their wishes and needs are heard. This highlights the aspect that including a wide range of actors and interest groups to find the best solution may not be enough in a transition process that is characterised by difficult political trade-offs and a structural reorientation that affects the society and social infrastructure (Wang and Lo 2021). In this context, we argue that both states missed an opportunity to create a process that actively promotes community-based advocacy and the building of coalitions, which could provide spaces to navigate difficult decisions in transition processes (Cha and Pastor 2022; Wang and Lo 2021; Törnberg 2018; Coy, Malekpour, and Saeri 2022). We see less handover of power and limited decision-making power for participants, which decreases their perceived and actual representation, negatively impacting their sense of empowerment (Arnstein 1969; Cha and Pastor 2022). The lack of resources of civil society organisations is a crucial aspect, as this forms the basis for the participation of actors in such processes and the transition process as a whole (Arnstein 1969; Späth and Scolobig 2017; Williams, Martin, and Stirling 2022). In this sense, we agree with Ryder et al. (2023) that the focus of processes needs to shift from outcomes to relationship-building.

We also observe a very powerful discourse around regional economic growth, physical infrastructure, and techno-economic innovation**,** which is reflected in the process design and selection of participants and affects the outcome in terms of selected projects. The sustainability and social discourses are much less powerful in comparison. This is highly relevant when asking about the potential of the participation processes to foster a just transition, as power dynamics strongly influence concrete outcomes (Brisbois 2020; Turnhout et al. 2020; Wilgosh, Sorman, and Barcena 2022; Musch and von Streit 2020). Therefore, as social and environmental actors are given less power, their influence on outcomes is also much smaller and their capacity to act as change agents for the just transition is reduced. This also directly relates to questions of recognition justice (cf. McCauley and Heffron 2018; Wilgosh, Sorman, and Barcena 2022). Our results therefore support the literature on success factors of participation for addressing sustainability issues, as a discursive power perspective emphasises the importance of socio-political context and the role of logics that are explicitly and implicitly applied to participation processes and the courses of action that are proposed and discussed (cf. Cattino and Reckien 2021).

This leads us to the responsibility of public actors and the government, who can facilitate participation and recognise actors' needs and wishes in the transition process (Harrahill and Douglas 2019; Huang and Chen 2021; Brisbois and de Loë 2016b). In the German federal system, the federal state level is quite powerful with a high degree of autonomy. They initiate the process, set the agenda, define the problem, design the process, and select participants. Public actors often equate the participation of non-state actors with information or consultation (Sønderskov 2019). This lack of distribution of power may be at least partly due to institutional restrictions and a lack of expertise on participation. While only democratically legitimised actors can make final decisions per law, non-state input should be formally considered beforehand to increase legitimacy (cf. Sønderskov 2019). An interviewee's description of the workshops as a "bottom-up process that is secured top-down" illustrates the need to balance the

ideal of bottom-up participation with institutional restrictions without reducing the participation process to mere tokenism (cf. Arnstein 1969).

Overall, the participation processes have not facilitated a shift in power dynamics; rather, they tend to perpetuate existing power structures (Avelino 2021; Wilgosh, Sorman, and Barcena 2022). The historical context and the contemporary political shift towards populist movements in Lusatia and beyond underscore the importance of engaging local communities in the participation processes. The frustration with the top-down management and the missed opportunities of the 1990s highlight the necessity for meaningful participation. This involves ensuring that all actors have the opportunity to influence outcomes and are provided with the capacity to contribute to the development of a just future.

3.6 Conclusions and policy recommendations

The German government aids regions impacted by coal phase-out with regional transition funds. In Lusatia, where economic decline has persisted post-reunification, these local non-state actors are involved in the distribution of funds, albeit with varying procedures across federal states. We reconstructed the phases of the participation processes to discern power dynamics in the participation processes and what factors enable or hinder the capacity of local actors to affect outcomes. Discrepancies exist between rhetoric and implementation of participation. Public actors dominate decision-making, limiting non-state actors to passive approval of proposals.

We derive recommendations for other regions as to the role and implementation of actor participation in regional transitions:

- Collective decision-making requires deliberative communication settings to balance power dynamics and prevent dominant actors from monopolising decisions. Further required are relationship-building, empowerment, and allowing local actors to develop ideas.
- Public actors play a crucial role in enabling effective representation and participation. Local politicians and administrators require increased resources and well-informed personnel, including dedicated positions for participation experts.
- Participation processes should prioritise capacity building to align with the wishes of local actors, enabling them to navigate the transition and shape fair outcomes.
- Balancing diverse actor involvement ensures inclusive transition planning, vital for just outcomes and acceptance of phase-outs.
- Without strong discourse on sustainability and social justice, participation outcomes suffer. Hence, considering aspects beyond the purely techno-economic early in participation processes is essential for a just transition.

We aimed to interview all relevant groups but could not reach every workshop and interest group. Environmental groups often specifically cited resource limitations as the primary obstacle to giving an interview. Furthermore, a contextualisation based on democratic theory, delving deeper into questions of legitimacy and the role of participation in representative democracies, was beyond the scope of our research.

The Lusatia case underscores the gap between the potential of participation and its implementation. Addressing power dynamics ensures equitable decision-making and strengthens local actors in sustainability transitions. Neglecting these issues limits the impact of participation, hampering regional empowerment and public acceptance. Comparative analysis across regions can deepen understanding of just transitions in diverse contexts.

Chapter 4

Continuation or transformative change: Disputed just transition imaginaries in the coal mining region of Jharkhand in India[*]

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4 Continuation or transformative change: Disputed just transition imaginaries in the coal mining region of Jharkhand in India

4.1 Introduction

A man living in the coal mining region of Jharkhand in India and working informally in the coal sector expressed: "*Just transition if implemented in the right spirit, can change the way we live in the area"* (focus group (FG) 03 in Ramgarh, Jharkhand). This quote reflects sentiments of individuals residing in the coal mining region, where coal extraction plays a significant role in the local economy. Jharkhand, with 26% of India's coal reserves, stands as one of the most coal-dependent states in India (Bhushan, Banerjee, and Agarwal 2020). However, the necessity to comply with the Paris Agreement mandates a transition from fossil fuels to renewable energies (RE), raising concerns about the implications for regions heavily reliant on coal and how to cushion the effects for people in the regions. The quote underlines the potential of a just transition in reshaping livelihoods, while also acknowledging the uncertainties inherent in such transitions, as they do not automatically guarantee just outcomes (Heffron and McCauley 2018; Alarcón et al. 2023; Wang and Lo 2021). In this research, we tap into this debate by exploring just transition imaginaries in the coal mining region of Jharkhand.

Coal remains the dominant energy source in India. It contributes to 70% of the country's power generation and 44% of its primary energy needs in 2020 (IEA 2021b). To meet its climate goals and net zero emission target by 2070, India will need to transition its power generation systems, ultimately phasing out coal. However, this transition will result in massive disruptions at the regional level, impacting economies dependent on coal (Bhushan, Banerjee, and Agarwal 2020; Lahiri-Dutt 2016; Pelz et al. 2024). Loss of livelihood and economic disruptions due to mine closures will further aggravate poverty and conflict in already 'resource curse' and fragile regions. Furthermore, the regional disparity of energy investments, with coal being concentrated in the Eastern states[28] and deployment of RE in the Western states, poses a challenge to the development of coal-dependent states (Löffler and Krumm 2022).

The discussion on the future of coal and the need for a just transition has gained momentum in India but is still nascent. National NGOs and think tanks have supported studies on coal dependency in India and Jharkhand, the Ministry of Coal formed a new division focusing on just transition regions to develop strategies for mine closure, and the state-owned coal company Coal India Limited (CIL) established committees dedicated to facilitate a just transition. Coal is strongly connected to the development of the country, energy access, and the state's identity and economic development (Mohan and Topp 2018). Furthermore, CIL has a quasi-monopoly power in coal regions and provides education and health investments and services (Montrone, Ohlendorf, and Chandra 2021).

The transition away from coal will be critical for Jharkhand, an economically vulnerable region with a long history of conflict, poverty, and dissatisfaction among the local communities and tribal people

[28] The key coal-producing states in India are Jharkhand, Chhattisgarh, Odisha, West Bengal, Madhya Pradesh, and Telangana.

(Ranjan and Prasad 2012). Jharkhand, which stands for "Land of Forest," is characterised by significant coal dependency, regional disparities, and a looming concern of resource depletion. Furthermore, the state grapples with high poverty levels, susceptibility to the impacts of climate change, weak governance, political instability, and a history of conflicts rooted in natural resource grievances, including land dispossession and disputes over forest resources and mining.

There is a growing debate among researchers, policy-makers, and practitioners on all levels on what exactly a just transition entails, especially in terms of the mechanisms that could ensure that current injustices are not exacerbated and new ones are not created (Sovacool et al. 2019; Alarcón et al. 2023; Otlhogile and Shirley 2023; Majekolagbe 2023; McIlroy, Brennan, and Barry 2022). The notion and practice of just transition is contested with different visions and interpretations, e.g. a focus on labour rights in fossil fuels or an emphasis on whole systems of inequality, including aspects such as environmental damage (Wilgosh, Sorman, and Barcena 2022; Stevis and Felli 2020; Wang and Lo 2021). The discussion also includes an analysis of who defines what is just and for whom (Alarcón et al. 2023; Wilgosh, Sorman, and Barcena 2022; Wang and Lo 2021; Newell and Mulvaney 2013). This is especially important in the Global South where empirical work on just transition remains scarce (Wilgosh, Sorman, and Barcena 2022; B. Ghosh et al. 2021; Marquardt and Delina 2019). Moreover, land acquisition and dispossession are often part of coal mining expansion and the implications on livelihoods, generational wealth and rights over land for vulnerable groups (Oskarsson, Lahiri-Dutt, and Wennström 2019; Chhotray 2022; Levien 2013)

Visions of just transitions can represent sociotechnical imaginaries, which, as defined by Jasanoff and Kim (2015), correspond to shared visions of desired futures. Imaginaries about just transition are tied to the role of technology as well as social innovations, values, and norms and, thus, make sense of the ideas, values and cultural meaning of visions (Marquardt and Delina 2019; Sovacool et al. 2020). Through the explanatory power of imaginaries, imaginaries are linked to present-day and future political decision-making and the agency of actors (Hirt, Sahakian, and Trutnevyte 2022; Hoffman et al. 2021). Imaginaries play a role in forming transformative change by bridging the individual imagination process with collective envisioning that informs socio-political decisions (Feola et al. 2023). Most research stays at the national level, analysing national imaginaries, with little attention to the regional level (Rudek 2022). In this regard, community-based imaginaries are little explored, see for example Marquardt and Delina (2019) who assess community-led social movements and their role in envisioning alternative energy futures in Thailand and the Philippines.

This paper analyses just transition imaginaries to explore visions of just futures and where (in)justices are reinforced, promoted, or reduced in Jharkhand. Empirically, we examined the perspectives of different actors and communities involved in and dependent on coal. Our research addressed the questions: (1) What are just transition imaginaries in Jharkhand? and (2) What tensions exist between them? For the data collection, we conducted twelve semi-structured expert interviews, four focus groups, and document analysis of 36 documents.

We identified two main just transition imaginaries in Jharkhand: *just transition as green growth and reskilling strategy and as self-determination and land ownership.* Tensions exist between them,

particularly regarding differing views on justice, land dispossession, and the role of participation. This empirical case contributes to the burgeoning just transition scholarship, particularly in informing policy discussions on the realities of implementing just transitions in coal regions of the Global South (Furnaro and Yanguas Parra 2022; Otlhogile and Shirley 2023; Alarcón et al. 2023). Additionally, we contribute to the turn in social studies on imaginaries in energy transitions, from a national-level to a local-level approach by focusing on Jharkhand and diverse visions of actors, from the coal industry to community members. Reconciling these imaginaries poses a challenge, with varying orientations towards maintaining the status quo or promoting transformative change. Addressing tensions in an inclusive and at best empowering manner can prevent amplifying injustices in the region.

4.2 Coal mining in Jharkhand

Spanning over two centuries of mining history, coal has a significant position in India's economy, playing an essential role in state government revenues, energy security, industrialisation, and livelihoods in coal-intensive regions (Tongia and Gross 2019). Coal's importance in India extends beyond the economy and is intricately linked to politics and social dynamics in mining regions, which is notably evident in Jharkhand. The state was formed in 2000 after a lengthy history of tribal movements and political struggles centred on ethnic identity rights and issues over land dispossession, forest resources and employment in mines (Jewitt 2008; Ranjan and Prasad 2012). Figure 8 gives an overview of coal in India and Jharkhand.

Jharkhand continues to be labelled a resource curse region, with 26% of India´s coal reserves and a vast presence of forest and mineral resources and stands as the second most multidimensional poor state in India with poor health, education, and living standards (Bhushan, Banerjee, and Agarwal 2020; NITI Aayog 2023). The coal industry in Jharkhand is widespread, with approximately 114 operational mines spanning half of the state's districts (12 out of 24). It covers a significant population and geographical expanse (Singhal, Gupta, and Faraz 2022). The sector constitutes a substantial socio-economic force, contributing around 10% to the state's GDP and serving as a source of livelihood for millions of people (Spencer, Pachouri, et al. 2018; Dsouza and Singhal 2021). Notably, CIL operates three of its subsidiaries in Jharkhand: Central Coalfields (CCL), Bharat Coking Coal (BCCL) and Eastern Coalfield Limited (ECL). Furthermore, private companies are operating in Jharkhand. The coal industry provides substantial direct and indirect employment, royalties, and local funds through the District Mineral Fund (DMF) and Corporate Social Responsibility (CSR) activities.

National and state government and coal company-driven welfare and regional development policies have been vital in coal regions. Key initiatives from national and state governments include MGNREGA's 100-day employment guarantee[29], NRLM's rural income support[30], DDUGKY's skill development[31], the Aspirational Districts program for underdeveloped areas, and various education, health, and sanitation policies. Additionally, the DMF is mandated in each district aiming to promote economic development and welfare planning and to minimise the adverse impacts during and after mining, e.g. through projects

[29] Mahatma Gandhi National Rural Employment Guarantee Act, 2005

[30] National Rural Livelihoods Mission

[31] Deen Dayal Upadhyaya Grameen Kaushalya Yojana

focusing on drinking water supply or health care facilities. However, challenges in DMF implementation persist, such as information gaps in planned projects, short-term planning, and limited community engagement in planning (Shalya 2020). Additionally, CSR efforts by CIL mandated by the Companies Act 2013 include various environmental sustainability, education, sanitation, and skill development activities and CIL has a role in road construction, housing, school operation, and healthcare services in coal-rich areas.

Mining operations led to adverse impacts on the environment and traditional livelihood practices of Jharkhand communities as a result of the clearance of land and forests for mining especially for tribal people dependent on agriculture and forests (Lahiri-Dutt 2016). Coal mining in Jharkhand has created land dispossession, and displacement of marginalised groups such as Schedule Tribes (ST) and Schedule Castes (SC), along with long and non-transparent processes and conflicts related to individual compensations and job placements arising out of land acquisitions. CCL acquired about 73,967 hectares of land under the CBA(A&D) Act 1957 and Land Acquisition Act 1894 (Ministry of Coal 2023) more than in any other state with several cases of pending compensations (Vats 2023). Oskarsson et al. (2019) call this form of land grab in coal regions an integral part of India's political economy.

In November 2022, the Jharkhand government formed a Just Transition Task Force with 17 state institutions, mostly state departments, to facilitate a seamless shift from coal dependency. The Task Force's role involves assessing coal reliance, advising the government on transition strategies, and guiding the adoption of cleaner energy, focusing on seven key areas: livelihood preservation, energy transition, coal phase-out management, electric mobility promotion, industrial emission reduction, climate finance acquisition, and capacity building. Criticism arises from actors such as unions and members of the communities as they are not directly part of the Task Force. However, the Task Force engages with the communities in doing surveys and discussions to assess socio-economic dependency and needs (Government of Jharkhand 2023).

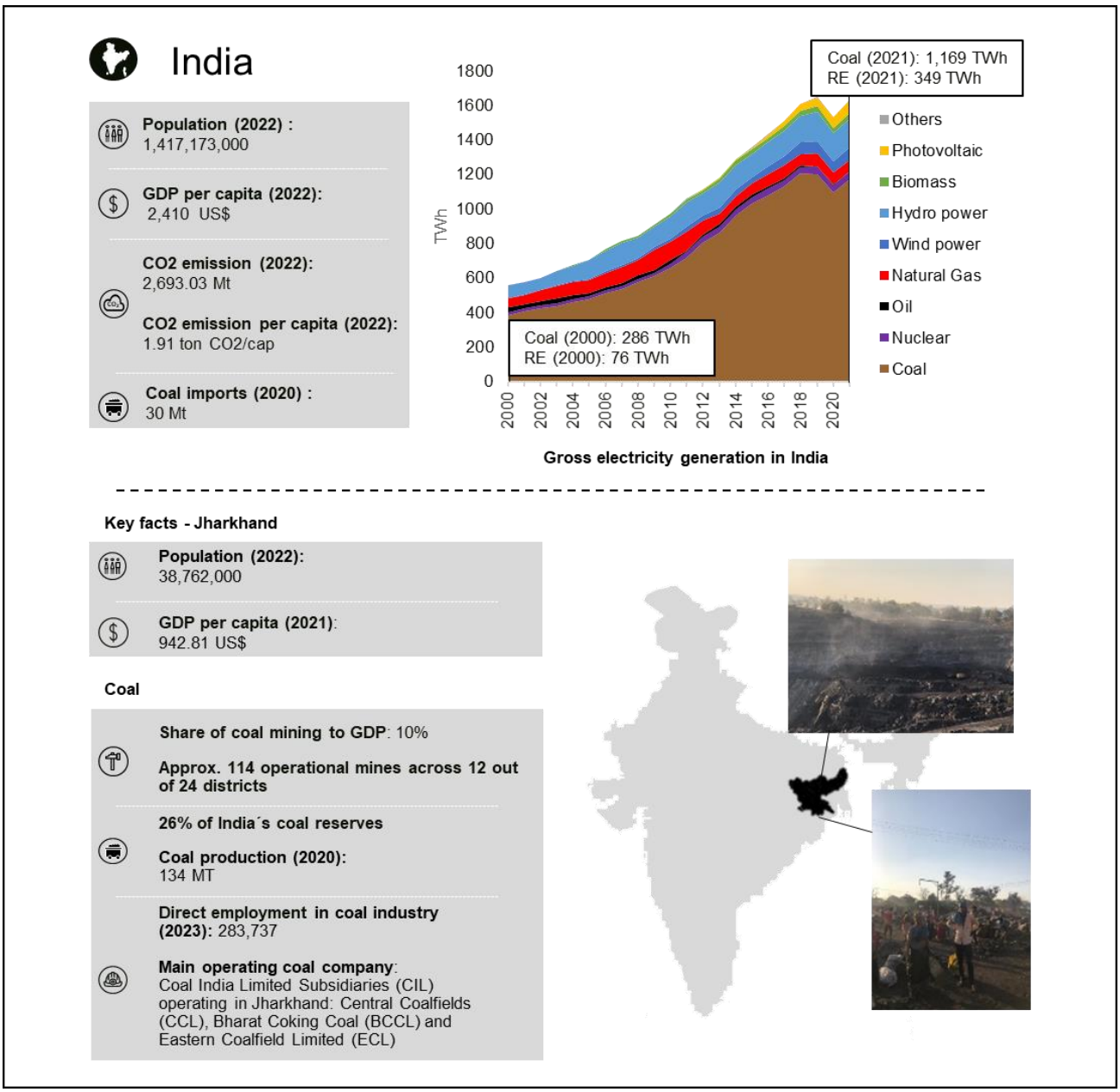

Figure 8: Overview of coal in India and Jharkhand.

Sources: Bhushan, Banerjee, and Agarwal (2020); CEIC (2024); IEA (IEA 2024a; 2024c; 2024d); MoSPI (2023); NITI Aayog (2023); Pai and Zerriffi (2021); Singhal, Gupta, and Faraz (2022); Spencer et al. (2018); The World Bank (2024); own pictures (2023).

4.3 Imaginaries about just transition

The concept of just transition was initially rooted in labour movements and since then evolved, encompassing broader socio-ecological aspects (Wang and Lo 2021). Scholars and institutions categorise notions of a just transition based on different factors such as the type of policies included and the scale and scope of the transformations proposed (Stevis and Felli 2020; Wilgosh, Sorman, and Barcena 2022; Just Transition Research Collaborative 2018). While the predominant discussion on energy transition among policymakers focuses on a green-jobs perspective, often neglecting policies targeting poor, rural, peasant, and indigenous communities (Alarcón et al. 2023), the notion of just transition can take on a transformative character, reshaping existing power structures (although it can

also inadvertently reinforce them) (Stevis and Felli 2020; Sovacool et al. 2019; Abram et al. 2022; Wilgosh, Sorman, and Barcena 2022).

Wilgosh et al. (2022) distinguish between a limited (affirmative) just transition approach, a continuation of status-quo and commonly reliant on market-based solutions and a green growth discourse, and an expansive (transformative) approach, aiming at an inclusive and structurally transformative process. They translate these into key attributes that categorise and inform the meaning and interpretation of approaches: depth and urgency, scale and scope, identity and inclusivity, material equity, and participation and power. These are informed by time and space, critical theory of power, as well as the justice pillars of distributive, representative, and procedural justice (Wilgosh, Sorman, and Barcena 2022). Furthermore, restorative justice, referring to the reparation of harm done to people and the environment, is of interest when it comes to coal transitions (S. Pai, Harrison, and Zerriffi 2020; Heffron and McCauley 2018; Schuster et al. 2023). These two extreme approaches differ in key attributes, with one relying on one-size-fits-all technological solutions, emphasising economic growth and the distribution of benefits through employment, while the other emphasises the role of historically marginalised people and decentralised democratic communities. Accordingly, their approaches range from consultation and top-down structures to bottom-up initiatives and the restructuring of power and ownership relations (Wilgosh, Sorman, and Barcena 2022).

Jasanoff and Kim define sociotechnical imaginaries “as collectively held, institutionally stabilised, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology“ (Jasanoff and Kim 2015, 19). With this updated definition, which represents a shift from an emphasis on the articulation of imaginaries by nation-states, they acknowledge the need that imaginaries can be “articulated and propagated by other organised groups, such as corporations, social movements, and professional societies“ (Jasanoff and Kim 2015, 4). And this can also be done “from below the seats of power” (Jasanoff and Kim 2015, 20). Imaginaries are performative, linked to practices, and have present-day implications (Jasanoff and Kim 2015). Studying imaginaries can also help determine what forms of agency as well as actions in the present, for example, policies and planning processes, can shape the future (Hoffman et al. 2021). The study of imaginaries allows an understanding of the desires and hopes of people as well as their belief systems, which give value and meaning to their imaginaries: “what is good, desirable and worth attaining” (Jasanoff and Kim 2009, 123). Furthermore, studies of imaginaries are useful for understanding power relations attached to established structures and processes as well as the implicit norms and visions reproducing them (Marquardt and Delina 2019; Ballo 2015).

Extractive industries exert significant spatial influence on specific regions, extending beyond their economic significance (Cha 2020; Heffron and McCauley 2018). The coal extraction has transformed landscapes and occupations, transitioning areas from agricultural to mining zones. Similarly, the ongoing energy transition, particularly in the context of coal, will also bring about deep spatial changes (Bridge et al. 2013; Oskarsson, Krishnan, and Lahiri-Dutt 2024; Pelz et al. 2024). Within the energy transition, especially concerning coal, localised spatial dynamics often centre around issues of land acquisition

and dispossession (Oskarsson, Lahiri-Dutt, and Wennström 2019; Chhotray 2022; Levien 2013). The study by Oskarsson, Lahiri-Dutt, and Wennström (2019) on the Karanpura Coalfield in India underscores the importance of analysing dynamics of land acquisition and their impact on rural landscapes. Moreover, space serves as an element in shaping social processes and human-nature interactions (Stevis and Felli 2020). Considering the spatial implications of energy transitions facilitates a deeper understanding of the experiences of transition and spatial identities, aiding in the evaluation of available pathways (Trencher and van der Heijden 2019; Bridge et al. 2013). Perception of space is dynamic and subject to constant revaluation, evolving based on diverse factors encompassing political, economic, and cultural dimensions (Heffron and McCauley 2018; Bridge et al. 2013). Bridge (2013) highlights the significance of considering space in understanding the coexistence of different energy pathways shaped by geographical factors. Furthermore, Chateau, Devine-Wright, and Wills (2021) emphasise the value of spatial analysis in exploring imaginaries, particularly in amplifying marginalised perspectives that may be overshadowed by dominant national narratives.

The temporality of just transitions deepens our understanding of justice in transition by considering the timing and pace of transitions and identifying affected actors (Malakar, Herington, and Sharma 2019; Jenkins, McCauley, and Forman 2017; Luning 2018; D'Angelo and Pijpers 2018). These connections influence how actors position themselves within the mining regime and also impact the transition itself by generating expectations, conflicts, and uncertainties. (D'Angelo and Pijpers 2018). In her analysis of German coal mine planning and the interplay of waiting for opening mines and protesting against, (Müller 2019) emphasises the transition's significance beyond pace; it extends to how individuals perceive and engage with the transition, especially in economically and ecologically stressed contexts and uncertain mining futures. Temporality reveals power dynamics, by showing who can control movements, sets the pace, beginning and endings, and gives rhythm (D'Angelo and Pijpers 2018). (Luning 2018) explores how financial compensation for land acquisition in mining areas is linked to future perspectives and power based on commenting on a wide range of mining experiences from Australia, North and South America, Europe, and Africa. She illustrates that losing land for short-term financial compensation results in the loss of future economic prospects, generational wealth, and identity struggles (Luning 2018). Additionally, the process of waiting, whether for displacement or mine closure, becomes a means of exercising power and control, raising questions in those waiting about the future and expectations, influencing present behaviour, which, in turn, affects the future (Luning 2018; Müller 2019; D'Angelo and Pijpers 2018). In light of these considerations, questions arise about the timeframe of just transitions, the temporal and spatial nature of policies, and how these factors impact the present and future lives of both people and the environment.

Imaginaries can be institutionalised by being "embedded within cultures, institutions and material practices and by being performed by powerful social actors, e.g. through official policies" (Christiansen and Carton 2021, 2). Researchers are also engaging in analysing emerging, non-institutionalised imaginaries that are not yet widely accepted and how that could challenge established imaginaries (Hirt, Sahakian, and Trutnevyte 2022; Christiansen and Carton 2021; Tidwell and Tidwell 2018; Rabiej-Sienicka, Rudek, and Wagner 2022; Marquardt and Delina 2019). Emerging imaginaries can be detected by expressions and practices of everyday life in the present (Hirt, Sahakian, and Trutnevyte 2022; J. M. Smith and Tidwell 2016; Christiansen and Carton 2021). Diverse visions of a future can exist

and these can contest and diverge from each other (Jasanoff and Kim 2015; Hirt, Sahakian, and Trutnevyte 2022; Christiansen and Carton 2021). In their study about imaginaries of the energy transition in Poland, Rabiej-Sienicka, Rudek, and Wagner (2022) conceptualise private sociotechnical visions that can become (part of) a sociotechnical imaginary by means of empowerment and performativity, e.g. through coalition building. Researchers emphasise the role of alternative imaginaries as they can emphasise progress and change (Longhurst and Chilvers 2019; Feola et al. 2023; Jasanoff and Kim 2015).

In this research, by accounting for the sociotechnical nature and the socio-spatial and -temporal dimensions of coal mining and just transition we attach the imaginaries to the values, history, and tension of Jharkhand.

4.4 Methodology

We use different data sources from different actors to gain insights into the imaginaries of just transitions and the future of Jharkhand. For this, we include actors based in or that have a strong connection to Jharkhand as well as actors on the national level that directly influence the state and regional levels due to the top-down structure of the Indian energy system. We conducted twelve semi-structured interviews. They lasted between 30 – 120 minutes and were conducted in-person or online between February and July 2023. Moreover, we did four focus groups in two coal-dependent districts (Ramgarh and Bokaro) with workers (formal and informal), community members, and local actors (Panchayats, unions, truck associations, and civil society organisations) with an overall 55 participants. They lasted around three hours and took place in December 2022 and February 2023 (Appendix 7.3 gives an overview of the participants and interview partners). In both, we explored perceptions of the role of coal in Jharkhand and just transition futures, including economic, social, and environmental challenges and opportunities. Furthermore, we analysed 16 policy documents and 20 policy interventions of relevant actors related to the just transition in India. Policy interventions are blog entries, newspaper articles, and summaries of workshops and dialogues. To identify relevant actors, we used the mind map by Teri and CIF on actors working on just transitions[32]. For both, we included one document per actor in the analysis, which is primarily concerned with the topic of just transition and prioritised documents that focus on Jharkhand. Additionally, we did four background interviews followed by site visits with researchers, coal industry actors, and social workers. To analyse the data, we used thematic analysis (Nowell et al. 2017) and structured the imaginaries based on the main themes that we found in the data.

4.5 Results

We identified two main just transition imaginaries in Jharkhand (see Table 4 for an overview) – *just transition as green growth and reskilling strategy* and as *self-determination and land ownership*. The

[32] The Energy and Resources Institute (Teri) is a NGO conducting research on energy and sustainable development and the Climate Investment Fund (CIF) is a multilateral climate fund financing projects to support low-carbon development and climate change mitigation. They conducted a case study on just transition in India and identified actors that work on just transition in the country: https://www.teriin.org/sites/default/files/2021-04/Mindmap.pdf.

first imaginary is institutionalised mainly through the articulation of powerful actors in India and the second imaginary is an emerging imaginaries expressed by communities and local actors.

Table 4: Overview of identified of just transition imaginaries in Jharkhand.

Just transition imaginaries	Key characteristics and themes
Just transition as green growth and reskilling strategy	• The main thematic focus is green growth and employment with the promotion of RE as the solution for generating new revenues and creating jobs alongside advocating for the development of a green hydrogen industry. • Establishment of reskilling institutions and financial and technological forms of support involving high-level actors, e.g. Just Transition Taskforce in Jharkhand and the Inter-ministerial committee on Just Transition (the latter includes unions to assess impact and challenges). • The imaginary highlights the dependency of Jharkhand on coal for revenues and jobs, envisioning the state as an energy hub for India that combines national and state economic development.
Just transition as self-determination and land ownership	• The imaginary centres on restoring community rights to land, water, and forests, ensuring sustainable livelihoods, and preserving cultural traditions. It is associated with the active participation of local actors in shaping the process (NGOs, communities, and grassroots organisations). • Jharkhand's focus shifts from coal to agriculture, forestry, fisheries, tourism, and small enterprises, aiming to create a self-sufficient economy (and development). • Just transition is connected to Jharkhand's history and community structure, shaped by coal mining, to the potential of a just transition that could revive local customs and explore new identities, emphasising the deep-rooted connection to land.

Source: Own depiction.

4.5.1 First imaginary: Just transition as green growth and reskilling

This imaginary focuses on green growth and reskilling measures, combined with support for national economic development. It is voiced by national and state government actors, and representatives of the coal industry, including coal unions[33]. Therefore, this is the imaginary reproduced by elites and powerful actors in Jharkhand who are part of the government and coal industry.

In the discourse of national and state government, as well as industry stakeholders, the narrative promoting coal for development is prominently featured. They emphasise Jharkhand's historical role as an energy hub for India and its contribution to the nation's development. Coal is portrayed as pivotal for Jharkhand's progress, particularly considering its status as a relatively new state characterised by political instability and limited industrial diversification compared to neighbouring states like Odisha, which have a stronger presence of other industries alongside coal mining. The reliance on coal revenues and employment opportunities is highlighted, alongside the perceived positive impacts of coal extraction on regional development, such as the establishment of educational and healthcare infrastructure[34]. Although not explicitly emphasised in public discourse and often discussed discreetly, it is commonly associated with the temporality of mining operations. The projected decline in mining activities in the

[33] To some extent, arguments and visions of national NGOs are also present in this imaginary. However, tension exists regarding central justice aspects, such as the responsibility to finance just transitions and addressing environmental impacts and rehabilitation.

[34] This stands in contrast to other arguments by people living in the regions stating that these facilities are insufficient to improve local welfare and that they either only benefit formal workers or that they do not provide many jobs (FG_04, int_10, int_05).

future is anticipated to lead to a reduction in revenues and potentially risk social infrastructure, thus linking the continuity of coal mining with the sustainability of social facilities.

The potential decline in employment is perceived as mitigated by the creation of green jobs, offering decent employment opportunities and aligning with reskilling initiatives. This transition to green jobs is viewed as a means to facilitate a just transition and provide support during the transition process. However, despite acknowledging the presence of informal workers, the focus of reskilling measures remains predominantly on formal workers. Moreover, regarding concerns over land acquisition and dispossession, which are under the control of the actors advocating this imaginary, there is a lack of perceived necessity to reform the regulatory framework. As articulated by a representative from CCL: *"When we take land from people, we either give them employment or if they don't want the employment, we give them a one-time payment or a part by part payment in which the payment is put in a fund and they get a monthly payment so that they can't waste that money. We are looking after them."* (int_06).

While further coal mining is supported by the coal industry and national and state government and these actors are normally unwilling to accept the need or risk of a structural decline in coal mining, their narrative is gradually changing in terms of highlighting the role of RE and government commitments at international forums to promote decarbonisation in India. The RE push is contributing to creating the alternative story of green growth. By highlighting the positive economic aspects of coal mining in the past and the promising future of RE (and to some extent other economic sectors) this imaginary tends to dismiss the negative aspects of the current situation and the past. RE is seen as a technological solution and opportunity to address environmental and economic challenges as well as create jobs. For example, this is reflected by the emphasis that is put on green hydrogen and the launch of the "Green Hydrogen Mission" and related "Green Hydrogen Task Force" by the Jharkhand government. With this, Jharkhand is promoted "*as a pioneer state for green hydrogen technologies*" (Government of Jharkhand 2023, 32). While national NGOs do not retell the success story of coal to the same extent as industry and government actors, they also emphasise the need to focus policy on reskilling and regional economic diversification.

When looking at institutions established to promote a just transition in Jharkhand, we see a planning process that relies mostly on industry and government-level actors, reflecting the overall top-down approach of the Indian policy. For example, CIL holds roundtable discussions involving actors primarily from ministries and the coal industry, occasionally engaging with unions, academics, and national NGOs[35]. Furthermore, the mandate of the Just Transition Task Force in Jharkhand is to *"enable a transformative journey through assessing, estimating, and recommending policy directions for a viable transition process away from fossil fuel economies"* (Government of Jharkhand 2023, 13). The Task Force includes state government departments but no other actors, something that raised criticism by unions. An argument for not including other actors is provided by an interviewee involved in assisting the Task Force. He says that the Task Force purely aims at making decisions for the future of Jharkhand

[35] For example the „Inter-ministerial committee on Just Transition".

and, thus, the active participation of community actors is not seen as beneficial: *"The Task Force aims at making decisions for the future and they want this to happen. They are very serious about it. So it's that you can't have more people involved if you're serious about it, and then it's just a talk show and nothing more."* (int_04). This exemplifies a common reliance on traditional power in decision-making processes with little sprinkles of participation and usage of local knowledge to assess the impact and challenges of a just transition.

Overall, this imaginary promotes a continuation of the status quo in the energy planning system: top-down and reproducing existing power relations and structures. The policy interventions centre on capacity building in terms of retraining and -skilling of workers and deployment of RE, seeing such interventions as their objective and arguing that compensations through e.g. programs for reskilling of workers will also help local communities. Incumbent actors predominantly take part in the design of the transition by dominating the decision-making. The negative socio-ecological impacts of coal mining in the past and the potential negative impacts of post-mining are to a certain degree recognised but are far from representing the driving force of this imaginary. Rather, they constitute a subordinate condition to green growth efforts.

4.5.2 Second imaginary: Just transition as self-determination and land ownership

The second imaginary focuses on a bottom-up approach to a just transition, challenging prevailing views and emphasising land ownership to community members living in the area. Thereby, the imaginary highlights the role of local NGOs and decision-makers like Panychatas in promoting a form of decision-making that allows the development of a community structure independent of the coal industry. This imaginary is mainly articulated by members of the communities near coal mines (including formal and informal workers, and tribal people) and local organisations (NGO and grassroots organisations).

Central to a just future in this imaginary is increased public participation, as it entails leveraging local knowledge and exerting pressure on the rights of Panchayats and traditional institutions, such as gram sabhas, in the decision-making process. *Panychat* (or *Panychayati Raj*) refers to the decentralised government system of local self-government in villages in India. Particularly, it stands for an assembly of wise and respected elders chosen by the community. G*ram sabhas* are an element of the *Panchayati Raj* system and describe an assembly of all registered voters of a village or group of villages. They function to discuss and make decisions on various aspects concerning the village(s) and facilitate participatory democracy at the grassroots level. This shift involves transferring responsibility from CIL to Panchayats. CIL is perceived as an "outsider", with the belief that familiarity with state and local circumstances enhances awareness of topics less known by policymakers, such as informality and traditional handicrafts, which may be overlooked in planning (int_05, FG_01). This presents an opportunity to foster the inclusion of vulnerable and marginalised groups and to pressure the necessity of their inclusion through participatory approaches: *"We always talk about some bottom-up policies and initiatives. Not only top-down; top-down was there. But we must hear the voice of the people who are at the back of the system"* (int 02).

This imaginary connects the regional history, dependence and community structure shaped by coal mining. Particularly, it highlights the historical attachment to the land and how it changed through coal

mining. A tribal woman, working informally in the sector, illustrated the omnipresence of coal in the daily experience: *"When I wake up, I think of coal. When I go to sleep, I think of coal"* (FG_3). Mining has affected the traditions of the tribal communities and their cultural practices. For instance, the acquisition by CIL of Adivasis' sacred land and forests has impacted their nature-based religious and cultural practices. Another tribal woman explained how the region changed from one dependent on agriculture and forest and the symbiotic *"relationship with Jal (water), Jungle (forest) and Jameen (Land) to a region of destruction of natural resources during the expansion of mining projects"* (FG_3). Moreover, displacement caused by mining has led to changes in the way people live now and the loss of social capital (doc_30). Land is seen as a symbol of security, generational wealth, and the identity that is lost in the mining process: *"Land is the identity of people. If you acquire the land of people, they lose their identity. This is the major problem"* (int_11). In this regard, coal is seen as a relic of the past and present, considering both its positive and negative aspects, and it is not essential to deal with its future. While the significance of RE is recognised, it is not the central focus of Jharkhand's future. Instead, the emphasis lies on agriculture, forestry, fisheries, tourism, traditional handicrafts, and small enterprises. However, interviewees and participants of focus groups expressed that they experience feelings of being misunderstood, frustrated and despaired about the future (FG_01, FG_02, FG_03, int_07, int_11).

From this perspective, land acquisition and dispossession are key issues. The temporal aspects of land acquisition go beyond compensation and have an impact on generational wealth and identity. In contrast to the first imaginary, they emphasise the process of land compensation due to coal mining activities that left people feeling helpless, powerless, exploited, and fuelled with regrets. Initially, when CIL began acquiring land, one member from each family who lost their land got a job. However, due to the lack of many other opportunities, many informal jobs were created in the coal sector, such as in transportation (trucks, railway sidings etc.), services (drivers/helpers/labourers, coal washery, local cells for hand loading coal, small shops around the mines) and distribution (coal gathering and selling in the local market). Furthermore, actors highlight the difficulties in the process of acquiring land ownership certificates (land has been passed down by generation without an official document to prove it) and the long and uncertain waiting time to get compensated for land acquisition (sometimes up to 20 years) (FG_01, FG_02, FG_3, int_05). This stands in contrast to views of actors that articulate the first imaginary.

This is highlighted by a retired worker in Ramgarh, who lost his land while being offered a job at CCL, which he saw as a significant gain for him and his family. With no formal education, it was a matter of pride for him to secure a government job in lieu of his land. However, after witnessing the operations over the years he realised the true damage mining caused in the region. Today, he can support his family with his pension but regrets that he lost a significant asset for future generations in his family (FG_03).

In sum, histories of land dispossession and feelings of despair translate into a vision of a just transition that is centred on the *"right of ownership"* (int_05), self-determination, and capacity building of people in the communities to invest in the social fabric of communities that were disrupted due to coal mining. A just transition offers an opportunity to return key resources to the communities, such as land, water, and

forests, initiating a healing process. In the words of one interviewee: *"If you are gradually stopping [coal mining], give the land back to them. If the owner is not there, provide development at a community level. This land belongs to that community. This land belongs to that village and the local people will get involved there because the right of ownership is the big problem here in Jharkhand, in India"* (int_05). The actors characterise a just transition as a restoration process that involves restoring water resources, promoting afforestation and reforestation, and closely aligning with the nature-based traditions of Jharkhand. A concern is that the just transition needs to address cultural and long-standing issues of the tribal communities and the protection of tribal land.

4.6 Discussion and limitations

Our analysis unveils two common imaginaries of just transition futures in Jharkhand (see Table 4). The imaginaries offer contrasting perspectives on the justice pillars, with notable differences to distributive justice, as seen in employment provision and land acquisition compensation, and in procedural justice, through their handling of decision-making processes. Furthermore, they differ in their recognition of vulnerable groups and their approaches to restorative justice about land rights. The analysis highlights the tension between the imaginaries, which sheds light on structural injustices and the complexity of just transitions. In the following section, we discuss the imaginaries in relation to the just transition approaches (limited and expansive approach), the issue of land dispossession, the role of participation, and, finally, the question of co-existence of the imaginaries.

The two imaginaries align with the approaches proposed by Wilgosh et al. (2022). The first imaginary follows the limited approach, advocating for affirmative responses that essentially sustain existing structures. It emphasises technological innovation for green growth, focusing on reskilling and fostering renewable energy business opportunities as alternatives to Jharkhand's coal-centric economy. Conversely, the second imaginary, reflective of an expansive approach, delves into local contexts, particularly tribal lands and community-specific concerns. This approach emphasises the recognition and strengthening of marginalised voices, addressing the unique identities and livelihoods within these communities. The perspectives diverge wherein the first perceives the region and its people as homogenous groups within a national framework, as opposed to the second that emphasises the distinctive individualised contexts of communities and tribal people. The discrepancies in the imaginaries underscore the complexities in conceptualising just transitions, highlighting the necessity of considering the heterogeneous impacts of the coal industry and the varying socio-economic implications for different actors. In her work on the diverse meanings of coal for actors in India, Lahiri-Dutt (2016) shows the non-homogenous nature and significance of the coal industry in India for different people. She highlights that a large amount of coal provides livelihood for the rural population, particularly the poor and involved informally, and further states that the regulatory framework largely neglects these livelihoods.

The analysis points to the aspects of land dispossession within the socio-political coal landscape in Jharkhand and India. The second imaginary critically examines land control and ownership, highlighting the marginalisation and injustices prevalent in the extractive industries. In contrast, the first imaginary portrays compensation processes as effective. Literature on space and temporality suggests that land acquisition is tied to power dynamics and control in transition processes (D'Angelo and Pijpers 2018; Luning 2018; Oskarsson, Lahiri-Dutt, and Wennström 2019). This is in line with Luning's (2018) analysis

of financial compensation for land acquisition that points to the long-term implications of acquisition to identity struggles and wealth implications. Lahiri-Dutt (2007) critiques the limitations and transparency deficits within the legal frameworks governing compensation. Notably, the transition to RE raises concerns about perpetuating these extractive paradigms. Chhotray's (2022) cautionary stance is that "RE projects need to be viewed as a continuum that unfolds within the same extractive regimes" (Chhotray 2022, 77). Yenneti, Day, and Golubchikov (2016) analysis of a large-scale solar energy project in India displays that the project comes along with the dispossession of life-sustaining assets in the form of land of vulnerable social groups. This raises critical questions regarding the actors who bear the substantial costs associated with energy production, enhanced energy access, and energy security, particularly in the realms of coal mining and RE deployment, where land acquisition is a central part and seemingly dominated by state and corporate interests (Yenneti, Day, and Golubchikov 2016; Chhotray 2022; Oskarsson, Lahiri-Dutt, and Wennström 2019; Levien 2013). This discussion underscores the need to scrutinise legal frameworks, enhance compensation transparency, and ensure just management of land ownership in energy transitions, prioritising the rights and aspirations of local communities.

The two imaginaries diverge in their view on participatory decision-making in the region's future. The first imaginary illustrates participation through mainly socio-economic assessments via surveys and workshops and decisions made by high-level entities, such as the Just Transition Task Force. However, the effectiveness of these structures is debated, especially when participation is confined to governmental actors, potentially overlooking key vulnerabilities. The second imaginary raises concerns about the coal transition amplifying existing injustices and vulnerabilities. As shown in the literature, while participation is vital for integrating local perspectives in the transition process, it does not automatically guarantee justice (Gürtler and Herberg 2021; Huang and Chen 2021). Meaningful inclusion requires that all voices, especially those from affected communities, are acknowledged (Delina 2018; Feola et al. 2023). Scholars caution against the co-option of just transition processes by influential groups to maintain existing power dynamics and keep the status quo (Wang and Lo 2021; Alarcón et al. 2023; Wilgosh, Sorman, and Barcena 2022). Particularly against the backdrop that informal workers and (poor) peasants are marginalised from decision-making processes, with industry and government entities asserting control over them (Lahiri-Dutt 2007). Lahriri-Dutt (2016) illustrates how the public sector may resist changes to maintain its monopoly power by introducing administrative delays and bureaucratic hurdles, as observed in the past in India. This emphasises the role of bridge actors in facilitating communication and interaction between communities and decision-makers and fostering bottom-up political engagement (Dutt 2022; Shukla and Swarnakar 2022b; Chhotray 2022). In this regard, just transition can be a process for communities to express their future (Johnson et al. 2020; Carvalho, Riquito, and Ferreira 2022; Hermwille et al. 2023). This underlines the role of leveraging the resources available to marginalised actors to define their future and express their desires ensuring their active involvement and agency.

Reconciling divergent imaginaries in Jharkhand presents challenges due to contradictions in underlying interests, particularly concerning justice, land ownership, and power dynamics. The literature on that points out the contradictions and frictions which can make a co-existence of imaginaries difficult,

especially when dominant, institutionalised visions, backed by powerful actors and resources, clash with localised, context-driven perspectives (Tesfamichael 2022; Simmet 2018; J. M. Smith and Tidwell 2016; Delina 2018; Sang-Hyun Kim 2015). Others explore the potential for coexistence, suggesting that identifying synergies and fostering collaborative spaces can facilitate mutual understanding and recognition of diverse actor needs and aspirations (Hirt, Sahakian, and Trutnevyte 2022; Trencher and van der Heijden 2019; Feola et al. 2023; Oomen, Hoffman, and Hajer 2022). In Jharkhand, critical discrepancies, particularly in power relations and land ownership, underscore the complexities of reconciling and finding a common imaginary. While both imaginaries envision a RE future for Jharkhand, their approaches to governance and inclusivity differ noticeably. However, imaginaries are never stable and are subject to negotiations and reimagining, temporally situated (Delina and Janetos 2018; Trencher and van der Heijden 2019; Jasanoff and Kim 2015). In this regard, the literature underscores the role of emerging, alternative imaginaries in challenging entrenched power structures and advocating for social change, emphasising the importance of interactions that may lead to contestations or synergies (Christiansen and Carton 2021; Longhurst and Chilvers 2019; Feola et al. 2023; Carvalho, Riquito, and Ferreira 2022; Trencher and van der Heijden 2019). The envisioning of future trajectories is a multifaceted process involving various actors with diverse aspirations and needs. We argue that recognising structural inequalities and fostering community-based, bottom-up approaches can offer new insights into just and equitable transitions, though the fluidity of imaginaries requires ongoing dialogue and negotiation, especially on contentious issues like land rights and participatory governance.

Overall the just transition future of Jharkhand remains uncertain and an exploration of the tensions and implications surrounding imaginaries can illuminate overlooked aspects present in the current system. We highlight that investigating land dispossession and compensation unveils structural inequalities within the coal industry. Moreover, we notice a challenge in imagining a future beyond coal faced by complex linkages and constraints shaped by historical, present realities, and spatial-temporal dimensions (Kuchler 2014; Oomen, Hoffman, and Hajer 2022; J. M. Smith and Tidwell 2016). Agency in shaping future trajectories lies with those who have greater influence, constraining the potential of a just transition to challenge prevailing power dynamics (Oomen, Hoffman, and Hajer 2022; Feola et al. 2023; Pohl 2023; Friedrich and Tups 2023). Especially in the context of India, where discussions on just transition futures in Jharkhand and India are nascent, predominantly steered by few actors, revealing power disparities. However, we argue that a just transition offers promise in empowering local communities and remedying historical injustices, fostering healing and reconciliation.

Our study has limitations that necessitate acknowledgement and prompt further research. Primarily, given the nascent nature of the just transition narratives, especially in the Global South, a significant portion of relevant discussions are published in newspapers and social media. While we addressed this by incorporating in our sample documents that describe policy interventions, we acknowledge the potential value of media analysis in capturing this emerging discourse. Our utilisation of focus groups and interviews proved effective in reaching and understanding the visions of informal workers and community members, groups that might not have been adequately represented through document analysis alone. However, we encountered challenges for people in envisioning the future. More transdisciplinary work that incorporates insights from decolonisation methods to collaboratively engage with communities in the transition planning would be beneficial for understanding diverse perspectives

(L. T. Smith 2012; B. Ghosh et al. 2021). In general, we faced difficulties in accessing data related to informality and the overall experiences of communities. Acquiring more comprehensive data in these areas is needed not only for research purposes but also for assessing the impact of coal mining closures on communities.

4.7 Conclusion

Explicit discussions about the need and the meaning of a just transition amid the coal transition in the Indian context have commenced in very recent years. Given that coal contributes 10% to state revenue in the state of Jharkhand, making these communities heavily reliant on it, understanding the perspectives of different actors on a just transition can help ensure that the decarbonisation process does not inadvertently reinforce existing injustices or create new ones. Utilising a diverse dataset comprising twelve expert interviews, four focus groups, and 36 documents, we identified two main imaginaries of just transition futures: *green growth and reskilling strategy, and self-determination and land ownership*.

These imaginaries align with limited and expansive approaches to just transition, where the former emphasises sustaining existing structures through technological innovation and green growth, while the latter delves into local contexts and marginalised voices. They differ notably in their perspectives on distributive and procedural justice pillars, recognition of vulnerable groups, and approaches to restorative justice concerning land rights. Additionally, the analysis highlights challenges in participatory decision-making and the harmonising land dispossession issues, influenced by power dynamics and differing interests. Reconciling divergent imaginaries faces challenges due to underlying contradictions in interests and power relations. Overall, the analysis sheds light on structural injustices and complexities inherent in envisioning a post-fossil future, emphasising the potential of just transitions to empower local communities and address historical injustices.

The paper engages in the discussion on the burgeoning debate on just transition policy in the Global South, the issue of land possession and ownership, the meaning of space and temporality in just transitions, and the perspectives of communities. That being said, the paper contributes to the just transition literature by analysing different perceptions of what justice means in transitions. We believe this work offers valuable insights into just transitions, which can benefit other transitioning regions.

Chapter 5:

Modelling social aspects of the energy transition: What is the current representation of social factors in energy models?*

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5 Modelling social aspects of the energy transition: What is the current representation of social factors in energy models?

5.1 Introduction

Achieving EU's commitments under the European Green Deal, the Energy Union Strategy, and the Paris Agreement requires a significant transformation of current energy systems into carbon-neutral and renewables-based systems. To facilitate this transformation in a socially, economically and politically accepted way is crucial, and 'just transition' has become a central term for the envisioned change to a sustainable and climate-neutral economy, leaving no one behind (European Commission 2020).

Models can assist policy- and decision-makers to explore possible energy futures and transition pathways to climate neutrality (Süsser et al. 2021; Silvast et al. 2020). Policy- and decision-makers increasingly use such computer-based energy modelling tools – hereafter referred to as models – and they also influence the modelling (Süsser et al. 2021). Models are becoming increasingly capable of describing technological and techno-economic developments, and partially policy assumptions (e.g., (Koppelaar et al. 2016; Lopion et al. 2018)). However, they often do not adequately represent social aspects[36] of the energy transition, although there is broad consensus that non-technical factors are important drivers and constraints of the transition, influencing the dynamics of the transition in various ways (e.g., (Biresselioglu et al. 2020; Savvidou and Nykvist 2020; Bayulgen 2020; Uhde and Malima 2020)). For example, on the one hand, citizens can play a facilitating role as prosumers and co-owners of community energy projects, by benefitting from on-site energy projects (Süsser and Kannen 2017; Bauwens and Devine-Wright 2018; Brown, Hall, and Davis 2020). On the other hand, public opposition towards renewable energy (RE) projects, such as onshore wind farms and accompanying transmission grids, slows down the energy transition (Kaldellis et al. 2013; Reusswig et al. 2016; Cashmore et al. 2019). Neglecting these social aspects in modelling could result in erroneous policy decisions. Therefore, techno-economic modelling needs to be re-examined to better reflect the social realities of the energy transition (Trutnevyte 2016), including societal actors, socio-political dynamics and the "co-evolving nature of society and technology" (Li, Trutnevyte, and Strachan 2015). This would allow for a better and more realistic analysis of energy system trajectories (Turnheim et al. 2015).

Combining socio-technical research and modelling approaches is a topic currently high on the research agenda, not at least because it can broaden the perspective on and understanding of energy transitions and real-world developments (Turnheim et al. 2015; Geels, Berkhout, and van Vuuren 2016; Li, Trutnevyte, and Strachan 2015; Hirt et al. 2020). A better representation of social aspects in energy models is essential to understand the effects of drivers and constraints of renewable energy technologies, including the effects of societal paradigm changes, on the speed of the transition and redesign of the energy system. To improve their integration, societal assumptions in existing models must be mapped and assessed (Trutnevyte et al. 2019). So far, current literature and model reviews do

[36] We define social aspects of the energy transition as all aspects that concern the people, their interactions, and relationships within the energy system. We use the term as a synonym to social dimension and social factors.

not systematically assess the integration of social aspects in energy models but rather focus on certain aspects or theories or staying within a discipline (e.g. (Pfenninger, Hawkes, and Keirstead 2014; Hirt et al. 2020; Li, Trutnevyte, and Strachan 2015). Therefore, we take this research gap as a starting point to investigate if, what and how social aspects are currently represented in modelling applications of key energy modelling tools. Our research questions are: Which model types are particularly good at integrating social aspects? What social aspects are represented in energy models? How are these social aspects integrated?

To answer these research questions, we conduct a systematic analysis focusing on open-source energy modelling tools of the EU Horizon 2020 projects SENTINEL[37], and openENTRANCE[38]. We choose these two modelling projects because they include a diversity of open modelling tools, ranging from energy demand and system design to economic models. Specifically, we analyse up to five scientific publications that apply the models to understand the integration of social factors along these different modelling steps: (i) storyline, scenario and input parameter, (ii) optimisation/simulation process, and (iii) model output discussion.

With this research, we provide an overview of state-of the art approaches for integrating social aspects into energy models, which offers a starting point for dialogue among scholar from different fields and the right model selection for interdisciplinary studies. Furthermore, our results help modellers and decision-makers to find appropriate model types for specific research questions and scenarios linking techno-economic and social perspectives. Last, we identify future research and development needs for energy modelling.

5.2 Background on energy modelling and social science

5.2.1 Energy models, an overview

There is a rapidly growing variety of energy models that address specific energy challenges, and along with this, scholars use different model categorisations depending on the purpose of the study (Lopion et al. 2018; Köhler et al. 2018; Nikas, Doukas, and Papandreou 2019; Hirt et al. 2020). We classified the models to fit our analysis (following (Hirt et al. 2020; Köhler et al. 2018)), meaning that the purpose is to analyse what model types are suitable for integrating social aspects and how it is done. Therefore, in this study, we classify energy models into energy system models (ESM), integrated assessment models (IAM), agent-based models (ABM), and computable general equilibrium (CGE) models.

ESMs are usually bottom-up models or hybrid models that are cost-oriented and calculate prices endogenously. They are often used to provide information on the energy system of specific sectors with a great technological detail (Nikas, Doukas, and Papandreou 2019; De Cian et al. 2018; Herbst et al. 2012). Optimisation and simulation are common underlying methodologies of energy models in general and ESMs in particular (cf. (Lopion et al. 2018)). ESMs provide least-cost economic solutions by

[37] https://sentinel.energy/

[38] https://openentrance.eu/

capturing technological and economic dynamics as realistically as possible (Nikas, Doukas, and Papandreou 2019; Herbst et al. 2012). However, they have limited representation and realism of microeconomic processes and social aspects, e.g. behaviour and lack macroeconomic completeness (Nikas, Doukas, and Papandreou 2019).

IAMs analyse the impact of policies in the long-term by including both human and nature dimension components and provide insights into systematic change. Cost and technological constraints are the basis for simulations and optimisations. One of the strengths of the model is the recognition of feedbacks between the global economy and the climate system (Belete et al. 2019). Therefore, IAMs are usually applied at a spatially large scale and work with a single agent representation (van Sluisveld et al. 2020; De Cian et al. 2018). They express cultural and social change and future uncertainties through exogenous assumptions, historical data and estimates of future developments. Therefore, these models are based on exogenous assumptions, e.g. about lifestyle, preferences, and technological changes (De Cian et al. 2018; Köhler et al. 2018).

In contrast, ABMs place more emphasis on the agents' decision-making about renewable energy technologies and analyse the behaviour of complex social systems (Köhler et al. 2018; Stavrakas, Papadelis, and Flamos 2019). This implies in particular behavioural aspects of the represented agents as well interactions between the agents and actor heterogeneity. ABMs are very well suited to represent social phenomena at microeconomic-level; although the energy system can only be represented to a limited extent (Köhler et al. 2018; De Cian et al. 2018). They are often based on social scientific theory, socio-psychological theory, game theory etc., and not on optimisation (De Cian et al. 2018).

CGE are macroeconomic models that often combine or complement energy models. They are top-down models and assess the impacts of policies on economic, social, and environmental parameters. Furthermore, they analyse macroeconomic effects and the linkages between different economic sectors with real world (exogenous) data (Nikas, Doukas, and Papandreou 2019; Babatunde, Begum, and Said 2017). For example, CGE models assess the impact of policy or economic shocks by comparing an initial general equilibrium and a recomputed equilibrium after changing parameters of the exogenous data to mimic policy interventions (Nikas, Doukas, and Papandreou 2019; Babatunde, Begum, and Said 2017). CGE models assume optimal behaviour by economic agents. They use exogenous data, scenarios and sensitivity analyses to account for changing parameters (Nikas, Doukas, and Papandreou 2019).

For each of the four categories, we analyse different models with respect to the current and possible integration of social aspects.

5.2.2 Social aspects of the energy transition

There is an increasing awareness that societies are critical for the success of the energy transition (e.g., (Bridge and Gailing 2020; Fast 2013; Miller, Iles, and Jones 2013)). Analysing energy transitions through the lenses of socio-technological systems enables to put more emphasis on the role of society within the transition process and its outcomes (Miller, Iles, and Jones 2013). Previous studies have focused on drivers and barriers (e.g., (Biresselioglu et al. 2020; Savvidou and Nykvist 2020; Bayulgen 2020; Uhde and Malima 2020)), social benefits and challenges (e.g., (Süsser and Kannen 2017; Brummer

2018; Lee and Shepley 2020)), of the energy transition (e.g., (Martin et al. 2020)). These studies address different geographical scales and levels of organisational behaviour and performance. This implies that some researchers rather investigate socio-demographics factors and societal patterns, such as lifestyle and social movements. Others analyse behavioural changes and aspects of social attitudes, including the acceptance of energy technologies and energy citizenships. Last, others study social innovations and experimentations, which can evolve and lead to new system configurations. Different levels and inherent social aspects are highly interlinked and interact.

It is not our intention to structurally review various social aspects. Instead, we recognise that different social aspects exist, and we place a particular emphasis on social and behavioural factors that scholars identified as relevant to socio-technical transitions and, therefore, where energy models need to be improved. In doing so, we refrain from looking at political and regulatory aspects to focus on the social and behavioural factors, although it should be noted that these aspects are linked to the social factors we are looking at. Recent transition literature identifies five strongly interrelated factors that are important for the energy transition:

- Behaviour and lifestyle (Hirt et al. 2020; Trutnevyte et al. 2019; Köhler et al. 2018; De Cian et al. 2018; Martin et al. 2020)
  The aspect concerns the behaviour and lifestyle of all types of actors in transformations and the influence on the dynamic and pathways of the energy transition (Trutnevyte et al. 2019; Köhler et al. 2018; De Cian et al. 2018). This includes aspects like material and non-material needs, values, norms, and preferences (Trutnevyte et al. 2019). Changes in the behaviour of actors affect the prediction of trajectories significantly as this implies changes in demand and, thus, influences the necessary development and allocation of renewable energy.
- Heterogeneity of actors (Hirt et al. 2020; Trutnevyte et al. 2019; Köhler et al. 2018)
  The aspect is linked to the concept of agency and “heterogeneity across and within societies” as there are many different actors involved in the energy transition (Trutnevyte et al. 2019; Köhler et al. 2018). The heterogeneity of the diverse actor groups (e.g., consumers and producers) in different states of the energy transition and the behaviour of the actors in the group influences the dynamics of the speed of the energy transition (Köhler et al. 2018). This includes contextual and environmental factors, distributional impacts of environmental change and policies, socio-economic conditions, and presence of incumbents and innovators (Trutnevyte et al. 2019).
- Public acceptance and opposition (Hirt et al. 2020; Trutnevyte et al. 2019; Martin et al. 2020; Upham, Oltra, and Boso 2015; Wüstenhagen, Wolsink, and Bürer 2007)
  The aspect considers public acceptance and opposition towards energy infrastructure that influences the speed of the renewable energy deployment. Acceptance is “a favourable or positive response relating to a proposed or in situ technology or socio-technical system, by members of a given social unit” (Upham, Oltra, and Boso 2015). Wüstenhagen et al. (2007) conceptualise three dimensions of social acceptance: (i) socio-political acceptance refers to the general acceptance of the public on the energy transition; (ii) community acceptance describes the approval of the local population by specific landscape decisions, and (iii) market

acceptance entails the reaction of the market to innovations. Furthermore, this social aspect accounts for jobs and local (economic) development that influences the people's attitude towards the energy transition (Oei, Brauers, and Herpich 2019).

- Public participation and ownership (Süsser and Kannen 2017; G. Walker and Devine-Wright 2008; Devine-Wright et al. 2017)
  Especially community acceptance is based on public participation and ownership. This is considered to be a main driver of the energy transition as it allows people to influence and actively participate in the local energy transition (Devine-Wright et al. 2017). Participation can be financial, e.g. through money transfers of local wind farms to citizens in the surrounding area. Alternatively, the participation of the population in project implementation and the processes of infrastructure measures, e.g. citizen assemblies referendum based on citizens' decision.
- Transformation dynamics (Trutnevyte et al. 2019; Köhler et al. 2018)
  The aspect concerns transformation dynamics at and across different scales and in time, which includes speed of transformations, path dependencies and the quality of different system states (Trutnevyte et al. 2019; Köhler et al. 2018). This refers to the non-linear and polycentric (e.g., multiple actors and temporal scales) process of the transition and the societal system within (Köhler et al. 2018).

5.2.3 Current approaches for linking social science and computer-based modelling

Quantifying and integrating social aspects into energy models is still one of the key modelling challenges (Pfenninger, Hawkes, and Keirstead 2014; van Sluisveld et al. 2020). Research groups use different approaches for addressing social aspects in energy modelling, mainly analysing socio-economic impacts and using economic theory, such as social costs (e.g., (Jasiūnas et al. 2021; Liu et al. 2018; Noel, Zarazua de Rubens, and Sovacool 2018; Wei et al. 2021; Nagatomo et al. 2021)). Current models tend to treat the social dimension of the energy transition as an exogenous narrative, or "broader societal factor" (O'Neill et al. 2014, 396). However, differences exist between modelling approaches, and especially ABMs are able to simulate heterogeneous agents' behaviour and interactions, and thus, advance our understanding of societal phenomena (e.g., (Squazzoni 2010; Hinker et al. 2017)). They can provide a suitable framework for analysing adoption decisions for renewable energy technologies, demand flexibility and smart grids (Stavrakas, Papadelis, and Flamos 2019; Ringler, Keles, and Fichtner 2016).

Modelling can provide different benefits to social science and transition research: Interdisciplinary modelling can provide explicit, clear and systematic system representations that induce learning and facilitate communication about the target system (Holtz et al. 2015). Furthermore, modelling allows us to make inferences about dynamics in complex systems and generate emergent phenomena from underlying elements and processes. Lastly, the use of models can facilitate systematic experiments (ibid). Hence, combining social science and modelling can enhance interdisciplinary learning, increase realism, and support finding solutions to energy and climate challenges (Trutnevyte et al. 2019).

Trutnevyte et al. (2019) differentiate between three strategies for linking models and insights from social sciences: bridging, iterating and merging strategy. The different strategies imply different levels of linkage between models and social science. In bridging, models and social science research are carried out in parallel and sometimes build 'bridges' for exchange between each other, especially with regard to common concepts and theories. The iterating strategy can be seen as "story and simulation" approach, where exogenous narratives defined by social sciences are "translated into quantitative input assumptions used by the models", and outputs may be used for revisiting the narratives. Merging implies an in-depth integration, assuming that "at least the key societal factors can be modelled", and leading to a structural modification of existing models, or creation of completely new models (Trutnevyte *et al.*, 2019:424-425). Trutnevyte et al. (2019) state that mapping and assessment exercise of societal assumptions in energy models focusing on specific dynamics and societal change exist (e.g., (Geels, Berkhout, and van Vuuren 2016; Köhler et al. 2018; McDowall and Geels 2017; Rosen and Guenther 2015)). For example, De Cian et al. (2018) focus on the depiction of actors, decision-making, and institutions in models by analysing their current implementation and possible further model development of four models (two IAMs, one ESM, and one ABM). They explain that achieving a lower degree of integration of these factors is already possible with existing modelling frameworks, whereas a higher degree of integration requires further model development. However, Trutnevyte et al. (2019) argue that these mapping exercises either remain more generic and do not look how the representation influence the model outcome or remain "outside the modelling community" so that the findings are not used by the modelling community.

Thus, we conduct a systematic analysis of the representation of social aspects in open-source energy models by focusing on the modelling process. We build on the mentioned research by combining the knowledge gained from social science, the energy model community, and current interdisciplinary research to assess the potential of integrating social aspects in detailed modelling steps and model types.

5.3 Research design

Different energy models can integrate or represent the five classified social factors (Section 2.2) along different modelling steps. Figure 9 illustrates our framework of integration along three modelling steps: (i) storyline, scenario, and input parameter, (ii) optimisation/simulation process, and (iii) discussion of model output. The modelling steps are based on the framework by Trutnevyte et al. (2019) (see Section 5.2) and, thus, the three strategies for linking social science and modelling can be found in the steps. By defining the steps, we delve deeper into the modelling process by breaking it down to the individual steps of modelling exercises and identify within potentials for integrating social aspects in models.

The first step constitutes of the linking process by developing exogenous storylines and translating them into input parameter, which become part of the scenarios. The softest integration happens via the "bridging" where concept and theories from modelling and social science are brought together. If an "iterating" approach is applied, empirical data are used to equip the input assumptions with more details on social aspects. Similar to that, "merging" can even go a step further by jointly developing or adapting a model with corresponding input parameters. In the simulation/optimisation process, an integration

means that the aspects are found in the mathematical formulations, and, thus, structurally defines the model. This is only the case in the "merging" strategy. The last step in our framework is the model output discussion. This step involves an exogenous discussion of the model results in context of a social aspect, e.g. what the output means for the expansion of wind energy in residential areas. This is the only potential of integration in the framework that does not have an impact on the actual model results, however, impacts the way the results are interpreted and discussed. Beyond, the output discussion could also lead to the adjustment of the storylines if needed ("iterating" and "merging" strategy).

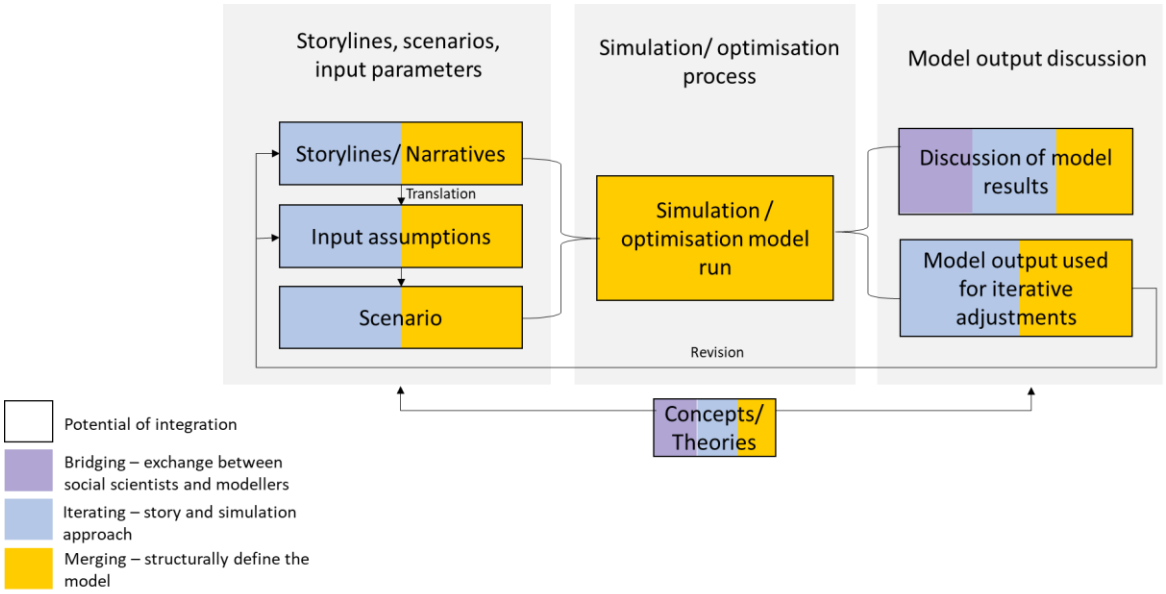

Figure 9: Potential of integration.

Source: based on Turnheim et al. (2015), Trutnevyte et al. (2019), and Hirt et al. (2020).

Depending on the model characteristics, different levels of representation are possible. To account for the model type characteristics, we apply the model classification described in Section 5.2 (ESMs, IAMs, ABMs, and CGE models). Within each type, we examine different energy model application to find the current levels of integration of social aspects by distinguishing between different ways of linking social science and energy modelling. We focus on model application to analyse how modelling teams currently integrate social aspects in scientific model publications. By focusing on these publications, we can also assess whether the scientist used theory or data from social science and if the work was done in an interdisciplinary way. We analysed scientific publications that apply or describe the energy models and use published model descriptions for indicating model specification, e.g. input and output parameters.

To explore what and how social factors are integrated into energy models, we analysed scientific publications models that are included in the modelling projects openENTRANCE and SENTINEL. We chose these models because (i) the modelling projects provide a diversity of models (from energy demand and system design to economic models) and (ii) the models are mainly open-source, which eases the analysis and future integration of new features. We found the selection to be appropriate for the – at least European – energy modelling landscape as these projects specifically aim for becoming major energy modelling suites in Europe. Between September and December 2020, we conducted a systematic literature search, to identify relevant publications that apply the models. This procedure provided "a comprehensive, unbiased and replicable summary of the state of knowledge" (Tranfield,

Denyer, and Smart 2003; Sovacool, Axsen, and Sorrell 2018, 22). We only considered scientific publications (exclusion of news feed, non-scientific magazine, encyclopaedia, and newspapers), published from 2015 onward, because model advancements may have changed the model design. For this, we used the ProQuest and Web of Science[39] search engines, because these are well-established databases that cover a broad range of scientific literature databases, and the model websites.

The search string we used to find relevant publications consists of three components connected via the logical operator AND (see Figure A 1). The first component consists of the short and long model names connected with the logical operator AND. The second component comprises the social factors: To identify whether publications address social aspects, we have identified and used keywords that are describing the nature of the social aspects using social science theory as well as existing linkage approaches. We used a brainstorming process based on the literature on social aspects among the authors to identify the social keywords and discussed them informally with scholars working in the field of socio-technical transitions. The social keywords are connected with the logical operator OR. The last component encompasses words such as energy, heat, transport etc. to limit the search to publications in the field of energy transition.

The first phase comprises the search for publications of models that we include in our detailed analysis. The two projects openENTRANCE and SENTINEL contain 28 models (see Figure 10 for the distribution of model types in the projects). We applied the search string for each of the 28 models resulting in 28 search strings. The initial search for all models resulted in 823 publications. We screened the abstracts to determine whether the publications applied the model that is stated in the search string and included social aspects in one of the modelling steps of our framework. We included the publication if the following criteria were fulfilled: (i) the publication contains an application of the model (that can also include a detailed description of the model), and (ii) includes the integration of a social aspect in one of the potential integration ways of our framework. For this, we used the social keywords to find the relevant passages. We excluded publications if a social keyword was not mentioned in connection with any of the potential of integration. For example, if we only found a social keyword in the introduction, e.g. to explain the importance of climate change, we did not include the paper as this is not a potential of integration as defined by us. Based on this screening, we found publications for 13 models that met the inclusion criteria and excluded 15 models because the search did not reveal any relevant publications for our analysis. Figure 10 shows (a) the distribution of model types in the two projects and b) the models included in our analysis.

For the 13 models, we included up to five relevant publications in our analysis that we identified in the screening process, as this provides a manageable amount of documents to analyse. We defined relevance in terms of the extent to which the respective research took social aspects into account. This resulted in 29 publications for the detailed analysis (Table A 7 - Table A 11 present an overview of all

[39] In ProQuest, we did not limit the search to title, abstract and keywords, as social drivers and barriers can also be found only partially within the paper, e.g. as a part of the discussion. Our search in WebofScience focused on the first component of the search term as the database searches only in the abstract and title

models and publications). We complemented the scientific publications with model documentations that provided further insights into the models.

In a second phase, we examined the publications by applying our analytical framework, to identify what and how modellers integrate social aspects in their models. We read the publications and marked relevant text passages using the social keywords, and sorted them according to the three modelling steps in Figure 9.

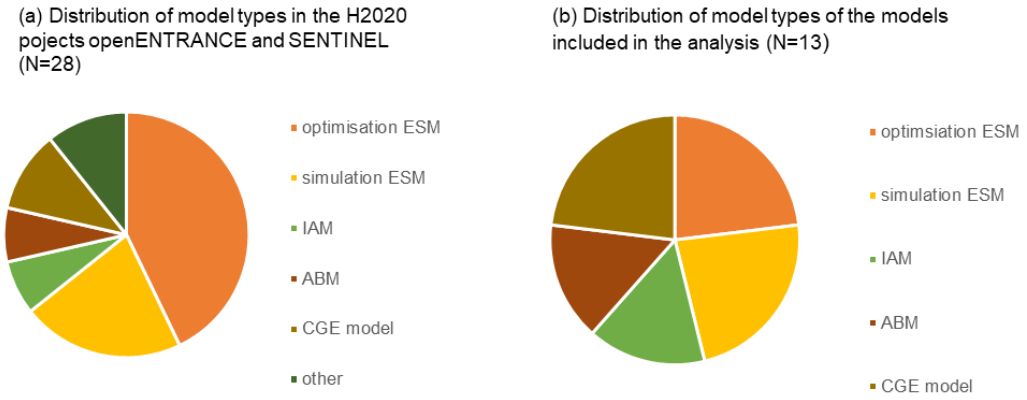

Figure 10: Overview of model types (a) all models in openENTRANCE and SENTINEL and (b) models included in the analysis.

Source: Own depiction.

5.4 Results – Representation of social factors

Out of 28 reviewed models, we present the result of the analysis of 13 modelling tools that incorporate social aspects to different extends. We investigated *what* social aspects and *how* social aspects have been integrated in the application of the energy-modelling frameworks. Table A 11 - Table A 7 provide short model descriptions, and summarise the findings regarding input and output parameters, information on the simulation/optimisation processes, and the publications which are included in the analysis of the integration of the social aspects.

5.4.1 Energy system models

We analyse the optimisation ESMs and the simulation ESMs separately, as they have a distinctly different mathematical approach and thus different analysis objectives.

5.4.1.1 Optimisation ESMs

We find that three out of 12 optimisation ESMs, deal with social aspects in scientific publications: Calliope, GENeSYS-MOD, and FRESH:COM (see Table A 7). Table 5 provides an overview of the included social aspects and how they are integrated in the models sorted along to the potential of integration. The social aspects ‘behaviour and lifestyle’, and ‘public acceptance and opposition’ are represented mainly in storylines, scenarios, and input parameter, as well as in the output discussion. However, we also find integration efforts of the aspects ‘behaviour and lifestyle’, and ‘public acceptance and opposition’ in the optimisation process.

Table 5: Representation of social factors in optimisation ESMs analysed.

Social aspect	Potential of Integration	Description of the integration into models	Model and publications
Behaviour and lifestyle	Storyline, scenario, and input parameter	- Household sizes, habits and meal behaviour, %-out-of-home meal, and consumption assumptions to account for behaviour and preferences	Calliope (Lombardi, Rocco, and Colombo 2019)
		- Input data for energy communities: electricity demand profile, a PV generation profile, and the battery parameters, community set-up, prosumer and household data, and willingness-to-pay	FRESH:COM (Perger et al. 2021)
	Simulation/ optimisation process	- Model considers local energy communities with properties, e.g. incentives for participant to joining the energy community, households connected to the grid, willingness-to-pay of community members	FRESH:COM (Perger et al. 2021)
Public acceptance and opposition	Storyline, scenario, and input parameter	- Differentiation between "technical" and "technical-social" potentials to balance techno-economic feasibility with social and political goals	Calliope (Lombardi et al. 2020), (Tröndle, Pfenninger, and Lilliestam 2019)
	Simulation/ optimisation process	- Alternative system configurations beyond single cost minimising designs, better balancing techno-economic feasibility with societal impacts and political goals	Callliope (Lombardi et al. 2020), (Tröndle 2020)
	Discussion of model output	- Discussion of the results in context of local opposition and potential broader social barriers; "indirect economic effects", e.g. local economic development, job creation	Calliope (Lombardi et al. 2020), (Pfenninger and Keirstead 2015), (Tröndle 2020)
Behaviour and lifestyle, and public acceptance and opposition	Storyline, scenario, and input parameter	Storylines and quantification/translation into scenarios: - Accounting for society´s attitudes and lifestyle changes, e.g. willingness of the society to invest in renewable energies or promote them, changes in demand - Incorporating trends in climate politics and the economy	GENeSYS-MOD (Auer et al. 2020) (Bartholdsen et al. 2019)
	Discussion of model output	- Qualitative discussion of (social) barriers for the transition based on literature - Description of results with reference to the importance of societal commitment and behaviour change	GENeSYS-MOD (Lawrenz et al. 2018), (Burandt et al. 2019), (Auer et al. 2020)

Source: Own depiction.

Calliope

We find that publications of Calliope address ‘behaviour and lifestyle’ in input parameters (Lombardi, Rocco, and Colombo 2019) and ‘public acceptance and opposition’ in input parameters and the output discussion (Lombardi et al. 2020; Tröndle, Pfenninger, and Lilliestam 2019; Tröndle 2020; Pfenninger and Keirstead 2015). For example, Lombardi et al. (2019) apply the Calliope framework and represent behaviour changes in the input parameters. Specifically, they use household sizes, habits and meal behaviour, %-out-of-home meal, and consumption assumptions to account for people’s behaviour and preferences in order to understand the effects of the electrification of Italian cooking devices and inherent changes in behaviour on the energy system. Lombardi et al. (2020) and Tröndle et al. (2019) also use the input parameters to address public acceptance and resistance. They distinguish between "technical" and "technical-social" potentials for renewable electricity. The latter incorporates social and ecological constraints, for example by not allowing electricity to be produced in nature conversation areas, or by prohibiting open field solar system on arable land, to ensure a socially more accepted deployment of renewables in Italy and Europe, respectively. Furthermore, Lombardi et al. (2020) generate “alternative system configurations that can be used to balance techno-economic feasibility with social and political goals” (Lombardi et al. 2020, 2185) (see also Tröndle (2020)). Tröndle et al. (2019) model the possibility of electricity autarky on different levels in Europe, and found that autarky on regional and municipal levels in Europe would require dense local generation, which could meet with local opposition. They point out that there is an uncertainty about the influence of socio-political

restrictions. Especially, public and political acceptance are dependent on local preferences, which vary greatly in different parts of Europe and over time, and are hard to assess in general (ibid). Lombardi et al. (2020), Pfenninger and Keirstead (2015), and Tröndle (2020) address public acceptance in the output discussion and put their results in context of local opposition and potential broader social barriers. For example, Pfenninger and Keirstead (2015) discuss the effect of local economic development and job creation of the results on concentrated solar power and nuclear power in South Africa.

GENeSYS-MOD

In the studies of GENeSYS-MOD, the social factors 'behaviour and lifestyle' as well as 'public acceptance and opposition' are included in the storylines, scenarios, and as input parameters (Auer et al. 2020; Bartholdsen et al. 2019), and in the discussion of the model output (Auer et al. 2020; Lawrenz et al. 2018; Burandt et al. 2019). Auer et al. (2020) and Bartholdsen et al. (2019) develop storylines and quantified scenarios to include social and political implications on decarbonisation pathways in Europe and Germany to account for underlying uncertainties, respectively. For example, Auer et al. (2020) take society´s attitudes towards renewable energy and lifestyle changes into account, by including assumptions on the societal willingness to invest in renewable energy or promote them, and changing demands in the input parameters. To translate the storylines, Auer et al. (2020) conduct an in-depth analysis of the storylines implications on the energy transition and rank the underlying features and drivers of the storylines into a scale by a structured comparative analysis. Whereas Auer et al. (2020) are the storytellers themselves, Bartholdsen et al. (2019) conduct stakeholder workshops to develop scenario assumptions. They incorporate assumptions on global trends in climate politics and the economy in their storylines and performed a qualitative foresight analysis to adjust the input parameters for the model cautions (e.g. different demands or cost assumptions) to develop scenarios (ibid).

Different authors (Auer et al. (2020), Bartholdsen et al. (2019), Lawrenz et al. (2018), and Burandt et al. (2019)) also use the discussion of the model output to reflect their findings against social and political realities. Auer et al. (2020) point out that societal commitments and changes in lifestyle and demand patterns are important for the transformation process to be successful and, they emphasised that behavioural change needs time. Against the backdrop of their model results, Lawrenz et al. (2018) and Burandt et al. (2019) discuss social barriers for the energy transition in India and China based on literature. They include descriptions of the role of actors and society, the importance of behaviour and consumption development, inequality, and job market developments. Here, they also refer to the fact that in GENeSYS-MOD a social-optimal planner with perfect foresight is used to optimise economic welfare, which implies that neither local actors nor specific barriers for the adoption of technologies are taken into account (Burandt et al. 2019; Lawrenz et al. 2018).

FRESH:COM

The application of FRESH:COM addresses 'behaviour and lifestyle' in the input parameters and within the optimisation process by considering individual actors' preferences in different local energy community configurations (Perger et al. 2021). They include different properties of energy communities in the model, e.g. incentives for participant to join the energy community, households connecting to the grid, and willingness-to-pay in the model (Perger et al. 2021). For example, higher willingness-to-pay of an individual community member reflects the greater preference to buy local PV generation. The

optimisation includes the objective function to maximise social welfare of the community. They also use input data related to prosumers: electricity demand profiles, PV generation profiles, battery parameters, as well as the community set-up, prosumer and household data, and willingness-to-pay.

5.4.1.2 Simulation ESMs

We analysed three ESMs – DREEM, DESTinEE, and EnergyPLAN (see Table A 8) – of the six simulation ESMs in the projects, because only those three include social aspects in model applications. Similar to the optimisation ESMs, the models mainly represent social factors in terms of 'behaviour and lifestyle', as well as 'public acceptance and opposition' in all three modelling steps, as show in Table 6.

Table 6: Representation of social factors in simulation ESMs analysed.

Social aspect	Potential of Integration	Description of the integration into models	Model and publications
Behaviour and lifestyle	Storyline, scenario, and input parameter	- Input data: identification of key socioeconomic drivers for annual demand (development of population growth and household sizes; the impact of cultural difficulties in regard to reduction of demand)	DESTinEE (Boßmann and Staffell 2015)
		- Input parameters: demand patters, household consumption, and behaviour; using stochastic methods and historical and statistical data - Scenarios include different consumption behaviour of households (e.g., heating, self-consumption)	DREEM (Stavrakas and Flamos 2020)
		- Input parameters: assumptions on various elements of the energy system infrastructure are based on population projections and structure - Data used to construct scenarios: socioeconomic indicators, and statistics of the energy system and transport sector (consumption and associated costs and economic benefits) - Different scenarios for the decarbonisation of the energy system including the transport sector in 2030 with reflections on policies that are not reflecting consumer behaviour or vehicle ownership patterns	EnergyPLAN (Cantarero 2019), (Child, Nordling, and Breyer 2017), (Dorotić et al. 2019)
	Optimisation/ simulation process	- Demand for energy services (e.g. distance people travel) projected to 2050 using macroeconomic relationships with population, income, energy prices, and sector-specific details - Model generates national load profiles for each sector by using stochastic variations mimic the natural variability of human behaviour and the sector profiles	DESTinEE (Boßmann and Staffell 2015)
		- Model incorporates modules addressing demand-response technologies, electricity demand, and household appliances including thoughts on household, consumer behaviour	DREEM (Stavrakas and Flamos 2020)
Public acceptance and opposition	Discussion of model output	- Qualitative assessment of barriers for PV and story deployment including behaviour barriers: general attitude, psychological resistance, and political will - Discussion of the results with regard to impact on economy and recommendations, socioeconomic impact (job creation, economic income) - Multi-criteria analysis based on sustainability factors - Socioeconomic impact on local communities	EnergyPLAN (Cantarero 2019), (Child, Nordling, and Breyer 2017), (Dorotić et al. 2019), (X. Sun et al. 2016) (Child, Haukkala, and Breyer 2017)

Source: Own depiction.

DREEM

Stavrakas and Flamos (2020) include the factor 'behaviour and lifestyle' in the scenarios and input parameter as well as in the simulation process of the DREEM model. They evaluate the impact of household demand patterns and consumer behaviour for the needed flexibility in the power sector. The model has a modular design that includes assumptions on demand-response technologies, electricity demand, household appliances, and household and consumer behaviour (e.g. demand-flexibility, use of appliances) in the simulation process. Demand patterns are used to reflect the complexity of

calculating accurate and sophisticated demand profiles and the importance of including the human dimension (Stavrakas and Flamos 2020). To save computational time and reduce complexity, the modellers implement many simplified assumptions, such as with regard to occupants 'behaviour, and they use "a minimal set of easily obtainable parameters and statistics, such as surveys and census data" (ibid).

Furthermore, Stavrakas and Flamos (2020) highlight the potential to link DREEM and the ABM ATOM (see Section 4.3 for more information on ATOM) to take advantage of the strengths of DREEM to be integrated with other models and explore adoption scenarios of relevant technological infrastructures for a decentralised energy system. Moreover, they provide an outlook stating that DREEM coupled with a monetary framework model can shed light on the importance of behavioural implications (Stavrakas and Flamos 2020).

DESSTinEE

We *find* that the DESSTinEE (Boßmann and Staffell 2015) modelling study accounts for 'behaviour and lifestyle' through input parameters and in the simulation process. Boßmann and Staffell (2015) investigate the future electricity load curves taking into account the variability of human behaviour in Germany and Great Britain. The analysis includes the identification of socio-economic drivers of demand, such as population and income growth, for the case studies. They also take into account the development of population growth and household sizes, cultural difficulties regarding past reduction of demand in homes as well as the macroeconomic relationship of population, income, energy prices, and sector-specific details for the country´s demand for energy services, e.g. distance people travel. To synthesise the hourly demand profiles, they add "stochastic variation to each profile to mimic the natural variability of human behaviour, and the sector profiles are summed to the national load profile" (ibid).

EnergyPLAN

We discover that applications of EnergyPLAN include 'public acceptance and opposition' in the output discussion (Cantarero 2019; Child, Nordling, and Breyer 2017; Dorotić et al. 2019; X. Sun et al. 2016; Child, Haukkala, and Breyer 2017) and 'behaviour and lifestyle' in input parameters (Cantarero 2019; Child, Nordling, and Breyer 2017; Dorotić et al. 2019). Cantarero (2019) applies EnergyPLAN to simulate the implementation of a mass public transport system in the capital of Nicaragua. For this purpose, Cantarero uses socio-economic indicators as input parameters, such as consumer behaviour, and empirical data from the energy and transport system for the scenario creation. The output discussion includes implications on the job creation potential and vehicle ownership, as well as transport choices of the population, which affect the society and outcome on the implementation of mass public transport systems (Cantarero 2019).

Furthermore, several studies address the effects of the energy transition on job creation in specific case studies in the output discussion. Child, Nordling, and Breyer (2017) use EnergyPLAN for a case study on sustainable scenarios of the energy system of Aland Islands by 2030. For this, they use different socio-economic input parameters, including population projections, installed heating systems and modes of transportation. Based on the results, they calculate the potential for job creation, by using job-years estimates from the International Renewable Energy Agency (IRENA). Dorotić et al. 2019 (2019) also calculate the potential for job creation based on the results of their analysis on the integration of

renewable energy in the transport and energy sector in island communities. To account for different residential household consumption and behaviour, they divide the household sector in five subsectors (heating, cooling, domestic hot water (DHW) demand, cooking and other household appliances). For this purpose, they create an average reference household based on a simple bottom-up method using statistical data (ibid). Furthermore, Sun et al. (2016) use the direct job creation as one of five criteria (total cost, total capacity, excess electricity, and CO_2 emissions) for a multi-criteria analyses to evaluate the sustainability of analysed scenarios for the electricity system in China. The authors quantify the job creation based on the results of the modelling exercise, using an employment factor approach (ibid).

In the study by Child, Haukkala, and Breyer (2017) on the role of PV and energy storages in an energy system based on 100% renwable energy in Finland by 2030, they combine their quantitative results of EnergyPLAN with an ex-post qualitative discussion of barriers for adoption of solar PV and define solutions and drivers for PV. Four categories comprise the barrier aspects: technological, economic, institutional and political, and behavioural. They account for the role of prosumers and the response of consumers towards prices, and state in their output discussion that empowerment and engagement of stakeholders as well as prosumer concepts can drive the PV deployment.

5.4.2 Integrated assessment models

We examine two IAMs models that are involved in openENTRANCE and SENTINEL: the optimisation MESSAGEix_GLOBIOM framework and simulation IMAGE framework (see Table A 9). Modellers address ‘behaviour and lifestyle’ in storylines, scenarios, and input parameters and the output discussion. Table 7 gives an overview of the identified representation of social aspects in IMAGE and MESSAGEix_GLOBIOM.

Table 7: Representation of social factors in IAMs analysed.

Social aspect	Potential of Integration	Description of the integration into models	Model and publications
Behaviour and lifestyle	Storyline, scenario, and input parameter	- Scenarios to analyse the implications of lifestyle changes including the lifestyle measures adjusted via the parametrisation - Changing the parametrisation, context-dependent variables, and increasing the level of detail in the housing and transportation sector to include lifestyle measures by curtailment measure - Socio-technical transition storylines using the theory MLP and subsequent quantification into scenarios and changing input parameter to quantify the MLP-storylines – e.g. cost assumptions and demand changes	IMAGE (van Sluisveld et al. 2020), (van Sluisveld et al. 2016), (Hof et al. 2020)
		- SSP narratives (simulate the extent of the impact of people´s effort on climate change mitigation under different policy scenarios)	MESSAGEix_ GLOBOIM (Zhou et al. 2019), (H. Sun, Niu, and Wang 2019), (Zhou et al. 2020)
	Discussion of model output	- Implications of lifestyle changes on transition pathways by describing results and qualitative discussion on barriers and policies for lifestyle change measures taking into account literature	IMAGE (van Sluisveld et al. 2016)
		- Analyses of results with regard to the assumptions of the storylines	IMAGE (Hof et al. 2020), (van Sluisveld et al. 2016)

Source: Own depiction.

MESSAGEix_GLOBIOM

Publications applying MESSAGEix-GLOBIOM address the social factor 'behaviour and lifestyle' by employing the widely used concept of shared socioeconomic pathways (SSP)[40] to depict trends in the evolution of society and ecosystems. Zhou et al. (2019) and Zhou et al. (2020) used SSP to analyse investment needs and future costs in different areas of the world on a national level and aggregated regions, respectively. In their output discussion, Zhou et al. (2019) point out that future research could explore co-benefits of low carbon investments and the relation to sustainable development goals, such as water availability. Furthermore, H. Sun, Niu, and Wang (2019) use population assumptions based on SSP2 to inform different decarbonisation policy scenarios to analyse the „extent of the impact of people´s effort on climate change mitigation" applying different IAMs including MESSAGEix_GLOBIOM and IMAGE. Both H. Sun, Niu, and Wang (2019) and Zhou et al. (2019) emphasise that the exogenous input parameter settings and the model structure do not capture the uncertainty about the speed of the socio-technical transition, which affects the mitigation potential.

IMAGE

Authors using the IAM IMAGE include 'behaviour and lifestyle' developments in storylines and inputs parameters (van Sluisveld et al. 2020; 2016; Hof et al. 2020) as well as in the output discussion (van Sluisveld et al. 2016) using insights from socio-technical transition studies. Van Sluisveld et al. (2016) develop a framework of 'lifestyle change interventions' to study behavioural changes in IMAGE, and they analyse the implications of different interventions on the mitigation pathways. For this purpose, they change context-dependent variables in the household and transportation sector (called parametrisation of contextual factors), which enables them to increase the degree to which transport behaviour changes (e.g. vehicle use) and heating demand changes (e.g. more efficient use of appliances) are incorporated in the model. They analyse and assess "the possible implications of lifestyle changes" and barriers in mitigation scenarios, as well as policy measure to encourage lifestyle changes (ibid).

Hof et al. (2020) and van Sluisveld et al. (2020) develop storylines based on socio-technical theory and translate the storylines into quantitative scenarios. To align IAM modelling and socio-technical transition theories, van Sluisveld et al. (2020) "identif[ied] transition narratives as an analytical bridge between socio-technical transition studies and integrated assessment modelling" (van Sluisveld et al. 2020, 1). The socio-technical narratives focus on the role of actors in meeting the European Unions' decarbonisation goals. For this purpose, they distinguish between two transition narratives: one driven by incumbent actors and a second driven by new actors with a negative attitude towards large-scale technologies, accounting for behavioural and cultural changes of the society. Hof et al. (2020) use a similar approach: they linked the three models, IMAGE, Enertile[41] (optimisation ESM), and WITCH[42] (simulation IAM) to investigate two contrasting transition narratives on the role of actors in meeting

[40] The shared socioeconomic pathways framework encompasses „pathways of future radiative forcing and their associated climate changes with alternative pathways of socioeconomic development" (O'Neill et al. 2014, 387). The scenarios are used as narratives for future socioeconomic developments and analyse emissions under different climate policies. There are five SSP scenarios with socioeconomic assumptions of mitigation and adaption. The SSP2 scenario stands for „Middle of the road". See O'Neill et al. (2014) for further information on the SSP framework.

[41] Enertile is a detailed bottom-up electricity system optimisation model with detailed technical representations of the underlying processes in the power sector (Hof et al. 2020).

[42] WITCH is a global dynamic model that combines an inter-temporal optimal growth model (able to capture the long term economic growth dynamics) with a detailed representation of the energy sector (Hof et al. 2020).

greenhouse gas reduction targets. The narratives are based on an analysis of actors' preferences, behavioural and cultural changes and social networks, and technological and social niche-innovations, and they inform the narrative-driven scenario development.

Van Sluisveld et al. (2020) state that the translation of qualitative insights into quantitative scenarios remains "the weakest link with no definitive solution": They distinguish between a straightforward translation for social features that are measurable (e.g. energy efficiency improvements) and a more "stylised" translation, of more vague aspects, such as social rules. All factors are specific to the model and Hof et al. (2020) point out that the assumptions are "tailor-made to the model" as models have different structures. The latter is based a lot on the "arbitrary" interpretations of the researchers as the parameters are harder to interpret into the models 'formulation (van Sluisveld et al. 2016). Hof et al. (2020) quantify actor preferences by making assumptions regarding costs and demand changes, e.g., improved learning rates or different ownership rates of vehicles. Furthermore, van Sluisveld et al. (2020) translate their qualitative assessment of niche momentum and actors behaviour into cost assumptions and adjustments of technological detail (straightforward) and assumptions of reduced household growth due to changing social norms (stylised). For this, both Hof et al. (2020) and van Sluisveld et al. (2020) apply an iterative process between scientist involved in MLP case studies and modellers.

5.4.3 Agent-based models

We examine the two ABMs of the two research projects: BSAM and ATOM (see Table A 10). ATOM extends the initial BSAM framework by focusing on consumers (BSAM focuses on power generators). Not surprisingly, we find that ATOM and BSAM are well able to examine agent decision-making under different conditions and account for 'behaviour and lifestyle', 'actor heterogeneity', 'public participation and ownership', and 'public acceptance and opposition' in all three modelling steps (see Table 8).

Table 8: Representation of social factors in ABMs analysed.

Social aspect	Potential of Integration	Description of the integration into models	Model and publications
Behaviour and lifestyle, actor heterogeneity, and public participation and ownership	Storyline, scenario, and input parameter	- Input: geographical and socioeconomic context of Greece including prosumers 'income, consumers' willingness to invest in residential PV, consumer attention, household´s demand, resistance of consumers to invest	ATOM (Stavrakas, Papadelis, and Flamos 2019), (Michas et al. 2020)
	Optimisation/ simulation process	- Model accounts for behavioural uncertainty of consumers by deriving forward-looking simulations for different behavioural profiles (i.e., different set of agent-related parameters), from willing to invest to risk averse consumers - Social parameters included to simulate decision of agents: agents 'initial beliefs, social learning, agents 'resistance, agents 'probability to invest, agents 'inertia to invest	ATOM (Stavrakas, Papadelis, and Flamos 2019), (Michas et al. 2020)
Public acceptance and opposition, and public participation and ownership	Storyline, scenario, and input parameter	- Scenarios: scenarios modelled with BSAM and MEMO (CGE)based on quantification of implementations risks identified by stakeholders (fuzzy cognitive map); BSAM used especially for the prosumer influence (also energy communities)	BSAM (Nikas et al. 2020)
	Discussion of model output	- Analyse output from BSAM and CGE to assess the micro-economic consequences, e.g. economic consequences of the prosuming-based part of the transition, (BSAM) of macro-socioeconomic consequences, e.g. social risks, employment, (MEMO)	BSAM (Nikas et al. 2020)

Source: Own depiction.

ATOM

We find that the studies of ATOM address different social aspects in input parameters and the simulation process. The authors use ATOM to simulate the technology adoption of PV and they quantify behavioural uncertainty of consumers regarding the decision-making criteria and agents' preferences (Stavrakas, Papadelis, and Flamos 2019). The model considers a variety of "intertwined factors" (social, market-related, and technological) and correlates "the adoption decision with its value for [the consumers]" (Michas et al. 2020, 3). The social parameters included in ATOM are agents' initial beliefs, resistance, probability to invest and inertia to invest, as well as social learning (Michas et al. 2020). ATOM consists of three so-called modules to assess agents' behaviour and preferences (Stavrakas and Flamos 2020; Michas et al. 2020): The first module defines the key set of the parameters and the calibration process for the quantification of behavioural uncertainty of the agents based on historical data and observations by specifying the appropriate ranges of the values. The second module is a sensitivity analysis to quantify uncertainties related to "characteristics and the decision-making criteria of the agents". The third module encompasses the scenario analysis of different policy schemes to study and simulate the behaviour under consideration of the socioeconomic and geographic context. Furthermore, Michas et al. (2020) apply ATOM in a participatory transdisciplinary way with the models STEEM (statistical approximation-based model emulator) and AIM (adaptive policymaking model). They explore the development of PV and dynamic adaptive policy pathways in Greece, which also allows them to consider interactions between the agents and policy context.

BSAM

In BSAM, the authors include 'public acceptance and opposition' and 'public participation and ownership' in scenarios and in the discussion of the model output (Nikas et al. 2020). In contrast to ATOM, BSAM is a power sector model that focuses on the expected behaviour of power generators, and simulates power bidding and investment decisions (Nikas et al. 2020). Nikas et al. (2020) use BSAM and MEMO, a CGE model, to analyse barriers to and consequences of a solar-based energy transition in Greece. BSAM assesses the micro-economic consequences and economic consequences of prosuming, and MEMO explores the macro-socioeconomic consequences and social risks, for example on employment. To capture uncertainty of the transition, they engage stakeholders in a participatory scenario definition process to assess risks and dynamics. They use the method fuzzy cognitive mapping to quantify the risks and dynamics (ibid).

5.4.4 Computable general equilibrium models

We find that all three CGE models of openENTRANCE and SENTINEL − REMES, EXIOMOD 2.0, and WEGDYN (see Source: Own depiction.
Table A 11) − consider the social aspects 'behaviour and lifestyle' and 'heterogeneity of actors' in the input parameters and the simulation process. Table 9 presents the findings of the integration of social factors in CGE models.

Table 9: Representation of social factors in CGE models analysed.

Social aspect	Potential of Integration	Description of the integration into models	Model and publications
Behaviour and lifestyle	Storyline, scenario, and input parameter	- Input parameter: Social Accounting Matrix SAM: includes preferences of consumers (and producers) for local, regional, and international products - Input parameter: household data (income- and educational/skill-levels and differences between urban and rural areas, labour) to capture their heterogeneity - Scenarios based on risk clusters identified by stakeholders including the cluster consumer/acceptance with social justice and behavioural change risks	REMES (Johansen, Perez-Valdes, and Werner 2018) WEGDYN (Bachner et al. 2020)
	Optimisation/ simulation process	- Regionally-differentiated analysis of households income groups and degree of centralisation of households and industry, and incorporates formulations that examines the relation between wages and unemployment rate for low-, medium, and highly-educated workers	REMES (Johansen, Perez-Valdes, and Werner 2018)
Behaviour and lifestyle, and heterogeneity of actors	Storyline, scenario, and input parameter	- Linking of a CGE, IAM, and ABM model to incorporate micro-level dynamics and behavioural aspects into the CGE model (and IAM)	EXIOMOD 2.0 (Belete et al. 2019)

Source: Own depiction.

REMES

The model application of REMES reflects the social factor 'behaviour and lifestyle' in the input parameters and the simulation process step. Johansen et al. (2018) apply REMES to explore the economic effects, particular the potential dividends, of a climate and energy tax reform in Norway. For this purpose, they consider four scenarios based on different assumptions about the income recycling scheme of the tax (transferred back to households or payroll tax reduction) and ways of labour market clearing (perfect or imperfect[43]). The Social Accounting Matrix (SAM)[44] database serves as a base for the input parameters that includes empirical data about the preferences of consumers (and producers) for local regional and international products and consumption of products that have a "repercussion on [all] prices, activity levels and incomes" (Johansen, Perez-Valdes, and Werner 2018, 7). Furthermore, the modellers use household data, allowing to make assumptions about the heterogeneity of households, income- and educational/skill-level in different urban and rural areas, and labour rates. They analyse the effect on low-income households regarding underlying model assumptions and the macroeconomic scope of the model.

EXIOMOD 2.0

We find that Belete et al. (2019) integrate 'behaviour and lifestyle' as well as 'heterogeneity of actors' as input parameters through linking EXIOMOD 2.0 with other models. They link the ABM BENCH[45], IAM GCAM[46], and EXIOMOD with the aim to provide the opportunity to include direct feedbacks between

[43] Perfect: flexible wages, no unemployment; imperfect: rigid wages, unemployment

[44] A Social Accounting Matrix (SAM) is comprehensive and economy-wide database that records data about transactions between economic agents in a specific economy for a specific period of time and is used as a standard database for economy modelling (CGE models) (European Commission. Joint Research Centre. 2018).

[45] Behavioural change in ENergy Consumption of Households (BENCH) is an agent-based energy market model to analyse the cumulative impacts on individual behavioural changes with regard to impacts of behavioural biases, energy use, and demand side policies on regional energy targets (Belete et al. 2019).

[46] Global Change Analysis Model (GCAM) is a global dynamic-recursive integrated assessment model that represents the behaviour of, and interactions between the energy, water, agriculture and land use, the economy, and the climate system and analyse climate change mitigation policies (Belete et al. 2019).

individual behavioural changes and general changes in market shares, and to analyse if policies have any effect on household consumptions. For example, EXIOMOD 2.0 outputs (e.g. household income, energy consumption data) are used as input data for BENCH in order to generate more insights into micro-level dynamics and impacts of individual decisions.

WEGDYN

The social factor 'behaviour and lifestyle' is considered in the scenario development using WEGDYN (Bachner et al. 2020). Bachner et al. (2020) develop transition pathways of the iron and steel, and electricity sector in Austria and assess pathway risks in a transdisciplinary, co-productive process with diverse stakeholders. For this purpose, they use different methods of stakeholder engagement: bilateral calls, semi-structured interviews, a survey, and two workshops. The stakeholders identified so-called risk clusters followed by a prioritisation that serves as basis for the scenario development. The risk clusters include aspects like consumer and acceptance and consider risks such as a "play-off between climate mitigation and social justice" and the implications of neglecting behavioural change. The risk clusters are used for the quantitative scenario analysis of economy-wide feedbacks of the transition pathways with WEGDYN, such as changes in employment. In the output discussion, Bachner et al. (2020) address that ABMs and micro-scale models could be used to capture more implementation risks, as the analysis of more detailed risks was beyond the scope of the model study and would also require the involvement of other disciplines, such as political science.

5.5 Discussion

Our findings show that almost half of the investigated modelling tools integrate social aspects to different extends in their model applications. Table 10 synthesis our results of what social aspects are how integrated in what model type. We find that specifically ABMs are well able to represent social aspects, but also find that ESM, IAM and CGE modelling teams incorporate specifically aspects of behaviour and lifestyle and partially of public acceptance and opposition. On the one hand, this clearly shows that modellers make attempts to integrate social aspects of the energy transition to their primarily techno-economic modelling approach. Hence, these modelling teams actively contribute to meet the needs by modellers and stakeholders for a better integration of social aspects in energy models (see survey at the EMP-E 2020 (Oei, Süsser, et al. 2020)). On the other hand, this also shows that modelling teams must further advance in representing important social drivers and constraints the energy transition.

Table 10: Summary of representation of social aspects in the analysed models.

Social aspect	Potential of Integration	Model type			
		ESM	IAM	ABM	CGE
Behaviour and lifestyle	Storyline, scenario, and input parameter	x	x	x	x
	Optimisation/ Simulation process	x		x	x
	Discussion of model output	x	x		
Heterogeneity of actors	Storyline, scenario, and input parameter			x	x
	Optimisation/ Simulation process			x	
	Discussion of model output				
Public acceptance and opposition	Storyline, scenario, and input parameter	x		x	
	Optimisation/ Simulation process				
	Discussion of model output	x		x	
Public participation and ownership	Storyline, scenario, and input parameter			x	
	Optimisation/ Simulation process			x	
	Discussion of model output			x	
Transformation dynamics	Storyline, scenario, and input parameter				
	Optimisation/ Simulation process				
	Discussion of model output				

Source: Own depiction.

We observe that most model applications address socio-economic aspects that are easily quantifiable, e.g. ex-post analysis of employment number or adjustment of input parameters to account for social acceptance and opposition. Whereas actor heterogeneity is only addressed by ABMs due to difficulty to represent different actor groups and their interactions in the other model types, transformation dynamics are not represented at all as this involves, among other things, the modelling of complex systems, which goes beyond the horizon of the models analysed (Köhler et al. 2018). Nevertheless, we agree with Pfenninger, Hawkes, and Keirstead (2014) that modellers should avoid to model only what is easily quantifiable, and instead look for new approaches to better quantify social aspects and dynamics. However, it is apparent that it remains a key challenge how qualitative narratives can be quantified into input assumptions and scenarios due to methodological uncertainties and missing profound, empirical data. Here modelling teams will be ahead that take up these challenges and build socially more robust models.

Our analysis shows that energy modellers integrate social aspects rather ad-hoc and “on top” of the existing model. This is particularly done in qualitative storylines, but also through adjustments in scenarios and input parameters. This might be not surprising as this form of integration follows a “softer” bridging or iterating approach, and thus, not demands a restructuring of the simulation or optimisation process. In fact, incorporating social aspects would add complexity to models and a super-integration of social sciences in energy models may be unlikely (Geels, Berkhout, and van Vuuren 2016) and not desirable. However, if the modelling exercises and the drawn implications of the model results ignore social aspects, this could lead to model results that are far off reality and could therefore jeopardise the usefulness of models especially for decision-makers. Adding to this, we find that all of the analysed models are dominated by a techno-economic modelling approach, meaning that they aim to reduce the overall system costs. But the “least costs future” might be not the one most desirable by the society. Lombardi et al. (2020) and Tröndle et al. (Tröndle 2020) present recent approaches going beyond single cost minimised electricity system designs, better balancing techno-economic feasibility with societal impacts and political goals in energy planning within the modelling framework Calliope.

We see three different ways to advance the integration of social aspects in energy models. First, model advancements are needed that go beyond the representation of social factors as exogenous assumptions, to model energy transitions that better incorporate social dynamics and change. This requires modellers to engage deeply with the requirements of integrating social aspects and to be open to alternative ways of modelling. Modellers must be willing to break up the modelling structure and simulation and optimisation process to reflect behaviour of different actors accordingly. This includes exploring alternative formulations of equations to better reflect societal dynamics in the mathematical process, but also adding additional modules or features to the existing model. These modules can complement the existing model, e.g. by capturing demand behaviour or run an employment analysis that is used as a constraint for the calculation to find energy pathways. Furthermore, increasing regional accuracy and allowing the ability to incorporate regional specifics into models, as well as including detailed household configurations could advance the representation of the social dimension (see also Köhler et al. (2018) and De Cian et al. (2018)). Alternatively, new models should be development that are designed to capture social factors ideally as open-source projects to include a broad modelling community and to increase transparency about the model and its results. The processes need to be co-designed with social scientist to discuss what is required for the integration. In this way, it can be ensured that the requirements for the integration of the social aspects are met. We already find inspiration from Trutnevyte et al. (2019) for an elaboration of this integration strategy and from the BLUE model of Li and Strachan (2017), which accounts for heterogeneity, consistency, and co-evolution of societal and political drivers.

Second, worlds of modellers and social scientist must move closer together in the framework of interdisciplinary, if not even transdisciplinary, research projects. Our analysis shows that studies lack interdisciplinary collaborations between modellers and social scientists and integrate hardly any insights from social science (e.g. theories.) in the modelling – except Hof et al. (2020) and van Sluisveld et al. (2020). As social science and energy modelling have epistemic and methodological differences (Turnheim et al. 2015), it appears necessary to increase the involvement of social and behavioural scientists in model developments. However, there are two sides to every coin: Modellers must be open to work with researchers from other fields, whereas social scientists must conduct research that is better tailored to the modelling work. By taking both modellers and users into duty, both could advance their understanding of the other discipline and dynamics of the energy transition, collect new empirical data, and explore ways of how social aspects should be integrated. For this, the collaboration between modellers and social scientists, as well as other stakeholders, should happen through the whole modelling process: Starting from defining the research questions, the theoretical and empirical foundation, and the input parameters to discussing the societal implications of the modelling results. To expand inter- and transdisciplinary research, decision-makers and funding bodies must also recognise the research demand and provide funding for such projects. This would accelerate the development of more transparent and transdisciplinary modelling tools and approaches and data that could support decision-makers in answering the social and political questions they are faced with. A better understanding of all dimensions of the energy transitions, its developments, interactions and dynamics is imperative to support decision-makers to enable a "just transition" in the sense of the Green New Deal (European Commission 2020).

Third, each model and model type has different capabilities to represent social aspects and hence, there are limits to what degree such aspects can be integrated (Köhler et al. 2018). It is clear from our results that none of the models has integrated all social aspects in all modelling steps. To encounter the limitations of single models in representing social factors, the linking of different models and model types can contribute to advance the understanding of social and behavioural aspects. We found that some modelling exercises already go this way. For example, the linking of an ABM and an ESM, IAM, or CGE presents the opportunity to provide behavioural insights and account for actor heterogeneity in the latter model types (see EXIOMOD 2.0 and BSAM). Even though, we believe that ABMs provide the highest potential for a holistic integration of social aspects, e.g., due to the ability to capture behaviour dynamics and interaction of agents, ABMs can also benefit from this, as they are often restricted to micro-level dynamics in specific places and lack the macroeconomic view of for example ESMs or IAMs. Thus, linking ABMs with other model types offers a broader scope of examination. For example, De Cian et al. (2018) propose further research to enhance actor and institutions representations by linking ABMs and IAMs to develop agent-based IAMS. Furthermore, we call for more studies that couple CGE models with ABMs, IAMs, or ESM, as we find that this can enhance the macroeconomic perspective of CGE models by including the assessment of social factors at the micro level. Therefore, modellers should work together to leverage the full potential of each model's capability to incorporate social aspects by linking models and different model types. The process may include also further model modifications to be able to link and incorporate the different model design styles, which opens up new possibilities due to the distinct methodological approaches of the models.

We also recognise that our research has some limitations. In our study, we focused on analysing open-source energy models from the H2020 projects SENTINEL and openENTRANCE, which allowed us to include in our analysis various models and model types. We have complemented the analysis with a literature review, also to discuss our findings and compare them with recent studies using other models. Nevertheless, we may have missed important modelling approaches in our analysis. Another limitation is the focus on the integration of social aspects in current model approaches, based on the scientific publications where the models are applied. This could exclude or neglect theoretical features and ways of applying the models as it focuses on existing linkages with social aspects. Thus, our results might underestimate the degree of integration of social factors in the analysed energy models. We also acknowledge that our generalisations may not be accurate for all models of a certain model type. Furthermore, the analysed papers vary in the degree in terms of how detailed the model description is, which can influence our results. For more recent models, there is no detailed model description or model documentation (e.g., FRESH:COM, DESTinEE), while for more established models (e.g. IMAGE) a detailed model documentation exists. We acknowledge that the inclusion of the model description could provide more insights on the input data and structure of the model while a focus on applications may provide more input on the model output discussion. Moreover, the limitations of a maximum of five publications per model can affect the results. For some models we had to select which publications we include in our analysis, while for others we "only" found one scientific publications. We are aware that these limitations could skew the results and make a comparison of the models more challenging. However, we acknowledged this in our evaluation by explicitly focusing on applications and considering

key characteristics of the models (e.g. input parameter, output parameter) and carefully scrutinising the implications we draw from the results.

Thus, our results represent the minimum status quo of what and how social aspects are integrated in energy models. With this, we provide an appropriate starting point for a dialogue for model improvements and for defining future research needs in the field of linking social science and energy modelling. Moreover, for modellers, social scientists, and decision-makers it is important to know what influence social factors have on the model outcomes. Therefore, we call for further research that explores the influence of social aspects on the model results, for example by conducting case studies with different social aspects and sensitivities, to understand better their effect on the energy transition.

5.6 Conclusion

Computer-based models are a popular tool to analyse future pathways of the energy transition and is widely used by decision-makers. However, energy modelling focuses mostly on techno-economic factors and do not represent social aspects in-depth. Particularly in the light of a just transition, the role of non-technical drivers and constraints of the energy transition becomes more prominent and hence, the inclusion of social aspects and social science in energy models is pivotal and can enhance modelling exercises.

Our results show that 13 out of 23 modelling tools in the H2020 projects SENTINEL and openENTRANCE account for social aspects in the modelling publications. When it comes to 'what' social aspects are integrated, we find that the energy models mainly incorporate behaviour and lifestyle, as well as public acceptance and opposition. Only the agent-based models consider partially the heterogeneity of actors and address public participation and ownership. When it comes to the 'how' of integrating those social aspects, the results show that modellers mainly use exogenous assumptions to integrate social factors, and thus, there is much potential to improve the integration of social aspects in the optimisation and simulation processes and to strengthen their representation in output and discussion. The linking of models should be further advanced to encounter the limitations of specific models and model types. Last, modelling mostly remains a disciplinary approach and there is no involvement of social sciences in study design.

We conclude that the integration of social aspects in energy models is far from being standard and common practice, but approaches exist on how to model behavioural and social aspects of the energy transition. Thus, for a more comprehensive consideration of social aspects, we emphasise that modellers must incorporate social aspects right from the start in the modelling design as we find most gaps of integrating social aspects in the simulation or optimisation process. Alternatively, modellers must be open to break existing modelling narratives within model improvements in close collaboration with social scientists. Our findings suggest that more interdisciplinary and transdisciplinary modelling projects are essential to better link energy modelling and social science. If models can depict the social realities of the energy transition better, they can become much more important and sound support tools for the transition to a climate-neutral energy system in Europe.

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7 Appendices of individual chapters

7.1 Appendix Chapter 2

7.1.1 Overview of Commission members

Table A 1: Overview of members, affiliation, and membership in Friends of Chair (FoC) groups.

Name	Organization	Position; Part of FoC
Matthias Platzeck	SPD, former minister president of Brandenburg	Chairman; structural development & employment
Ronald Pofalla	CDU, Members of the Board of Management of Deutsche Bahn AG	Chairman
Barbara Praetorius	Economist, political scientist and former vice-director of the ecological think tank Agora Energiewende.	Chairwoman
Stanislaw Tillich	CDU, former minister president of Saxony	Chairman; structural development & employment
Antje Grothus	Citizens' Initiative Buirer für Buir and Coordinator Coal Policy NRW at Climate Alliance Germany	
Gerda Hasselfeldt	CSU, DRK e.V.	
Christine Herntier	Mayor of Spremberg	structural development & employment
Martin Kaiser	Greenpeace Deutschland e.V.	
Steffen Kampeter	BDA	structural development & employment
Stefan Kapferer	BDEW	Energy & climate
Dieter Kempf	BDI	Energy & climate ; Holger Lösch (Dieter Kempf´s Sherpa)
Stefan Körzell	DGB	Energy & climate
Michael Kreuzberg	Head of the District Authority of Rhein-Erft-Kreis	structural development & employment
Felix Matthes	Ökoinstitut e.V.	Energy & climate
Claudia Nemat	Deutsche Telekom AG	
Kai Niebert	NABU, Universität Zürich, Leuphana Universität Lüneburg	Energy & climate

Annekatrin Niebuhr	IAB Nord, Christian-Albrechts-Universität zu Kiel	
Reiner Priggen	Landesverband Erneuerbare Energien NRW	structural development & employment
Katharina Reiche	CDU, VKU e.V.	Energy & climate
Gunda Röstel	Stadtentwässerung Dresden	structural development & employment
Andreas Scheidt	SPD, ver.di	
Hans Joachim Schellnhuber	PIK	
Christiane Schönefeld	Federal Employment Agency	structural development & employment
Eric Schweitzer	DIHK	
Michael Vassiliadis	IGBCE	structural development & employment
Ralf B. Wehrspohn	IMWS	
Hubert Weiger	BUND e.V.	
Hannelore Wodtke	Chairwoman of the electoral group "Green Future Welzow	

Source: Source: Based on Löw Beer et al. (2021).

7.1.2 Collaborative Governance elements in the Coal Commission

Table A 2: Elements of collaboration dynamics in the Coal Commission.

Principled Engagement		Description	Importance for process
Discovery	Expert hearings and site visits in coal mining regions	67 external experts were heard in the first Commission meetings; Field trips to three lignite regions of Germany	Opportunity for participants to highlight their positions (by inviting specific experts) and to get to know other participants and their positions outside of bargaining situation [int_1; int_5; int_6; int_13]; Varying perception of added informational value depending on participants' previous knowledge levels [int_5; int_10; int_13]
Definition	Mandate	Mandate provided definition of tasks and goals	Discussion of interpretation of mandate in Commission meetings, but as each interest group persisted on the most favorable interpretation in their sense the initial mandate remained the point of reference [int_1; int_5; int_13; int_16]
	Content related definitions		No joint synthesis or definitions of common knowledge made [int_3; int_13];
Deliberation	Plenary assembly	Often more than 100 participants; public character [int_10]	Members rarely departed from their initial positions, leaving little room for constructive compromise [int_12]; E.g., ultimate phase-out date was not seriously discussed in the plenary session until the last night [int_11]
	Deliberation of core contents	Took place mostly outside of the Coal Commission's plenary assembly, e.g., in FoC groups	Members without access to the other formats – such as FoC groups – where controversial topics were discussed, were largely excluded from the

			direct process of deliberating the core content [int_13; int_15; int_4]; Confidential nature of the FoC groups allowed their members to depart from their public demands, or temporarily surpass their constituency's "red lines" (which would not have been possible in public), to explore possible compromises [int_9; int_5].
	Agenda setting		All members were able to make demands and suggest topics for debate in the plenary session, such topics only had little chance of being discussed in further depth unless they were supported by other influential members or FoC groups [int_16]
Determination	Procedural rules	No preset procedural rules but had to be decided upon by the members in first meetings	Procedural rules passed at the start of the Commission; Some procedural arrangements changed in the course of the process, such as the creation of FoC groups. Individual or group influence on these arrangements varied [int_3; int_10; int_11; int_12]
	Official decision process	Final decisions required voting in plenary assembly	Drafts for key elements, such as the procedural rules, meeting agendas, and the interim and final reports, were prepared by the administrative office, the chairs, and the FoC groups [int_10; int_11; int_14; int_18]
	Unofficial decision processes	Many decisions based on informal talks and meetings; decisions taken by the chairs [int_3; int_5; int_11; int_12]	Decisions on additional arrangements (e.g., FoC); Selection of possibilities to be available for final vote

Shared Motivation		Description	Importance for process
Trust	Historic relations of participants	Personal relationships from interactions prior to Commission's work	Relatively strong distrust between some individual members [int_2; int_5; int_8]
	Site visits and joint dinner	Field trips to coal regions with all Commission members; one joint dinner	Informal atmosphere allowed sharing positions more freely, and building personal relationships [int_5; int_11]
	Information leaks	Information from Commission meetings and discussions was forwarded unofficially to the press	Leaks were perceived as a standard procedure by those with more experience in political negotiation processes, while members with less experience perceived them as a breach of trust and disappointment in the group. In general, the high media attention made work in the Commission difficult [int_2; int_5; int_8; int_17].
	Personal ties	Large size of commission (number of members); limited number of informal meetings	It was not possible to build a personal bond with all members due to the size of the Commission and the lack of informal meetings [int_2; int_5; int_8].
Mutual Understanding	Site visits		Site visits and exchange fostered understanding of actors' objectives and constraints [int_1; int_10]
	Joint work in Commission		The atmosphere improved over time and it was possible to establish respectful interaction "at a distance" throughout the Commission [int_5; int_13]. Some members were able to find "a common language" across interest group borders, while others struggled, depending on their personality and their experience with negotiation processes [int_11]
	Attendance of individual members during assembly meetings	a few members were repeatedly absent	difficult to establish personal relationships or trustful collaboration with them [int_2; int_5]
Internal Legitimacy			High confidence in the process and its effectiveness among most members [int_1; int_8; int_10; int_16];

Commitment	Joint work in Commission		Rapprochement among Commission members, and a common desire to reach a compromise [int_15; int_16]

Capacity for Joint Action		Description	Importance for process
Procedural and Institutional Arrangements	Plenary assembly	Members (voting right) + sherpas + non-member participants ; Right to speak for federal state representatives	Federal state representatives very actively involved as speakers [int_16]
	Sherpas	Members' assistants (no voting right)	Important role, engaged in exchange, discussion, and coordination outside the limited meeting times [int_10; int_11]
	Friends of Chair (FoC) groups	1) “energy and climate” (from August on, six members) 2) “structural development and employment” (from November on; seven members)	Critical details were mainly discussed in these small circles involving only a few members [int_5; int_6; int_9]
	Interest groups	members with similar interests formed interest groups to discuss possible negotiation strategies, red lines for compromises, and demands	Deliberation space within interest groups and possibility for members without seat in FoC to introduce and discuss negotiation points for FoC meetings [int_12; int_13; int_16
Leadership	Chairs (four)	Selected and appointed by government; Task to lead Commission's work and meetings	Very different roles taken by the four chairs; Large discrepancies in political experience and personal networks, resulting in different levels of power and influence; Perceived as advocats for certain interest groups instead of neutral moderators [int_3; int_9; int_12]; Important role in moderation of negotiations [int_15]; No concept/strategy to balance stakeholders' interests and achieve compromise [int_3]
	Administrative office	Organizational work of Commission (e.g., site visits, plenary meetings), provision of text drafts, meeting agendas	Non-transparent working procedures and politically influenced [int_5; int_8; int_10; int_12]; Staff from ministries and administrations of affected federal states not perceived as neutral [int_5; int_8]
Knowledge	Expert hearings		No joint synthesis or definitions of common knowledge made [int_3; int_13];
	Expert hearings		Debates were generally based on scientifically sound and by experts supported arguments [int_17]
Resources	See Table A 3		

Source: Own depiction.

Capacity for joint action

The element of ***procedural and institutional arrangements*** encompasses all formal and informal structures of the Coal Commission to enable discussions and to reach a compromise. The institutions included a plenary assembly involving all members, the inclusion of at least one assistant per member, referred to as sherpas, and a division between Coal Commission members with voting rights and non-member participants without voting rights who were able to participate in the general exchange and discussion. The sherpas played an important role because they also engaged in exchange, discussion, and coordination outside the limited meeting times [int_10; int_11].

One important arrangement that emerged during the work of the Coal Commission were the so-called *Friends of Chair* (FoC) groups. Critical details were mainly discussed in these small circles involving only a few members [int_5; int_6; int_9]. The ability to work and meet in smaller groups was an important

aspect on the path to a compromise, given that they offered the opportunity for more concrete and confidential discussions. Furthermore, since the size of the plenary assembly made it an inappropriate instrument for writing texts for the interim and final reports, the FoC groups provided the opportunity to draft such texts. Even though several interviewees stated that the composition of FoC groups represented all interest groups [int_5; int_6; int_9; int_13], the meetings remained exclusive and non-transparent [int_3; int_11; int_15]. The first FoC group on "energy and climate" was set up in August after several members approached the chairs requesting changes in the Commission's working structures because little progress had been made in the general sessions [int_5; int_14]. Two out of six of the first FoC's members represented environmental interests, while the others represented the energy sector, industry, and unions.[47] The second FoC group on "structural development and employment" was only implemented in November, after several federal state prime ministers had intervened and demanded greater support for affected coal regions. This group mainly included members that represented local and regional economic interests, as well as employees' and employers' interests. Furthermore, members from environmental associations, for instance, were generally also in support of the demands for just transition and structural change processes [int_1], ultimately leaving them with little to offer the unions in return for their support for an earlier phase-out. Furthermore, this split into these two FoC groups also separated the deliberations on energy and climate issues on the one hand, and structural development and employment issues on the other.

In addition to establishing FoC groups, members with similar interests formed interest groups to discuss possible negotiation strategies, red lines for compromises, and demands. Another arrangement concerned the participatory possibilities of federal state representatives. The members decided that federal state representatives should have the right to speak during the Commission's meetings [int_10], which they proceeded to make extensive use of [int_16].

The chairs had different roles in the ***leadership*** of the Coal Commission, mainly due to their diverse political experience and personal networks, resulting in different levels of power and influence. Two chairs, former prime ministers of federal states with coal mining regions, were associated with the structural and economic interests of coal regions. Another chair, a former federal minister, was perceived as also representing Federal Government interests, due to his being in constant exchange and contact with the government. The fourth, a university professor, was associated with environmental interests. The chairs were perceived by many of the interviewees as advocates for certain interests, rather than as neutral moderators [int_3; int_12, int_9]. One interviewee noted that the chairs often only saw themselves as responsible for a certain group [int_12], which reinforced the power imbalance and unequal treatment of members. Interviewees generally described interaction with the four very different chairs as being challenging [int_3; int_6; int_11; int_9]. However, one interviewee pointed out that the

[47] Members of the FoC energy & climate: Stefan Kapferer (BDEW), Stefan Körzell (DGB), Holger Lösch (BDI, Dieter Kempf's sherpas), Felix Matthes (Öko-Institut), Kai Niebert (DNR), and Katharina Reiche (VKU). Members of the FoC structural development & employment: Christine Herntier (Mayor of Spremberg), Steffen Kampeter (BDA), Michael Kreuzberg (Head of the District Authority of Rhein-Erft-Kreis), Matthias Platzeck (Commission Chair), Reiner Priggen (Landesverband Erneuerbare Energien NRW), Gunda Röstel (Stadtentwässerung Dresden), Christiane Schönefeld (Federal Employment Agency), Stanislaw Tillich (Commission Chair), and Michael Vassiliadis (IGBCE). Source Löw Beer et al. (2021).

different positions were brought together by the chairs, and especially by one chair due to his political experience [int_15].

Overall, cooperation among chairs and the administrative office, as well as with governmental institutions, was considered rather weak [int_5; int_8]. In particular, it was criticized that there was no concept of how the Coal Commission was to reach a compromise that actually balanced the stakeholders' interests, rather than simply achieving the lowest common denominator [int_3]. The administrative office, tasked with providing administrative assistance to the Coal Commission in the form of organizing expert hearings and site visits, or drafting texts, was also criticized for not working transparently, as well as for reaching politically influenced decisions [int_5; int_8; int_10; int_12]. This criticism was nourished by the staffing of the administrative office, which was thought to be politically motivated. For example, some staff had been posted from administrations of affected federal states [int_5; int_8].

A large number of experts were invited to speak on different topics. However, several interviewees mentioned limited efforts to create a shared ***knowledge*** base [int_3; int_11; int_15]. Especially established and well-informed members had a limited interest in reducing knowledge deficits of other members or in revisiting their own positions and creating a common knowledge base [int_1; int_5; int_9]. Although specific information was requested from external experts, no joint synthesis of the presented expert input or definitions of common knowledge was prepared [int_3; int_13]. However, debates were generally based on scientifically sound and by experts supported arguments [int_17].

Collaborative ***resources*** may take different forms, such as time, funding, technical and logistical support, power, and expertise (Emerson, Nabatchi, and Balogh 2012). Resource disparities and mismanagement can affect the outcome and the "perceived and real fairness, legitimacy, and efficacy of CGRs" (Emerson, Nabatchi, and Balogh 2012, 16). Table A 3 describes the identified differences in resource endowment, grouped into five resource types. Overall, the differences in expertise, capacity, and financial resources led to the actors' different starting conditions and the differences in the opportunities to engage in the process [int_11; int_9; int_7]. It was mentioned that although it was difficult to fully erase the initial resource disparities, it was possible to compensate for some of them [int_11].

Table A 3: Identified differences in resource endowment.

Type of resource	Resource disparity	Perception and influence on the process
Time / financial / organizational	Voluntary members of organizations vs. boards of large industry associations	• No level playing field regarding organizational support [int_9]. • Results in power disparities and fewer time resources for the Coal Commission [int_12].
	Majority of formal and informal meetings held in Berlin	• Difficult for members who do not live or work in Berlin [int_7; int_11].
	Time	• Need to prioritize which (informal) meetings to attend [int_7].

Human resources	Differences in staffing	• Differences in staff support and organization of support [int_15; int_12; int_13; int_7] → power imbalance [int_12; int_2].
Network	Different network with chairs	• Differences lead to different treatment of members [int_12].
	Links between some members (before the Coal Commission)	• Agreements in informal meetings: difficult for members outside Berlin to comprehend processes and decisions [int_11]. • People with a stronger existing network who knew each other had more opportunities to influence the outcome. • However, few new connections between interest groups were formed [int_11].
Negotiating and political experience	Understanding the way things work	• More work for people without experience (reading "all" the papers) [int_4]. • At the beginning especially, it remained unclear, particularly for inexperienced members, how decisions were to be reached, and who would decide on the agenda or write the reports [int_12; int_5; int_11].
	Negotiation experience	• Correlation of level of experience and influence on outcomes [int_8; int_3; int_2]. Several personalities are said to have had a larger influence on the Coal Commission, especially due to their goal orientation, capacity in building compromises, and in-depth knowledge [int_5; int_9; int_10; int_13; int_16]. • Negotiating and strategic experience helped to steer decisions.
Expertise (knowledge)	Access and capacity to gain sector-specific knowledge	• No level playing field due to disparities in knowledge and access to information [int_9].

Source: Own depiction.

Principled engagement

For successful principled engagement, it is important that participants ***discover*** the interests and positions of others, enabling them to acquire expert knowledge in the broad field of topics addressed. During the first few months of the Coal Commission, information and insights were provided by 67 expert hearings, as well as field trips to coal mining regions. Interestingly, participants assessed this input very differently. Some stated that they acquired a lot of new information thanks to this input [int_10], while others gained little from these processes [int_13; int_5]. However, some of the particularly well established and informed actors emphasized that these processes gave them the opportunity to highlight their own positions, and to get to know the other participants without having to engage in fierce discussions and bargaining [int_6; int_13; int_5; int_1].

The ***deliberation*** on the main decisions largely took place outside of the Coal Commission's plenary assembly. In the plenary discussions, members rarely departed from their initial positions, leaving little room for constructive compromise [int_12]. This was due at least in part to the ultimately public nature of the plenary meetings, caused by constant leaks to the public, as well as the size of the meetings, often with 100 or more participants [int_10]. As an example, the debate on the ultimate phase-out date was not seriously discussed in the plenary session until the last night [int_11]. Members without access to the other formats – such as FoC groups – where controversial topics were discussed, were largely excluded from the direct process of deliberating the core content [int_13; int_15; int_4]. Although all members were able to make demands and suggest topics for debate in the plenary session, such topics only had little chance of being discussed in further depth unless they were supported by other influential members or FoC groups [int_16]. The confidential nature of the FoC groups allowed their members to

depart from their public demands, or temporarily surpass their constituency's "red lines" (which would not have been possible in public), to explore possible compromises [int_9; int_5].

The element of ***definition*** was rather implicit in many instances and is intertwined with ***determination***. For example, the understanding of the tasks and expectations of the Coal Commission according to the political mandate introducing the Commission was discussed among the members [int_13; int_5; int_16], yet no side was willing to accept a more favorable interpretation for their opponents [int_1; int_5]. Similarly, the interpretation of expert information, as stated above, was subject to each participant's own judgement, since no joint synthesis of the presented expert input was prepared [int_13; int_11]. The procedural rules were discussed and passed at the start of the Coal Commission. However, some procedural arrangements changed in the course of the process, such as the creation of FoC groups or the right of federal state government representatives to speak. Individual or group influence on these arrangements varied [int_12; int_10; int_3; int_11].

As with the deliberation of core elements, determination was also linked to the work of FoCs and other small groups. However, final decisions had to be reached in the plenary assembly. Drafts for key elements, such as the procedural rules, meeting agendas, and the interim and final reports, were prepared by the administrative office, the chairs, and the FoC groups [int_18; int_10; int_11; int_14]. However, many of the underlying decisions on content, or who would belong to the FoC groups, were not discussed or decided in the plenary session, but were based on informal talks and meetings, and decisions were taken by the chairs [int_12; int_3; int_5; int_11]. Another prominent example of this non-transparency was the gathering of a small number of members on the very last night of the Commission to bargain over the remaining unresolved questions, such as the phase-out date. The members who were not party to this special meeting simply noticed at some point that all of the chairs and some of the members were no longer present in the Coal Commission meeting room [int_11]. Members without experience of such bargaining processes found it hard to know how to introduce and enforce their demands at the right place and the right time.

Decisions on the mandate and Commission members during the pre-Commission phase were not part of the Coal Commission's internal processes, but may well have largely determined its course: Some established members were also involved in the development phase of the Commission. For example, government officials asked them to comment on the selection of invited stakeholders or they themselves attempted to influence the wording of the mandate. Some were completely surprised by the call asking them to participate, while others were closely involved in discussions about the Coal Commission before it was officially launched [int_5; int_11; int_12; int_4].

Shared motivation

Trust and ***mutual understanding*** build the basis for collaboration among participants. In the Coal Commission, events that were frequently referred to in this regard were the field trips to coal regions and a joint dinner. For example, one interviewee mentioned that he became aware during these trips that trade unions are membership organizations, which helped him to understand those actors' constraints [int_1]. Others stated that they gained a better insight into the local situation in the coal regions [int_10]. Several members emphasized their appreciation of the joint dinner organized on one

of the trips. This dinner was one of the rare occasions when members were able to meet in an informal atmosphere. This enabled them to share their positions more freely, and to build more personal relationships. Several interviewees mentioned that arranging more meetings of such nature would have been a means of increasing trust and understanding among members [int_5; int_11].

Generally, the atmosphere improved over time and it was possible to establish respectful interaction "at a distance" throughout the Commission [int_5; int_13]. Some members were able to find "a common language" across interest group borders, while others struggled, depending on their personality and their experience with negotiation processes [int_11]. There was rapprochement not only among individuals, but also in the whole group, and a common desire to reach a compromise [int_15; int_16], leading to a shared ***commitment***.

However, a latent sense of mistrust shaped the work of the Coal Commission because several aspects limited the trust-building process:

- Leaks: Information was constantly leaked to the press, which made trusting cooperation more difficult. However, this was perceived differently by different actors. Leaks were perceived as a standard part of the process by those with more experience in political negotiation processes, while members with less experience perceived them as a breach of trust and disappointment in the group. In general, the high media attention made work in the Commission difficult [int_2; int_5; int_8; int_17].
- Attendance: Presence at meetings is particularly important for shared motivation. Only a few members were repeatedly absent, making it difficult to establish personal relationships or trustful collaboration with them [int_2; int_5].
- Personal ties: It was not possible to build a personal bond with all members due to the size of the Commission and the lack of informal meetings. Interviewees referred to a relatively strong distrust between some individual members [int_2; int_5; int_8].
- Administrative office: Since the administrative office was perceived as being biased, some members found it difficult to work with it.

The federal state prime ministers played a special role. Several interviewees considered their behavior to be negative for the process [int_16]. The prime ministers were described as dominant in the plenary sessions, although they only had the right to speak, and not to vote. Furthermore, their major influence became apparent from their interactions with the Federal Government in general, and in particular from the decision on funds for affected regions in November 2018. These funds led to an intervention by Chancellor Merkel, effectively delaying the Coal Commission and potentially increasing total funds for the coal regions, although all Commission members had already agreed on a compromise.

Internal legitimacy refers to individual members' confidence in the process and the effectiveness of the Coal Commission. Confidence in the process and its effectiveness was high among most members [int_1; int_8; int_10; int_16], although there was some disillusionment about the possibilities to have their own positions included in the final report [int_12]. However, most members had serious intentions to find a solution, and were committed to the process, even though it was not clear at the beginning what the final outcome would be, and how the agreements would be incorporated into the political process.

7.2 Appendix Chapter 3

7.2.1 Overview of data collection

Table A 4: Overview of interviewed persons and relevant documents/websites.

	Brandenburg	**Saxony**
Interviews		
Ministries, state chancelleries, regional transition agencies	2	2
Workshop spokespersons	2	
Workshop members	3	
RBA voting members		1
RBA advisory members		4
Other	1	
Documents and websites		
Websites of regional transition agencies	*https://wirtschaftsregion-lausitz.de/strukturentwicklung/foerderung-regional-kommunal/*	*https://sas-sachsen.de/*
Policy documents	Lausitzprogramm 2038 (LPB)	Handlungsprogramm Sachsen (HPS)

Source: Own depiction.

7.2.2 Interview guideline

Table A 5: Interview guideline.

Topic	**Question**	**Follow-up questions if needed**
Introduction	Could you please start by telling us briefly how you are involved in the regional transition? How long have you been involved in the transition?	Motivation, objectives, what does the Lusatia of the future optimally look like for you; central points in the transformation of the area?
Understanding of civil society	When it comes to the transformation of the coalfields, one frequently hears the statement that civil society participation is important. In conversations with various actors in Lusatia and the Rhineland, we got the impression that the term civil society is used very vaguely. What is your impression, and does this ambiguity have an impact on participation offerings?	What, in your opinion, is the role of organised civil society actors in the transformation of the coalfield? Are you aware of any concepts by organised civil society for the transformation of the coalfield? Are you aware of any development concepts for the coalfield by civil society?
Participation processes	The “Entwicklungsstrategie Lausitz 2050” (development strategy) was developed in a very elaborate and participatory way - what role does it play in the development of Lusatia today?	Who was involved?
	Distribution process of transition funds at the federal state level: Could you please tell us how the workshop process/RBA came about and who initiated it?	Was civil society involved in the development process? Why are civil society actors and others involved in the workshop process/RBA?

		How were the participants selected? Why is there no workshop on sustainability? How did the topics of the workshops come about?
	What experiences have you had in the process? How do you experience the process?	Which actor do you consider to be particularly influential in the process, and why?
	How should the process develop in the future?	
	Resources: Some members participate in the workshops/RBA on a voluntary basis, which could lead to an unequal distribution of resources. What is your view on this?	
	Are there other structures, formal or informal, outside the workshops/RBA that are important?	
Closing remarks	Do you have any wishes for improvement for the coming work in structural change? What do you wish for structural change in Lusatia?	
	Is there anything else you would like to tell us?	

Source: Own depiction.

7.2.3 Background information on the institutional and legal framework of the German coal transition

The Coal Phase-out Law in 2020 was accompanied by the Investment Law for Coal Regions (*Investitionsgesetz Kohleregionen*), and the Structural Support Law for Coal Regions (*Strukturstärkungsgesetz Kohleregionen*). The Structural Support Law prescribes the distribution of transition funds until 2038 for the German coal regions. The main target groups to receive funding are local and regional authorities. To be eligible, project proposals should contribute to managing the transition, focusing on safeguarding employment during the coal phase-out. Examples of funding areas include business infrastructure, public transport, the expansion of healthcare and youth facilities, urban development, digitalisation, infrastructure for tourism, research and development, and climate and environmental protection.

Of the overall €40 billion funds, €17.2 billion go to Lusatia. Out of these, ca. €6 billion are administrated by the federal states Brandenburg and Saxony. Each state created the position of a transition officer, officially called *Lausitz-Beauftragter des Ministerpräsidenten* (Brandenburg) and *Beauftragter für Strukturentwicklung in der Lausitz und in der Region Leipzig* (Saxony). They are responsible for coordinating and steering the structural change process in their state. This also includes the stakeholder participation processes which are part of the process of distributing the transition funds. Each state has its own process design with differences in thematic foci and participant selection.

In Brandenburg the four workshops are (1) “Unternehmen, Wirtschaftsentwicklung & Fachkräftesicherung” (“Business, Economic Development, & Skilled Workforce Retention”); (2) “Innovation & Digitalisierung” (“Innovation & Digitalisation”); (3) “Infrastruktur & Mobilität” (“Infrastructure & Mobility”); and (4) “Daseinsvorsorge, ländliche Entwicklung & ‘smart regions’” (“Public services, rural development, & ‘smart regions’”); and (5) “Kultur, Kreativwirtschaft, Tourismus & Marketing” (“Culture, creative industries, tourism, & marketing", own translations). The WRL provides lists of participants on their website, however, the lists are incomplete and/or outdated. When we requested a full list of

workshop spokespersons and participants from the WRL, they were reluctant to share it with us in case the information might get public, which they did not want because they feared it might lead to external persons trying to influence decisions through individual workshop members. The list we eventually received was up to date but only included participants' affiliations, not their names.

In Saxony, the interests groups in the RBA are as follows: (1) Arbeitgeber/Wirtschaft (employers/businesses); (2) Arbeitnehmer (employees); (3) Soziales (social actors); (4) Inklusion, Geschlechtergerechtigkeit und Demokratie (inclusion, gender equity, and democracy); (5) Wissenschaft und Bildung (research and education); (6) Kultur, Tourismus und Sport (culture, tourism, and sports); (7) Umwelt und Naturschutz (environmental and nature protection); (8) Klima und Energie (climate and energy); (9) Land- und Forstwirtschaft (agriculture and forestry); (10) Regionale Planungsverbände (regional planning associations); (11) LEADER-Gebiete ("LEADER" regions); (12) Kinder und Jugend (children and youth); (13) zivilgesellschaftliche Netzwerke (civil society networks; own translations).

7.3 Appendix Chapter 4

7.3.1 Overview of interview partners and participants of the focus groups

- Interviews:
  - 4# Academics and Think Tanks
  - 1# International cooperation
  - 2# Coal industry
  - 2# Union representatives (district and state level)
  - 1# Jharkhand newspaper
  - 2# State and district-level NGO
- Focus groups (FG):

Table A 6: Overview of focus groups.

FG 1 - Bokaro workers	• 7 participants
	• The participants in the FG included people who have a direct dependence on coal and engaged in formal and informal work in coal mines and related industries. The participants were selected from the following categories of coal dependents:
	  • Informal workers (transportation drivers/helpers, washery workers, local cell workers,
	  • Formal workers (formal workers employed by the Central Coalfields Limited, a subsidiary of Coal India Limited)
	  • Contractual workers- deployed by outsourcing company
	  • Coal gatherers and sellers (women gatherers/cycle pullers)
	  • Community members- affected by mining and displacement
	• Participants ranged in age group of 19-55 years and had completed their school education. It was a mixed group, represented by the schedule tribe (ST), scheduled caste (SC), other backward caste (OBC), general and minority.

FG 2 - Bokaro local actors	• 15 participants
	• The FG participants comprised individuals who were local actors and represented institutions of the area. Members from the following institutions attended the discussion:
	  • NGO/CSOs
	  • Local governing body (panchayat)

	• Truck Association- coal transport • Coal Unions (INTUC, AITUC, HMS, JCMU) • Social workers • Frontline government functionaries

FG 3 - Ramgarh workers	• 19 participants
	• The participants in the FG included people engaged in formal and informal work in coal mines. The participants included the following category of coal dependents:
	  • Informal workers (transportation drivers/helpers, local cell workers, daily wage)
	  • Formal workers (formal workers employed with Central Coalfields Limited, a subsidiary of Coal India Limited)
	  • Coal gatherers and sellers (women gatherers/cycle pullers)
	  • Community members- affected by mining and displacement
	• Participants ranged in age group of 20-65 years. It was a mixed group, represented by members from the scheduled tribe, OBC and minority.

FG 4 - Ramgarh local actors	• 14 participants
	• The FG participants comprised individuals who were local actors and represented local institutions of the area. Members from the following local institutions attended the discussion:
	  • Block administration-government
	  • NGO/CSOs
	  • Local governing body (panchayat)
	  • Truck Association- coal transport
	  • Coal Union (BMS, INTUC)
	  • Social workers

Source: Own depiction.

7.4 Appendix Chapter 5

7.4.1 Search string.

((short model name) AND (long model name) AND (model))
AND
((Acceptance) OR (demand) OR (controversy) OR (opposition) OR (attitudes) OR (value) OR (behavior*) OR (behaviour*) OR (consum*) OR (household*) OR (lifestyle) OR (sufficiency) OR (decision*) OR (heterogeneity) OR (heterogeneous) OR (individual*) OR (actor*) OR (participation) OR (ownership) OR (citizen) OR ("just transition") OR (access) OR (poverty) OR (wealth) OR (equality) OR (worker) OR (social*) OR (socio*) OR (society) OR (societal) OR (personal) OR (people) OR (incumben*) OR (population) OR (cultur*) OR (income) OR (agency) OR (agent) OR (prosumer) OR (belief*) OR (habit) OR (choice) OR (motivation) OR (communit*) OR (responsibl*) OR (employment) OR (job*) OR (justice) OR (equity) OR (labor) OR (labour) OR (educat*) OR (empower) OR (trust) OR (engage*) OR (preferences) OR (resistance))
AND
((energy) OR (power) OR (heat) OR (transport) OR (climate) OR (electricity))

Figure A 1: Search string

Source: Own depiction.

7.4.2 Overview of models

Table A 7: Overview of optimisation energy system models.

Model name	Short description	Input parameter	Output parameter	Optimisation/ Simulation	Publication
Calliope	- Calliope is an energy systems linear optimisation framework, with a focus on flexibility, high spatial and temporal resolution, the ability to execute many runs based on the same base model, and a clear separation of framework (code) and model (data)	- Time series data, e.g. on generation potentials, demands - Capacity constraints per model location Connections between model locations (e.g. electricity transmission grid) - Energy technology definitions such as cost and performance characteristics	- Capacities of each technology at each location Operational decisions for each technology, location and time step - Fixed costs, variable operational costs, levelized costs - Capacity factors	- User-dependent, including financial cost, CO2, and water consumption	(Lombardi, Rocco, and Colombo 2019), (Lombardi et al. 2020), (Tröndle, Pfenninger, and Lilliestam 2019), (Pfenninger and Keirstead 2015), (Tröndle 2020)
GENeSYS-MOD	- Global Energy System Model (GENeSYS-MOD) - The model endogenously determines cost-optimal investment paths into conventional and renewable energy generation, different storage technologies, and some infrastructure investments until 2050	- Technologies, their costs and efficiency, availability - Demands and residual capacity - Fossil fuel prices - Political boundaries	- Total costs (discounted sum of all costs in all regions and all time periods, development of those over long time horizon) - Generation and shares of technologies - Trade	- Calculates the lowest-cost-solutions for the transition pathway towards largely decarbonized energy systems	(Auer et al. 2020), (Bartholdsen et al. 2019), (Lawrenz et al. 2018), (Burandt et al. 2019)

FRESH:COM	- FaiR Energy Sharing in local COMmunities (FRESH:COM) - The model is a multi-objective optimisation tool for optimal local renewable technology portfolio design.	- PV generation and demand of prosumers - Max. Capacity of batteries and discharging power - Efficiency of batteries - Willingness-to-pay of prosumers - Prices: average spot market electricity price, retailer´s electricity price - Marginal emissions from the grid	- Purchase of prosumers from the grid and from prosumers - Sales from prosumers to the grid - Charging, discharging, and state of charge of prosumers battery	- Objective: maximize social welfare of a community	(Perger et al. 2021)

Source: Own depiction.

Table A 8: Overview of simulation energy system models.

Model name	Short description	Input parameter	Output parameter	Optimisation/ Simulation	Publication
DESTinEE	- Demand for Energy Services, Supply and Transmission in EuropE (DESTinEE) - The model is designed to test assumptions about the technical requirements for energy transport (particularly for electricity), and the scale of the economic challenge to develop the necessary infrastructure.	- energy demands, service demands and technology parameters - Assumptions about the mix of technologies and technical efficiency - installed capacity of different types of power station in 2050 for each country - the capacity of transmission interconnectors between regions	- Project annual energy demands at country-level forwards to 2050, Synthesise hourly profiles for electricity demand in 2010 and 2050, Simulate the least-cost generation and transmission of electricity around the continent	- Costs, welfare, carbon emissions, fuel mixes	(Stavrakas and Flamos 2020)
DREEM	- Dynamic high-Resolution dEmand-sidE Management (DREEM) - DREEM serves as an entry point in Demand-Side Management modelling in the building sector, by expanding the computational capabilities of existing Building Energy System models to assess the benefits and limitations of demand-flexibility, primarily for consumers, and for other power actors involved.	- Parameters for buildings: Demand-Response, activity profiles, occupancy profiles, HVAC control settings, weather-climate data	- Net building electrical demand, benefits for consumers, aggregated results for n buildings, urban energy system analysis	- Modular and therefore user dependant analysis of building energy and control systems by using the open modelling library "buildings"	(Boßmann and Staffell 2015)

EnergyPLAN	- EnergyPLAN is a simulation energy model that explores "national energy planning strategies on the basis of technical and economic analyses of the consequences of different national energy systems and investments" (Henrik Lund and Zinck Thellufsen 2020).	- Detailed hourly distributions such as heating, cooling and electricity demand (exogenous variable in the tool.) - Technology efficiency, specific CO2 emissions or fuel cost	- Overall running and capital costs of a system - Environmental impact in terms of CO2 emissions, including other key performance parameters such as share of renewable energy sources in primary energy supply, etc.	- Method is based on energy and masses flow balancing between different sectors on an hourly basis for the whole year.	(Child, Haukkala, and Breyer 2017), (Cantarero 2019), (Child, Nordling, and Breyer 2017), (Dorotić et al. 2019), (X. Sun et al. 2016)

Source: Own depiction.

Table A 9: Overview of integrated assessment models.

Model name	Short description	Input parameter	Output parameter	Optimisation/ Simulation	Publication
IMAGE	- Integrated Model to Assess the Global Environment (IMAGE) - IMAGE is an integrated modelling framework of interacting human and natural systems. The model framework is suited to large scale (mostly global) and long-term (up to the year 2100) assessments of interactions between human development and the natural environment, and integrates a range of sectors, ecosystems and indicators.	- Policy responses (climate policy, air pollution and energy policies, land and biodiversity policies), drivers (population, economy, policies, technology, lifestyle, resources); - Macro-economic scenarios and exogenous assumptions on technology development and changes, preference levels, lifestyle, population, restrictions to fuel trade, and policies	- Impacts (climate impacts, agricultural impacts, water stress, terrestrial biodiversity, aquatic biodiversity, flood risks, land degradation, ecosystem services, human development)	- The impacts of human activities on the natural systems and natural resources are assessed and how such impacts hamper the provision of ecosystem services to sustain human development	(van Sluisveld et al. 2020), (van Sluisveld et al. 2016), (Hof et al. 2020)

MESSAGEix_ GLOBIOM	- The MESSAGEix_GLOBIOM framework soft links the energy model MESSAGEix and the land use model GLOBIOM, and is an economic-environment-engineering model that is used to for energy system planning, scenario development, and energy policy analysis (IIASA IAM framework)	- Socio-economic development - energy demand, use, technologies, conversion - macro-economic developments - Land-use, water - Emission factors	- Estimates of technology-specific multisector response strategies for specific climate stabilization targets - Least-cost portfolio of mitigation technologies, with the choice of the individual mitigation options across regions, fuels, and sectors driven by the relative economics of the reduction measures	- Linear programming energy-economy-environment-engineering (4E) model	(Zhou et al. 2019), (H. Sun, Niu, and Wang 2019), (Zhou et al. 2020)

Source: Own depiction.

Table A 10: Overview of agent-based models.

Model name	Short description	Input parameter	Output parameter	Optimisation/ Simulation	Publication
ATOM	- Agent-based Technology adOption Model (ATOM) - ATOM is an agent-based model that, apart from simulating the expected effectiveness of technology adoption under policy schemes of interest, allows to consider and explicitly quantify uncertainties that are related to agents' preferences and decision-making criteria (i.e., behavioural uncertainty)	- Market-related parameter - Specification of the key parameters under the geographic and socio-economic context (historical data) - Initial beliefs, social learning, resistance toward PV investment, probability of investing	- Technology adaption scenarios	- Consists of three main modelling modules calibration, sensitivity analysis (SA), and scenario analysis	(Stavrakas, Papadelis, and Flamos 2019), (Michas et al. 2020)

BSAM	- Business Strategy Assessment Model (BSAM) - BSAM is an agent-based simulation model which simulates the Day-Ahead Scheduling (DAS) of wholesale electricity markets	- Constantly changing historical data and projections containing the electricity demand, RES generation, hydro generation, electricity import prices, and fuel prices - No-/slowly-changing data containing technical and economic characteristics of thermal resources, interconnection capacities with neighbouring countries, market-related data - RES subsidies	- In an hourly resolution the system marginal price (SMP) - The total electricity costs when subsidies are considered, the electricity mix, the generation schedule of all resources, the profit/loss of each generator, and the level of curtailment applied to RES generation	- Simulates the Day-Ahead Scheduling (DAS) problem	(Nikas et al. 2020)

Source: Own depiction.

Table A 11: Overview of general computable equilibrium models.

Model name	Short description	Input parameter	Output parameter	Optimisation/ Simulation	Publication
REMES	- Regional equilibrium model for Norway with focus on the energy system (REMES) - REMES represents the Norwegian economy with a particular focus on the energy system. REMES is used to study the effects of macroeconomic policies on the Norwegian economy and aims to improve the understanding of regional differences, needs, and barriers towards a more sustainable energy system [68].	- Social Accounting Matrix (SAM), describing all the monetary flows between the different agents and sectors in a given base year	- Evolution of value added in different sectors and regions, the composition value for inputs and outputs for each sector and the monetary flows between different actors and sectors in the economy	- Computing the effects of counterfactual policies, which assume the role of what-if analyses, simulating the state of the economy at the end of the considered horizon	(Johansen, Perez-Valdes, and Werner 2018)

EXIOMOD 2.0	- EXtended Input-Output MODel (EXIOMOD 2.0) - EXIMOD 2.0 considers the interaction and feedbacks between supply and demand of the economy (analysis of environmental impacts, energy, or transport systems and interactions and feedbacks between supply and demand of the economy). As a multisector model, it accounts for the economic dependency between sectors. - The model assumes cost-minimizing behaviour of producers and households´ demands are based on optimising behaviour.	- EXIOBASE is the underlying database - Various modules: land use, carbon pricing, material use etc.	- separate volume and price effects	- Link between the economic activities of various agents (sectors, consumers) and the use of a large number of resources (energy, mineral, biomass, land, water) and negative externalities (greenhouse gases, wastes)	(Belete et al. 2019)
WEGDYN	- WEGDYN is a global multi-regional multi-sectoral model, which is able to assess the economy-wide and indirect effects of economic (e.g. sectoral) system interventions such as policies or technological changes. The model is separated into different production sectors and demand agents.	- different crude steel production technologies - different electricity generation technologies - macroeconomic development according to SSP	- electricity mix, weighted average costs of capital, trade, electricity supply price, gross domestic product	- Supply-side constrained, meaning that capacities (capital, labor6 and resource endowments) are fully utilized, constraining macroeconomic expansion through scarcity	(Bachner et al. 2020)

Source: Own depiction.