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How to Explain Major Policy Change Towards Sustainability? Bringing Together the Multiple Streams Framework and the Multilevel Perspective on Socio-Technical Transitions to Explore the German "Energiewende"

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Most efforts at explaining major policy transformation apply a single lens to study specific cases. Recent contributions have called for a more plural use of theories to facilitate the production of valuable new perspectives and research agendas. The German energy transition is a good example of such a transformative change. This article takes up the call for cross-fertilization of theories, using two complementary lenses to explain the German energy transition: (i) applying the multiple streams framework (MSF) demonstrates how political factors and public opinion have opened a "policy window" for reform from a political dimension. (ii) The multilevel perspective on sustainability transitions (MLP) sheds more light on the importance technological innovation for transformation processes. Exemplified through the German energy transition, we highlight limitations of both lenses, as well as the value of using multiple lenses to analyze specific cases of major policy change. The MSF highlights the role of agency and power relations. The MLP demonstrates how niche-technologies uproot the incumbent regime. Employing both lenses together offers insights as to how major policy change goes beyond single instances of decision-making but is the product of a larger trajectory of path-dependence that emerges from the interplay of socio-technical and political dynamics.

KEY WORDS: institutional change, multiple streams framework, multilevel perspective, Energiewende

大多数解释重大政策转型的研究都采用单一视角研究特定案例。近期研究呼吁更多元的使用理论，以促进产生有价值的新视角和研究议程。德国能源转型则是这类转型变革的优秀例证。本文响应关于结合不同理论的呼吁，透过两个补充视角解释了德国能源转型：（*i*）应用多源流框架（*MSF*）证明政治因素和舆论如何为政治改革打开了"政策之窗"。（*ii*）可持续发展转型多层视角（*MLP*）聚焦于科技创新对转型过程的重要性。通过德国能源转型的证明，我们强调了这两个补充视角的局限性，以及使用多种视角分析重大政策变革案例的价值。*MSF*强调了能力和权力关系的作用。*MLP*证明了利基技术（*nichetechnologies*）如何颠覆现存制度。结合这两种视角并加以应用，解释了重大政策变革如何不仅仅是单个决策，而是更大的路径依赖轨迹的产物，它源于社会技术动态和政治动态之间的相互作用。

关键词: 制度变革, 多源流, 多层视角

[Correction added on 20 January 2022, after first online publication: An affiliation to Leuphana Universität Lüneburg has been added for Pim Derwort.]

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La mayoría de los esfuerzos para explicar las grandes transformaciones de las políticas aplican una sola lente para estudiar casos específicos. Contribuciones recientes han pedido un uso más plural de las teorías para facilitar la producción de nuevas perspectivas y agendas de investigación valiosas. La transición energética alemana es un buen ejemplo de un cambio tan transformador. Este artículo retoma el llamado a la fertilización cruzada de teorías, utilizando dos lentes complementarios para explicar la transición energética alemana: (i) La aplicación del Marco de Flujos Múltiples (MSF) demuestra cómo los factores políticos y la opinión pública han abierto una 'ventana política' para r desde una dimensión política. (ii) La perspectiva multinivel sobre transiciones de sostenibilidad (MLP) arroja más luz sobre la importancia de la innovación tecnológica para los procesos de transformación. Ejemplificado a través de la transición energética alemana, destacamos las limitaciones de ambos lentes, así como el valor de usar múltiples lentes para analizar casos específicos de cambios políticos importantes. MSF destaca el papel de la agencia y las relaciones de poder. El MLP demuestra cómo las tecnologías de nicho desarraigan el régimen actual. El empleo de ambos lentes juntos ofrece una idea de cómo el cambio de política importante va más allá de instancias únicas de toma de decisiones, pero es el producto de una trayectoria más amplia de dependencia de la trayectoria que surge de la interacción de las dinámicas sociotécnicas y políticas.

PALABRAS CLAVE: cambio institucional, múltiples corrientes, perspectiva multinivel

1. Introduction

Explaining major policy change still is one of the great challenges to the policy sciences. Although a number of theories and frameworks are available, the explanation of any given major policy change remains difficult (Heikkila et al., 2014; John, 2003). This is especially the case with issues where policy change involves the change of technology and large infrastructure—as it applies to many sustainability-related issues that humanity is currently facing (Dryzek, 2016; Kanie, Betsill, Zondervan, Biermann, & Young, 2012; Meadowcroft, 2009; Schmidt & Sewerin, 2017). One instance of a fundamental, policy-guided shift towards sustainability is currently under way with the German energy transition, aiming to replace nuclear and fossil-fuel electricity generation with a renewables-based one. Although changes of policy tools and instruments are common in policymaking, a major institutional change such as the German Energiewende—constituting a massive deviance from the politics-as-usual—is very particular and asks for understanding the underlying interwoven dynamics of policy and socio-technical change.

Explaining such major shifts in policy and societal change more generally will be of great value for all those engaging in the governance of sustainability transformation (Meadowcroft, 2009; Patterson et al., 2017; Westley et al., 2011). Identifying and understanding the crucial dynamics and processes that drive the key decisions and developments that initiate, guide, and maintain such transformations will be essential for policy-makers in different parts of the globe. Such knowledge, however, is still in its infancy (Meadowcroft, 2009; Patterson et al., 2017; Westley et al., 2011). With this contribution, we argue that major policy change goes beyond

single instances of decision-making but is the product of a larger trajectory of path-dependence and path-deviance that emerges from the mutual interplay of socio-technical and political dynamics.

Recent contributions have called for a closer dialogue between policy studies and innovation and technology studies to understand major changes in energy politics and beyond (e.g., Roberts & Geels 2019; Schmidt & Sewerin, 2017). To this end, we suggest to put into dialogue two theoretical frameworks with complementary foci that help structure and guide the analysis in these fields: Lending from policy sciences, John Kingdon's multiple streams framework (MSF) focuses on political factors including the role of public opinion to explain why some policy alternatives come about (Herweg, Zahariadis, & Zohlnhöfer, 2017; Kingdon, 1999). Second, we draw on the socio-technical transitions literature that explicitly considers the role of technological innovations and industry dynamics for explaining fundamental regime shifts towards sustainability. Building on innovation studies and evolutionary economics, the multilevel perspective (MLP) on transitions (Geels, 2002; Geels & Schot, 2007; Kemp, 1994) explains regime shifts through an interplay of dynamics in socio-technical regimes, technological niches, and contextual conditions (landscape). Although the MSF strives to explain the way in which policy processes are translating demands into outputs—with change resulting from coupling problems with policies and politics—the MLP serves to explain how the coevolution of socio-technical developments constitutes major change, of which the institutional sphere is only one part. With this extended focus, we highlight how socio-technical evolution and innovation provide the background determining the potentials for path-dependent or path-deviant change to occur. Through their complementarity, we were able retrace important elements for change towards sustainability that would have otherwise eluded the analysis.

In applying different lenses to the case of the German Energiewende, this article joins recent attempts at the cross-fertilization of theories. A number of recent publications have applied the MSF and transition management lenses, combining them to explain the transformation of the UK's climate change and energy policy (Carter & Jacobs, 2014) and transformative change in the case of local transportation Phoenix, Arizona (Harlow, Johnston, Hekler, & Yeh, 2018), or to develop a new conceptual framework to establish low-carbon energy scenarios in illiberal democracies in Latin America (Noboa & Upham, 2018). Furthermore, Elzen, Geels, Leeuwis, and van Mierlo (2011) have attempted to synthesize rather than compare the two theories in relation to animal welfare in pig husbandry. Transitions research on Germany's energy transition has also been combined with other frameworks, such as the Advocacy Coalitions Framework and policy feedback theory (Schmid, Sewerin, & Schmidt, 2019) or discursive approaches (e.g., Leipprand & Flachsland, 2018). Others argue in favor of the integration of existing theoretical frameworks, with Cherp, Vinichenko, Jewell, Brutschin, and Sovacool (2018) developing a meta-theoretical framework of techno-economic, socio-technical, and political perspectives, using a brief discussion of the transition of Germany's electricity system as an illustrative application.

This contribution adds to the literature because (i) a combination of the MSF and the MLP helps to uncover the technology-policy feedback links, that is, those socio-technical dynamics that underlie the political selection procedures for different policy alternatives, often seen as "primeval soup" of ideas out of the reach of analysts and decision-makers; (ii) it highlights how in turn previous policy decisions plant the seed for such larger socio-technical dynamics to emerge and unfold; (iii) it contributes to a better understanding of the role of agency in processes of major change, both in the political and the socio-technical realm as well as the interlinkage of those; (iv) bringing together political and technological aspects enables for more meaningful policy recommendations that go beyond unrealistic technological "solutions" ignoring political constraints or myopic expectations for technological innovation and evolution (Schmidt & Sewerin, 2017).

The remainder of the article proceeds as follows. In Section 2, we introduce the selected frameworks and explain how their combination allows for an enriched perspective for major policy change, followed by Section 3, a brief explanation of the research methodology. Subsequently, we introduce the case and apply the two frameworks to Germany's Energiewende, setting out in detail how a series of key developments paved the way for the country's current energy transition. In penultimate Section 5, we compare the two frameworks in terms of their analytical strength, discuss to what extent the narratives presented complement each other, and identify gaps in the approaches. We close by summarizing what we found to be the decisive factors shaping German energy transition and by outlining avenues for further conceptual and empirical advances (Section 6).

2. Two Complementary Lenses to Explain Major Policy Change

We argue in this paper that, together, the MSF and the MLP on socio-technical transitions can help explain how technological innovation and policy change coevolve, potentially cumulating in such transformational change as the "Energiewende".

We chose the two approaches because both serve to explain large-scale transformations that involve innovation and policies. They share many commonalities, which makes them compatible and suitable for combined application to a given case. Both approaches adopt a "complex adaptive systems" perspective (Kingdon, 1999, p. 224; Loorbach, 2010)—even though those perspectives may not necessarily be mutually compatible. Moreover, in that both approaches are "universal," they are not restricted to any particular sector, region, or time. While both share important similarities, they also complement each other, compensating for the respective other's blind spots. We argue that only in combination, they serve to explain essential dynamics of large-scale sustainability transformation.

We begin by outlining how each of the frameworks understands change to take place. Although the MSF strongly focuses on the political factors behind policy change, the MLP looks at the evolution of intertwined technological and societal factors in bringing about regime shifts. Table 1 outlines both the phenomenon explained by each framework (the *explanandum*) as well as the mechanisms through

Table 1. Description of Selected Theoretical Frameworks

Name of the Framework	Principal Source	***Explanandum*** of the Framework	***Explanans*** of the Framework
Multiple-streams framework (MSF)	Kingdon (1984)	Explaining agenda-setting dynamics: Why do some issues move up on the agenda of decision-makers, while others do not? Later works on the MSF also consider policy change	Policy process consists of three largely independent streams (problem, policy, and politics), which may be coupled by policy entrepreneurs at the right time ("policy windows"), resulting in policy change
Multilevel perspective (MLP)	Geels (2002)	Explaining transitions from one stable socio-technical regime to another (more sustainable) regime	Regime shifts come about through interacting processes on three levels (niche, regime, and landscape): radical innovations emerge in niches, which may break through if landscape developments create pressures on the regime and create a "window of opportunity" for change

which it explains it (the *explanans*). Below, we discuss important similarities and differences, before identifying the crucial complementarities.

2.1. MSF: Explaining Policy Change Through the Convergence of Multiple Streams

The MSF (Kingdon, 1984, 1999) is one of the most well-known approaches to empirically study the policy process for those who aim to understand how specific policy decisions may come about (Cairney & Heikkila, 2014; Jones et al., 2016). The framework emphasizes the complexity of policy-making, including the ambiguity of individual behavior, the importance of situational configurations, and of chance events (Bandelow, Vogeler, Hornung, Kuhlmann, & Heidrich, 2019; Capano, 2009; Carter & Jacobs, 2014; Zahariadis, 2014). In broad terms, the approach asks why some issues become prominent on the policy agenda, whereas others are ignored, and why some policy alternatives are seriously considered, whereas others are not (Kingdon, 1984). Although increased attention does not generate substantive policy change automatically, agenda-setting literature provides abundant evidence that heightened political attention can result in such change (Carter & Jacobs, 2014). In this vein, the MSF has been widely employed to assess instances of major policy change in several policy fields, including energy policy (e.g., Bandelow et al., 2019; Harlow et al., 2018; Carter & Jacobsm 2014; Kagan, 2018; Kammermann, 2018).

The MSF argues that major policy shifts occur when the three "streams" of problems, policy, and politics converge and open a policy window for change. The "problem stream" refers to problems in society that are considered to require attention (Howlett, McConnell, & Perl, 2015). They usually come to political attention through indicators, feedback from existing programs, or through focusing events like crises or disasters that draw critical attention (Birkland & Warnement, 2015; Herweg et al., 2017). The "policy stream" or "solution stream" contains potential policy proposals developed by policy makers, specialists, academics, and lobby groups sharing a common concern. Kingdon (1999) originally perceives these ideas to float around in a policy "primeval soup". To be considered seriously as a policy option, an idea must meet certain "survival criteria," such as technical feasibility, value acceptability, public acquiescence, and financial viability (Herweg et al., 2017, p. 23). Finally, the "politics stream" comprises factors such as national mood and public opinion, interest group campaigns, election results, changes in the administration, and legislative turnover (Béland & Howlett, 2016; Whiteford et al., 2016). In this stream, majorities for proposals are sought by means of bargaining and power (Herweg et al., 2017).

Although these streams are perceived to operate largely independent of each other, there are rare moments where these converge, opening up a policy window (see Figure 1): that is, a problem is recognized, a viable solution is available, *and* political developments make it the right time for policy change (Kingdon, 1999). These windows are exploited by policy entrepreneurs, who can influence the policy process by coupling the three streams together (Mintrom & Norman, 2009; Weible & Schlager, 2016), in order to seek attention for their specific problem and/or to push their pet solutions (Kingdon, 1999; Orach & Schlüter, 2016) and foster policy change in their desired direction. Policy entrepreneurs work either in or around policymaking venues—in elected or appointed positions, interest groups or research organizations (Kingdon, 1999; Orach & Schlüter, 2016). In order to be successful, they must act swiftly to focus political attention to specific problems and indicate an acceptable

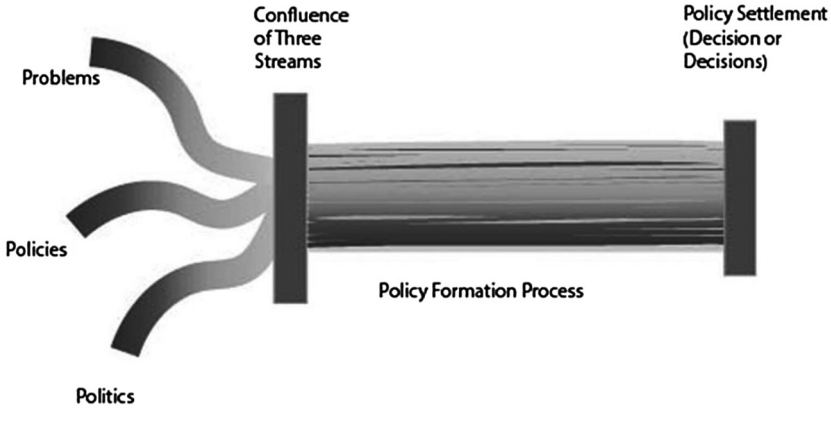

Figure 1. Three-Stream Framework.
Source: Howlett et al. (2015).

policy solution (Whiteford et al., 2016). The process of coupling itself is a "search for fit" (Carter & Jacobs, 2014, p. 127).

2.2. MLP: Explaining Socio-Technical Regime Change Through Niche-Regime-Landscape Interactions

The MLP on sustainability transitions (Geels, 2005; Geels, Sovacool, Schwanen, & Sorrell, 2017) seeks to explain how innovations emerge and, over a longer period of time, may lead to multidimensional shifts in socio-technical regimes (Dóci, Vasileiadou, & Petersen, 2015), including shifts in institutions and policy. The MLP has gained vast attention in the study of fundamental, systemic societal change, especially in areas that contain a strong technological aspect, such as energy (e.g., Geels, Berkhout, & Van Vuuren, 2016), but also in others, for example, agriculture (e.g., El Bilali, 2019; Hörisch, 2018) or the field of transportation and mobility (e.g., Goyal & Howlett, 2018).

Regime shifts are explained as outcomes of alignments between developments on the three levels of niche, regime, and landscape (Geels & Schot, 2007). Socio-technical regimes have been defined as "relatively stable configurations of institutions, techniques and artefacts, as well as rules, practices and networks" (Smith, Stirling, & Berkhout, 2005, p. 1493) that dominate the functioning of a system (de Haan & Rotmans, 2011; Geels, 2002; Kemp, Schot, & Hoogma, 1998). Understood in this way, the regime determines the logic and direction for incremental socio-technical change along established lines of development (Markard, Raven, & Truffer, 2012). New ideas and technologies, as basis for larger changes, develop in technological niches. These act as "incubation rooms" or "safe havens" without the strong selection pressure of the established regime for radical novelties or innovations to develop (Geels, 2002). The socio-technical landscape constitutes the wider environment made up of deep structural economic, cultural, and macropolitical factors beyond the direct influence of regime and niche actors. Interactions between these three levels are the determining feature of the MLP in that regimes are embedded within landscapes and niches within regimes (Geels, 2005).

Major socio-technical change is determined by processes within the niche but also by developments at the higher regime and landscape-level. As Kemp, Rip, and Schot (2012) argue it is the alignment of developments on all three levels which determines if a regime shift will occur. Radical innovations in niches may break through on the market and contribute to fundamental change if exogenous landscape developments create sufficient pressure on the regime, thus creating a "window of opportunity" for a transition to take place (Shove & Walker, 2010) (see Figure 2). Depending on the nature and timing of the interaction in this window of opportunity, these innovations may have a competitive or disruptive effect on the incumbent regime—creating impulses for change and allowing niche-innovations to challenge the regime—or help improve its performance and thus strengthen its foundations (Geels & Schot, 2007; Smith et al., 2005).

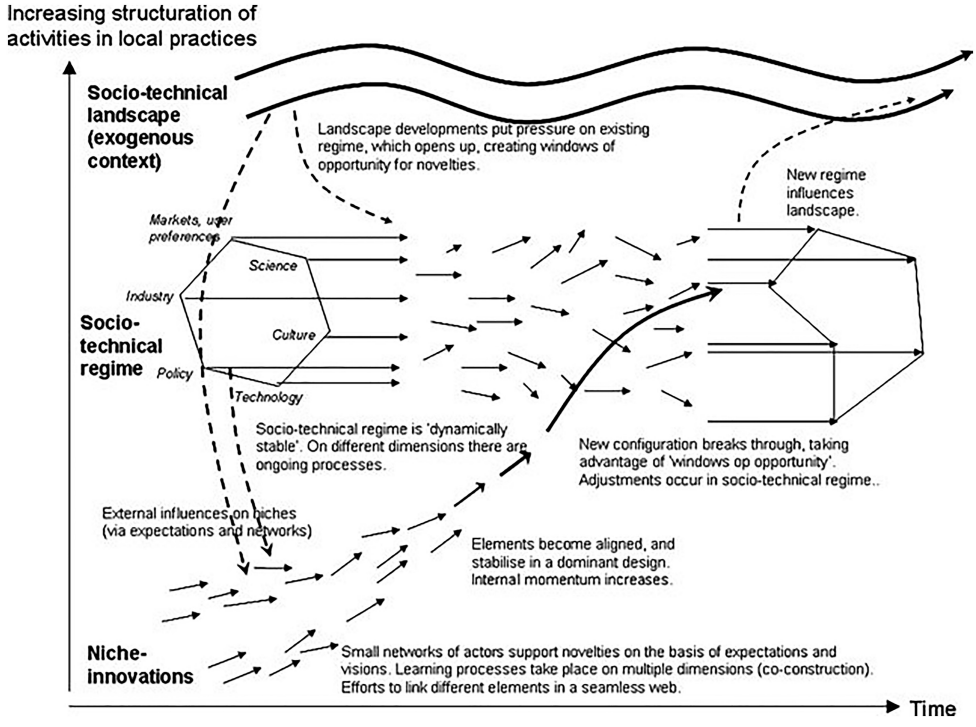

Figure 2. Multilevel Perspective On Transitions.
Source: Geels and Schot (2007).

Although the levels do not themselves have agency, agency can be associated with particular levels (Fischer & Newig, 2016). On the niche level, agency is exerted by small actor networks who aim to push forward their innovation (Leipprand & Flachsland, 2018; Smith & Raven, 2012); on the regime level, actors tend to oppose change (Rock, Murphy, Rasiah, van Seters, & Managi, 2009); and on the landscape level—although less clearly defined—agency largely occurs in the form of political coalitions (Leipprand & Flachsland, 2018).

2.3. Using the Complementarity of the Two Approaches to Understand Major Policy Change

We argue that bringing together the MSF and the MLP offers an innovative, wider perspective and enables to understand major policy change more fully and in greater detail. We perceive major policy change as fundamental shift in the goals and instruments of policies (Hall, 1993) with massive influence on society and its natural or built environment. This includes the element of implementation of changes. This presupposes that policy change is not simply on paper but includes an element of implementation as well. Such dynamics, we argue, go beyond the actual point, where a policy decision is taken but involve a longer, interwoven, and

context-dependent process of path-dependence and path-deviance. In that, the combination of these two theories allows us to (i) uncover important policy-technology feedback links; (ii) specify the influence of previous political decisions of technological development and maturity; and (iii) explore the different forms of agency involved in these interwoven dynamics.

The MSF is perceived as a theory of path-deviance (Spohr, 2016), conceptualizing changes as discrete events, that is, happening at a specific moment in time where three streams converge and open a policy window. Policy entrepreneurs may take advantage of such situations by pushing their interests and pet policy ideas, and thereby influencing which solutions may enter the political agenda and may have a chance of eventually becoming new policies. While offering great explanatory power to redraw these processes, the origin of policy ideas remains rather vague; policy ideas, somehow pre-existent in the "primeval soup," are very fluid and get filtered and substantiated in policy communities in an arguing process called "softening up" (Kingdon, 1999). Which ideas survive this filtering process is dependent on various criteria, such as technical feasibility, value acceptability, public acquiescence, and financial viability (Herweg et al., 2017). Bringing in the MLP offers here a new perspective to this process. The MLP strives to explain socio-technical "regime change" (*inter alia*-dominant technologies, practices, and policies) through the evolution of niche innovations (Geels & Schot, 2007). Rather than a primeval soup, technological innovation may develop in technological or market niches as "hopeful monstrosities" (Schot & Geels, 2008, p. 537) and may substantiate through processes of social learning across multiple experiments, articulation of promising expectations, and heterogeneous networking among actors (Markard et al., 2012). Hence, what appears to be technically feasible, financially viable, and socially known and acceptable is not external factors in a black box (cf. Schmid et al., 2019) but is determined by those niche dynamics and the way these challenge the dominant socio-technical regime.

Path-dependency and structural lock-ins play a pivotal role in the MLP as transitions are perceived to happen in a long-term, evolutionary manner (Geels, 2002), involving also aspects of change of practices, infrastructures, technologies, and institutions (Markard et al., 2012). This evolutionary perspective has been subject to criticism, as it leaves aside important political struggles and decisions shaping the overall trajectory (e.g., Meadowcroft, 2011). The MSF, in this vein, offers the perspective to structure such an evolutionary process through identifying a number of decision points with policy outputs of one decision impacting on future ones. Understood in this sense, policy decisions at one point in time feed back into the socio-technical system potentially shaping developments on the regime and niche levels. On the regime level, new policies may change the ways in which technology, culture, or markets interact while at the niche-level innovation may be fostered and spurred. To close the full policy-technology feedback cycle, those developments may then determine at the next decision point what appears problematic in the problem stream, and, as outlined above, which policy alternatives may be available in the policy stream.

Finally, both approaches conceptualize windows of opportunity as preceding major change and explain under which conditions such windows are likely to open. For the actual promotion of change, both are not blind to agency (political entrepreneurs and change-agents) (see, e.g., Avelino, 2017; Mintron & Norman, 2009). Whereas the MLP places emphasis on technological innovations developed by niche agents, the MSF studies policy innovations developed by political actors and the ways in which policy entrepreneurs try to bring to the political center stage, together offering a more nuanced grammar for the different roles actors may acquire to influence change processes.

In conclusion, we argue that for the kind of change we are looking here—sustainability transformation—and for which the German Energiewende is one important case in point, a fundamental change from one socio-technical regime to another will naturally involve important changes in the institutional and policy system. Vice versa, policy change in many fields—notably if concerning sustainability—almost invariably involves technological change. It is because of this broader perspective involving policy-technology feedback that the two approaches unleash their full explanatory power in conjunction in this particular case. Although the MSF explains policy change once certain conditions are met—notably the existence of viable solutions—it does not explain how these solutions develop, in particular when these are of a technological nature and involve economic actors in their development. Precisely this, however, is the domain of the MLP. The MLP, in turn, regards policy change in so far as it can be considered landscape change, that is, external to the regime as a black box, coevolving with several other aspects such as technology, culture, or markets, but provides little insight on how these developments are a product of the policy process; a field, where the MSF offers conceptual explanations.

3. Case Selection and Data Sources

We chose the case of the German energy transition ("Energiewende"), as a frontrunner in a non-nuclear, low-carbon energy transformation (Geels, Kern, et al., 2016), and with that a critical and widely regarded case example for a major, transformative policy change towards sustainability. The case involves major policy changes, combined with a strong technological and innovation dimension, and, as such, has been scrutinized using both the MSF and the MLP independently (e.g., Geels, Kern, et al., 2016; Stefes, 2016b). Hence, it provides a critical case for cross-fertilization, by means of a congruence analysis (Blatter & Haverland, 2012).

Transitions are long-term processes. In order to capture how genuine change unfolds over time, a long-term analytical perspective is crucial. Hence, to redraw the long-term development of this well-studied case, we rely on a mix of secondary and complimentary primary sources to reconstruct the narrative of Germany's energy transition (for a similar approach, see, e.g., Geels, Kern, et al., 2016).

We drew from a vast collection of academic books, articles, and reports (e.g., Hager & Stefes, 2016; Hostenkamp & Radtke, 2018; Kaiser, Rhomberg, Maireder, & Schlögl, 2016; Mez, 2012; Quitzow et al., 2016; Renn & Marshall, 2016; Wedel, 2016); quantitative energy statistics (e.g., AG Energiebilanzen, 2020); and official documents

(e.g., BMWi, 2010; Deutscher Bundestag, 2011; Vattenfall, 2012). The synthesis of this material and the analysis of the case were conducted through a congruence analysis, that is, the case-based comparison of different theories and their propositions (Blatter & Haverland, 2012). In this method, information is not transformed into variables scores and codings, but case material is rather arranged and regarded in line with the expectations and propositions contained in the chosen theories. We traced the chains of events and developed a respective narrative through the lens of the MLP and the MSF. To this end, the evolutionary process of the energy transition was decomposed into multiple phases, comprising landmark policy decisions (MSF) and changes in the socio-technical regime (MLP), to be able to retrace the events and developments that led to these trajectories through historical narrative explanation (see also Turnheim & Geels, 2013). In this way, commonalities and differences between the theories in the explanations of the case trajectory are made apparent to arrive at a comprehensive picture and fostering cross-fertilization between theories.

4. The German Energiewende

Although today, the term "Energiewende" is widely associated with the political project of fundamentally transforming the German energy system following the 2011 Fukushima disaster (e.g., Renn & Marshall 2016; Wedel, 2016), it has in fact been a much longer process, with the origins of the term dating back more than 30 years (Kaiser et al., 2016). Consistent with much of the literature, we refer to the term Energiewende as the replacement of both nuclear energy and fossil fuels with renewable resources (Quitzow et al., 2016). Although we do not aim to provide an exhaustive description of Germany's long trajectory towards an energy transition (see, e.g., Hager & Stefes, 2016; Hake, Fischer, Venghaus, & Weckenbrock, 2015 for more detailed accounts on this subject), below, we summarize the key aspects of the case study context that relate to our analysis.

As in many European countries, the oil crisis of 1973 constituted an important external shock for Germany (Hake et al., 2015), fundamentally transforming the way the country approached its energy policy. Strongly dependent on fossil fuels, the threat of resource scarcity made energy security one of the dominant topics on the political agenda (Berlo, Wagner, & Heenen, 2017). Although, on a political level, nuclear energy was seen as an important technology to guarantee energy supplies (Renn & Marshall, 2016), on a societal level, Germany witnessed a growing antinuclear movement, particularly following nuclear incidents at Three Mile Island in 1979 and Chernobyl in 1986 (Mez, 2012). Similarly, opposition to coal-fired energy increased in intensity, particularly as the effects of greenhouse gas emissions and acid rain on the global climate became better known (Matthes, 2017; Quitzow et al., 2016). It was in this political environment that first policies to stimulate the development of renewable energy technologies were developed (Hake et al., 2015). Despite opposition from the German government and large utilities, a number of small support programs for the development of wind and solar-PV were introduced by Parliament (Lauber & Mez, 2004), and innovative technologies and business-models

(e.g., community-led energy initiatives) were developed in protest to state-sponsored industrial projects during the 1970s and 1980s (Hager, 2016).

The first major policy change occurred in 1990, when Germany introduced its Renewable Electricity Feed-In Law, or *Stromeinspeisegesetz*. This law required electricity providers to (i) connect small-scale renewable energy of up to 5MW to the grid and (ii) to purchase the energy produced at a fixed rate from these small producers. In effect, the Feed-In Law served to create a protected environment for renewable technologies by making them economically viable (Mez, 2012). Nevertheless, throughout this period, the energy system continues to be dominated by monopolistic energy structures and vertical integration of the energy market, with large utilities forming the "backbone" of the electricity regime (Geels, Kern, et al., 2016). In this first decade, following the passing of the Feed-In Law, electricity production continued to predominantly rely on lignite, hard coal, and nuclear power (see Figure 3), with the share of renewables, while increasing, remaining at a low absolute level.

However, by the year 2000, the Electricity Feed-In Law was no longer considered to be able to accommodate the expansion of renewable energies (see, e.g., Hirschl, 2008) and became replaced by the Renewable Energy Act (EEG). Under the EEG, electricity produced from renewables significantly increased, with onshore-wind, solar-PV, and biomass, in particular, experiencing strong growth rates (see Figure 4). In 2000, the German government also announced its decision to gradually phase

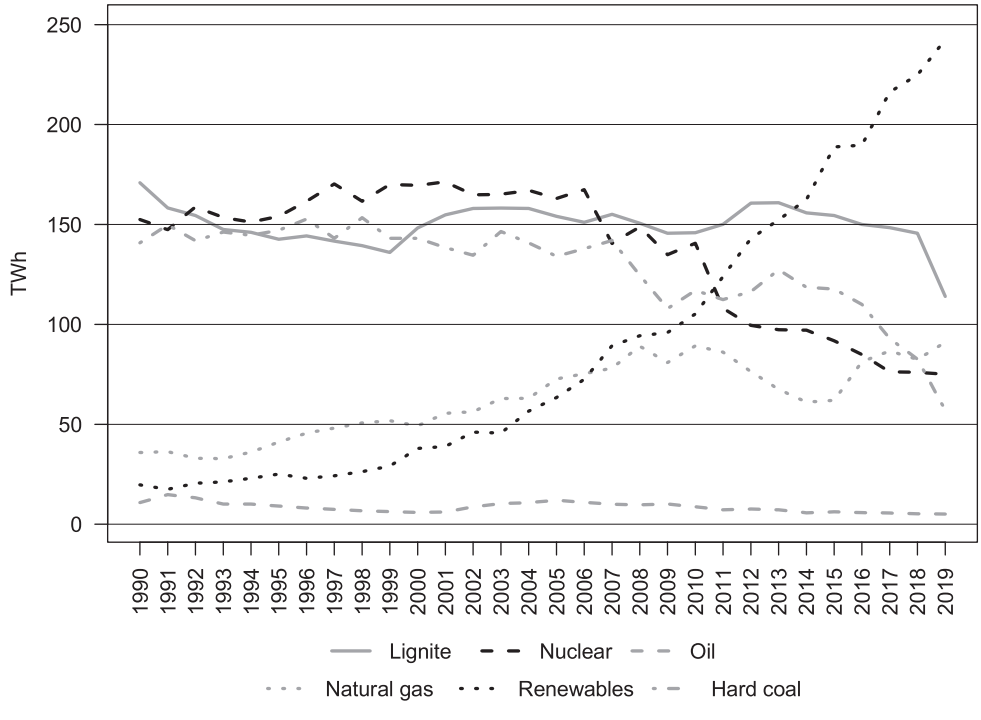

Figure 3. Gross electricity production by fuel type, 1990–2016 in TWh.
Source: AG Energiebilanzen (2020).

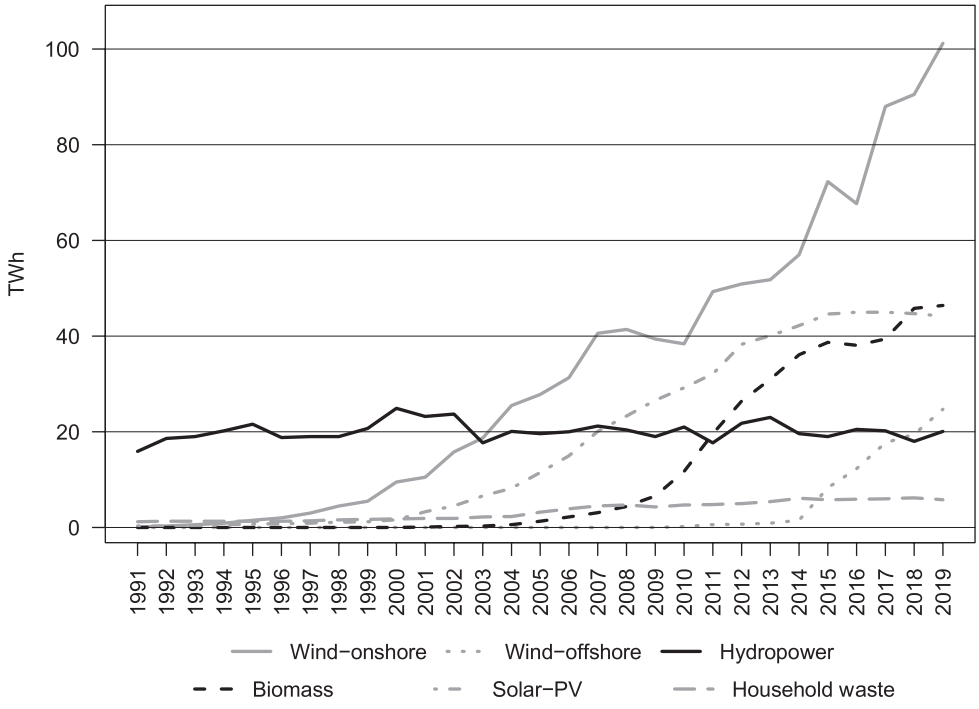

Figure 4. Gross Electricity Production from Renewables, 1990–2019 in TWh.
Source: AG Energiebilanzen (2020).

out existing nuclear power plants in its Nuclear Energy Phase-Out Act, banning the future construction of new nuclear power plants and limiting the lifespan of existing nuclear power plants to 32 years. Faced with considerable public and political opposition to nuclear energy, investments strongly concentrated on coal and gas-fired power plants, with the share of electricity produced by nuclear power stations dropped from its height at 30.8 percent of gross electricity production in 1997 to 22.2 percent in 2010. Furthermore, this change was accompanied by a strong shift in ownership structures and a professionalization of the renewable energy sector (Geels, Kern, et al., 2016; Kungl, 2015). Despite controlling over 80 percent of electricity production capacity in 2004 (Kungl, 2015), large energy companies only possessed around 6.5 percent of the growing renewable production capacity (Strunz, 2014). By 2009, the share of renewable energies had increased to 15.9 percent (AG Energiebilanzen, 2020), owned and operated by more plural and diversified structures such as energy cooperatives (see, e.g., Holstenkamp & Müller, 2013).

In 2010, as part of its wider Energy Concept, the new German government announced a long-term energy strategy, planning to gradually increase the share of renewables in electricity generation to 55 percent–60 percent by 2035 and to 80 percent by 2050 (BMWi, 2010). As part of this energy strategy, the government delayed the previous nuclear phase-out decision, arguing that nuclear energy would be required to make this transition to a renewable energy system technically and economically feasible (Hermwille, 2016). However, in June 2011—in the wake of the

nuclear catastrophe in Fukushima, Japan—German Parliament voted in favor of a series of laws that would come to more fundamentally transform the country's energy system, phasing out nuclear power by 2022 and decommissioning the seven oldest reactors per immediately (Hermwille, 2016). That same year, renewables—for the first time in modern German history—overtook nuclear as an energy source for electricity production. By 2020, the share of renewable energy in electricity production had increased to 40 percent of gross electricity production in 2019 (see Figure 3), far more than nuclear (12 percent) and even more than hard coal and lignite combined (AG Energiebilanzen, 2020).

Taken together, these changes constitute a fundamental shift away from fossil and nuclear fuels, and towards renewable energies. In the following sections, we apply the MSF (Section 4.1) and the MLP (Section 4.2) to the case at hand, explaining how interactions between policy changes and technological changes enabled the Energiewende to take place.

4.1. Explaining the Energiewende Using the MSF

In the previous section, we identified the three key instances of policy change—in 1990, 2000, and 2017—that together paved the way for the current transformation of Germany's energy system. Below, we will apply the MSF as an analytical lens to study the energy reforms.

1990: Supporting Small-Scale Renewables. Over the course of the 1970s and 1980s, a number of indicators and events, such as the oil crisis and nuclear incidents (described in Section 3), brought the issue of energy security and environmental sustainability to the attention within the *problem stream*. In the *policy stream*, first policies to stimulate the development of renewable energies were developed in the 1970s and 1980s, mostly for onshore-wind and solar-PV (Hake et al., 2015; Lauber & Mez, 2004). Proposals for feed-in tariffs were first brought up in the late 1980s but were facing strong opposition by the government majority and large utilities (Hirschl, 2008; Stefes, 2016b) and, hence, did not figure very successful on the agenda. In the late 1980s, however, two politicians—Matthias Engelberger (a CDU-politician in his final year in German parliament) and Wolfgang Daniels (Green Party) (Berchem, 2006; Hirschl, 2008; Stefes, 2016b)—acted as policy entrepreneurs, bringing together a small policy community from different parties. Their proposal required electricity providers by law to connect renewable energy generators to the grid and to purchase the renewable energy produced at a set price, with rates varying from 65 percent to 90 percent of the average tariff for final customers (Lipp, 2007; Mez, 2012).

A number of developments could be observed in the *political stream* around the same time, with some of them opposed to policy change and others in favor. As the Green Party entered the German parliament (*Bundestag*) in 1983, changes in the administration and legislative turnover meant that environmental concerns featured strongly on the political agenda (Stefes, 2016a). Nevertheless, interest group

campaigns by large utilities—seeking to protect their business models—strongly lobbied the government against support for renewables (Hirschl, 2008; Stefes, 2016b).

The three streams converged and opened a *policy window* for change around the time of German Reunification (see Figure 5). Although if at all only indirectly connected to energy policy, this huge political project caught up and bound most attention of political and economic actors. With the framing of the proposal as being about technical infrastructure development and market access rather than about direct political intervention in the means of energy generation—and the attention of the opposition absorbed by grid expansion into former East-Germany—the policy entrepreneurs managed to push a proposal that was estimated as only a minor change with little impact and, thus, deemed acceptable to a parliament majority (Lauber & Mez, 2004; Stefes, 2016b). The *Stromeinspeisegesetz* was therefore passed into law on December 7, 1990 and came into effect on January 1, 1991.

2000: Expansion of Renewable Energies and First Attempt at Nuclear Phase-Out. Around the turn of the century, concerns about the climate and the environment continued to play an important role in the *problem stream*. The subject of climate change continued to be a salient issue during the 1990s, and following reunification, Germans were suddenly confronted with the pollution and other negative effects of coal mining in the former East-German areas (Renn & Marshall, 2016). The Green Party, now in government, appeared to be an important "problem broker" (Knaggård, 2015), bringing to political attention issues such as ecological modernization and climate change policy, the phasing-out of nuclear power, and the promotion of renewable energy sources (e.g., Hirschl, 2008; Mez, 2012). Feedback from the *Stromeinspeisegesetz*, however, indicated that the law was no longer sufficiently able to accommodate the rate of expansion of renewable energies and thus in need of reform.

In the *policy stream*, a handful of Green Party representatives at this time acted as policy entrepreneurs by single-handedly rewriting the existing law. Under their proposal, rates were determined for each technology in relation to its costs and fixed for a period of 20 years, aiming to at least double the share of renewable energies by

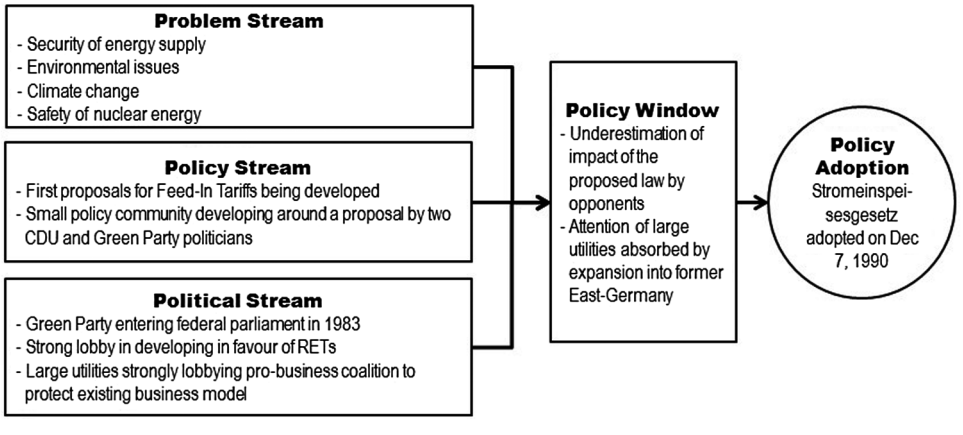

Figure 5. Explaining the Adoption of the 1990 Feed-in Tariff Law.

2010. Solar-PV and biomass technologies, in particular, received increased support under this proposal, with wind-technology increasingly considered to already be economically and financially viable (Hirschl, 2008; Stefes, 2016b).

In the *political stream*, the most important development in favor of green policy came following the 1998 elections. With a new coalition of social democrats (SPD) and Greens coming into office, a major reshuffling of the policy agenda occurred and environmental policies rose on the political agenda (Renn & Marshall, 2016; Schiffer, 2002). With both parties elected on an antinuclear platform, the future construction of nuclear power plants was to be banned, and existing nuclear power stations were to be gradually phased out by limiting their lifespan (Mez, 2012). With coal under increasing pressure and existing climate commitments under the Kyoto Protocol, the new government made the expansion of renewable energy a priority (Stefes, 2016b). With the incumbent energy players (e.g., large utilities) unable to see a threat to existing business models, lobbying activities were limited to "the defence of the status quo" (Kungl, 2015).

Here, a *policy window* came about through changes in the political stream, with the election of a new political coalition against nuclear energy. With the Green Party in government, the policy entrepreneurs were in a strong position to push their preferred solution, with renewable energy sources framed as an acceptable policy solution for the problems posed by nuclear energy and polluting coal-fired power. The new EEG was unanimously approved by both governing parties on December 13, 1999 and passed into law on January 1, 2000 (see Figure 6).

2011: Break-Through in the Energiewende. Throughout the 2000s, the *problem stream* continued to be dominated by sustainability-related indicators, with the publication of influential climate change reports and popular documentaries ensuring that the topic remained in the spotlight. However, dynamics of the political stream (explained in more detail below) at the time effectively block any meaningful movement on the issue of nuclear power in Germany's energy system. The 2011 earthquake off the

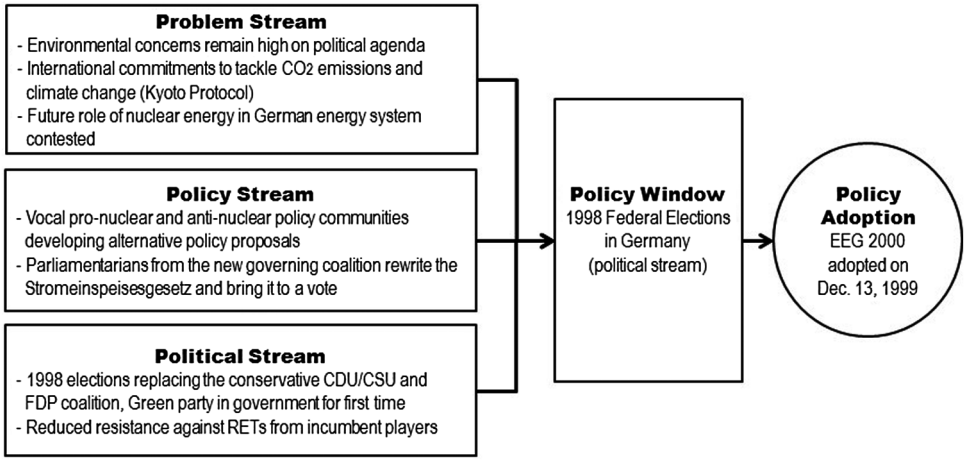

Figure 6. Explaining the Adoption of the Renewable Energy Act 2000.

Japanese coast and subsequent nuclear disaster in Fukushima, however, radically changed the political landscape, serving as a focusing event in the sense of Birkland (1997).

In the *policy stream*, a variety of potential policy proposals existed with two opposing policy blocks around the topic of nuclear energy. On the one hand, the SPD, Greens, and Left party wished to maintain the nuclear phase-out agreement of 2000. On the other hand, CDU/CSU and FDP aimed for extending the operating period of nuclear power plants to keep in check the costs of the transition and secure a sufficient supply of energy (Huß, 2014). Between 2005 and 2009, the CDU/CSU and SPD government fundamentally disagreed on the future role of nuclear power in Germany's energy system, effectively blocking movement on this issue. Key selection criteria for the "success" of policy proposals are technical feasibility and financial viability (Kingdon, 1999). During the 10 years preceding the Fukushima event, electricity production from renewable sources (not counting hydropower) had risen by a factor of five to the level of 14 percent of total German electricity production. At the same time, technological development ensured that renewables were close to becoming financially viable. It is around this time that nuclear phase-out strategies became feasible because the technical alternatives had become manifest—rather than mere political wishes.

Developments in the *political stream* initially favored the pro-nuclear coalition. A change in the political administration following the 2009 elections put in power a conservative-liberal (CDU/CSU and FDP) government, which subsequently announced the extension of the lifetime for existing nuclear power plants to ensure continued security of supply and economic affordability during the transition to a clean and renewable energy future (Huß, 2014). The decision was greeted by interest group campaigns from the fossil-nuclear regime, which used their political influence to stress the threat of a nuclear phase-out to the security of supply in the short to medium term (Strunz, 2014). However, the events in Fukushima led to a strong shift in the national mood and fundamentally undermined support for nuclear energy in Germany. As one indication of these dynamics, on 27 March 2011, 16 days after the events in Fukushima, the Green party received the second-most votes in the state elections of *Baden-Württemberg*, and subsequently succeeded in heading the state coalition government, previously led by the conservative party for 58 years.

Hence, the nuclear disaster at Fukushima opened a *policy window* in the problem stream. In line with Kingdon's argument, the Fukushima disaster can be considered an important mobilizing event, combining a new appreciation of the problem to be combined with ideas already in circulation, but lacking a receptive audience (see Figure 7). Public approval of nuclear energy further diminished into overt opposition to the extent that political parties could no longer mobilize core voters in favor of the subject (Huß, 2014). Faced with such a strong antinuclear political climate, the federal government immediately shut down seven of its oldest reactors and, following the recommendations of a hastily installed "ethics committee," moved to phase out nuclear power altogether by 2022, a proposal that was immediately supported by all main political parties (Renn & Marshall, 2016). In this case, instead of there being clear policy entrepreneurs, policymakers simply selected that solution

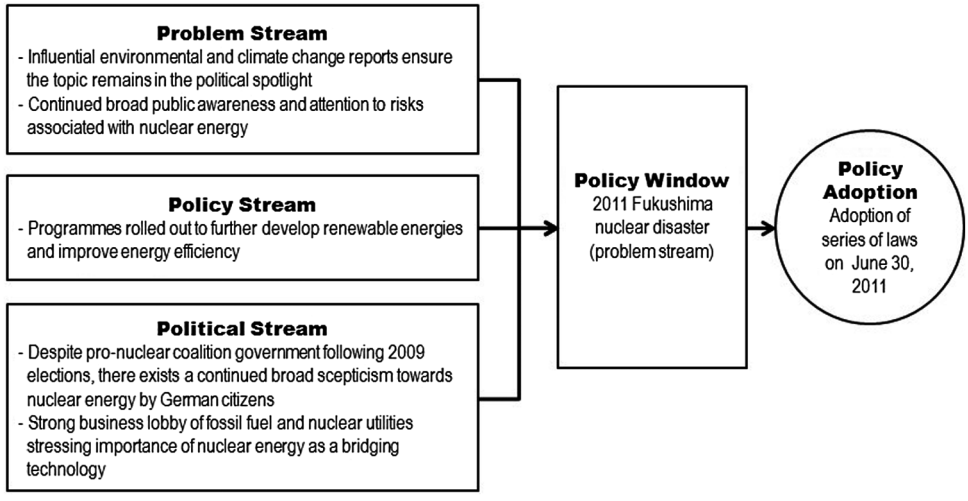

Figure 7. Explaining the Nuclear Phase-Out Decision in June 2011.

that they deemed most appropriate under the circumstances. It is important to note here that none of the post-Fukushima measures were actually new, but had in fact been around for a while, with various policy proposals floating around when the nuclear disaster occurred. Existing plans for the nuclear phase-out were accelerated, with renewable energies—in the long—expected to generate most of the electricity supplied.

The explanatory power of the MSF becomes particularly apparent when comparing policy change after Fukushima 2011 with policy change after Chernobyl 1986. Even though Germany was far more affected by the meltdown of the Soviet nuclear power plant, suffering from radioactive fallout in many German regions, political action remained largely symbolic in that the federal government shifted responsibilities regarding the environment from the Ministry of the Interior to create a new Ministry for the Environment and Nuclear Safety. Yet it was out of question that nuclear energy would continue to play a major role in Germany's electricity mix (Joppke, 1990). Indeed, a nuclear phase-out would have been difficult to realize because, in MSF terms, viable policy solutions had not been developed in 1986—whereas they were available in 2011.

4.2. Explaining the Energiewende Using the MLP

Applying the MLP lens to the German Energiewende, we now turn to how niche-level innovations, coupled with pressures on the landscape level, including incremental changes in the institutional context, were—over time—able to destabilize the conventional electricity production regime and open a window of opportunity for an energy transition to take place. Distinguishing several typical phases in sustainability transitions (see, e.g., Geels, 2005), we identified three distinct stages in the development of the energy transformation (see Figure 8): first, before the 1990s,

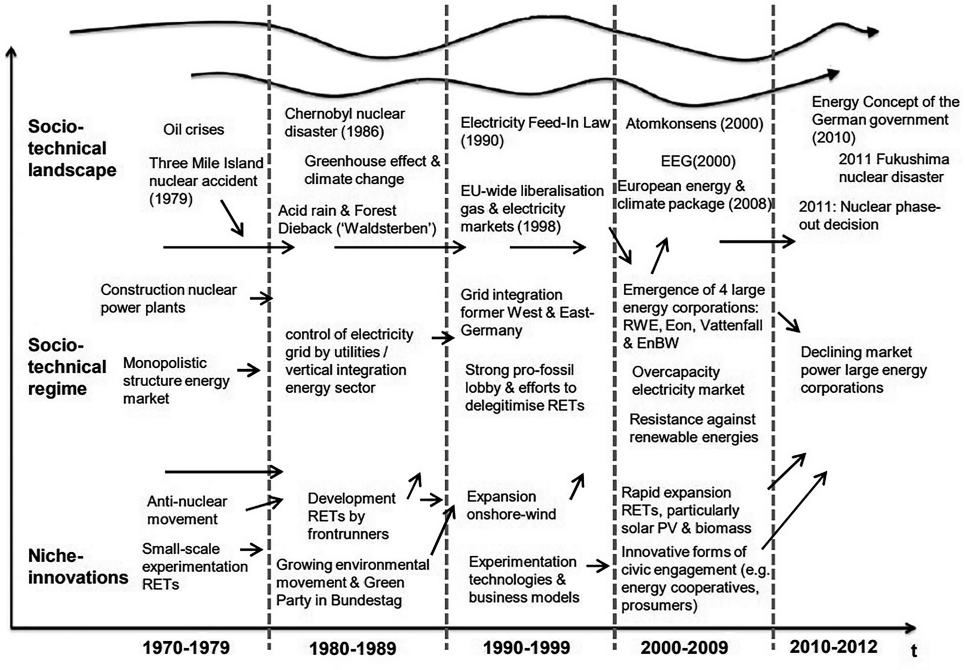

Figure 8. The Energy Transition Presented Through the Multilevel Perspective, Based on Geels (2002) and Berlo et al. (2017).

early renewable energy innovations emerged in niches, posing little threat to the regime; second, in the phase between 1990 and 2011, the new technologies rapidly developed but ultimately did not yet seriously threaten the existing regime; and third, following the Fukushima disaster in 2011, renewable energy technologies have been entering the center stage and are now in the course of replacing the established regime.

Phase 1: Emergence of Renewables in the Niche (Pre-1990). During this phase, the socio-technical regime (or energy market) was characterized by monopolistic energy structures and vertical integration, in which utilities controlled the electricity grid. The electricity regime consisted almost exclusively of fossil fuel technologies, particularly hard-coal and lignite. In the 1970s, several new nuclear power plants were constructed, with long technological lifespans. Renewable sources were met with overt refusal by incumbent energy companies, who in the mid-1980s constructed a technically failing large wind turbine ("Growian") only "to demonstrate that wind power does not work" (Johansen, 1982). The fact that this view was shared both by companies and the federal ministry of technology demonstrates the close interconnectedness of regime actors from industry and politics.

On the landscape level, a number of factors beyond the direct influence of regime- and nice-level actors can be identified, such as the 1973 oil crisis, the anti-nuclear movement following nuclear incidents, and growing environmental awareness. At this point, however, they did not yet create sufficient pressure on the regime to create fundamental change.

On the niche level, small-scale experimentation took place with renewable energy technologies. While renewable energy has always played a small role in energy production—in 1950, renewables accounted for around 10 percent of electricity production, almost exclusively in the form of hydropower (Hirschl, 2008)—frontrunners increasingly experimented with new technologies such as wind or solar-PV and business models (e.g., community-led citizen initiatives). Niche actors were largely motivated by antinuclear or pro-environmental beliefs and acting in protest to state-sponsored industrial projects such as nuclear power plants (Hager, 2016).

Phase 2: Parallel Developments in Niche and Regime (1990—March 2011). During this phase, the regime continued to be characterized by a reliance on fossil-fuel technologies and large utilities. With nuclear power facing considerable public and political opposition, investments concentrated on coal and gas-fired power plants. Perceived as a threat to existing business models, incumbent regime actors strongly opposed the expansion of renewables through legal proceedings, political pressure, and efforts to delegitimize renewable technologies (see, e.g., Hake et al., 2015). They declined to invest in renewables due to the comparatively lower return-on-investment offered compared to fossil fuels (Kungl, 2015; Strunz, 2014), and the belief that centralized large-scale energy production would continue to dominate the energy regime in the future (Wassermann, Reeg, & Nienhaus, 2015).

The landscape level was characterized by a number of major national and international developments. On the macropolitical level, utilities were confronted with a number of challenges, including the EU-wide deregulation and liberalization of the electricity-market in 1996 and gas market in 1998, the German government decisions banning the construction of new nuclear power plants and gradually phasing-out existing facilities, and legislation levelling the playing field for renewable energy technologies. With liberalization, consumers became able to choose "green" electricity providers, with market share rising from less than 5 percent in 2008 to more than 20 percent in 2016 (Bundesnetzagentur, n.d.). Culturally, environmental concerns became increasingly mainstream. Finally, by the end of this period, structural economic factors further threatened the dominant position of utilities, with a reduction in the electricity demand following the financial and economic crisis, leading to an oversupply on the electricity market.

The introduction of the feed-in tariff in 1990 can be seen as an instance of "strategic niche management" (Kemp et al., 1998) that enabled and protected technology development not yet competitive under market conditions. Following the EEG in 2000, niche technologies could rely on a more stable policy framework and increased support for more expensive energy sources, particularly solar PV and biomass (Matthes, 2017; Quitzow et al., 2016), giving these technologies the opportunity to develop as a viable alternative to established energy sources. The largest share of renewable capacity was owned by actors without ties to the conventional energy sector, such as individuals (35 percent), project developers (14 percent), and farmers (11 percent) (Matthes, 2017; Wassermann et al., 2015), with onshore-wind, biomass and solar PV making up the highest share of renewable energy production (see Figure 3). During this phase, small-scale experimentation was increasingly replaced by a growing professionalization by niche-level actors.

Phase 3: Competition Between Renewables and Established Regime (Post-March 2011). In the third phase, the established regime increasingly has to compete with renewable energies. While initially given a boost by the lifespan extension of existing nuclear power plants in the lead-up to the catastrophic events in March 2011, subsequently, the incumbent energy regime was put further under intensive pressure, taking away their most profitable technology and leaving utility providers with "stranded assets" (Geels, Kern, et al., 2016). During this phase, the "Big Four" energy companies (E.ON, RWE, EnBW, and Vattenfall) were forced to admit that traditional business models were under serious—even existential—threat (EnBW, 2013; Vattenfall, 2012), and responded by, on the one hand, adopting cost-cutting strategies (see, e.g., Kungl, 2015), selling off divisions and reducing its staff and, on the other, developed new business strategies that specifically included renewables, that is, absorbing niche-level technologies.

On the niche level, thanks to the subsequent policies that allowed innovative technologies to develop in a relatively "safe haven" in the 1990s and 2000s, renewable technologies (particularly onshore-wind, biomass, and solar-PV) were now sufficiently advanced technologically and in terms of market share to be considered a viable alternative to nuclear energy.

In this case, the March 2011 nuclear disaster resulted in sufficient pressure from the socio-technical landscape to finally open the window of opportunity needed for a fundamental transformation of the German energy system. Fostering a regime shift (Strunz, 2014), it led the German government to decide to reverse its decision to extend the lifespan of nuclear energy in Germany and shut the last nuclear power plant by 2022. While in the short term, this decision resulted in an increase in the use of hard coal and lignite, these sources of fuel too have increasingly come under pressure from renewable energy technologies in recent years (see Figure 3).

It is highly doubtful that the Fukushima nuclear disaster would have led to a regime shift had it not been for the large investment and stimulation programs for renewable technologies. When disruptive change occurred, fully developed niche innovations—wind, solar-PV, and biomass—were readily available, allowing them to substitute the incumbent regime. These dynamics is much in line with the "technological substitution pathway" put forward by Geels and Schot (2007, p. 409, emphasis in original): "If there is much landscape pressure ('specific shock', 'avalanche change', 'disruptive change') at a moment when niche innovations *have* developed sufficiently, the latter will break through and replace the existing regime". This was precisely the case in 2011: The Fukushima "shock" came at a moment when niche innovations had developed both technologically and in terms of market share to an extent that they are now "breaking through" and replacing the existing electricity regime.

5. Discussion

By applying the MSF as well as the MLP on sustainability transitions to the German Energiewende, we were able to present a richer, more complex, and more

complete explanation than would have been the case by singularly applying either one of the frameworks. The analysis highlights the complementarity but also the compatibility of the two approaches, tying together political and socio-technical aspects in the explanation of Germany's energy transition. Applying the two lenses to the same case study demonstrates how political and technological developments went hand in hand and, in fact, reinforced each other in the studied case. In doing so, it provides a more holistic picture of the Energiewende.

First, the MSF strongly emphasized the role of policy entrepreneurs who played a key role in formulating and advocating for (politically) viable alternatives to the energy system dominated by fossil fuels and nuclear. Particularly, in the first two instances of policy change, a small number of likeminded political representatives were able to develop and successfully push forward proposals that gradually allowed nuclear and fossil-fuel electricity generation to be replaced by renewables, to some extent facing strong opposition. In the final instance of policy change, the national mood and public opinion strongly shifted away from nuclear energy so that those solutions that were already available could readily be applied. Here, the MLP provided a convincing explanation for this form of policy change, where coupling and change occurred with a less important role of policy entrepreneurs. Relying on the idea of niche innovations and landscape pressures, the MLP accounts for this abrupt policy change as a result of long-term evolutionary developments.

Complementarity of the theories became also apparent when considering the somewhat puzzling situation why strong provisions for the expansion of renewable energies provided by the Feed-In Act and Renewable Energy Law did not result in immediate shifts in the energy mix. Using the MSF alone, there appears to be a paradox between the shift in the political mood in favor of renewable energy and the low share of renewable energy technologies. However, applying the MLP lens provides valuable insights on the role of technological infrastructure and developments, which demonstrates how niche technologies, supported by developments on the landscape level, are increasingly able to compete with the technological regime as they are further advanced and developed. These developments took off at times when specific technologies were commercially ready, first in the case of onshore wind, followed by biomass, and solar-PV in the second half of the 2000s (see Figure 4). By looking at the technical feasibility of niche-technologies as a decisive factor for transitions, the MLP therefore internalizes one important external factor of the MSF, that is, it provides insights on how ideas in the "primeval soup" come to light, as "hopeful monstrosities" developed, nurtured and established in socio-technical niches.

On the other hand, describing the case through the MLP lens alone largely obfuscates the issue of how socio-political agency brings about change on the landscape-level (see, e.g., Levidow & Upham, 2017) in so far as political developments are treated as exogenous contextual factors. In fact, as the long-term analysis of the MSF highlights, the energy transition can also be interpreted as a series of interdependent policy decisions, highlighting the political intervention points within what is considered a long-term, steady socio-technical evolution. Furthermore, by providing a detailed narrative of the political factors behind policy transformation, the MSF

provided important insights into how niche developments were fostered and structured over time.

Taken together, the principal contributions of the MSF in explaining German energy transition were to explain the path-deviating political decisions, that is, the 1990 introduction of the feed-in tariff (which largely sparked the whole project) through policy entrepreneurship, profiting from the policy window that opened in the course of German reunification; the 2000 introduction of the renewable energy act largely by the change in political majorities at the federal level; and the 2011 nuclear phase-out decision through both the focusing event of the Fukushima disaster and the technical feasibility and financial viability of alternative electricity sources, namely wind, solar-PV and biomass.

The latter development was explained by the MLP in a very similar way: as described by Geels and Schot's (2007) "substitution pathway," the ongoing effective replacement of nuclear energy by wind and solar was possible through the combination of already developed niche innovations (wind and solar) and the "shock" provided by the Fukushima disaster. Here, MSF and MLP go hand in hand to explain, first, the phase-out decision as major policy change (MSF) and then its effective implementation in the sense of actually replacing nuclear with wind and solar energy (MLP). Similarly, the 1990 introduction of the feed-in tariff was explained by the MSF, but this could not have predicted its success in terms of sparking niche innovation and massively increasing the share of renewable electricity generation.

6. Conclusions

Taking the German Energiewende as an illustrative case, in this article. we have shown how two different theoretical frameworks—the MSF and the MLP on sustainability transitions—can cross-fertilize each other to understand societal transformations. These frameworks offer clear "lenses" through which developments can be explained. As each contains its own cluster of assumptions and limitations, the application of multiple, complementary, lenses offers important insights into why and how transitions may follow a trajectory of path-dependent and path-deviant changes. Viewing societal transformation towards sustainability as either a political *or* a socio-technical process will cut short of how change develops—and how change can actively be fostered—in reality. Instead, considering these perspectives together, our analysis has highlighted important policy-technology feedback cycles, where (i) political decisions triggered socio-technical change directly (e.g., government decision on nuclear phase out) or paved the way for new, innovative technological developments shielded from strong market pressure (e.g., feed-in-tariff) and where (ii) technological advances provided new solutions in the policy stream feeding back into the political agenda.

Policy change not only involves the political system, at least in those sectors where technology and infrastructure are part of the game. This applies to many if not most issues of relevance to sustainability. As the example of the German Energiewende shows, policy creates the conditions for its own change. This may not mean that transitions can be steered directly, but rather that political decisions can

play an important role in planting the seed for and accompanying emerging self-reinforcing policy-technology feedback dynamics that may eventually accumulate to more fundamental change. In fact, policies can actively contribute to such change dynamics through enabling and fostering new technology, while disincentivizing—and even abolishing—old technology. As such, it can be argued that the purposeful termination of existing infrastructure, technology, and policies can be just as important as the role of innovations in bringing about this shift towards a sustainable energy system (Newig, Derwort, & Jager, 2019).

What does all this mean for the policy sciences? The embeddedness of policy into other aspects of society is clearly recognized by the scholarly community. Anderies and Janssen (2013), for example, look at the system-wide outcomes of the policy process in coupled social-ecological systems. However, to date, major frameworks of policy change have only started to approach dealing with the technological or infrastructural aspects of sustainability transitions (see, e.g., Schmid et al., 2019).

Reflecting on this study, we should like to point to two considerations for future research.

First, more reflection and engagement are required on the system-wide outcomes of policy change in socio-technical systems. Research presented here would benefit from the application of further policy change or transitions frameworks that shed light on aspects of this case that have not yet been reviewed. Theories from a socio-psychological perspective could be applied, for example, to analyze why the nuclear disaster in Fukushima received a much stronger response in Germany than it did in other European countries that are dependent on nuclear energy for a large share of electricity production, such as France. Also, alternative theories of the policy process could be used to highlight other aspects, such as the Advocacy Coalition Framework (Schmid et al., 2019) for the competition of actors, or a Narrative Policy Framework study to look into the role of narratives and frames. Second, understanding societal transformation towards sustainability is as much a conceptual as it is an empirical mission. What we have learned on the conceptual level from this study needs to be applied to further cases, aiming to achieve empirically generalizable results that will, in turn, inform conceptual development. Given the mounting sustainability challenges ahead of humanity, a lot more systematic inquiry that is not narrowly limited to the application of one particular framework is urgently needed. Ultimately, these efforts could lead to more useful, while methodologically rigorous, inquiries into fundamental societal change towards sustainability.

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