Expectation dynamics in growing niche markets: A case study on the rise of renewable energy in Germany

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Abstract

Novel technologies typically emerge in niches, i.e. in protected spaces with a favourable selection environment. The creation and articulation of expectations about a technology's future capability and situation is considered to be a key process within such niches. By managing uncertainties, expectations have been found to effectively shield and nature niches. Particularly if shared in the wider society, expectations may also empower niches by enabling niche actors to compete with and transform incumbent regimes. Such processes become especially relevant for more mature niches. Because previous empirical research on technological expectations has dealt mainly with early stages of niche development, in this study, we focussed on the German electricity sector in order to deconstruct the evolution of expectations about three novel energy technologies that have already matured into growing niche markets: wind power, solar photovoltaics and biogas. We conducted a media analysis and analysed close to 12 000 newspaper articles in order to reveal how, for each of the three technologies, collective expectations have been developed between the years 1992 and 2017. Furthermore, these dynamics were compared with and related to the changes in the socio-political settings and the development of the respective markets.

Key words: low carbon electricity transitions; renewable energy; collective expectations; niche management

1. Introduction

Meeting the ambitious targets of the Paris climate agreement will require a strong and rapid transition of the energy sector towards low-carbon technologies (Bruckner et al. 2014). In order to stimulate such a transition, it is of utmost importance to understand the nature and dynamics of technological change (Grin et al. 2011). Indeed, scholarly work on the emergence of novel technologies has rapidly grown during the last two decades and has brought about widely-used concepts such as the strategic niche management (SNM) approach or the technological innovation system (TIS) framework (Markard et al. 2012). Rooted in evolutionary economics and the related Schumpeterian view of creative destruction, these concepts compare the emergence of novel technologies with the evolution of species. Driven by variation, selection and retention, so the argument goes, new technologies grow in (sometimes intentionally created) niches, i.e. in protected spaces which provide a favourable selection environment (Geels and Schot 2007a; Schot and Geels, 2008; Suurs, 2009). Based on this understanding, scholars have identified and analysed (different sets of) key processes that shield, nurture and empower niches (e.g. Hekkert et al. 2007; Smith and Raven, 2012).

A key process that has been highlighted repeatedly by different studies relates to the creation and articulation of expectations (e.g. Geels and Raven 2006; Ruef and Markard 2010; Alkemade et al. 2012). Particularly at very early stages of technology development, where the technology is often ill-defined, networks are loose and uncertainties are high, positive expectations about the infant technology were found to fulfil shielding and nurturing functions by managing uncertainties, coordinating innovation activities or creating legitimacy (Borup et al. 2006). But the creation of expectations might also be detrimental to niches, if material performance does not live up to the high expectations (Brown and Michael, 2003). In fact, several empirical studies have shown that periods of strong optimism were typically followed by disillusionment, and sometimes by strong disappointment, which slowed down or even completely stopped innovation actives (e.g. Bakker and Budde, 2012; Van Lente et al. 2013; Melton et al. 2016). Nevertheless, in order to have an impact, whether positively or negatively, expectations need to be shared by a large enough number of actors. Hence, scholars have also studied how individually-held expectations diffuse and sometimes even transform into collective expectations, i.e. belief systems that are widely shared in society (Konrad, 2006; Bakker et al. 2011).

Related to this, Smith and Raven (2012) suggest that expectations not only fulfil shielding and nurturing functions, but also enable niche actors to compete with, or even transform, incumbent regimes. More specifically, they view the creation of expectations as a collective process that enables niche actors to link up with the broader society in order negotiate and transform the 'boundary between niche content and context'. Attributing expectations such an empowering function implies that expectations are pivotal also at later stages of technology development, because it can be assumed that the ability to interact with the broader society becomes particularly relevant when technologies have emerged from infant technological niches and grow into more developed market niches, or even into mainstream markets. However, so far, maturing technologies have received little attention in empirical literature on technological expectations.

In this study, we thus conducted a media analysis in order to investigate how collectively-shared expectations about wind power, solar photovoltaics (PV) and biogas have developed in Germany during the period from 1992 to 2017. Over the last two decades, all three technologies have grown out of early development stages and have moved into (partially substantially) growing market niches of the German electricity sector. The remainder of the paper is structured as follows: we first give an overview of the conceptual understanding of expectations. More specifically, we elaborate on the sociology of expectations, describe stylized patterns of expectation dynamics over time and discuss why expectations are located at the interface between niche content and context. In section 3, we explain how we identified and analysed expectations dynamics. In section 4, we chronologically present the dynamics and put them in context both with changes in the underlying political settings and with the development of the respective markets. In the final section 5, we discuss the revealed dynamics and conclude.

2. Theory

Whereas expectations about novel technologies are constantly created by innovation actors, they are not by itself shared by a large number of people, let alone by the wider public. Different actors raise different expectations that often compete with each other for the limited resources from the selection environment. Bakker et al. (2011) compares this situation with an arena, where proponents of different novel technologies, the enactors, fight for attention of those actors who hold resources, the so-called selectors. Because the technologies in question are still 'in the making', the enactors are not able to fight on the basis of actual performances but of expected future capabilities. Selectors, who can have different selection requirements, have no other option than to choose those technologies that entail the most credible expectations. In some cases, expectations about technologies may be 'accepted' in the wider society and may thus become a part of the 'taken-for-granted' social repertoire (Konrad, 2006).

In order to attract attention, enactors also raise expectations about the 'societal' performance, and not only about purely technological capabilities. Thereby, expectations are used as moralizing systems, which indicate the (expected) goodness or the badness of a technology (Berkhout, 2006). The importance of expectations about the societal impact is particularly obvious in the context of sustainable transitions. To consider the different technological and non-technological aspects on which expectations about innovation may draw, Van Lente et al. (2013) and Ruef and Markard (2010) suggested to distinguish between specific, general and frame levels of expectations (Table 1). Whereas specific and general expectations refer to the technological aspects such as projects, diffusion pathways or profitability, frame expectations refer to societal hopes and fears that go along with a technology such as the expected impact on the job market, on the environment or on the standard of living.

Level	Description
Specific	Expectations with regard to specific manifestations of a technology.
General	General Expectations about the technological field as a whole.
Frame	Frame Societal hopes and fears that go along with a technology.

Table 1: Different levels of expectations

Because expectations about technologies underly social processes and are constantly created, shared or rejected, they may strongly vary over time. A generally observed pattern over time are so-called hype cycles, in which expectations increase strongly and rapidly in order to then decrease again, often equally strongly and rapidly (Dedehayir and Steinert, 2016). One of the explanations for the emergence of such hype cycles is the strategic creation of inflated expectations by innovation actors (Bakker, 2010). To successfully compete with other technologies, innovators tend to raise overly high expectations, which, at later stages, cannot be lived up to. As a consequence, expectations fall and disillusionment sets in. But if we consider the before-mentioned interplay between enactors and selectors, the creation of hypes cannot be attributed to innovators solely, but also depend on whether or not expectations are accepted by selectors or, more generally, by the wider society. Indeed, most of the scholars refer to hypes only if expectations dynamics are accompanied by rising societal attention levels (Van Lente et al. 2013).[1] Moreover, some scholars suggest that, during hypes,

[1] Some scholars suggest that hypes may occur as well in the absence of broader societal attention, e.g. within research communities. However, in the core literature on technological expectations, scholars associate hypes

expectations are not necessarily inflated; instead, they argue that in these periods, the contextual conditions enable technology opponents to share positive expectations more successfully than in surrounding periods, where criticasters have the opportunity to voice negative expectations (Bakker and Budde, 2012).

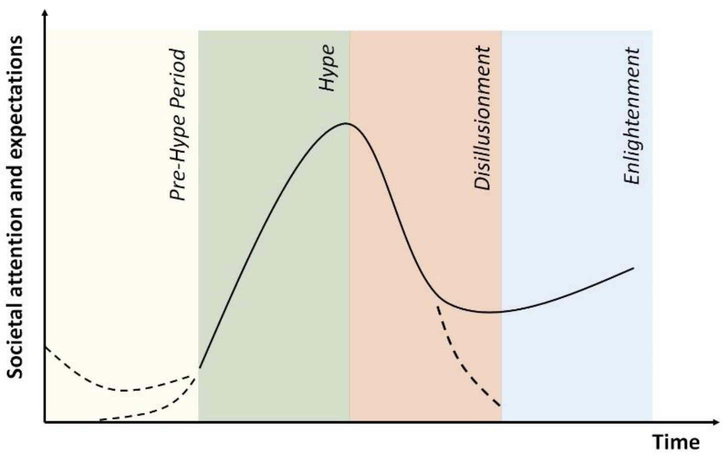

Figure 1: The original hype cycle (solid line, based on Fenn and Raskino, 2008 and the Gartner's Hype Cycle) and further refinements (dashed lines).

By referring to the important role of contextual factors, scholars have also criticised the deterministic view taken by initial (business-related) research on hypes. According to this view, hype cycles are an intrinsic characteristic of novel technologies and move in three predetermined phases: hype, disillusionment and enlightenment (Fenn and Raskino, 2008). Because hypes are deceptive, so the argument, investors need to wait until the hype is over, which is when the technology reveals its real value, enters the 'path of enlightenment', and will get widely diffused. Critics of such interpretations have pointed out that both the shape and the duration of hype cycles are neither always similar nor determined upfront, but, vary substantially depending on the influence of social processes, political settings and other environmental factors (Van Lente et al. 2013; Konrad et al. 2012; Kriechbaum et al. 2018). Furthermore, scholars highlighted that technologies may not always reach a 'phase of enlightenment' but fail to overcome the phase of disillusionment (Melton et al. 2016; Van Lente et al. 2013). Finally, some studies suggest that that previous expectation dynamics such like periods with more stable expectations or earlier hypes may also influence the shape of hypes (Kriechbaum et al. 2018; Van Lente et al. 2013). Figure 1 incorporates the latter two points of criticism into the original version of the hype cycle.

with increasing public visibility, which, in fact, originally was even used as a proxy for expectations and associated hype dynamics (see Fenn and Raskino (2008)).

Scholars that have dealt with niche dynamics have acknowledged increasingly the importance of considering external processes as well. The multi-level perspective (MLP) concept is probably the most prominent outcome of the resulting efforts to conceptualize the context of the niche (Schot and Geels, 2008). It suggests that niches are embedded in a nested structure that contains three interacting levels: the niche itself, the regime, which represents the established broader institutional setting of the niche (regulations, but also relevant norms and belief systems), and the landscape, which is the exogenous environment that is neither affected by the niche, nor by the regime (e.g. macro-political patterns, deep cultural structures). One of the key assumptions behind the MLP concept is that specific interaction patterns among the different levels allow niches to grow into regimes, which, under normal circumstances, are both quite resistant and resisting (Geels and Schot, 2007b).

Smith and Raven (2012) have suggested that expectations might underpin and reflect the emergence of niches into regimes, since they are located at the interface between niche content and context. More precisely, they view the articulation of expectations as a boundary work that empowers niche actors by enabling them to compete and transform regimes. Although such empowering processes are important at each development stage of a niche, it is plausible to argue that the relevance of these processes increases with rising maturity. Although this means that expectations play also a key role for already more mature niches, previous research on expectations has predominately dealt with infant pre-market niches. Only Kriechbaum et al. (2018) recently analysed the evolution of expectations about solar photovoltaics in Germany and Spain. However, although they revealed interesting dynamics and indicated the strong relationship between expectation dynamics, niche development and broader societal processes, they refrained from analysing this relationship in-depth.

3. Methods

To detect collective expectations, we selected Germany's largest newspaper, the *Süddeutsche Zeitung* and conducted a content analysis of articles published between 1992 and 2017. More specifically, we searched through the newspaper's archive for articles that, within that period, mentioned the respective technologies. Table 2 shows the specific search terms for each of the technologies as well as the resulting number of articles. In total, the query yielded 11.964 articles. To analyse the media attention, first, the number of articles per year was counted for each of the technologies. Subsequently, the dynamics of expectations were analysed. For this purpose, all articles were examined for explicit expectations statements by using the software MAXQDA. After the expectations had been identified, it was assessed whether they were positive (optimistic), negative (pessimistic) or neutral.

Technology	Key Terms	Yield
Wind Power	Windr!d* OR Windkraft* OR Windstrom* OR Windenergie*	5569 Articles
Solar PV	Photovoltaik* OR Fotovoltaik* OR Sonnenenergie* OR Sonnenstrom* OR Sonnenkraft* OR Solaranlagen OR Solarpark* OR Solarstrom*	5219 Articles
Biogas	Biogas* OR Biomethan* OR Bioerdgas*	1176 Articles

Table 2: Search query and yields

Following Borup et al. (2006), expectations were generally defined as 'real-time representations of future technological situations and capabilities'. To consider the different levels and contents of expectations, the coding scheme developed by Kriechbaum et al. 2018 was adopted (see Figure 2 for an overview and Appendix 1 for a detailed description of the respective codes).[2] The content analysis was carried out by two coders. At the beginning of the analysis, a pilot test was carried out, where, after the coding scheme had been discussed thoroughly, 250 randomly selected articles were analysed by both coders. Based on the test results, which were compared and discussed, the definitions of the codes were further refined and a coding guideline was initiated. During the main analysis, regular meetings were held, where difficult statements were discussed and the coding guide was updated. The articles were allocated in such a way that each coder was responsible for half of the articles published within a year. This enabled the coders to compare the coding results with regard to the

[2] In contrast to Kriechbaum et al. (2018), however, the newspaper articles, and not the expectations statements themselves, constituted the sample units. As a result, each code could only appear once per article, even if several statements could have been attributed to the code.

dynamics over time. Furthermore, all coded statements were cross-checked by the respective other coder in order to minimize the risk of analytical bias.

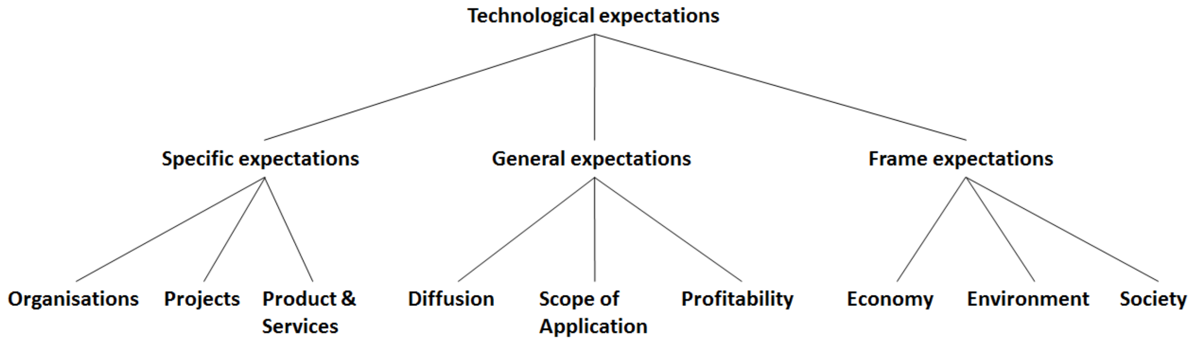

Figure 2: Overview of coding scheme

The method of content analysis allowed us to include both quantitative and qualitative aspects. By counting the number of positive and negative statements per year, a trend over time could be revealed in quantitative terms. Based on these trends, the degree of expectations was measured; the higher the number of net positive expectations (positive minus negative expectations), the higher the level of expectations, and vice versa. Consequently, a hype was regarded as a period of a strong and rapid increase in the number of both positive expectations and published articles about the technology. Disillusionment in turn was regarded as a period of declining net expectations and media attention. Finally, disappointment was seen as a phase, where negative expectations were predominating. The method also allowed us to quantify the dynamics for each of the defined codes (and, thereby, for each of the levels).

Additionally, the content of the coded expectation statements, all of which were stored in an adequate database, was analysed even deeper in qualitative terms. By doing this, we could reveal important additional information. First, further characteristics of the identified expectations were examined such as their time horizon (short-term versus long-term) or the associated actor groups that were raising the expectations. Second, by analysing the contextual information of the identified expectations, inferences could be made about how the expectations dynamics interrelated with the formation both of the respective markets and of formal institutions such as relevant laws and regulations. For this purpose, primary and secondary literature was additionally analysed in order to gain understanding of how Germany's energy policy had evolved and of how the markets of the respective technologies had emerged during the period of analysis.

4. Results

In this section, an overview is given of the dynamics of collective expectations over time (Figure 3). Furthermore, these dynamics are put in context with the history of the German Renewable Energy Sources Act[3] and with the formation of the respective markets. All three technologies were associated with hype cycles, and disillusionment was always strongest at the frame level (Figure 4). The content and strength of the associated frames, however, was different for each technology (Figure 5; Table 3). The shape and duration of the cycles, too, differed according to the technology. Moreover, in the case of wind power and solar PV, the phase of disillusionment was followed by a renewed, albeit slight, increase in expectations, whereas in the case of biogas, both media attention and expectations almost disappeared.

4.1. The 90s: Positive expectations about solar PV, expectations about wind power in the making

Against the background of emerging awareness about climate change and rising legitimacy problems of nuclear power, the German government showed initial efforts to support the deployment of renewables in the early nineties. Particularly wind power benefited from these efforts, but also the niche-markets of solar PV and biogas were growing. The expectation dynamics that we have revealed during that period, showed significant differences between the technologies. While media attention and expectations were insignificant in the case of biogas, they were rising in the case of wind power. With regard to solar PV, both media attention and expectations were comparatively high already in the early 90s.

4.1.1. Formal institutional setting

Political efforts to support the deployment of renewable energy technologies can be traced back to the *Electricity Feed-in Act (1990)*, which obliged public energy utilities to accept electricity from third parties and to pay them a remuneration (Hake et al. 2015). The amount of the payment was fixed on an annual basis and was coupled to the average revenues that the utilities made by selling the electricity. In addition to this Act, two government programmes were implemented in parallel, i.e. the *100 MW Mass Testing Programme* for wind power and the *1000-roofs programme* for solar PV (Bechberger and Reiche, 2004). After the latter program ended in 1995, citizen initiatives successfully lobbied for local support policies for PV (Jacobsson and Lauber, 2006; Dewald and Truffer, 2011). In general, the early support for

[3] See the supplementary material for a graphical representation of the main events that were related to the development of the German Renewable Energy Sources Act.

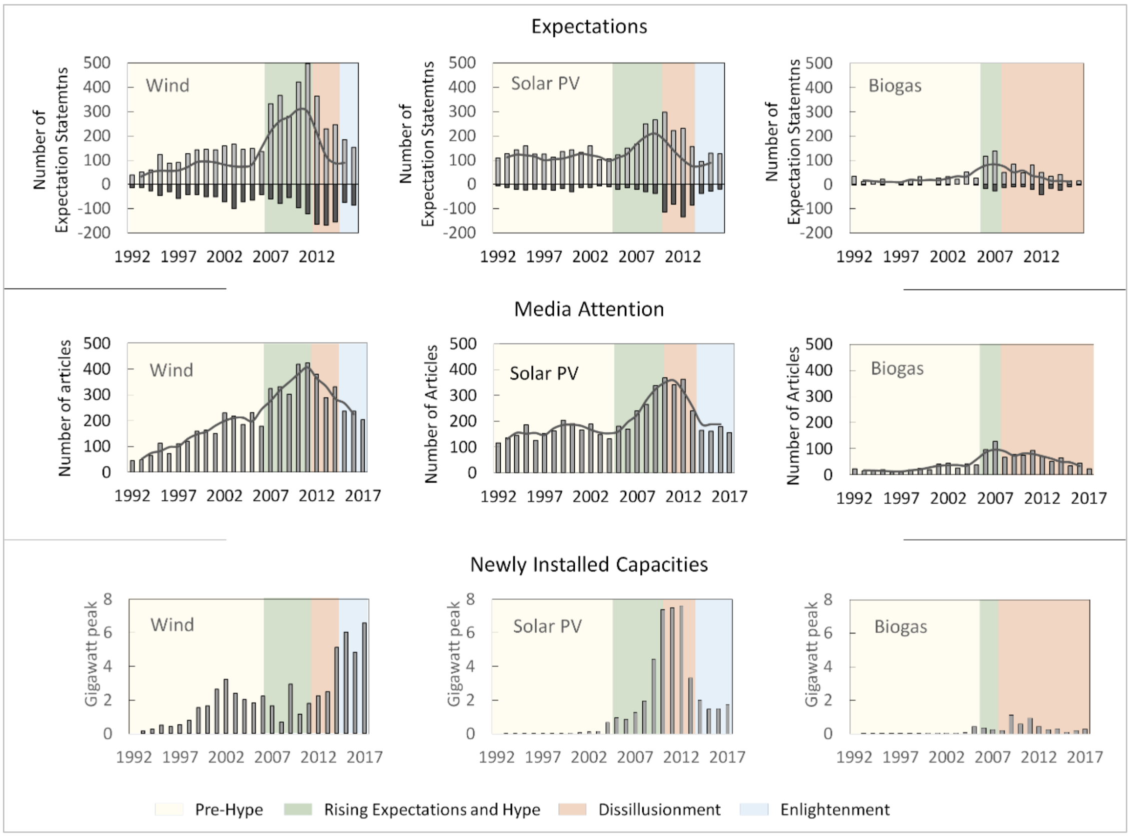

Figure 3: Dynamics of expectations, media attention and newly installed capacities for the different technologies.

renewables was driven by advocacy groups such like Eurosolar or the Wind Power Association, citizen-led initiatives and strategic coalition set up by the green party, rather than by the conservative-liberal government itself, which was known for its reluctant attitude towards renewables (Lauber and Jacobsson, 2016; Hake et al. 2015).

4.1.2. Market formation

The measures had a different impact on the technologies. In the case of wind power, which was comparatively mature, they were indeed triggering a strong growth of the industry (Hake et al. 2015). Between 1990 and 1998, the cumulative installed capacities rose from 55 to almost 3000 MW_{peak} (BMWi, 2017). Particularly towards the end of this period, however, the wind industry needed to deal with regulatory uncertainties. First, the large energy utilities challenged the legality of the feed-in law and even filed a law suit at the EU court. Second, the building law at that time severely hampered approval processes of building permits. Compared to the wind industry, the growth of the solar industry was more moderate; in 1998, the total number of installations accounted for only 54 $MW_{peak.}$ However, given the high costs of the technology, even a moderate growth was remarkable. Finally, biogas technology also was showing an increase in installed capacities, which amounted to 43 MW_{peak} in 1998 (BMWi, 2017). Unlike the wind and the solar industry, the biogas industry was in that time still in its pioneering phase, where the users (i.e. farmers, who wanted to handle their residues) typically constructed the plants themselves (Markard et al. 2016).

4.1.3. Expectation dynamics

The identified dynamics of expectations differed among the technologies. While wind power and solar PV were already (or at least increasingly) in the public eye, the media attention paid to biogas was rather insignificant at that time. In the case of wind power, media attention and expectations were rather low in 1992, but started to increase in the subsequent years, driven by positive expectations at the specific level (which mainly referred to the construction of wind power plants) and at the general level (optimism with regard to the future diffusion). At the frame level, expectations were rising rather moderately due to fears of negative impacts on the landscape. In 2006/2007, the rising trend of overall expectations stopped due to the regulatory uncertainties mentioned above, which created negative expectations with regard to the future of the industry (general level) and a fear of associated negative economic impacts such like job losses (frame level).

Solar PV had already a strong media presence from 1992 onwards. Moreover, this strong presence was accompanied by a high number of positive expectations both at the specific and at the frame level, which well reflects the beforementioned broad support for PV technology within civil society. The expectations at the specific level referred to planned or already implemented solar systems but also to other types of projects such like research projects, local support programmes or citizen initiatives. The optimism at the frame level referred to the expected positive impact of solar PV on the environment (particularly on the atmosphere) and to the vision of a ‘Solarzeitalter’, i.e. a solar age that would leave nuclear energy and fossil fuels behind. Driven by the *1000 roofs programme*, expectations about the market development and the profitability of solar systems (general level) additionally rose from 1992 onwards, but started to decline again in 1996 (after the programme had been expired).

4.2. The turn of the millennium: Increasingly mixed expectations about wind power

Under the new red-green government, the political conditions for renewables improved substantially. The most important push arose from the *EEG 2000*, which amended the *Feed-in Act* of 1991 and not only boosted the wind industry but also initiated the take-off of solar power and, to some extent, of biogas. The dynamics of expectations continued to be different for each technology. While positive expectations both about solar PV and wind power were rising in the beginning and slightly falling in 2002/2003, in the case of wind power, negative expectations appeared increasingly as well. Expectations about biogas were still insignificant.

4.2.1. Formal institutional setting

At the end of the 90'/beginning of 2000s, renewables gained strong legitimacy and the respective markets were given increasing legal and planning certainty. The Green Party's entry into the Bundestag in 1998 (coalition with Social Democrats) led to a radical shift in focus of Germany's energy policy (Hake et al. 2015). In the coalition negotiations the parties agreed to initiate a nuclear phase-out and to stronger support renewables, both of which always had been core concerns of the Green Party. As a first step, the *100.000 roofs programme* for PV technology, which offered favourable loans for the purchase of rooftop applications, was implemented in 1999 (to prevent a downturn of the PV market). One year later, the Electricity *Feed-In Act 1990* was amended by the *Renewable Energy Sources Act (EEG) 2000*, which referred explicitly to climate change, guaranteed (increased) and technology-specific tariffs over a period of 20 years, and decoupled the tariffs from electricity prices. The latter was particularly important, because the liberalisation of the energy market and the subsequent breakdown of the monopolies in 1998 led to falling electricity prices and consequently to lower remunerations for RES operators (Lauber and Jacobsson, 2016). Already in 1997, before the new government was formed, a new act was implemented in the building legislation, which now gave priority to the construction of wind turbines (Bruns and Ohlhorst, 2011). In parallel to the supportive national political conditions, the European Union implemented a directive on promoting renewables (the first of its kind) in 2001. Furthermore, in the same year, the EU court dismissed the lawsuit of German electricity companies and thereby increased legal certainty.

4.2.2. Market Formation

The favourable political conditions triggered both a veritable boom in wind power installations and the take-off for solar PV. Driven by both the improved planning security that was ensured by the *EEG 2000*, and a favourable building act, the cumulative capacity of wind power increased fivefold from 2877 to 16419 MW_{peak} between 1998 and 2004 (Bruns and Ohlhorst, 2011). Furthermore, incumbent German manufacturers entered the wind industry, which, so far, had been dominated by Danish producers (Geels et al. 2016). The strong growth of the wind industry, however, also created new challenges that were related to (i) increasing

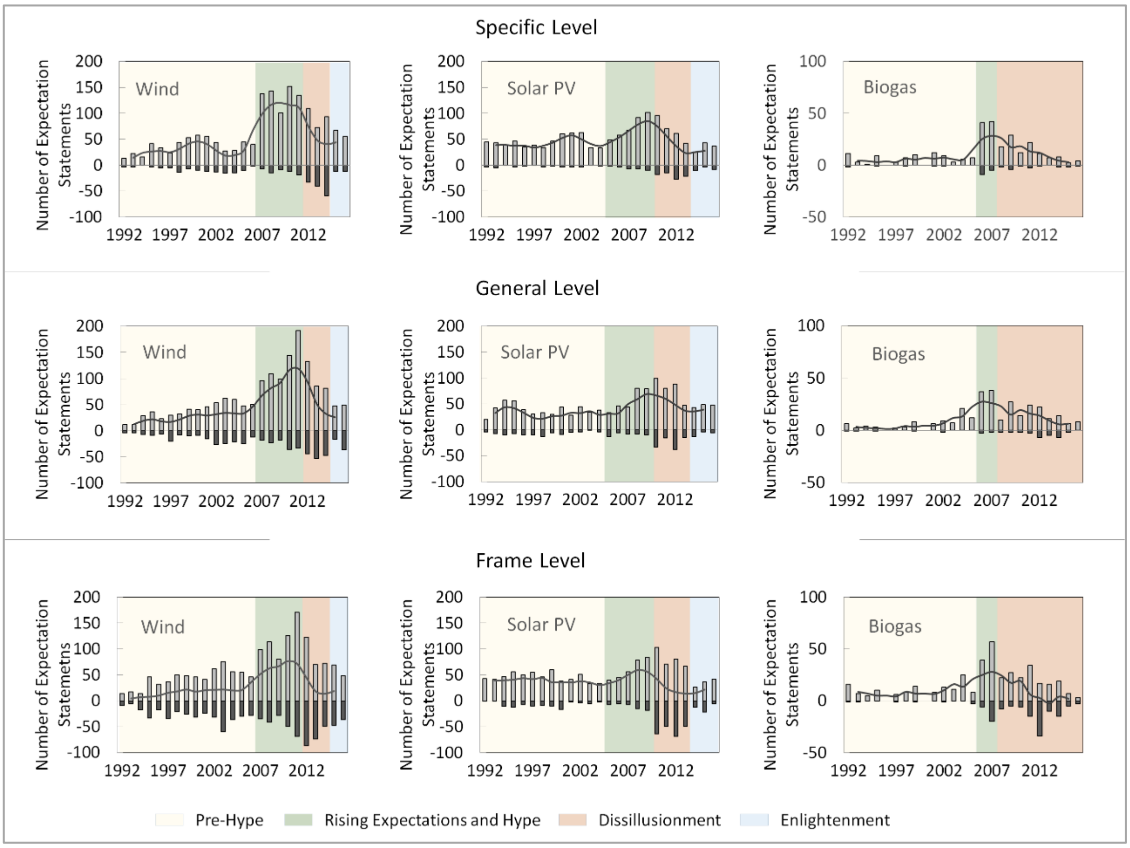

Figure 4: Dynamics of expectations at different levels

public opposition due to landscape impacts, and (ii) decreasing availability of profitable sites (Bruns and Ohlhorst, 2011). The *EEG 2000* also greatly stimulated investments in solar PV (Dewald and Truffer, 2011). Compared to the initial Feed-in Act, the remuneration for PV was dramatically increased under the new law and amounted to €0.506/kWh (for wind energy, the remuneration was €0.091/kWh). In combination with the *100.000 roof programme*, was integrated into the *EEG 2000*, investments in PV became profitable, which lead, between 1998 and 2004, to a speed-up in in installations from 54 to 1105 MW_{peak}. Because of the *100.000 roof programme*, the emerging PV market consisted mainly of distributed roof-mounted systems that were installed on residential, commercial or industrial buildings (Dewald and Truffer, 2011). Finally, the regulatory support stimulated the diffusion of biogas technology as well (249 MW_{peak} total installed capacity by 2004) and initiated a professionalization of the market, which was characterized by increasing system sizes and corn silage as additional input apart from manure (Markard et al. 2016).

4.2.3. Expectation dynamics

Whereas expectations about biogas were still insignificant, expectations about wind and solar PV initially showed an increasing trend, but, after 2000, levelled off. Both in the case of wind and solar PV, the upward trend was mainly driven by expectations at the specific level, which referred to planned (or already implemented) power plants, but also by strong optimism of organisations. Newly formed solar and wind companies communicated positive outlooks, incumbent energy firms such like Siemens or Shell announced to make more investments, and municipal utilities planned to increase their shares in wind and solar power. In 2002/2003, however, project-specific expectations fell and the optimism raised by organisations disappeared or, in the case of wind power, even turned into pessimism.

The drop in specific expectation happened in each case for different reasons and under different circumstances. In the case of PV, it is plausible that both the rise and fall in specific expectations was linked to the *100.000 roofs programme*. Because the programme's aim to support 300 MW was achieved already in 2003, it expired earlier than planned and a gap of support was imminent, which seems to have brought down expectations with regard to individual projects and has led organisations to raise less optimism. Interestingly, expectations at the general level (including expectations about the development of the PV market) did not seem to be affected by the expiry of the program, as they remained rather stable or showed even a slight upward trend. At the frame level, expectations increased in 1999, particularly with regard to the environment, but slightly declined in the subsequent years. Although declining, however, expectations were still almost consistently positive.

In the case of wind power, the decline in project-specific expectations and the emergence of organisational pessimism was accompanied by rising negative expectations at the other two levels and happened in the above-mentioned context of limited availability of profitable building sites as well as rising public opposition. At the general level, increasing concerns were raised with regard to the future of the wind industry. Opponents demanded an exit from wind power and industry-analysts made pessimistic predictions. At the frame level, the public opposition was manifested through increasing fears of negative landscape impacts. Additionally, increasing economic concerns (economic inefficiency of feed-in tariff but also fears about the loss of both jobs and competitiveness due to the looming crisis of the industry) and fears with regard to the energy security (rising volatility in electricity production) appeared. Both at general and frame levels, however, positive expectations appeared as well and still prevailed. At the general level, for instance, positive long-term expectations about the diffusion of wind power out-weighted the negative expectations, which referred rather to the short-term development of the wind industry.

4.3. The *EEG 2004* & increasing climate awareness: Rising expectations about all three technologies

In the *EEG 2004*, the red-green government increased the remuneration again for PV and Biogas and, for the first time, specified long-term targets for the deployment of renewables. Accompanied by a strong increase in public awareness of climate change, the conservative party, which, together with the social democrats, led the government from 2005 onwards, continued the support for renewables and even increased the deployment targets. The *EEG 2004* sped up the rate of diffusion of solar PV and biogas. At the same time, expectations about both technologies started to rise significantly. By contrast, installations rates of and expectations about wind power were declining. However, driven by the increased climate awareness from 2007 onwards and by the associated announcements of policy makers to increase deployment targets, wind power eventually experienced a rapid and strong increase in expectations as well, which outweighed the rise in expectations about the other two technologies by far.

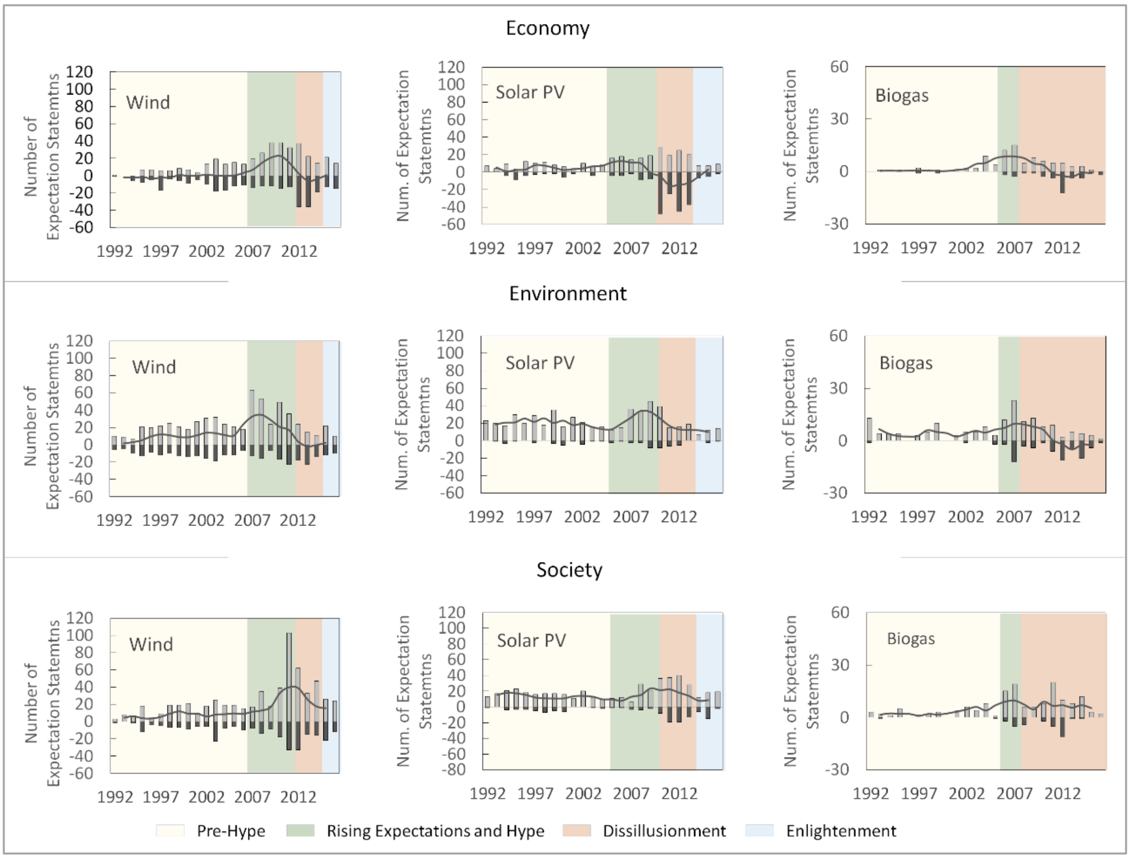

Figure 5: Dynamics of expectations within the frame level.

4.3.1. Formal institutional setting

Already in 2003, the red-green coalition, which was leading the government for a second term, implemented the *PV Interim Act 2003*, which came into effect in 2004 and raised the tariffs for rooftop PV systems in order to compensate for the end of the *100.000 roofs programme*. In 2004, the entire feed-in law was amended for a second time. The resulting *EEG 2004* raised the tariffs again for photovoltaics, but also for biogas and offshore wind technology, whereas the tariffs for onshore wind remained the same. The new act also defined concrete expansion targets, namely a 12,5% share of renewables in the electricity production by 2010 and a 20% share by 2020. In 2005, a new government was formed. Although this government was led by a coalition of the Conservatives and the Social Democrats, it agreed to maintain the targets hat had been defined by the *EEG 2004* (Hake et al. 2014). Moreover, in the upcoming years, the coalition even increased these targets several times and finally specified the ambitious target of 'at least 35% share of renewables by 2020, 50% by 2030 and 80% by 2050'. This ambitiousness was mainly driven by the Stern Report (published in 2006) and the fourth report of the Intergovernmental Panel on Climate Change (published in 2007), both of which led to increasing public attention to climate change and a strong response from the government led by chancellor Angela Merkel (Hake et al. 2014).

4.3.2. Market Formation

Whereas the growth of the wind market was declining, the solar PV and the biogas market were picking up. Driven by the limited availability of suitable building sites, the German wind companies expanded internationally and started to focus on repowering (i.e. replacing old turbines by new and more efficient turbines) and on offshore technology (Bruns and Ohlhorst, 2011). However, whereas repowering was hampered by height restrictions of the building law, the offshore technology was still in its infancy (*ibid.*). The solar market, by contrast, grew even more strongly than in the previous years due to the further increase in remuneration (and falling system prices). In 2008, the cumulative capacity of installations amounted to 6120 MW_{peak}, which was almost 40% of the globally installed capacities. With the end of the *100.000 roofs program* and the removal of a cap that previously limited the size of installations to a maximum of 100kW_{peak}, large-scale ground-mounted systems were increasingly installed as well, which led to the entry of new actors such like professional project developers or capital investors (Dewald and Truffer, 2011). The *EEG 2004* now also triggered a take-off of biogas technology. Driven by the increased tariffs, new manufacturers entered the market and produced ever larger plant sizes (Markard et al. 2016). Because of an additional bonus, these plants were increasingly run by energy crops, first and foremost, by maize.

4.3.3. Expectation dynamics

During this period, expectations about all three technologies skyrocketed. Depending on the technology, however, the dynamics showed clear differences. Expectations jumped up at different times, at varying degrees and even at different paces. A notable example were expectations about the potential to protect the climate, which, in 2007, were strongly increasing, regardless of technology, and which were clearly linked to the simultaneous rise in public attention to climate change.

The strongest increase in climate-related expectations showed wind power. Moreover, in the case of wind power, the rapidly growing public interest in protecting the climate (and the associated political response) stimulated also the formation of specific and general expectations and, thereby, initiated a period of strong optimism in general, which lasted for several years. Whereas in previous years, specific and general expectations about wind were stagnating or even declining, in 2007, they showed an unprecedented increase. Apart from newly planned wind parks, a considerable part of the expectations that were raised at the specific level referred to incumbent energy companies, which wanted to invest in wind power in order to reduce carbon emissions. For example, RWE, the second-biggest electricity utility, announced investments of billions of euros into wind power to contribute to government's climate goals. General expectations, too, were mainly linked to climate change and the associated deployment targets announced by the government. The momentum towards climate protection also provided a window of opportunity for offshore wind, as illustrated by the following statement: 'Without offshore wind parks in the North Sea and in the Baltic Sea, the ambitious emission targets will be unachievable'. The rising optimism with regard to offshore technology was also visible at the specific level, were almost every second project-specific expectation statement referred to planned offshore wind parks. Finally, expectations about the creation of jobs were also rising from 2007 onwards.

Whereas the significant jump in expectations about wind power in 2007 was clearly linked to the strong increase in public attention to climate change, expectations about solar PV started to pick up already in 2004. Furthermore, expectations rose more steadily and less strongly. The initial increase was mainly driven by optimism of solar companies (specific level) and high hopes for the creation of jobs (frame level). The new conditions of the *EEG 2004* seemed

Technology	Phase	Frame	Strength	Example
Wind Power	Hype	Economy	(++)	*'Many of the automotive suppliers, which are now in a crisis, could start to produce wind mills.'*
		Environment	(++)	*'Due to the threat of dramatic climate change, we have no time to discuss the aesthetics of wind mills.'*
		Society	(++)	*'Wind parks will soon be the main pillar of the energy supply.'*
	Disappointment	Economy	(−)	*'Operators of offshore parks might be protected from financial risks in the future – at the expense of consumers.'*
		Environment	(−)	*'Extensive deployment of wind mills will destroy our landscape.'*
Solar PV	Hype	Economy	(+)	*'The industry associations expect 100 000 jobs by 2012.'*
		Environment	(+)	*'Climate change is challenging, and we as cities need to set a good example with solar parks.'*
	Disappointment	Economy	(−−)	*'Now, the solar industry fears for many jobs.'* *'Because of the rapid deployment, high consumer costs are feared.'*
Biogas	Hype	Economy	(+)	*'Particularly the boom of bioenergy is providing future opportunities for farmers.'*
		Environment	(+)	*'With biogas, the carbon emissions can be reduced substantially.'*
		Society	(+)	*'With a rapid deployment of biogas, we will get more independent from energy imports.'*
	Disappointment	Economy	(−)	*'The costs for renewables such as biogas is likely to strongly increase in 2013.'*
		Environment	(−−)	*'Environmentalists fear that the intensive maize cultivation will lead to over fertilisation of the soil.'*
		Society	(−)	*'(...) [the increasing demand for maize due to biogas] will lead in times of food shortage to famines.'*

Table 3: Positive and negative Frames that were associated with the technologies.

to have created confidence among solar companies. Flotations, positive outlooks and additional investments were announced. The rising expectations about future jobs, in turn, were not only raised by organisations, but also by politicians and researchers. The then environmental minister, for instance, predicted 300.000 solar jobs for the year 2020. The rise in climate awareness in 2007 additionally supported the formation of positive expectations about solar PV. Expectations about the technology's potential to protect the climate jumped up and were accompanied by the hope of ensuring long-term energy security by replacing conventional fuels. Finally, in 2008, general expectations about the expected development of the market and about increasing profitability of the technology through falling prices started to rise significantly as well. In contrast to wind power, the market-related expectations about PV referred not only to the (long-term) deployment targets set by the government, but also to a positive short-term outlook.

After low media attention in the previous periods, both the number of articles and the number of expectations jumped up also in the case of biogas, albeit to a lesser extent and for a shorter period. The optimism set in in 2006, lasted for two years, and was driven by an increase in expectations at all three levels. However, in contrast to the specific expectations, which were mainly related to planned biogas plants and optimistic outlooks of upcoming biogas companies, general and frame expectations had been rising slightly already in 2004, when the amended feed-in law brought improved conditions for biogas. At the general level, this initial increase in expectations referred to the confidence on the biogas market, while at the frame level, it related to the potential of biogas to provide farmer with additional income opportunities, but also to climate change and broader societal hopes such like energy security and independency from energy imports. These contents remained basically the same in 2006/2007. In 2007, however, a considerable amount of negative frame expectations about the environmental impact of biogas appeared as well. These expectations related mainly to the fear of over-fertilization and soil depletion, i.e., to the anticipated impacts of the intensive cultivation of maize that was increasingly necessary for the operation of biogas plants, which were ever-increasing in number and size.

4.4. Increasing emphasis on wind power, Fukushima & rising disillusionment

From 2009 onwards, the emphasis of Germany's energy policy was increasingly on wind power. This, and the announcement to phase-out nuclear power in response to Fukushima, further boosted expectations. In 2013, however the strong optimism about wind power started to fall. Expectations about solar PV started to decline already in 2010, which was strongly interlinked with the emerging debate about the costs of the EEG and the government's decision to cut the support for PV. Expectations about biogas, which also faced cutbacks, continued to fall as well. In the case of all three technologies, the decline in optimism was reinforced by the rising negative expectations, which were particularly strong at the frame level.

4.4.1. Formal institutional setting

While the Fukushima accident in 2011 brought a radical shift in Germany's nuclear energy policy (immediate phase-out of nuclear power plants), it did not change the basic direction of the country's policy with regard to renewables, which increasingly shifted its focus to wind power (Hake et al. 2015). Already in 2009, the grand coalition increased the support for biogas and wind power, but reduced, albeit slightly, the tariffs for PV (*EEG 2009*). In parallel to the EEG, the state-owned KfW bank started a loan program of €5 billion for investments in offshore wind projects. After the elections in 2009, the Conservatives formed a coalition with the Liberal Party, which traditionally had been rather critical of the EEG. The new government agreed to continue to support renewables, but, driven by rising costs of the remuneration payments, announced to put emphasis on cost efficiency as well. The resulting energy concept (published in 2010) clearly focussed on wind power. By contrast, the support for PV was considered as too costly.[4] As a result, the tariff structure for PV had been subject to continuous amendments. After Fukushima, the government stayed on its course and further increased the support for wind (*EEG 2012*). At the same time, support for PV now declined drastically ('*PV-Novelle 2012*'), mainly because previous efforts to limit the increase in costs had failed (Hoppmann et al. 2014). Furthermore, support for biogas decreased as well. In 2012, the government also started a debate on introducing deployment corridors for all renewables in order to better control for costs (Hake et al. 2015).

4.4.2. Market formation

After the implementation of the *EEG 2009*, the markets of all three technologies showed an upward trend. The particularly strong growth of the PV market[5] was mainly driven by falling system prices, which were falling stronger than the amount of the tariffs and made investments in PV highly profitable (Hoppmann et al. 2014). Only in 2012, the harsh cutbacks eventually stopped the growth of the market (*ibid.*) and, in fact, created a severe crisis of the PV manufacturing industry, which already suffered from increasing competition from China (Geels et al. 2016). With its premiums for manure and energy crops, the *EEG 2009* also stimulated a massive boom in the biogas sector. Between 2009 and 2012, almost 4,000 new

[4] Indeed, only from 2009 to 2010, the annual remuneration payments skyrocketed from €2.7 billion to €4.5 billion

[5] Between 2010 and 2012, installed capacities rose by 23.5 GWpeak.

biogas plants were build, most of which used maize as main input (Markard et al. 2016). In 2012, the growth was slowed down substantially by the *EEG 2012*, which withdrew the premiums, cut the tariffs and limited the share of maize to 60% in order to avoid extensive monocultures[6]. In contrast to PV and biogas, the growth of the annually installed capacities of wind power continued also after 2012. An increasing share (up to 25%) was due to repowering, for which the *EEG 2009* offered special premiums. First offshore parks have been successfully put into operation as well. Nevertheless, in the offshore sector, many problems had to be dealt with such as unexpectedly difficult weather conditions that were severely hampering the construction process or problems with connecting to the grid (Reichardt et al. 2016).

4.4.3. Expectation dynamics

Whereas expectations about PV and biogas fell throughout the period, expectations about wind further increased until they ultimately started to decline in 2012. The strong increase in the case of wind (which happened at all levels of expectations) was interlinked strongly with the commitment of the new government towards wind energy and the announcement of the nuclear phase-out one year later. At the general level, wind power (and increasingly offshore technology specifically) was now considered as the key pillar of the future energy system. The planned nuclear phase-out after Fukushima shorten the time horizon of the positive expectations about the diffusion of wind power, which, in previous periods, had rather referred to the medium or long term. This was strongly interlinked with the dynamics at the frame level, where there was a massive increase in expectations about the ability of wind power to secure energy supply, once nuclear power is off the grid. At the specific level, the large energy companies continued to spread optimism – now all major energy suppliers announced large investments in wind power, often in offshore projects.

In parallel with the rise of positive expectations, negative expectations started to increase as well, albeit at a much lesser extent. The strongest increase in pessimism occurred at the frame level. While the climate-related expectations gradually disappeared, fears of negative landscape impacts were getting stronger and, in 2013, even dominated-environment related expectations. Similarly, positive economic expectations (job creation, competitiveness), were, from 2012 onwards, overshadowed by fears of overly high costs. Particularly with regard to offshore technology cost concerns were increasingly raised. The rise in negative expectations

[6] Although the *EEG 2009* linked the use of energy crops to sustainability criteria, the boom lead to a substantial increase in maize acreage.

at the general level referred mainly to hampering building regulations (particularly for the large new generation wind mills), ongoing political discussions to cap the future deployment in order to control for costs, and increasing disappointment with regard to offshore park, the construction of which took usually longer than expected. The increasing pessimism with regard to offshore wind was even more visible at the specific level, where the optimism declined and an increasing number of negative expectations were raised both with regard to companies active in the offshore sector and with regard to specific offshore projects.

As with wind, the declines of expectations about PV and biogas were reinforced by negative expectations, which were strongest at the frame level. In the case of PV, these negative frames were present over several years and referred predominantly to economic fears, more specifically, to fears both of overly high economic costs caused by the remuneration payments, and of job losses in the country’s PV industry. By contrast, in the case of biogas, the negative expectations appeared mainly in 2012, but not only dominated economic, but also environmental and societal frames. Apart from excessive economic costs, biogas was now associated again with intensive maize monocultures and their environmental downsides. Additionally, ethical concerns with regard to the impact on the food industry (food versus fuel) were raised and replaced the optimism with regard to energy security, which the announcement of the nuclear phase out had created in the previous year.

4.5. The EEG 2014: Wind and solar PV on the ‘path of enlightenment’?

To be written

5. Discussion and Conclusion

To be written

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