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Explaining energy transition: A systemic social mechanisms approach illustrated with the examples of Germany and Poland

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ABSTRACT

In our conceptual paper, we develop a systemic social mechanisms model to explain change and inertia of energy systems. Situational, action-formation, and transformational mechanisms that drive change in a transition require corresponding framing and framing contests to create legitimacy for that transition. We conceptualize mechanisms of socio-technical transitions and of creating legitimacy for transitions as mutual drivers and outcomes, with framing contests as crucial for achieving legitimacy for change. We propose that the social mechanisms approach supports evidence-based policy-making, underlines the need for flexibility in the face of changing contexts, and highlights the key role of framing contests for meaning making and for activating further mechanisms. We illustrate our proposition with two examples, the Polish and the German electricity system.

1. Introduction

Socio-technical systems such as electricity or transport are in urgent need of transition towards more sustainable developments, but this urgency is met with hesitancy. The many barriers that impede a transition are interlinked in a systemic way: actors, artefacts, and institutions are related to each other and systemically embedded, which restricts socio-technical change [1]. This complex systemic reality is captured in frameworks such as transition management, the multi-level perspective on socio-technical transitions, strategic niche management, and technological innovation systems [2]. We complement these frameworks with a systemic social mechanisms perspective that focuses on explaining how a transition does or does not happen.

Transitions involve a variety of innovations. To be developed and supported, these innovations need legitimacy [3–5]. Legitimacy is related to the social acceptance of, for example, a new industry [6], new technologies, or material elements. Acceptance as a relational concept is in the eye of the beholder [7] and in the case of a socio-technical transition there are many beholders, such as citizens, companies, regulators, and national and supra-national policymakers. As actors differ regarding knowledge, norms, values and perceptions, are embedded in different contexts and, thus, pursue different agendas, legitimacy struggles are highly likely. Our social mechanisms perspective depicts framing contests as a key driver, and legitimacy of a new system as a key outcome of change to explain how sustainability transitions of large socio-technical systems evolve.

To explain both progress and reluctance of pursuing a transition, we illustrate the social mechanisms-based framework of change, taking the socio-technical system of electricity in Poland and in Germany as examples:

Although the two neighboring countries possess rich domestic coal resources and are exposed to climate change, increasing environmental awareness, EU climate commitments and decreasing prices of renewable energy resources, they vary significantly in their approaches towards sustainability transition.

The Polish electricity system that has the highest degree of coal dependency in Europe, out-dated electricity generation infrastructure, supply security concerns [8] and enormous air pollution, has so far shown a reluctance to transition [9]. In the public arena in Poland, topics of energy costs and employment take precedent over CO_2 reduction [10]. Poland's successive governments have exhibited a strong attachment to conventional electricity generation as a guarantee of supply security [11,12]. Thus, here it is not only resistance to policies that hamper a transition [13] but to a great extent the policies themselves. Proactively blocking international decarbonization efforts [14,15], Poland is being perceived as a major climate laggard in the EU [16–18].

Germany on the other hand, with an over 55 % share of electricity from renewable energy resources [19], embarked on an ambitious energy transition journey, initially with the aim to cover half of the

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electricity supply through renewable energy sources by 2030 [20] and, following intermittent overachievement, increasing that target to 65 % by 2030 [21]. It aims to become GHG neutral by 2045 [22] and has committed to phase out coal by 2038 at the latest [23]. In recognition of this, Germany has been ranked as 5th regarding its transition efforts. What is, however, being frequently overlooked is that Germany is not on track in terms of the GHG emissions reduction, which is in particular because of the transport and building sector [24].

Our conceptual study is guided by the research question: How can it be *explained* that a sustainability transition does or does not happen?

The study contributes to the understanding of sustainability transitions (ST).

First, the *systemic mechanisms approach* complements transition research by identifying and categorizing mechanisms of change across nested systems. This systemic nature [25] is implemented by explicitly considering (micro-) individuals' behaviours, relations, and the (macro-) system's features as jointly and interactively relevant for explanation. Such thinking provides a lens to appreciate elements, relations and synergies, that is, *emerging* features that cannot be reduced to individuals' actions: Systems shape their components and relations and these in turn shape systems.

Second, we focus on *social* mechanisms: actors (as individuals and organizations) need to perceive and process natural as well as human-caused developments and technical features to act on them. In particular, frames of mind and changing frames across systems through framing contests are key mechanisms in a socio-technical transition, which involves then change regarding technologies, material and immaterial components, agents, habits, and reasoning. Providing legitimacy for these 'new elements' through framing contests is key for the *actual* transition to take place.

Third, we illustrate our framework with two cases that differ regarding the initiation of ST: while Germany's push for change has been coined 'Energiewende', Poland has been so far interested in conserving the status quo [26,27]. By sketching mechanisms for the Polish and the German electricity systems, we demonstrate the explanatory power of the mechanisms approach for both a more reluctant and a more enthusiastic pursuing of a transition. This serves to show that the mechanisms unfold very differently in two different systems, depending on the respective components and relations. It underlines the importance of system analyses in order to develop suitable policies for a transition.

To sum up, we combine insights from the literature on framing, social mechanisms and systemism to advance the understanding of sustainability transition and draw on publicly available sources to illustrate the systemic social mechanisms model with two examples.

We proceed as follows: Section 2 distinguishes our approach from prominent transition frameworks and highlights the complementary nature of the systemic social mechanisms approach. Section 3 depicts social mechanisms that work on different levels. Section 4 focuses on particularly important mechanisms to achieve a transition, namely framing and framing contests. While we give examples for mechanisms throughout the article, Section 5 illustrates the interplay of mechanisms on different levels with the two examples of the Polish and the German electricity systems. This is followed by a discussion (Section 6) and conclusion (Section 7).

2. Sustainability transition frameworks and mechanisms

Socio-technical systems are complex clusters of elements including humans, technologies, physical infrastructures, and institutions that together provide a specific function such as transport or electricity supply, and that are in need of a transition towards sustainability [28]. Given the complexity, scholars have explored sustainability transition [29] emphasizing different units of analysis: whereas 'strategic niche management' [1,30] focuses on the development of a protected space for a fledgling technology, literature on 'technological innovation systems' [31,32] explores the context and embeddedness of a specific technology (not just in a niche). The 'multi-level perspective' (MLP) [33–35] introduces a socio-technical regime around a specific function, and 'transition management' [36,37] is concerned with governance and policy design of changing a system. These frameworks align processes and interactions across levels and are testament to the existence of mechanisms and their importance for inducing change. Especially the MLP, through highlighting the importance of the socio-technical regime, introducing the landscape as broader context of change, differentiating between different levels, and emphasizing interactions between them, provides a systemic account of dynamic change.

Our approach departs from those frameworks as we take systemism further: we do not focus on one system (such as a niche, a regime) but rather view systems as nested, with interactions within and between systems: We propose a framework that categorizes social mechanisms in sustainability transitions within and across systems and that explains change through the emergence and submergence of components and relationships. The systemic social mechanisms approach thus complements transition frameworks by identifying key mechanisms including actors' framing and thus, explaining change.

For example, increasing awareness of climate change-related problems affects individuals who have different mindsets, are members of different systems and have different relationships: Polish and German policy makers as actors in the political system have relationships with the European Union (as both countries are members of the EU) and with the electricity system (since they shape the rules of the game for this sector). Positions held in the political system will be affected by these existing as well as emerging relationships. Being part of different networks means that actors experience a range of motivations, which adds to the 'extensive range of human agency' in the context of transitions [38]. Thus, identifying and categorizing mechanisms within and across systems is important to explain the dynamics of the system of interest.

Our approach is grounded in *scientific* realism [39] and focuses on *social* mechanisms:

Similar to critical realism [40,41], Bunge's scientific realism focuses on explaining reality through mechanisms. Bunge [39] views reality as a material multi-level world of nested systems where the interplay between levels gives rise to phenomena that could not be explained by an individualistic or a holistic approach. This systemic ontology treats structures as properties of systems and explores bottom-up and top-down interactions [42,43]. Geels [35] emphasizes these linkages between different levels, which we propose can be elucidated further through applying a systemic social mechanisms approach: "systemism maintains that bulk properties, such as social cohesion, voter turnout, and public opinion, emerge from individual attitudes, actions, and interactions – all of which proceed, though, within given social contexts" [39: 22].

While mechanisms related to for example technological interrelatedness [44] and to diminishing returns [45] are important for transitions and for economic assessment, we focus here on social mechanisms and highlight the role of framing. Frames and framings impact decision making and public opinion [46]; humans process events, act, frame their actions and react towards frames. Commonalities of Poland and Germany are a history of coal dependence with coal still playing a significant part in the energy mix of both countries, increasing awareness of climate change in the population, and being subject to EU climate and energy policy. The key players' political power [37], frames (as views on the energy system) and the framing by members of the government, incumbents, new organizations and media differ between the two countries and we propose that the dynamics of these are important for the legitimation of a transition.

3. The systemic social mechanisms approach

In Bunge's scientific realist philosophy [43,47,48] the world is seen ontologically as a system of systems, with each sub-system incorporating

its own dynamics. A concrete system has Components, an Environment, a Structure (relationships between components), and Mechanisms (CESM). The approach accounts for emergent properties, which in turn influence each (sub-) system.

Systems exist on different levels: for example, we can view a nation, an industry, a city, or an organization each as a system. In particular, a national electricity system can be understood as involving a respective political system, energy utilities as organizational systems, and innovative niches as systems, where new technologies are developed and demonstrated. At the same time, the national electricity system is part of the natural environment, the national economy, or the EU energy system. To explain change, systemism combines bottom-up and top-down processes. Relationships between these components make up the structure. Describing and understanding the characteristics of components, differentiating between several systems, for example the socio-technical, the political, and the niche, is important for explaining the effects of a system's peculiarities (types of components, relationships and dynamics) on the operation of social mechanisms and thus, on emergence and submergence of components, relationships or whole new systems.

Mechanisms are drivers in processes of change [49] and unveiling them means to explain the change process, which opens possibilities to influence it. While the term is applied broadly and covers many different things [50,51], here, we focus on socio-technical systems and on social mechanisms. The approach links behaviour on the micro level with systemic outcomes [52], thereby delivering explanations of social phenomena [53,54]. It requires specifying types of actors and their activities and motivations, their relations, and how their behaviour collectively brings about change on the macro level [55].

Hedstrøm and Swedberg [53] describe three types of social mechanisms:

(1) *Situational* (macro - the effects of structure and events - to micro - on beliefs and desires), where experiencing a specific situation affects actors in a certain way: belief-formation, opportunity-generating, and preference-formation mechanisms. Situational mechanisms are (slowly evolving or suddenly occurring) developments and events that can hardly be influenced by individual actors in an electricity system, but affect it. Actors will differ in recognizing the importance of these events, which is influenced by the context and history of the existing system. In Germany, for example, nuclear power used to play an important role with a share of around 30 % in the generation mix in 2020. The development of nuclear power has, however, always been accompanied by protests of local activists. Supported by media and some politicians, these protests evolved into an ani-nuclear movement that perceived nuclear energy as a threat to the environment [56]. Nurtured by catastrophes in the USA (1979), Chernobyl (1986) and Fukushima (2011), the movement provided a fertile foundation for the nuclear phase-out decision [57]. Poland, on the other hand, does not have any nuclear power but there is significant public support for this energy source, which is seen as a means to mitigate climate change [56].

(2) *Action-formation*, where (micro-to-micro) psychological and social-psychological mechanisms generate certain actions such as framing, mending or innovating. For the purpose of explaining a transition from an old to a new system, we specify the outcome of action-formation mechanisms as follows: With regard to the electricity system, the action of 'innovating' refers to introducing something to push towards transition to a new system ('innovating the future'), 'defending' refers to measures aimed at strengthening the actor's current position such as enlarging investment ('defending the past'). We add this qualification because a new regulation can aim at strengthening the new (for example the Renewable Energy Sources Act, EEG (Erneuerbare Energien Gesetz) in Germany) or at restricting the new (for example the 10H distance law restricting the construction of new onshore windmills in Poland). 'Framing' refers to strengthening the actor's position through arguments in the discourse, and changing frames refers to changing the actor's own position.

(3) *Transformational*, where interactions, such as framing contests, development of master frames, struggles and alliance building, lead to collective outcomes (micro-to-macro transformation). Transformational mechanisms refer to changing relations between (groups of) actors that are required for a transition: 'struggles' juxtapose positions, for example a 'job versus climate' narrative [58], 'alliance building' refers to defining a common ground, articulating common demands, and pursuing joint projects, and 'framing contests' refer to comparing and weighing of arguments and positions in a public discourse, through which new meaning can be constructed, with the potential of changing frames and actions.

A transition is driven by a multitude of mechanisms on different levels, accelerating or slowing down the development.

In the case of ST, key macro-to-micro situational mechanisms are for example floods and heatwaves associated with climate change, actual or perceived risk of power cuts associated with electricity supply shortages, catastrophes such as the Fukushima nuclear disaster or pandemics, and wars such as the Russian invasion of Ukraine, that underline the need for change and influence actors' beliefs and preferences. According to the Eurobarometer 501, which reports on attitudes of Europeans towards the environment as of December 2019, 78 % of respondents perceive climate change as a very serious problem. These longer-term developments as well as potentially disruptive events take place in contexts that are positioned on trajectories of conjunctural (events and conditions on different levels coming together) and configurational (different events interacting) developments [35]. These events and developments need to be noticed and therefore need to be articulated to achieve social significance [59].

The occurrence of action-formation mechanisms depends on the dominant framing used in this context, as aligned with actors' preferences and possibilities. For example, the meltdown of the nuclear fuel rods in Fukushima as a macro-to-micro situational mechanism led to the German chancellor Angela Merkel changing her position regarding nuclear energy, followed by action-formation mechanisms 'weighing the options' and 'deciding' that Germany will phase out nuclear power [60]. Russia's war on Ukraine as another key event causes political and business leaders to review energy systems [61]. Respective decisions and framing in turn provide an impetus for pushing (as another outcome of action-formation mechanism) Renewable Energy Sources (RES). Thus, events open opportunities for some entrepreneurs, but the same event as a macro-to-micro situational mechanism also leads to other reactions such as actors engaging in warnings regarding price increases or promoting nuclear power as a means to halt carbon emissions [62] or to ease an energy crisis. In this vein, faced with the demand to decrease emissions, the Polish government plans to use nuclear power [63].

Generally, resulting actions vary and interact. These relational aspects are expressed in mechanisms of social norms [64] and social influence. In the case of the nuclear phase-out decision, the majority of the German population perceived nuclear power as dangerous (after years of disputes, see [65,66]) and welcomed the move of pushing RES. The results of action-formation mechanisms (phase-out decision, increased engagement in alternative energy sources) strengthened anti-nuclear sentiment and became the social norm [62]. Advocacy coalitions between actors such as NGOs and social movements are important to influence policy making [67]. In Poland, the low visibility of NGOs and of anti-nuclear movements in the public sphere restricts the discourse on a transition to the economic dimension [68].

Collective outcomes of transformational mechanisms (struggles, alliance building) are difficult to predict. The related institutional change will more likely be seen as legitimate, if it alleviates people's worries concerning the consequences of energy transition [69]. Fig. 1

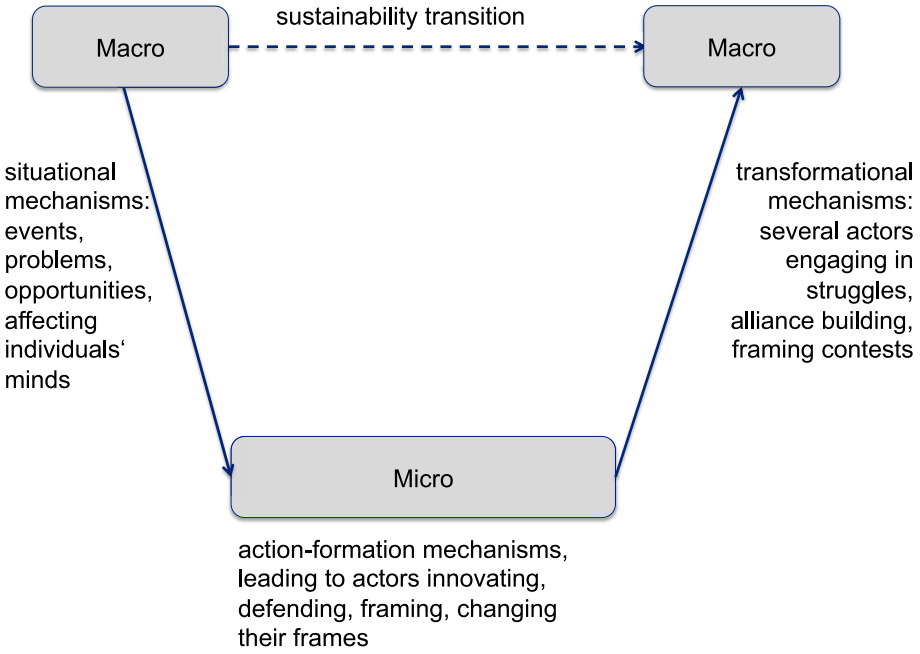

Fig. 1. Social mechanisms in ST: a schematic model.
Based on [52,53].

depicts types of social mechanisms in the context of ST.

Situational mechanisms then are events that influence actors in any system they are embedded in. The meltdown of the nuclear fuel rods in Fukushima as a macro-to-micro situational mechanism influenced actors in the political system (strengthening doubts about an established technology), in the niche as a system for boosting innovations (bolstering entrepreneurs engaged in renewable energy sources) and in the current socio-technical system (established actors fearing technological disruption), initiating respective action-formation mechanisms.

The effect of a situational mechanism on an actor in the shape of initiating an action-formation mechanism thus depends on the actor's knowledge, beliefs, preferences and capacity, which are – crucially – also shaped by the peculiarities of the system(s) that the actor is part of. The sequence of situational and action-formation mechanisms can take place in each of the different systems. A system's components and relationships influence actors' beliefs and preferences, but it is important to consider the heterogeneity of actors within systems regarding their preferences, competences and their openness for 'something new'.

To summarize, social mechanisms as drivers of change help to explain how transitions evolve through specifying how actors respond to situational mechanisms. A systemic view on ST explains the different impacts and conditions of social mechanisms in the current socio-technical system and in niches as well as in the political system. Applying the systemic view through a thorough system description and analysing actors' positions and relationships with other system elements further the understanding of actors' motivation for specific actions such as pursuing change or defending the status quo. Key mechanisms for transition are developments and events that lead to socio-technical system problems (situational mechanisms), and actors' activities such as mending, innovating and framing (resulting from action-formation mechanisms) and interaction patterns including framing contests and alliance building (transformational mechanisms).

Scholars have stressed the important role of legitimacy for transitions [70], Berek et al. [32] identify the process of legitimation formation as crucial for the emergence of new TIS, and Stefes [71] depicts a legitimation path alongside political and economic-technological paths. However, how does social approval of actors, technologies, and habits change; how is legitimacy eroded in an established system and how is legitimacy built for the new? We pay particular attention to framing and framing contests as social mechanisms for legitimacy creation.

4. Framing and framing contests to achieve legitimacy for a transition

Legitimacy relates to the social acceptance of something. Suchman's [72] definition of legitimacy as "a generalized perception or assumption that the actions of an entity are desirable, proper or appropriate within some socially constructed system of norms, values, beliefs and definitions" highlights the relevance of the respective system and the related 'frame of reference' for legitimacy assessments. For our purposes, we relate legitimacy not only to the 'actions of an entity': Social acceptance of something may relate to technologies (for RES, see [73]), the use of natural resources (for coal, see [74]), new ventures ([75]), agents (for entrepreneurs, see [76]), positions (for cultivation bans on genetically modifies organisms, see [77]), and whole systems (for energy system, see [71]).

Legitimacy involves knowing about the 'something', possibly taking it for granted, which Aldrich and Fiol [7] call 'cognitive legitimacy', and the degree to which 'something' fits with recognized principles and rules, which Aldrich and Fiol [7] define as 'socio-political legitimacy'. If technologies deliver cheap energy, infrastructure and practices are part of traditions, and actors and their decisions are not questioned, the system possesses legitimacy. This has been the case for coal in Poland and in Germany: Before the second world war, from an economic point of view the use of coal made sense and coalmines as artefacts built on coal as natural resource were seen as significant for prosperity [78]. These decisions about a technology might have been opportune in the past but the technology may have lost its advantage. However, citizens are 'socialized' into an energy system, with self-reinforcing dynamics supporting the system's legitimacy [69].

We explore *legitimacy of a transition* as a shift from the social acceptance of key elements of the current socio-technical system (such as technologies, actors pursuing them, infrastructures and practices) to the social acceptance of key elements from an emerging socio-technical system. How does such a shift evolve? Here, social mechanisms affect change within and across systems: Legitimacy as social acceptance of

actions and interactions is created and contested through framing [3]. When introducing something new into the socio-technical system, actors try to legitimate their novelty and here, frames play an important role both as action formation and transformational mechanisms:

Frames and *framing* encompass a broad range of cognitive, linguistic, and cultural processes within different contexts such as individual sensemaking, meaning creation, and mobilizing support [79]. On the one hand, frames provide an outlook on situations, they are means to see or 'to organize experience', [80]. Established actors' frame is based on their socialization and experiences from within the socio-technical system, whereas new actors' frame is based on their experiences with their technological or institutional innovations in a niche. On the other hand, frames are a means to influence or steer the seeing of others (selecting information and making it more salient in communication [81]), and in that capacity framing is an important social mechanism bridging individual perspectives and social processes [82]. Thus, frames are constraints and resources.

To achieve legitimacy for a transition, both the frame as a lens to see and framing as a way to make others see are important: The seeing as a *frame of reference* relates to goals, perceived problems and challenges, and appropriateness of strategies and solutions [83]. In the context of the energy sector, frames could relate to environmental benefits or economic aspects [84] and security issues. Path-dependent developments provide incumbents with powerful frames: Decades-long developments had cemented the positions of incumbents [71], leading to a frame that lends legitimacy to dominant 'large-scale, centralised technologies, like coal power stations' [83: 17]. The frame might thus include national energy supply security envisaged as a goal, ambitious international decarbonization efforts seen as a challenge, and investment in modern coal technologies proposed as an appropriate solution.

Framing as a way to *make others see* aims at garnering support and mobilizing for action through diagnostic, prognostic, and motivational framing [85]: attributing causes to problems, articulating strategies to address problems, and voicing calls for action. Through framing, actors position 'their' technology in the respective context [5]. Actors use framing as an important means to convince relevant audiences of 'their' components and relationships, and to delegitimize other components and relationships. Advocating new technologies might include drawing attention to different goals such as reducing pollution, thereby affecting the socio-political legitimacy of established components such as coal.

Framing contests take place when coalitions of actors engage in disputes on public stages to influence the perception of relevant audiences as to what is legitimate [3]. While Aklin and Urpelainen [86] point out the undermining effect of counter-frames, Setvowati and Quist [87] find that the involvement of different stakeholders and the resulting negotiation and contestation in energy transition helps overcoming institutional and policy barriers. In this sense, pluralism of actors engaged in framing contests can facilitate change, thus making framing contests dynamic processes of meaning construction [88] that might become transformational mechanisms contributing to redistribution of access to decisive resources such as finance and political support. Contests may occur as framing and counter-framing [85] between camps of proponents and opponents of a particular issue (for example, contest between camps of pro- and anti-nuclear power), as framing disputes within a camp (for example, dispute in an anti-nuclear camp about delaying the phasing out), and at the intersection of frames and events (for example, the re-consideration of phasing out in the face of an energy crisis). Framing contests imply that frames are not just presented and repeated. Rather, framing and counter-framing constitute engagement that takes place within and across systems. For example, within the political system, actors holding different government posts might disagree on a policy and try to win over fellow politicians in order to change policies. To achieve legitimacy, coalitions engage in framing contests with other actors. These framing contests have a performative role in producing legitimacy [3], which may lead to a predominant collective frame as a productive outcome [88], initiating respective change, which in turn impacts frames and framing: framing contests may produce new frames and new framing, implying a continuous development of sustainability trajectories. Thus, rather than going through one round of 'actions, frames, framing and framing contests' – as depicted schematically in Fig. 2 – transitions are driven by repeated cycles of discourses that may produce a collective frame.

Fig. 2 visualizes processes of changing frames and framing in the context of ST:

As visualized above, we propose that the interplay between what people do, see and say is important for the transition to take place:

Situational mechanisms can shed light on existing frames: In the face of increasing climate change anxiety, or serious risk of socio-technical system failure, actors might experience cognitive dissonance between their frame and the changing requirements of reality. Thus, *relating frames to situational mechanisms* helps to communicate opportunities and threats, and opens up actors' readiness for change. This may lead to actors *changing their frame* and subsequently their actions, and the *framing of these actions*. These activities on the micro level result in new frames and framing. In *framing contests*, frames and counter-frames can be identified and compared. However, contests require space for arguments and, in the context of complex socio-technical systems, the media has an important role as a stage for presenting these arguments [60], either as a mouthpiece for certain interests or juxtaposing arguments and positions, thereby providing a public platform for the discourse. In the course of framing contests, the legitimacy of established elements of the socio-technical system is brought into question, and the legitimacy of new elements may be created.

Thus, the transition of a socio-technical system is interlinked with legitimacy of that transition: The impetus (situational mechanism) leads to rethinking one's frame (action-formation mechanisms) and initiating different actions in the systems, each accompanied by respective framing, thereby trying to undermine or defend the socio-political legitimacy of established components. Interactions as mechanisms of socio-technical transition expose actors to alternative frames, and resulting framing contests may produce legitimacy for increasingly more elements of an emerging system.

Framing contests as a transformational mechanism do not guarantee a transition: While a lack of framing contest implies a lack of new meaning construction [88], an extensive framing contest, drawing on frames beyond the function of the socio-technical system, could lead to polarization as Lee and Hess [84] demonstrate with the example of distributed solar energy in the USA: Here, a struggle between incumbents and new entrants evolved into partisan polarization, hardening existing frames and hampering a transition. Thus, a limitation of the social mechanisms approach is its lack of predictive power: it *explains* developments, but, given the many possible constellations of social mechanisms unfolding, the approach does not provide a roadmap to achieve a transition.

To conclude, framing and framing contests are social mechanisms to influence legitimacy: In framing, actors portray a way of seeing, which is used to influence the perception of others. In framing contests, socio-political legitimacy is challenged, and frames may change. Productive framing contests lead to coalitions that achieve impact, which translates into policy. Legitimacy of the transition is achieved when the legitimacy judgements of various components of the new socio-technical system reinforce each other and the system by and large becomes accepted.

5. Systemic social mechanisms in the Polish and the German electricity system

In this section we illustrate the relevance of social mechanisms using the examples of the German and Polish electricity systems and in particular we highlight the importance of framing contests in the context of sustainability transition. To do so, we sketch the status quo of the sustainability transition process in the electricity systems of both

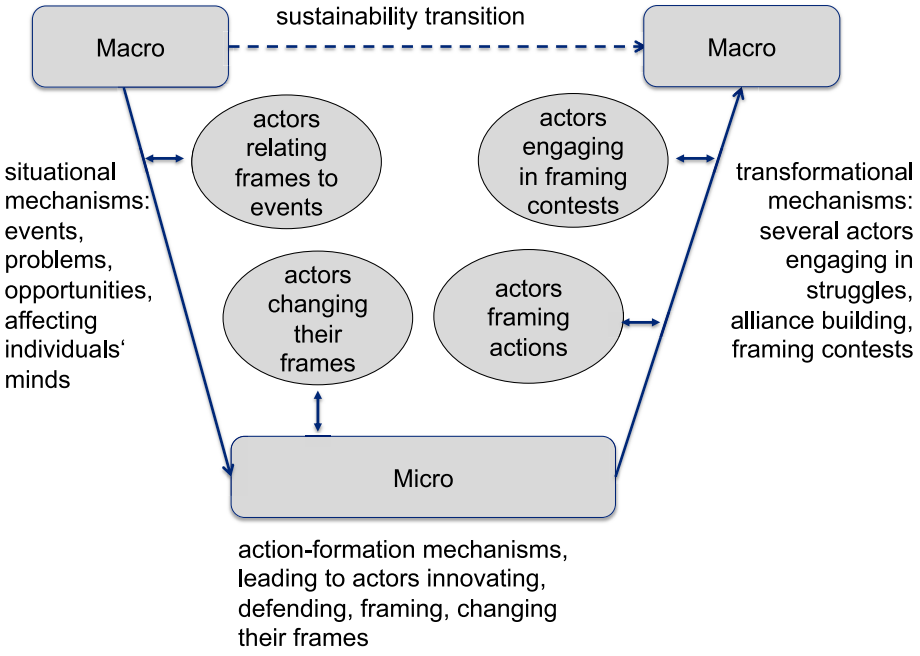

Fig. 2. Frames and framing in the social mechanisms model.

countries (5.1). This status quo assessment is based on key data regarding (at the time of writing) current energy mix and policy objectives per energy source, relevant literature, and the results of the Energy Transition Index survey. Then, we discuss the main situational mechanisms that have been affecting the electricity systems, sketch actions as a result of action formation mechanisms and describe key frames and indicators of framing contest in the field of energy policy (5.2 and 5.3). It is important to note that the transition processes in both countries are ongoing and that electricity systems are a volatile field exposed to many situational mechanisms such as geopolitical developments. Thus, we provide a snapshot of the status quo and sketch some historic developments.

5.1. The status quo of the sustainability transition in the national electricity systems of Germany and Poland

Owing to rich domestic deposits of coal and lignite, Germany and Poland have a long history of coal mining. As neighboring countries of similar land area size, both have also a significant and comparable potential of renewable energy resources [89]. Both countries are signatories of the UN Paris Agreement and, as EU member states, are obliged to implement its climate and energy policy goals to mitigate climate change.

Despite these similarities, Germany and Poland have so far presented rather different approaches to sustainability transition of the electricity system, which is visible for example in energy policy, regulations, international rankings of transition readiness and the actual electricity generation mix.

For more than 25 years, successive German governments have committed to the Energiewende [90]. In line with international commitments, which Germany has significantly co-shaped, the country has been dedicated to sustainability transition and strives to achieve climate neutrality by 2045, five years earlier than the EU net zero GHG emissions goal, by defining sector specific GHG emissions reduction targets [91]. In the electricity system, this is visible in the political decision-making with mechanisms supporting the development of renewable energy sources that were kicked off in the 1990s and institutionalized as the Renewable Energy Sources Act EEG, regularly updated since 2000 [92] and in the announced coal phase-out with the last coal mine to be closed by 2038 [17,93]. Furthermore, Germany decided to abandon nuclear power by 2023 since it is perceived as a high-risk technology (especially after the Fukushima disaster in 2011; [94]). Despite Germany's image as a climate leader, coal and lignite are still important pillars of the German electricity system and provide approximately 30 % of its electricity generation [95]. In parallel, the share of renewables has surged and reached 55 %, with onshore wind playing the major role [19]. In the worldwide Energy Transition Index Germany reached the 11th position. Regarding transition readiness it takes the fifth place, which highlights its regulatory and political commitment [17].

In contrast to Germany, Poland is still seen as one of the chief opponents of the EU decarbonization policy and its government still has not committed to the EU goal of carbon neutrality by 2050 [96]. Poland is also one of very few countries in the EU that still has not released its long-term strategy to implement the obligations under the UN Paris agreement [97] and has no legally binding climate law [9]. Although there were policy targets set to reduce coal dependency and measures implemented to diversify energy mix and support renewables development, they are seen as neither consistent nor sufficiently ambitious [56,98,99]. Poland's Energy Policy, PEP 2040, foresees a decreasing share of coal-fired generation to 56 % (or to 37.5 % with increased prices of CO_2 emission allowances) by 2030 (from 70 % coal and lignite share today; [100]), replacing it with renewables and nuclear power. In electricity generation, renewables are envisaged to grow to 32 % by 2030 and (to be newly launched) nuclear power to reach 16 % by 2040 [101]. The Council for Energy Security and Climate, an independent expert body, points to the necessity of increasing the renewable energy target to 50 % of net electricity demand by 2030. To accelerate their development, the Council postulates reforms regarding permitting, planning and support instruments [99]. Despite sub-optimal conditions, renewables capacity continues to grow. In 2021, it was decided to close the last coal mine by 2049, but lignite is not included in the phase-out plan [63].

5.2. Mechanisms in the German electricity system

The German ambitious sustainability transition course is broadly seen as legitimate in society. We propose that it is the result of productive framing struggles concerning environmental issues that go back

to the 1960s and that impacted policy making.

Following the student movements of the 1960s, in West Germany environmental movements protested against pollution, atomic energy, and big industry, which influenced the landscape of political parties and their policies [102], and was picked up by the media. These movements "framed the environmental impact of nuclear power primarily through the risk of breakdown and radioactive contamination, rather than a lower environmental footprint and climate benefits" [56]: 2). The nuclear meltdown in Chernobyl in 1986 was a key situational mechanism that increased dramatically the already existing public opposition to nuclear power generation in West Germany [67]. Around the same time, increasing worries about climate change were acknowledged and in 1987, an expert and cross-party parliamentary committee on 'preventive measures to protect Earth's atmosphere' was set up to develop recommendations [103]. While the decision to phase out nuclear power was furthered by a strong civil society [104] and has hardly been contested in the public (though watered down by the big four incumbent utilities' demands [105]), this has not been the same for the exit from coal: here, the complex relationships between utilities, the national and local governments, and regional employment has led to a fierce struggle over the extent and timing of a transition [58,104,106].

Thus, it was especially the rejection of nuclear power, combined with strong public awareness of climate change as a problem, that furthered the endorsement of renewable energy and led to respective innovations, such as the '1991 Electricity Feed-in Law', which obliged the utilities to provide grid access for electricity generated from renewable energy sources and to remunerate electricity suppliers [20,67]. Initially, this institutional innovation had limited impact on the utilities and its effects were generally underestimated [71]: it referred mainly to hydropower, which played only a small part in the portfolio, and the preparation of the Electricity Feed-in Law coincided with the (situational mechanism of) reunification process of East and West Germany, which kept the utilities busy with organizing their stakes [67,71,103]. Underestimating the future relevance of renewables and exploring carbon capture and storage (CCS), the established companies, who had political power [71], continued to invest in fossil fuel plants and proposed an extension of the nuclear phase-out period [105]. As incumbents, they were engaged in centralized electricity generation via coal and nuclear power and challenged the Electricity Feed-in Law in court and in the public. Another means to slow down the energy transition was to support citizens' resistance to the installation of wind turbines [71].

However, different actors (companies, farmers, municipalities, consumers) as electricity producers have disrupted traditional ownership and have furthered the decentralization of electricity generation [107]. Especially feed-in tariffs that are coupled with generous remuneration divert profit from centralized utilities to many producers [108], which has been very successful in Germany.

Over time various regulations supported a range of new players investing in renewable energy and threatened the four incumbents' positions [107,109] and the growing 'advocacy coalition' [67] of renewable energy associations and activist groups gained influence on politics, affecting regulation and frames.

The extension of the lifetime of nuclear power plants came abruptly to an end with the Fukushima accident in 2011 – again, the utilities fought against respective regulation in court [105].

While the situational mechanisms of nuclear power accidents and climate change-related catastrophes strengthened frames that endorsed renewable energy sources, in the political landscape these frames differed regarding the proposed role of renewables in electricity generation, from being the key source to being only complementary [67]. The established companies framed renewables as costly and unstable [104,110], pointed to efficiency improvements and capture & storage possibilities regarding fossil fuels [105], and complained about the sector's strong regulation [106]. However, the debate in the public about the necessity of change [111] and the strong policy commitment to the 'Energiewende' [112] further pushed the endorsement of renewables.

Eventually, the many pressures on incumbents led to them questioning their traditional business model: as Kungl and Geels [105] show, exogenous shocks (the situational mechanisms of the 2008 economic crisis and the 2011 Fukushima accident) and regulation detrimental to incumbents' position (EEG, nuclear phase-out) decreased the incumbents' profitability and encouraged them to change their frame and to consider their strategies.

Framing contests in the public arena have occurred between opponents of the energy transition, such as (at the outset) the Ministry of Economy, incumbents, and the Federation of German Industries, and proponents of the transition, in particular the Green Party and their parliamentarians, the Ministry of Environment, environmental groups, and renewable energy associations [71]. Conflicts between frames concerning sustainability, economics and energy security surface for example in the coal-related 'jobs versus climate narrative' [58]. However, they also provide opportunities for forging new alliances, for example when a union (here ver.di, one of the largest union worldwide, with only few coal employees as members), despite internal struggles between pro-coal and pro-climate members, signals solidarity with the environmental youth movement Fridays for Future [58].

A broad coalition of environmental groups, economic beneficiaries such as farmers and citizens making use of feed-in tariffs, local municipalities, and 'green' politicians have been lobbying for further support of renewables, and a coalition of (amongst others) big utilities, Liberals, and Conservatives have been challenging for example the distribution of subsidies ('costs discourse': [113]).

Thus, the political arena has been influenced substantially by various societal actors [106]. The success of the legitimization of the Energiewende can be attributed to the long-lasting framing struggles that involved different parts of society [113], were picked up by the media and translated into policies and regulation by coalitions of actors in the political arena [114]: these were productive framing contests.

In conclusion, frames, framing and framing contests (in the social mechanisms model: Fig. 2 above) have played an *amplifying* role for the impact of situational mechanisms (events such as nuclear accidents and climate developments) on the German energy transition. Concerns about pollution and nuclear power were framed in ways that influenced public opinion and policy-making, leading to rejection of nuclear power and the promotion of renewable energy sources. Framing contests between different societal actors, such as political parties, environmental groups, and industry associations, have influenced public discourse and policy decisions. These framing contests have ultimately contributed to the legitimacy and progression of the German energy transition, despite ongoing conflicts and challenges.

5.3. Mechanisms in the Polish electricity system

Poland's reluctance to sustainability transition of the electricity system might be explained by a lack of productive framing contests concerning sustainable development. Although Poland is perceived as a nation that is eager to participate in debates and protests, which contributed to the abolition of the communist regime [115] and of the right-wing national-conservative government (in October 2023), productive framing contests have not taken place in the field of sustainability transition.

In Poland, the 1986 nuclear meltdown in Chernobyl was also an important situational mechanism that affected people's attitudes towards nuclear energy. The government's actions – playing down the catastrophe and continuing to plan the construction of a nuclear power plant in Poland – furthered the de-legitimization of the communist regime [116], which eventually gave up the plans to construct the power plant. In 1990, the new democratic government placed a moratorium on constructing nuclear power plants [116].

During the 1980s, conjunctural and configurational developments [35] came together in that the Solidarity trade union was created in

Poland in 1980 and in Central Europe social movements protested for a range of 'innocuous' (political, economic, environmental and other) causes to destabilize the communist regimes [115]. Thus, nuclear power was one amongst several issues that people in Poland contested, and on the back of environmental activism "anti-systemic protest was spreading widely" ([116]: 37).

From 1989 onwards, frequent change of governments, strong position of unions, and mining related to strong cultural identity meant that domestic coal mining has shrunk as a reaction to crises in the industry rather than as part of a deliberate energy transition [78,117]. From 2015 to 2023, the government was led by the right-conservative party PiS, Right & Justice, which did not commit to achieve carbon neutrality by 2050 [63]. With the state owning or controlling companies responsible for the generation, transmission and distribution of electricity [63] and also having stakes in the coal and lignite mines [118], coal has been protected as a strategic source to secure energy supply [119].

Environmental protection and climate change mitigation have not been treated as priorities by leading politicians in Poland and there is neither a dialogue between the government and opposition in this field nor do politicians have detailed concepts on how to reform the energy system [120].

Municipalities have not been encouraged to play a significant role in the development of renewable energy as an alternative to coal [121], and the political arena is hardly influenced by societal actors [122]. Public consultations in the legislation process have been only cursorily conducted [123–125], although the EU requires such public consultations especially in the context of energy and environment related law. This has been even more frequently observed since 2018. For example, the Polish government excluded civil society from the preparation of the National Recovery and Resilience Plan required by the EU. In response, an alliance of NGOs initiated their own public consultations involving over 460 speakers (citizens, local government, trade unions, businesses etc.). However, the government did not engage with the submitted comments [126].

Restrictive regulation had hampered the installation of wind turbines: In 2016, the so-called 10H distance law introduced a ban on the construction of new onshore windmills at a distance less than ten times the height of the turbine from dwellings, which contributed to blocking investments [127].[1] Similarly, the regulation regarding prosumer installations (mainly as photovoltaic) does not encourage feed-in to the national grid as excess generation of energy is not remunerated [121].

In the meantime, however, even right conservative politicians have started to acknowledge that the share of coal in the energy mix needs to decrease, which is envisaged in the Polish energy policy PEP2040. Some actions with the claim of a more sustainable future involve preparing for nuclear power to reduce carbon footprint [63], developing 'clean' coal [128], addressing pollution (2018/19 'Clean Air' act), and introducing the 'my electricity' program 2021 with subsidies for further decarbonization, improving air quality, and reducing energy poverty [129]. Nuclear power has been, in particular, indicated as a reasonable alternative, and polls reveal that over 80 % of Polish people generally approve the nuclear plans of the government [131]. A lack of knowledge on energy topics and low willingness to bear additional cost of sustainability transition can be observed [132]. Despite a sub-optimal regulatory framework, the share of renewables has been growing, but below its actual potential [133,134]. This increase is thanks to a growing group of actors lobbying in favor of renewables including energy communities, municipalities, associations and businesses.

[1] In 2023, the instrument that stopped the development of onshore wind energy, was repealed as a result of pressure from the EU. The amended law now permits the distance of 700 m, which increases the availability of land for onshore wind investment (ITA, 2023). Originally, 500 m were foreseen, but PiS again introduced a last-minute amendment "to protect citizens who are afraid that [turbines] will be put in their gardens" [130,131]).

The situational mechanisms of nuclear power accidents and climate change-related catastrophes did not lead to strong frames that endorsed renewable energy sources: environmental awareness of the population has been lower than for example in Germany [56] and "on the whole environmentalism did not take root in the Polish society" [116: 45]. Rather, coal mining has been framed as supply security at reasonable prices and energy independence from Russia [119].

Coal and coal mining still have significant legitimacy: Coal has long been endorsed by a powerful coalition of incumbent actors. In the political landscape, successive governments as well as the main political parties have framed coal as the foundation for the economy and for national sovereignty [18]. Kuchler and Bridge [128: 136] express well the frame that endorses coal: "Contemporary policy makers in Poland mobilise a national imaginary inherited from communist times – encapsulated in the slogan 'Poland stands on coal' – that fuses infrastructures of coal extraction and combustion with the fate of the nation". PGE, the largest state-owned energy utility, referred to this frame in its PR campaign against the closure of a lignite mine in Turów in 2021. In addition to highlighting the mine's contribution to energy security and national sovereignty, the PGE campaign seized anti-European sentiments and played on criticism against the EU decarbonization plans [135]. This narrative has been frequently used in the context of energy policy by the governmental coalition of PiS, Right and Justice and Sovereign Poland, Suwerenna Polska (2015 to December 2023) and picked up by the media including in particular the state-controlled media outlets to satisfy their Euro-sceptic right-wing voters [134].

This frame is challenged through for example, youth climate strike [136], large street demonstrations [137], anti-smog protests [138], and actions to stop a new lignite mine [139], but they have not been translated into broader societal debates and political pro-transition alliances, and accordingly did not result in a coherent strategy and legislation process [134]. There is no strong coalition of supporters for renewables: citizens are not encouraged to make use of feed-in tariffs, local municipalities are hardly involved in infrastructure decisions, and environmental groups do not have strong support in the media. On the other hand, policy makers and big utilities, partly as the same persons, still affirm coal and tend to discredit renewables [140–142].

Thus, energy security and sovereignty frames dominate the public discourse, counter-frames are not supported in the media and the political arena has so far not been influenced substantially by societal actors. The perceived high costs of renewables coupled with price sensitivity of Polish customers lend support to policymakers' framing of coal's high importance, thereby playing to citizens' socialization [71] within the current energy system.

In conclusion, pro-coal frames and framing by powerful actors and the lack of framing contests in the field of energy (in the social mechanisms model: Fig. 2 above) have played a *decelerating* role in shaping the impact of situational mechanisms (events such as nuclear accidents and climate developments) on the Polish energy transition. Throughout the years, the frame of coal being indispensable has been reinforced, with successive governments framing it as essential for affordable electricity supply and national sovereignty. This narrative has been further strengthened by powerful incumbent actors, including state-owned energy utilities, and spread by the media to mobilize support against EU decarbonization plans. Despite some challenges from youth climate strikes, street demonstrations, and anti-smog protests, these counter-frames have not translated into broader societal debates or political alliances supporting a consequent policy shift towards transition away from coal.

6. Discussion

Sustainability transitions are about changing existing structures and practices in order to achieve a more sustainable socio-technical system. *Explaining* transitions requires the identification of mechanisms that

make 'a system tick' [49] and in the case of socio-technical transitions it is in particular *social mechanisms* that explain how actors process developments, how actors act and react individually and in combination with other actors, and how frames (through which people perceive) and framing (to make other people see) are key for the legitimacy of sustainability transitions.

There is a large body of literature addressing different aspects of sustainability transitions, including the role of framing (Smith 2005, Lee and Hess 2019) and of discourses [58,113]. The literature on sustainability transition has been reviewed [2,29], however, a systemic consideration of the role of social mechanisms has been lacking so far. Such a systemic account is important because mechanisms are decisive for transitions by influencing actors' beliefs, preferences, and actions. Frames shape perceptions, framing is applied to garner support, mobilize for action, and produce legitimacy within and across systems, and productive framing contests fuel dynamic processes of meaning construction and transformation.

Our findings confirm the applicability of our conceptual framework: The two examples of Germany and Poland illustrate how the systemic interplay of various mechanisms may encourage or slow down the transition of the electricity system; they demonstrate that the same situational mechanisms of climate change problems and nuclear power catastrophes can lead to different paths and that productive framing contests are needed to legitimate a transition. In Poland, the lack of 'change of frames' and the lack of productive framing contests concerning sustainable development have contributed to the conservation of the coal dependence and the country's reluctance to transition towards a more sustainable energy system even in the presence of a window of opportunity created through situational mechanisms. Unlike in Germany, where framing contests have influenced public discourse and policy decisions, Poland has not experienced similar productive framing contests in the sustainability transition realm.

Situational mechanisms are sudden events or accumulating developments that – given attention – make people think [53]. This thinking is systemically affected [48]: actors as citizens, politicians, managers, scientists, members of NGOs or movements differ regarding their aims and preferred means to reach these aims, they are situated in a certain (civil, political, organizational) environment that is characterized by a certain structure (CESM: [143]). The corresponding psychological and social-psychological (action formation) mechanisms on the individual level generate certain actions: defending existing structures and practices or innovating new ones, accompanied by respective (change of) frames and framing. The social mechanisms are causal, but not in a deterministic way [49]: the unfolding effects are influenced by the systems' characteristics.

The electricity systems in Poland and in Germany are both subject to EU decarbonization policies, which in turn are shaped by the member states. Actors in both countries have been exposed to situational mechanisms of climate change-related problems and nuclear power plant accidents. The coal-focused incumbents have reacted similarly in that they have been defending existing structures and practices: looking for efficiency gains, suggesting carbon capture & storage and other 'clean coal' measures, and framing renewables as costly and unreliable or insufficient. Close ties between utilities and policy makers can be observed in both countries, expressed variously in the extent of lobbying (Germany), state ownership (Poland) and practices of revolving doors [18,71,144].

However, the *change of frames* and the nature of *framing contests* differ between the two countries:

In Germany, counter-frames emphasizing high costs and supply security concerns did not succeed in undermining legitimacy of renewables. The German media coverage broadly supports the energy transition while acknowledging challenges [114]. Discourses about energy transition institutionalized decarbonization [113], with the environmental movement being a prominent part of the debate for many decades. The movement's claims about the state of the environment and of the necessity of counter measures are broadly seen as sensible and legitimate, which indicates a discursive opportunity structure [145] that enhances the effectiveness of framing [146]. Many actors are members of different systems, for example some members of the environmental movement are also members of the Green Party, which has been part of the federal coalition and part of some state governments and local councils. Politicians might - as prosumers - actively engage in niche development. Thus, actors are exposed to a variety of framing and take part in framing contests: as union members, as concerned citizens, as politicians from different parties.

However, the 'jobs versus climate' struggle affects the legitimacy of a quick transition away from coal and a discourse takes place how to reconcile the various demands to achieve a just transition [58].

In Poland, genuine framing contests in the energy sector, that is, comparing and weighing of arguments and positions in a public discourse, hardly occur. The lack of framing contests is especially visible in the legislation process and in the narrow range of perspectives presented in the media when addressing energy policy topics. Pro-environmental actors voice their concerns but do not have an effective presence in the media or significant influence on policies. The lack of a respective discourse limits the effectiveness of framing. The members of the political system are also in the driving seat of state-owned utilities, emphasizing energy security, independence and costs as key criteria for policy development. Many politicians have variously discredited renewables, call coal a national treasure, point to technologies making coal mining safer and more profitable, and blame the EU for high energy costs [140,141,147]. Societal pressure has not reached a momentum to motivate politicians to navigate the transition process towards decarbonization more effectively. The media broadly supports the conservation of coal as key energy resource and the dominant narrative revolves around increasing quality standards and efficiency [114]. It is striking that one of the first actions of the incoming government (December 2023) has been to dismiss top management of state TV and radio: "The new Polish government has gutted the top management of public television, making good on a campaign promise to reform a broadcaster that functioned as a mouthpiece of its rightwing populist predecessor" (The Guardian, 20.12.2023).

The conceptual analysis and the illustrative examples provide three key insights:

The lens of systemism helps modelling the influence and dynamics of nested systems and treats context (here esp. history, public sphere and economic system) as systemic and as key to understand energy transition: Describing each system and the relationships between systems (embeddedness and multiple memberships) illuminates causes and effects of change.

The social mechanisms approach enhances the explanatory power of transition studies: Transitions are driven by the interaction of macro-to-micro situational mechanisms such as catastrophes or supply security risks that influence actors in systems, action-formation mechanisms on a micro level, leading to actions such as framing, innovating and defending, triggered both by situational mechanisms and the peculiarities of each system, and micro-to-macro transformation mechanisms such as framing contests and collaborations that might promote the legitimacy of a transition as a collective outcome. Multiple systemic pressures (as situational mechanisms) create a window of opportunity for transition [148]. However, even if innovations are ready to enter a socio-technical system, a system transition is unlikely to proceed without respective legitimacy. This entails the development of social approval for key components of the new socio-technical system reinforcing each other, leading to the new socio-technical system becoming more accepted. Framing is used to mobilize for and against significant change, and the resulting framing contests as transformation mechanisms may produce legitimacy for the new [3]. The acceptances of key elements do not just add up but reinforce each other [71]; similarly, a domino-effect might unfold when 'hegemonic forms of legitimacy' [149] break down.

A lack of *framing contests* hinders the build-up of legitimacy for a transition, which in turn hampers a ST: Poland and Germany have a long history of coal mining, with powerful incumbents, low labour mobility [150] and strong unionization. In both countries, coal still plays a significant role in electricity generation, with affordability, energy security and, in case of Poland independence from Russia, being key arguments [104,113]. Poland and Germany are part of the European Union and subject to respective regulation and policy developments.

Given these similarities, the two countries differ remarkably in the development of their electricity systems. While German governments, facing critical public discourses, have been pursuing the 'Energiewende' for decades through pushing renewable energy and phasing out nuclear energy, Polish governments have been reluctant towards the integration of renewable energy and the commitment to phase out coal.

Framing contests as transformational mechanism can lead to polarization, if frames and counter-frames aim at undermining positions [84,86].

On the other hand, Nisbet et al. [151] show that in a competitive information environment (that is, frames and counter-frames are at play), open-minded individuals are more likely to weigh arguments, and as a result see mitigation of climate change as legitimate.

Thus, productive framing contests as 'engaging with arguments' are important to achieve just transitions through juxtaposing positions and scrutinizing different narratives in the public arena.

However, when considering the two countries' paths, it is important to take into account their political and institutional history: As a founding member, Germany has been able to shape EU regulation from the start, including the energy policy, whereas Poland has joined the EU only in 2004, and Poland has become a democratic state only in 1989, thus having a shorter history of providing more space for public discourse on sustainability. This is visible especially in the Polish legislation process, media coverage on energy issues, and in the course of parliamentary elections. Governmental policymakers and state-controlled incumbent energy companies have been avoiding to engage in framing contests with proponents of change. The focus of the media has been primarily on political and economic perspectives, and civil society and niche actors have not received enough space [152–154]. As a result, an agenda of preserving the old system has been set and seen as legitimate. The legitimacy-constructing role of framing contests has not played out yet.

While citizens seem to support increasingly decarbonization [155], the lack of framing contests that results from the peculiarities of the Polish electricity system makes legitimacy transition unlikely to evolve soon, which slows down systemic change. The incoming government has announced a shift towards green energy and a 'tougher approach towards its state energy company' (Financial Times 1.12.2023). It will be interesting to observe how respective actions will be framed and whether constructive framing contests can unfold to legitimize a transition of the energy sector in general and of the electricity system in particular.

7. Conclusion and policy implications

Research on sustainability transition led to rich frameworks that consider different levels of analysis and mechanisms to describe and understand trajectories of concrete cases [2,29]. The systemic social mechanisms approach, rooted in scientific realism, complements this transition research by focusing on explanation (see also [35]): it consists of a comprehensive compilation of mechanisms that work within and across systems and explains how the interplay between mechanisms furthers or hampers a transition. Thus, the approach is applicable within different frameworks: it involves a thorough system analysis including actors, artefacts and their historical background, identifying mechanisms at different levels including the framings used and the framing contests that unfold.

The shortcomings of the systemic social mechanisms approach are its complexity and the lack of predictive power in terms of the transition outcome: the multitude of mechanisms and the interactions of mechanisms (weakening or enhancing each other) within and across systems propose various trajectories. For example, counter-frames may weaken frames or they may lead to a change of frames; framing contests might lead to polarization or might become productive framing contests that create legitimacy for a transition. Furthermore, the relevance of a particular mechanism for a transition is difficult to predict. Therefore, the power of the systemic social mechanisms approach lies mainly in explanation. This, however, can be used for policy implications.

We propose to incorporate the systemic social mechanisms-based lens into the sustainability transition frameworks to enhance their explanatory power and to guide the identification of crucial mechanisms in the transition process.

We show with the examples of the Polish reluctance to change and the German Energiewende, that framing contests are crucial to drive change and to produce legitimacy for a transition. As Fuchs [156] points out, the outcome of transition attempts cannot be pre-determined and there are multiple interrelated mechanisms at play. The systemic social mechanisms approach addresses this complexity and the dynamic through the systematic identification and the description of the interplay of mechanisms.

This is useful for policy development and reflection:

Policy design and implementation should be *evidence-based* [157]. Applying the systemic social mechanisms approach provides an effective lens for continuous and systematic data collection because it entails the identification of relevant systems, actors, artefacts, reactions, interrelations and mechanisms on different levels. Mechanism-based evaluation of implementation provides evidence over time.

Policies need to *respond to current developments* without losing sight of the key aim of decarbonization. Identifying events as situational mechanisms sheds light on the appropriateness of current strategies, with implications for action and framing. This emphasizes the need for *flexibility*: situational mechanisms change material circumstances (e.g., scarcity of an energy source) and initiate action-formation mechanisms in the field (e.g., leading to promoting an alternative energy source), which alters the setting for formerly conceived strategies.

Finally, to be effective, policies need to be *approved* by a significant part of society. Key actors should understand *framing contests as necessary* for creating legitimacy: through contests, stakeholders' arguments can be exchanged and, if taken seriously, these exchanges may improve implementation and acceptance. This underlines the importance of pluralistic media as an arena for framing contests.

In conclusion, sustainability transition requires a fundamental reorientation of investment away from incumbent fossil fuels-based technologies towards greener alternatives. This needs to be complemented by social approval of sustainable alternatives, which requires policy strategies guiding the expectations of key actors such as technology developers and investors. These strategies should, however, provide a certain degree of flexibility to respond to situational mechanisms.

A turn-around away from the fossil fuel-dependent status quo is particularly challenging if policymakers are reluctant to drive sustainable change, and if the media does not provide an arena for framing contests, as shown for the Polish electricity system.

Based on our examples, we have emphasized the key role of productive framing contests for a transition. Further research is needed to provide more evidence for their role in transitions and to explore the respective context. The application of the systemic social mechanisms model to other countries requires an assessment of the respective energy mix, policy objectives and current transition readiness (Energy Transition Index survey), the effects of key situational mechanisms affecting the electricity system, responding actions, key framings and indicators of framing contests in the field of energy policy.

CRediT authorship contribution statement

Ursula Weisenfeld: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Conceptualization. **Katarzyna Ewa Rollert:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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