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Are we ratcheting up?
Measuring the transformative impact of climate policies

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Eva-Maria Mauer[1], Anna Leipprand[2], Michael Pahle[1]

[1] Potsdam Institute for Climate Impact Research (PIK), Potsdam, Germany

[2] Mercator Research Institute on Global Commons and Climate Change (MCC), Berlin, Germany

Abstract

This paper addresses the question of how to measure the progress of national policies towards attaining a sustainable energy system characterized by high shares of renewable energy. We propose a set of "soft" indicators that focus on policies and their impact on the energy system.

Our choice of indicators is informed by a conceptual model at the core of which are feedback loops between a policy and the changes it induces in different dimensions of the energy system. Our indicators correspondingly relate to the design of the policy itself on the one hand, and to its effects on the energy system on the other. We first introduce each indicator conceptually and explain its role in the model. In a second step, we use the case of the German Renewable Energy Sources Act (EEG) to identify stages of development that characterize the progress of the policy over time and thus may represent distinct and typical steps of transformation paths. For each indicator we propose a coding scheme to describe the transition from one stage to the subsequent one.

Our work integrates different perspectives from the theoretical literature. It specifically contributes to developing a framework for climate policy sequencing by investigating the timing and ordering of policy events and by identifying feedback mechanisms that may facilitate a step-wise ratcheting-up of climate policies. We hope that the tools we propose will be useful for analysing different case studies of energy system transformation, and specifically for measuring policy progress in the context of the Paris Agreement.

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Contents

1 Introduction

For progress of negotiations in the context of the Paris agreement, Parties will have to ratchet up their policies and measures, as successive nationally determined contributions are to represent a *progression beyond* preceding ones (Article 4.3). Achieving de-carbonization of societies at the required scale will require policy targets that become ever more ambitious over time, but it will also entail transformative change on a broader dimensional scale.

The main interest of this paper is to better understand processes of successful ratcheting-up in their temporal and policy dimensions. Our basic assumption is that the effects of policies introduced at early stages in the policy process may set in motion trajectories characterized by positive and negative feedback processes, and that they may thus significantly influence the options for policy-making in later stages (Howlett, 2009a). The sequencing of introduction and reform of policies thus matters far beyond their immediate effect on policy targets (Meckling et al., 2017, 2015; Pahle et al., 2017).

There is a widespread perception that low-carbon transitions involve sequential, dynamic changes over time with possibly divergent, but characteristic and possibly generalizable patters of development. For instance, the concept of transition "pathways" has been adopted widely as a problem frame for low-carbon transitions (Rosenbloom, 2017). Pathways have been characterized based on the role of new entrants versus incumbent actors (Geels et al., 2016; Geels and Schot, 2007) and on the competing governance logics of government, business and civil society actors (Foxon, 2013). Research has investigated the variation in the policies and dynamics of transition processes between countries in comparative studies (Cherp et al., 2017) and the case-specific mechanisms of system change in longitudinal studies (Turnheim and Geels, 2013). Later phases of transition, where existing systems are increasingly being destabilized, have become a focus of transition research (Geels, 2014; Kivimaa and Kern, 2016). Also, while sustainability transitions research has traditionally been motivated by the desire to understand technological change, politics and political economy aspects are increasingly becoming the subject of transition studies (Markard et al., 2016; Rosenbloom et al., 2016)

This paper aims to contribute to the literature on climate policy pathways, sustainability transitions and policy sequencing by zooming in on the mechanisms of policy interventions in a temporal perspective. We provide a framework for the systematic analysis of policies with respect to their effects on transformation progress.

We develop a conceptual model based on several approaches in the literature that are concerned with policy evolution and system change: The socio technical transitions approach, the literature on policy innovation and governance experiments and the framework of climate policy sequencing. The model operationalizes feedback processes between low-carbon energy policies and the energy regime based on the definition of indicators that (1) relate to the policy itself, and (2) describe the effect of the policy on the energy regime. In a second step, we use the model as a framework to analyse a specific case study and develop a stage-specific coding for the indicators that illustrates the sequence of distinct policy stages. We hypothesize three subsequent stages that mark the steps of the transformation path: introductory, operational and transformative.

We focus on the transformation the energy system because of its key role in combating climate change (see e.g. Edenhofer et al., 2011), and we develop the stage-specific coding based on the case study of the development of the German feed-in tariff system. We hope that the model and indicators will prove useful also for other policies and policy fields relevant in sustainability transitions. We also assume that a better understanding of transformation pathways may facilitate the governance of sustainability transitions by offering tools and strategies for policy-makers and proactive non-governmental actors. This is especially relevant with regard to developing countries, where the linking of climate and development policies is of great importance in order to achieve the sustainable development goals of the UN.

The paper is organized as follows. Section 2 first introduces the theoretical literature we draw on (2.1), and then presents our model for dynamic ratcheting-up in climate policy-making (2.2). Section 2.3 introduces the indicators that operationalize the model in more detail. The case study approach is presented in Section 2.4. Section 3 applies the indicators to the case study and derives a stage specific coding-scheme for each of them.

2 Model development

2.1 Theories informing the model

Our model builds on the literature on socio-technical transitions and on policy innovation and contributes to the emerging framework of climate policy sequencing.

First, we draw on the socio-technical transition literature to conceptualize the transformation of the energy system from a high-carbon to a carbon-neutral renewables-based regime, which is assumed to be necessary to avoid dangerous climate change (Bruckner et al., 2014). Drawing on the multi-level perspective (MLP), we distinguish three levels: niches, the socio-technical regime and the socio-technical landscape. At each level, different dynamics take place that might align to and reinforce each other, thereby leading to the transition of the whole system (Geels, 2004). With the MLP we conceptualize the energy system as a socio-technical regime which is shaped by cognitive, normative and regulative rules as well as user practices and preferences that stabilize current trajectories (Geels, 2004; Geels and Schot, 2007). On the niche level, the regime rules and norms do not apply such that technological innovations (e.g. renewable energy technologies) can develop and improve. Changes at the landscape level, such as macroeconomic or political shocks, might exert pressure on the regime, which opens windows of opportunities for niche developments to break through.

Second, our model is informed by the literature on policy innovations and governance experiments. This accounts for the role of (new) policies in stabilizing or destabilizing the current regime (Smith and Raven, 2012) and their impact on the niche-regime relation (Hess, 2016). The role of climate policy innovation within socio-technical transitions has been discussed by Upham et al. (Upham et al., 2014): Innovative policies, i.e. policies that are applied for the first time at all or policies that have been adopted from another policy field, may challenge the status quo by creating or nurturing niche markets. Similarly, governance experiments can act as an important driver of sustainability transformations (for a review of case studies, see Kivimaa et al., 2017).

Third, this paper builds on and contributes to the climate policy sequencing literature. While climate policy-making may be motivated by the necessity of radical change in the long term, it has to search for short-term measures (Frantzeskaki et al., 2012) that are appropriate to cumulatively build up transformative momentum (Schaffrin et al., 2014). The climate policy sequencing approach, in line with the broader literature on path dependency, sequencing and historicity in policy-making processes (Howlett, 2009a; Mahoney, 2008; Pierson, 2000), aims to address this tension by analysing the dynamic effects of sequential steps in policy-making (Meckling et al., 2017, 2015; Pahle et al., 2017). In the climate policy sequencing framework, policy-induced change is related to the removal of barriers to higher levels of ambition, which is a precondition for the policy to be ratcheted up. Among these barriers are costs, distributional dynamics as well as institutions and governance (Pahle et al., 2017). Hence, climate policies that intentionally or unintentionally aim at reducing or removing these barriers may both become more stringent over time themselves as well as enable other more ambitious policies. This paper contributes to further developing the sequencing approach by conceptualizing the mutual influence between changes in policy and changes in relevant dimensions of the energy system, and to investigate how incremental changes may pave the way for a larger transformation through their multi-dimensional effects.

2.2 A model for dynamic ratcheting-up of policies

Our model aims to operationalize the feedback processes between a policy and the changes it induces in the energy system which facilitate the sequential ratcheting-up of ambition. The reason we focus on ratcheting-up, in contrast to "undirected" transformation, is the aim to develop indicators that can be useful for the stocktaking process in the context of the Paris Agreement. Key for this is the measurement of progress implying the specification of an aspirational end state (deep decarbonization) to which ratcheting-up is supposed to lead up. As such, the model implicitly defines a benchmark that also captures if a policy falls short of making progress.

The ratcheting-up of the policy settings is captured by three indicators that relate to the targets, scope and monitoring provisions of the policy itself. These indicators are presented in more detail in Section 2.3.1. Changes in the energy system are characterized by five indicators in the areas of politics, governance, regulatory framework, business and discourse. These are presented in Section 2.3.2. The model provides a heuristic to investigate how sequences of changes in the policy settings and the resulting effects in the energy system indicators may lead to a progressive transformation of the whole system. If the introduction of a policy with certain settings, or the ratcheting-up of its settings in later reform steps, succeed in inducing favourable changes in the dynamics and structure of the energy regime, this may facilitate further ratcheting-up of the policy settings that would not have been feasible politically in previous stages. Each cycle in the model thus can be seen as corresponding to a new stage in the process.

The model contributes to the development of the climate policy sequencing framework by introducing the concept of cyclical feedback processes between policy and energy system, and by proposing indicators for assessing progress in transformation. Moreover, it integrates key insights from the multi-level perspective and policy innovation theories that allow to specify the mechanisms behind the mutual influences between policy settings and energy systems, and to identify and operationalize the indicators. For instance, drawing on the multi-level perspective, a first step of climate policy would be to provide protection to niches where renewable energy technology can be developed and improved. If these niche technologies and surrounding actor networks grow sufficiently strong, this may influence the energy system (such as its politics, governance and regulation, business models and discourses) in a way that then enables policies that further strengthen these new structures or that even introduce more far-reaching systemic changes. Furthermore, our concept of policy "ratcheting-up" accounts for the fact that policies or policy mixes for sustainability transition may start small, but eventually need to achieve the substitution of an old by a new regime. It thus resonates with policy innovation theory, where policy experiments that are first applied at a very small scale may induce changes in the energy system that allow them to diffuse more broadly later, and it helps to conceptualize the mechanisms that lead from early niche development to eventual regime destabilization in the MLP.

In summary, our model considers the transition from one regime to the other to be the result of sequences of policy change and the multi-dimensional effects that the new policy settings induce. The co-evolution of the energy system and the policy and the feedback mechanism between the two is depicted in Figure 1. The change from an energy system based on conventional energies (mostly coal and nuclear) to one based on renewable energy sources (RES) as a result of the policy being repeatedly ratcheted up corresponds to the comprehensive transformation of the energy system through the three stages.

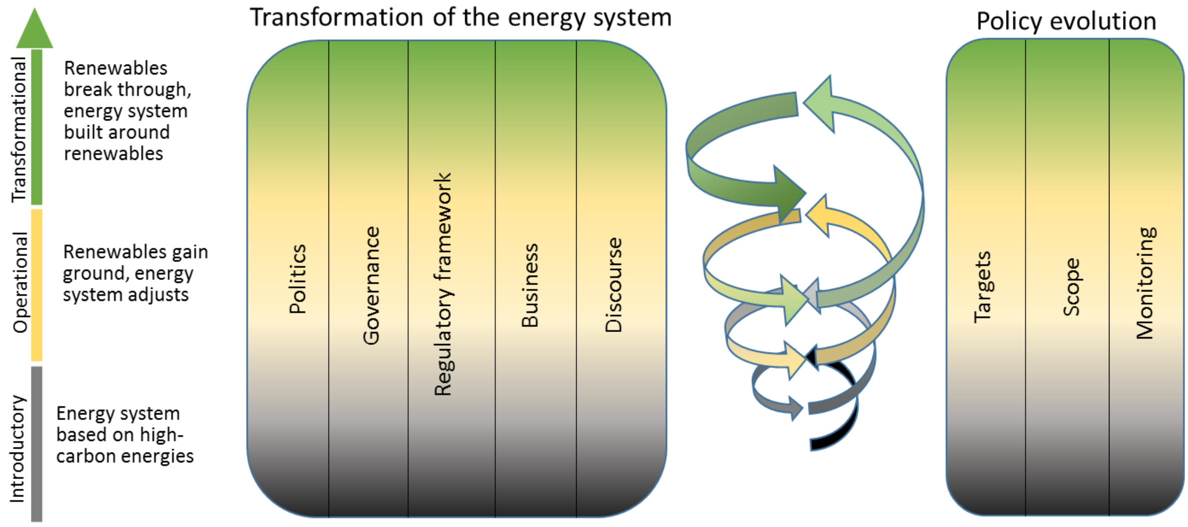

Figure 1: Policy and Energy system coevolve through the three stages of transformation

2.3 Definition of indicators

Measuring progress in transition processes requires indicators. While existing indicator systems usually look at specific policy targets and the degree to which they have been achieved, we take a broader approach that includes the policies and their targets themselves, but also their transformative impact on different dimensions of the energy regime. Being interested primarily in feedback processes within the system, we exclude external factors such as shocks from environmental disasters (e.g. Fukushima) or the influence of international climate negotiations from our model. However, these can be considered in applications of our model when looking at the reaction of a particular energy regime to such developments.

2.3.1 Indicators related to policy setting

Our first group of indicators, those that relate to the settings of the policy in question, comprises the *policy targets*, the *scope of the policy*, and its provisions on *monitoring and evaluation*. They are partly adopted from the Climate Policy Activity Index developed by Schaffrin (2013) and Sewerin (2014).

P1: Policy targets

We propose specific policy targets, such as the envisaged share of renewables at a certain point in the future, as a first key indicator to trace the evolution of policy settings. Such specific quantifiable deployment measures (Howlett, 2009b, p. 75) are required to reach more general objectives of cleaner energy production and climate protection. Our assumption is that the specific targets set by policy makers reflect their ambition to reach the overall policy goal. We expect four target characteristics to be indicative of the stage of the transformation: (1) the actual existence of a quantitative target, (2) its stringency, (3) the time horizon it covers (long vs. short term), and (4) its legal status.

From a policy design perspective, if no explicit target is stated, the policy may play a rather symbolic role not associated with an aspirational end state. Moreover, the political commitment to a target for instance by making it legally binding rather than indicative is also important, as it makes clear that policy makers will invest effort into achieving it and not give up on it easily as the political costs of reverting or missing the target are higher (Brunner et al., 2012).

Targets reflect the ambition of policy makers to change the structures of the current energy supply regime. With targets becoming more stringent relative to business-as-usual expectations, the policy can be assumed to aim at substantially changing the composition of energy production. The time-horizon in policy target formulation reflects whether more short-term measures are embedded in a long-term vision and thus may indicate a serious commitment of policy-makers to initiate regime change.

P2: Policy scope

A second indicator is the scope of the policy, which we define here as the targeted actor groups, that is, firms and households that produce and use energy. Scope might also differ with regard to the size of the operators that are covered.

We assume that the broader the target group, the more effective the policy will be in inducing transformational changes, and that the expansion of the target group reflects the expansion of renewable technologies from the niche to the regime level. The scope of the policy is closely related to its the distributional effects since the selection of target groups creates winners and losers (Ingram et al., 2007). Therefore, with increasing scope the policy will create larger distributional implications, which will influence the size and strength of supporting and opposing coalitions and thus the politics of the system (see indicator E1).

P3: Monitoring and evaluation

The achievement of long-term targets requires continuous monitoring and observation of market impacts to determine if a policy is on track or not, to identify potential for improving its effectiveness and cost-efficiency, and to inform adjustments.

In this context, monitoring and evaluation allows for policy learning as an important mechanism for a sequential policy development. The quality of the monitoring regime closely relates to the governance system's (see indicator E.2 below) ability to be open for learning processes and flexible in changing current trajectories based on experiences or studies on future developments. More specifically, by providing a mechanism to receive and respond to feedback, monitoring allows to respond to unintended consequences, thereby sequentially refining the policy instrument (Schaffrin, 2013). Instead of coincidental policy learning, an institutionalized monitoring and evaluation mechanism enables "innovation and flexibility in policymaking" (Donner et al., 2016). This is an essential precondition for policy-induced system transformations. We expect the sophistication of the monitoring system to increase with the transformative ambition of policies, starting from limited to highly differentiated monitoring provisions, and an increasing emphasis on quantitative measurement and data quality.

2.3.2 Energy system indicators

We propose a second set of indicators to capture relevant dimensions of the energy regime that are expected to be influenced by climate policies and that at the same time influence the level of policy change that is possible. Our proposed indicator set is inspired by Jacobsson & Lauber (2006) who formulate four conditions for transformative processes to take off: Institutional changes, market formation, the formation of advocacy coalitions, and the entry of firms and other organizations (p. 258). Drawing on the literature on socio-technical transitions and the sequencing approach, we modify this list and identify five domains that we assume to be relevant with regard to the transition of the energy sector: Politics, governance, business, regulatory framework and energy discourse.

E1: Politics - actors and coalitions

Politics is an essential component of the energy system that interacts strongly with its policies. In politics, the transformational impact of a policy becomes visible, while at the same time politics can constrain or enable ambitious climate policies. For building our indicator, we focus on structures of actor groups supporting or opposing a policy.

Political science suggests that the more policies interfere with the existing regime that opposes them, the stronger is the need to build up a supporting coalition. Coalitions of actors who share beliefs and interests and who coordinate forces to influence policy-making play a central role in policy change processes (Jenkins-Smith et al., 2014; Sabatier, 1988).

To form protected niche markets for innovative, clean energy production, niche actors require a constituency that can effectively articulate their interests. By forming alliances with political parties and social movements, niche actors increase their influence (Hess, 2016). Coalition building is thus likely to be a priority strategy of niche actors to influence the policy outcome. The implementation of an ambitious policy thus will be easier if the policy is backed by a broad support coalition, and once implemented, the policy will be less likely to be reversed in the future. Thus, in later stages of the transformation, a broad support coalition reflects the legitimacy of the policy (Jacobsson and Lauber, 2006).

However, not only is the policy implementation facilitated by a strong support coalition, but the implementation of the policy can itself strengthen and expand the support coalition, which in turn will allow for ratcheting-up the policy in subsequent stages of policy-making. The creation of "winning coalitions" (Meckling et al., 2015) allows to overcome distributional concerns as a strong barrier to more stringent policy action (Pahle et al., 2017). Thus, we assume that the transformative effect of a policy is visible in whether it is successful in increasing its own support coalition.

E2: Governance – administrative capacity and participation

This indicator relates to the governance structures in the energy system. Governance generally relates to institutions, social norms, and formal and informal procedures for political decision-making (Hufty, 2011, p. 5). Given the complexity of sustainability transformations, governance as a deliberate process is essential (Markard et al., 2012), and needs the consideration of a multitude of aspects such as power relations, data availability, and actor involvement (Turnheim et al., 2015).

Existing governance structures may hold significant barriers to stringent climate policies. Reasons for this might be the lack of expertise and capacity or the priority of short-term over long-term goals. Another potential barrier are insufficient participation processes and thus insufficient openness of the system to new ideas (Pahle et al., 2017). Hence, governance systems that have credible long-term priorities regarding emissions abatement, allow for participation processes and that apply appropriate evaluation methods in order to learn from experiences are expected to facilitate the regime change of the energy system. Our indicator correspondingly focuses on strategic planning processes, the administrative capacity of key government bodies, and informal aspects such as the participation of stakeholder groups.

The relationship between the policy in question and energy regime governance again is two-way. On the one hand, even very ambitious policies may not succeed in inducing a transformation process if they do not change governance structures, given the complexity and path-dependent nature of the energy system. One reason for this is that "previous existing governance processes were often out in place prior to the adoption of new climate mitigation public policy goals" (Kuzemko et al., 2016). On the other hand, if policies aimed at regime transformation come along with governance changes, they might pave the way for ratcheting-up. Following Smith et al. (Smith et al., 2005), we assume that relevant governance changes prominently include an increase in available resources such as capabilities and expertise, and an increase in the level of coordination across regime actors.

E3: Regulatory Framework

The regulatory framework establishes the rules under which energy is produced, transported, and consumed. It denotes the set of legislative provisions in place that regulate the energy system and in which the low-carbon policy under scrutiny in our model is embedded. The evolution of innovations from the niche to the regime requires the formation and nourishment of new markets. Whether these innovations succeed in entering the regime depends to a large extend on the regulatory framework, which shapes the conditions for the integration of new technologies and business models and their relationship to incumbent structures (World Economic Forum, 2018, p. 11). Especially in early phases, changes in the regulatory framework can be essential to trigger transition processes (Jacobsson and Lauber, 2006).

Also in later stages, the transformation of the energy market requires substantial changes in the regulatory framework. The large-scale diffusion of (variable) renewables changes the market conditions, which likely leads to tensions with the regulatory framework in place that is typically tailored to conventional energies. When renewables enter the regime, adjustments of the broader regulatory framework become more and more necessary to accommodate the new energy sources.

E4: Business

Within the business dimension, we choose the development and adoption of new business models as an indicator for the degree of change that the policy has induced. Innovative business models can be considered key drivers in accelerating the energy system transition (Wainstein and Bumpus, 2016). We adopt the definition of business model as "the rationale of how an organization creates, delivers, and captures value" (Osterwalder et al., 2010). Since decentralized generation and intermittent supply are key characteristics of an energy system based on renewables and not prevalent in the old regime, business model innovations to commercialize renewable energy technologies are required.

Consequently, in the course of the transformation of the energy system, incumbents' business models are challenged while new ways of creating and capturing value from the production and marketing of renewable energy emerge. In general, given that renewable energy is mainly produced in a decentralized, small-scale manner, new business models imply the production of electricity very close to where it is consumed (Richter, 2013). The logic of this business model is very different from conventional energy production with regard to how electricity is generated, delivered, and consumed. Consequently, we assume that the development of innovative business models by new market actors as well the adoption of these business models by the incumbent utilities reflects the progress of a policy in transforming the business dimension of the energy system.

E5: Energy discourse

Lastly, we assume that the way energy issues are framed in the public discourse may serve as an indicator for the progress of transformation and its societal legitimacy. In transformation processes, material changes in technologies, policies and practices are reflected by and interact with changes in public discourses. Dominant discourses are part of the existing regime and may constrain actors' perception of what is feasible, while actors associated with niche innovations through their narratives aim to offer new perspectives and facilitate change (Smith and Raven, 2012). When a new discourse becomes hegemonic in a society, actors have to draw on it to be credible. The discourse is "translated into institutional arrangements" (Hajer, 1995) such as specific policies.

Actors in transition debates creatively and strategically produce narratives that build or challenge the legitimacy of technologies and policy changes (Geels and Verhees, 2011; Rosenbloom et al., 2016). Resistance against regime change may be enacted through discursive strategies by the coalition representing the incumbent interests (Geels, 2014), while discursive repositioning of incumbent actors may indicate pending regime destabilization (Bosman et al., 2014). Thus, discursive change may both contribute to driving transition processes and serve as an indicator for transformations that are taking place.

2.4 Case study approach and stage-specific coding

We use the German renewables policy (StrEG and EEG) as a case study to test the model and to develop proposals for the stage-specific coding. The German feed-in tariff system has undergone several reforms since its first introduction in the year 1990, and it has been the main driver of the increase of renewables deployment in the German power sector since 2000. There is a large amount of literature on the German feed-in tariff policy, its development and its effects on other energy regime dimensions (Gründinger, 2015; Hake et al., 2015; Hoppmann et al., 2014; Jacobsson and Lauber, 2006; Lauber and Jacobsson, 2016; Sühlsen and Hisschemöller, 2014). The German case has also served as prominent reference in the MLP literature (Geels et al., 2017). This allows us to assess the impacts of this policy in various dimensions and to relate transformative stages for the different indicators to changes in the policy.

We refine our model by developing a stage-specific coding for our indicators. Inspired by the Bertelsmann Index of Transformation (Donner et al., 2016), we use our indicators to measure the extent to which the interaction with the policy has induced change in the most relevant dimensions of the energy regime. We hypothesize an idealized, prototypical development, where transformational, sequential policy pathways start with an experimental or *introductory stage* where a policy is introduced on a small scale or with very low ambition. In the following *operational stage* the policy has acquired a considerable impact on the energy system, while in the final *transformative stage* it has proceeded to transform it. Our indicators are operationalized by tracing each of them through these stages. By applying our model to the case study, the selection of the indicators is tested and refined.

3 Stage-specific coding of indicators: the case study

In this section, we infer a coding scheme to distinguish the three stages for all dimensions from the case of renewable support in Germany. We trace the development through three periods for both groups of indicators, deriving a stage-specific coding for each individual indicator which is summarized in Table 1.

3.1 Policy Settings

Introductory stage

We consider the introductory stage to begin with the early feed-in law passed in 1990 (*Stromeinspeisungsgesetz*, StrEG). This policy formulated specific tariffs for different technologies but did not state an explicit quantitative **policy target** for the expansion of renewables

(Wüstenhagen and Bilharz, 2006). This reflects the fact that renewables were not expected to play a major role in the energy market in the foreseeable future by many actors (Hake et al., 2015).

In terms of **scope**, the law was applicable to wind, solar, biomass, as well as small landfill gas, sewage gas and hydro (less than 5 MW). However, the rates applicable for the different technologies differed. While the policy made wind power feasible and thus stimulated investment (Geels et al., 2017) the undifferentiated tariff rate was far too low to cover operation costs for solar and the other renewables (Zitzer, 2009, p. 6). Thus, while the policy in theory targeted all relevant RE sources, in practice, the low rate initially limited its scope to those renewable energy producers that were already in the market– except for wind power, where the policy did lead to a significant expansion of the market (Jacobsson and Lauber, 2006).

The original feed-in law of 1990 did not include any **monitoring provisions**. Again, this reflects the lacking goal of the policy to have a major effect on the energy system. Accordingly, reform was not a built-in feature and rarely took place. Only in 1998, when the market effects of the feed-in-law had become visible and hence opposition by the utilities intensified, there was a major modification of the law by creating a new mechanism for distributing the costs among the utilities more equally (Lauber, 2006). This instant of policy learning however was only a reaction to external challenges rather than based on internal evaluations.

Operative stage

We use the entry into force of the Renewable Energy Sources Act (EEG) in 2000 as marking the onset of the operative stage of policy settings development. The EEG included **explicit quantitative targets** with its aim to at least double the share of renewable energy sources in electricity (EEG 2000, §1). The EEG amendment of 2004 added a specific timeframe including mid-term targets: the aim now being an increase in the share of renewables to 12.5% until 2010 and at least 20% by 2020 (EEG 2004, §1). In addition, objectives were justified by the need to reduce the cost of energy supply by internalizing external costs of energy generation and thus became more elaborated and defined (Wüstenhagen and Bilharz, 2006).

The EEG considerably enlarged the **scope of the law**. It introduced guaranteed fixed remuneration rates for electricity generated by renewables for a period of 20 years, which was tailored to small investors like households and farmers. This increase in investment security attracted new actors. Further, the new law extended the range of hydro generators and geothermal power that was applicable for the feed-in-rates (from less than 5 MW to less than 20 MW). Because of higher and technology-specific rates, the investment in solar became profitable for the first time. With the EEG reform in 2009, the scope of the policy broadened further by increasing the support for offshore wind. Hence, now also large-scale generators and investors entered the market.

With regard to **monitoring and evaluation**, the EEG 2000 introduced biennial reporting ("*Erfahrungsberichte*"). It required the government to report to the parliament about the status of market introduction and cost development of RES (EEG 2000, §12). Moreover, if necessary according to the actual developments of costs and technologies, the report should propose adjustments of the feed-in tariff rates and their degression over time for new plants. By providing extensive data on the performance of the policy and the market development of renewables, monitoring results informed EEG amendments in 2010 and 2014 that helped to enhance both effectiveness and cost-efficiency of the policy and to respond to challenges created by the growth of renewables (Schuppe, 2017), among them the introduction of market mechanisms to facilitate the market integration of renewables (see Indicator P2). The regular adjustment of the policy according to market effects and outcomes can be considered a major reason for the success and durability of the EEG (Kuzemko et al., 2016, p. 101).

Transformative stage

The EEG amendment in 2012 introduced fundamental changes that we consider to have initiated the transformative stage. For the first time it set a **long-term target** by formulating the aim to increase the share of renewables in power consumption to 80% until 2050 (EEG 2012, §1). Hence, it created the legal basis for a comprehensive transformation of the energy system envisaging eventual regime dominance by renewables, in accordance with the development of the government's overall climate and energy strategy (Energiekonzept 2010).

In terms of policy **scope**, given the increasing share of RES in the electricity market the focus shifted from broadening the target group towards the intended large-scale integration of renewables into the electricity market. The EEG reform in 2012 introduced a market premium for operators of renewable energy for direct marketing, thus paving the way for a transition from a subsidies-based towards a market-based model. In 2017, this development was strengthened by switching from government-defined feed-in-tariff to auctions. These developments indicate that policy evolution responded to the need to organize the transformation from an energy regime tailored to centralized fossil fuels and nuclear to one based on more strongly decentralized energy production by renewables. Policy-makers essentially started mainstreaming the EEG to consolidate it with general societal principles, namely reducing dependence on subsidies and the introduction of more market elements and competition. They attempted to make the policy fit for a situation where a mostly or fully renewables-based electricity supply system would be close or achieved. The policy thus underwent deep structural reform and a fundamental change in character.

In terms of **monitoring**, the transformative stage brought a monitoring process that evaluated not only the policy, but the progress of the energy transformation as such. Since 2012, the federal government issues an annual report on the state of the *Energiewende* (energy system transformation), called "Energy of the Future" (BMWi, 2016). This report condenses a wide range of data on the energy market to a number of key indicators in order to determine the progress of the implementation of the energy transformation. An independent energy experts' committee accompanies the monitoring process. Every third year, the government issues a progress report that analyses the transformation of the energy system in more detail. Thereby, trends in all relevant areas such as energy efficiency, emission levels and the effect on the labour market are monitored. This new quality of monitoring reflects the progress of the transformation process.

3.2 Energy system dimensions

Introductory stage

In the introductory stage of policy formation**, political support** for renewables was marginal and mainly limited to activists and green entrepreneurs, the new Green Party, and pioneer researchers and writers providing utopian visions for a nuclear-free energy supply. Individual parliamentarians that were in favour of supporting renewable energy from different political parties were key in preparing and promoting the 1991 feed-in-law (Clausen, 2017, p. 14). On the industry side, small industry associations such as Förderverein Solarenergie (established in 1986) and Eurosolar (founded in 1988) effectively campaigned for the law by providing a voice for a number of small and medium sized firms (Jacobsson and Lauber, 2006). At the same time, the coalition that adheres to the status quo, which includes the major political parties (Leipprand et al., 2017) and the incumbent utilities (Stenzel and Frenzel, 2008), is still dominant.

At the **governance** level, the introductory stage was characterized by limited capacity and the absence of strategic planning. There was no explicit monitoring process in place (see above), presumably reflecting the low strategic relevance of the law for the government. However, because of the federal structure of the German political system, there was potentially strong governance capacity at the regional and local level, where more processes and institutions were in place that enabled decision-makers to support new technologies (Jacobsson and Lauber, 2006; Kuzemko et al., 2016).

The **regulatory framework** in this stage was built around the long-existing centralized electricity supply regime based on conventional power plants, mostly fossil and nuclear conventional technologies, and suited to large-scale actors, such as supra-regional network companies. Early regulation for the support of renewables was an addendum to the overall regulatory framework but did not impact on it significantly. The opening of the electricity market to competition in 1998 was the most important regulatory change in the energy regime – actually running somewhat counter to the idea of subsidizing new technologies.

In the **business** field, this stage is characterized by the parallel development of the newly created niche for renewable energy production and the regime (Wassermann et al., 2014). On the niche side, the original Feed-in-Law triggered investments mainly from small actors that became new entrants, such as environmentalists but also farmers and project developers. These actors mostly relied on the fixed remuneration rate guaranteed be the feed-in-law instead of marketing the electricity directly. More specifically, they sold their electricity to the network operators, which were obliged to grant them priority dispatch and pay them the legally determined rate. Thus, given that there was no dedicated market for renewable energy in this phase, the new actors relied on existing channels to distribute electricity. On the incumbents' side, the big utilities did not invest in renewables even after the adoption of the EEG in 2000. Given their significant profits as a result of market liberalization – between 2002 and 2007, the total profit of E.ON, RWE, EnBW and Vattenfall tripled (Leprich and Junker, 2009, p. 7) – they had no incentive to adjust their business strategy.

In terms of the **energy discourse**, there was an overall positive framing of renewables, also supported by concerns over energy security after the oil crisis. However, their potential in transforming the energy system was not foreseen by many. At the time of the first introduction of renewables support (StrEG 1990), the idea of a transition to a renewables-based energy supply system was put forward by some progressive actors (Krause et al., 1980; Scheer, 1989) in opposition to the mainstream energy discourse that considered renewables as an add-on to the existing system with limited potential. However, awareness of climate change risks existed across political parties, with a basic consensus on national climate targets that emerged towards the end of the 1990ies (Hake et al., 2015, p. 7).

Operative stage

In the operative stage, the policy succeeded in extending the **supporting coalition** to more "conventional" actors (Lauber, 2006) such as powerful industry organizations, which in turn increased the legitimacy of the policy and enabled even more comprehensive policy measures. With the rapid expansion of the renewables sector, powerful and well-organized interest groups joined the support coalition. Among early supporters of renewables were the Industrial Union of Metalworkers (IG Metall) and the Mechanical Engineering Industry Association (VDMA) who backed the introduction of the EEG (Hirschl, 2008). When around 2003 the very nature of the support scheme was questioned by conservative and liberal leaders, two other important actors joined the support coalition: the Federal Association for Small and Medium-sized Businesses (BVMW) and the German United Services Trade Union (ver.di) (Jacobsson and Lauber, 2006). While the political influence of the support coalition was growing, the opposition parties had disagreements among themselves and were not able to offer "a coherent alternative" (Jacobsson and Lauber, 2006).

Given the significantly increasing share of renewables, the main issues at the **governance** level were (1) building up capacity and expertise at the national level and (2) facilitating the implementation at the local and regional level by responding to distributional concerns and integrating the local population into the implantation process (Klagge, 2013). At the national level, ministerial responsibility became an important issue. In 2002, the competency for renewable energy sources was shifted from the Ministry for Economic Affairs to the Green Party-led Ministry for the Environment, which naturally had a more ambitious and strategic perspective on the diffusion of renewables (Wüstenhagen and Bilharz, 2006). A growing number of studies commissioned by the German government on the perspectives and impacts of renewable technologies contributed to building expertise and supported strategic planning(Nitsch, 2008; e.g. Nitsch and Wenzel, 2009).

At the local and regional level, an important challenge to implementation of the law was to reduce conflicts with local citizens opposing the construction of renewable plants. Community co-ownership models, such as the so called "Bürgerwindparks", or citizens' wind farms, were one way to deal with this challenge (Musall and Kuik, 2011). The number of energy cooperatives in Germany rose significantly from 2009 onwards because of the EEG, increasing the acceptance for renewables and allowing policy-makers to ratchet-up their ambition with regard to the diffusion of renewables.

Legislation on renewables support became a major pillar of the overall **regulatory framework** and was itself subjected to reforms to accommodate higher shares of renewables. For instance, the EEG amendment of 2009 was a major revision of the law, including measures to ease tensions from higher system imbalances caused by renewables (§11 Einspeisemanagement-Maßnahmen). More precisely, for better management of the feed-in of RES it comprised "curbing" the dispatch priority in cases of capacity constraints while obliging the transmission system operators to remunerate curtailed RE generators. This already foreshadowed the incompatibility of rules and regulatory struggles that later on intensified. Overall, however, the EEG's effect on the rest of the regulatory framework was still very limited.

In the operational stage, characterizing features of the **business** dimensions were the development of new business models by niche actors towards direct marketing of renewable energy and the reluctantly changing attitude of incumbents towards renewables. An important factor for this was §37 of the EEG, the so-called green electricity privilege (*Grünstromprivileg*), which exempts electricity providers from the EEG levy if they have at least 50% of green power in their portfolio. Because of the increase in the EEG-levy (the difference of the compensation rates for RES and the price at the electricity exchange), this became an interesting option for electricity providers. New intermediaries entered the stage that pooled the electricity production of several EEG utilities and then marketed it according to §37 (Zimmermann, 2011, pp. 37–38). In 2011, the announcement to phase out nuclear and to complete the energy transition within the next decades forced the incumbents to adapt their business models to the changing regulatory framework in order to survive. Nevertheless, the shares of RE in their portfolio remained negligible compared to national figures and were mainly made up by large hydro power plants that were already built before the EEG was implemented (Dallos, 2014).

Over time, the vision of an energy transition was successively adopted in the **discourses** of all major political parties in the German Parliament. When Social Democrats and the Green Party together formed the government between 1998 and 2005, they succeeded in establishing parts of their more progressive energy discourse and institutionalized it through the EEG. While Christian and Free Democrats initially opposed the EEG, they later focused their criticism on reform needs rather than rejection. In the process, economic concerns gained more and more weight in the arguments of both supporters and sceptics, regarding the benefits of energy transition policies as well as their potential costs and risks (Leipprand et al., 2017). This indicates that the EEG was taken more and more seriously as a policy with economic implications at a relevant scale.

Transformative stage

While the transformative stage is not yet completed, changes in **actor coalitions** point to a new quality of developments. Political support not only increased through the strengthening of the support coalition, but also through the declining power of incumbents who were eventually forced to increasingly embrace renewables. The weakening of the incumbent utilities (Kungl, 2015; Kungl and Geels, 2016) also most likely decreased their influence on policy-makers and their power in lobbying against transformative policies, and contributed to a beginning disintegration of the coalition that defends the status quo (Leipprand and Flachsland, 2018).

At the same time, reform attempts in this phase are met by the lobbying power of the renewables industry and the associated support coalition, which both have grown strong. Here a risk identified by policy sequencing theory may materialize: namely, that initial support for low-carbon technologies, by creating strong constituencies, will be hard to change later-on when it no longer represents an adequate or cost-efficient policy setting (Meckling et al., 2017; Pahle et al., 2017).

In the **governance** dimension of the energy system, the transformative stage is shaped by a further sophistication of the planning process and a comprehensive integration of the different levels of decision-making. Large-scale consultation processes aim to integrate both interests and knowledge of a broad range of stakeholders and experts, both at the national level (e.g. Forschungsforum Energiewende, consultation process on National Climate Plan 2050, Energiewende-Plattform Strommarkt[1]) and at the regional and local level (e.g. Netzwerk Bürgerbeteiligung[2]). With the energy concept (Energiekonzept) adopted in 2010/2011 (BMWi and BMU, 2010) and the Climate Action Plan 2050 (Klimaschutzplan 2050) adopted in 2016 (Bundesregierung, 2016), targets for renewable energy became embedded into long-term plans for decarbonization and system transition across sectors.

With the share of renewables growing further, grid extension and the adjustment of the grid to fluctuating energy supply became important issues in terms of the **regulatory framework**. The Electricity Market Act in 2016 was an essential step in this phase, announcing the development of the electricity market 2.0 (BMWi, 2015). The electricity market 2.0 deals with security of supply concerns by flexibility options such as demand side management and by providing for strong price signals. The decision for the optimized electricity market with flexibility options instead of an explicit capacity market reflects the renewables as the centrepiece of the future electricity market around which the regulatory framework is built. Several other regulatory changes towards the electricity market 2.0 were introduced. The Law on the Digitalization of the Energy Transition (*Gesetz zur Digialisierung der Energiewende*) was passed in 2016, providing the framework for smart grids by defining technological requirements and data security standards of advanced metering infrastructure. Moreover, the Ruling Chamber 6 of the Bundesnetzagentur decided in 2017 on new specifications for the tendering procedure of balancing power, facilitating the participation of renewable energy in the market for balancing power. These were essential steps in preparing the infrastructure for the completion of the energy transition.

In the **business** sphere, the transformational stage is marked, first, by the development of new business models towards direct marketing of renewable energy, and second, the fundamental adjustment of the incumbents' business models. The introduction of the optional market premium in 2012, which two years later became obligatory for large wind and solar farms, finally succeeded in establishing direct marketing in the renewables sector (Wassermann et al., 2014). Intermediaries entered the market, offering newly developed services to RE-producers, most importantly creating virtual power plants that allow matching supply and demand with renewables instantaneously. Also, among incumbents, awareness increased that their traditional business models were eroding, and they eventually started seriously restructuring their businesses (Kungl, 2015). In 2013 EnBW announced to increase the share of renewables generated by its utilities to 40% until 2020 (EnBW, 2013). Since 2016, RWE's subsidiary, Innogy SE, that bundles the renewable, network and

[1] http://www.bmwi.de/Redaktion/DE/Textsammlungen/Energie/energiewende-plattform-strommarkt.html.
[2] https://www.netzwerk-buergerbeteiligung.de/leitidee-netzwerkorganisation/.

distribution sections of the company, is listed at the stock exchange. E.ON took a different approach, pooling its conventional power plants under its subsidiary Uniper while keeping the renewables with the parent company (Waidner, 2016). In the case of E.ON for example, the company increased its generation of renewable energy by 20% compared to the previous year (E.ON, 2017). In its first interim report of 2018, Vattenfall declared renewable energy to be the most cost-effective alternative for building new power plants (Vattenfall, 2018).

While climate protection rose in priority on the political agenda, the vision of a long-term energy transition eventually became a routine reference in all parties' **discourses**. Conservative and liberal democrat MPs around 2010 referred to energy transition as regularly as everyone else, and it was under their government that energy transition legislation after Fukushima was adopted (Leipprand et al., 2017). The increased attention to the total costs of the FIT system is a direct result of the increase in renewables development and constitutes an important feedback loop in the ratcheting-up process. It became clear that on the way to even larger shares of renewables in electricity supply, the structure of the support system had to be adjusted. This need to reform the EEG in order to increase cost-efficiency increasingly was acknowledged also by the environmental constituency (e.g. SRU, 2011, p. 34).

The evolution of both the policy and the different dimensions of the energy system through the three stages are summarized in Table .

Table 1: Stage-specific codings for policy settings and energy-system dimensions

Indicators		Coding through the three stages		
		Introductory	**Operational**	**Transformational**
Policy Settings	**P1: Policy goals**	No explicit quantity target	Explicit short- and midterm targets	Long-term targets formulating a potential technological endpoint
	P2: Policy scope	Small niche actors	Scope increases with regard to range of technologies and size of actors	Niche is mainstreamed, and policy undergoes deep structural reform
	P3: Monitoring & evaluation	No monitoring and evaluation	Regular publication of performance data	Comprehensive monitoring and evaluation including assessment and strategic planning
Energy system dimensions	**E1: Politics**	Small-scale producers and environmental activists	Powerful actors such as industry organization and trade unions join	Widespread support, disagreement with regard to details rather than fundamental opposition
	E2: Governance	Simple policy execution	Policy making capacity and expertise is expanded	Consultation processes are implemented, integrated planning between different governance levels
	E3: Regulatory framework	Sector development guided by and built around prevailing technologies	Latent regulatory struggle leading to adjustments of regulatory rules	Policy dominates the development of the regulatory framework
	E4: Business	Entrance of new actors, incumbents stick to old business models	New marketing models appear, intermediaries enter the market	Incumbents change business models to adapt, other sectors and institutional investors get involved
	E5: Energy discourse	Energy transition not an issue in the majority discourse	Policy receives states of the key instrument for energy transition, controversies focus on reform rather than abandonment	Energy transition as the dominant discourse, whereby a systemic perspective gains ground

4 Discussion and conclusion

To achieve the ambitious goals enshrined in the Paris-Agreement, national climate policies have to become more stringent in the future. In order to measure progress, we propose a set of indicators that allows locating climate policies on a hypothetical economic-societal transformation path towards a sustainable future. Drawing on the literature on socio-technical transitions and policy innovation, we develop a conceptual model characterizing the co-evolution of the policy level and the most relevant dimensions of the regime level undergoing transformation. We contribute to the emerging framework of climate policy sequencing by identifying feedback mechanisms between policy development and energy regime change, and by assigning them to different stages of the transformation process.

We derive a set of indicators to operationalize the conceptual categories for empirical analysis. These indicators offer a toolkit with which the multidimensional progress of a policy-induced transformation process can be evaluated. In applying the model to the German case of the feed-in tariff (EEG), we assume that the transformation pathway can be discretized in three distinct stages: introductory, operational and transformative. Building on this case study, we develop stylized codings for the three distinct stages of transformation for each indicator.

Using such indicators comes with some caveats, which mainly stem from the limitations of our approach. First, the use of a single case study might entail results that are specific to the German case and cannot necessarily be generalized to other policies and transformation pathways. Thus, the framework has to be tested and refined by applying it to other case studies. Moreover, there is no straight-forward causal relationship between events at the policy level and changes in the different dimensions of the regime. Instead, we base our conceptual model on the assumption that the policy settings and the different system components co-evolve without suggesting that one change singularly and linearly led to a change in another dimension. Lastly, our list of indicators is not exhaustive, and further work may discover additional aspects to include.

The above limitations notwithstanding, the "soft" indicators we describe can have high practical value for the upcoming stocktake in the context of the Paris Agreement (PA). More precisely, by capturing the transformative effects of policies in many dimensions and relating them to policy characteristics, they provide a sound conceptual basis for measuring institutional progress. This can complement existing "hard" indicators, which typically only focus on directly measurable physical quantities like the share of renewables in the power mix, and thus not explicitly consider how a policy has transformed the broader system. Combining both types of indicators seems to be the most promising approach to assess if a country's "nationally determined contribution (NDC) indeed represents a progression beyond [its] then current NDC" as stated in Article 4 of the PA.

Besides the practical considerations, we hope that our work also contributes to a better understanding of the role of policies in supporting transformation processes, and that it will thus enable a more strategic use of policy sequences to prevent lock-in of non-optimal solutions and facilitate transformation towards sustainability.

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