Niche construction and empowerment through socio-political work. A meta-analysis of six low-carbon technology cases

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Abstract

In the sustainability transitions literature the idea of 'protective space' shielding niche innovations from unfriendly selection environments is a fundamental concept. Few studies pause to consider how and by whom such protective space is created, maintained or expanded. The paper develops three propositions to deepen our understanding of the 'outward-oriented socio-political work' performed by technology advocates. The paper conducts a meta-analysis of six low-carbon technology case studies in the UK and the Netherlands. In each case, analysis finds the cases relevant to the propositions, but requiring finer nuance and further development.

Key words: protective space; niche; politics; sustainability transitions; technology advocacy

1. Introduction

A founding assumption in the literature on sustainability transitions is that incumbent systems of production and consumption need to change fundamentally in order for more sustainable technologies to become widely adopted (Rip and Kemp, 1998; Elzen et al., 2004; Bergh et al., 2011; Markard et al., 2012; Dangerman and Schellnhuber, 2012). Consequently, research in this field has tried to understand where and how these new sustainable technologies emerge and contribute towards transforming systems (Kemp et al., 1998;

Hekkert et al., 2007; Jacobsson and Bergek, 2011). The concept of 'protective space' has been deployed to denote a wide variety of 'niches' favourable to new low-carbon technology development in contexts otherwise disadvantageous towards them, such as R&D settings (Belt and Rip, 1987), geographical locations (Coenen et al., 2009; Verbong et al., 2010), NGOs and environmental user groups (Verheul and Vergragt, 1995; Truffer, 2003) and grassroots communities (Seyfang and Smith, 2007; Ornetzeder and Rohracher, 2013). When innovations are empowered to 'break out' of their protective spaces, some induce far-reaching implications for wider institutions, infrastructures and other structural dimensions of the selection environment. This makes them potentially path-breaking innovations. This paper aims to make a contribution to this particular topic.

The niche concept has been most prominent in the Multi-Level Perspective (Geels, 2002) and Strategic Niche Management frameworks (Schot & Geels, 2008; Raven et al., 2010). These related frameworks presume sustainable technologies are disadvantaged and require strategic support to protect them against premature rejection by investors, customers and users whilst the performance, price and infrastructures for these technologies develop. In evolutionary terms, novel technological varieties with more environmentally friendly and socially just characteristics struggle to develop under unfavourable, multi-dimensional selection pressures (i.e. incumbent 'socio-technical regimes') (Nill and Kemp, 2009). Protective spaces, where these selection pressures can be reduced or modified, are required in order that sustainable technological developments have a chance to become sufficiently robust to eventually compete with incumbent technologies and/or exert an influence over wider selection environments.

Until recently, however, analysis has rarely paused to consider how protective spaces are created, maintained and, if at all, removed. Spaces have tended to be taken as given, and analysis focused on the development of technological expectations, actor networks and social learning processes that nurture technological development within those spaces (Kemp et al., 1998). Recognising this lacuna, Smith and Raven (2012) developed a framework conceptualising the construction of 'protective space' as consisting of three features: shielding, nurturing and empowering. The aim of this paper is to develop the framework by discussing three propositions regarding the ways in which those who aim to promote a certain low-carbon technology, i.e. technology advocates, mobilise and maintain protective space. Our concept of advocates does not only include technology developers, but also other interested actors such as lobby groups, environmental NGOs, policy makers and politicians, potential users, etc.

Our analysis also responds to calls for more politically informed analyses of transition dynamics and system transformation more generally (Aklin and Urpelainen, 2013; Hendriks and Grin 2007, Shove and Walker 2007, Scrase and Smith 2009, Meadowcroft 2011, Kern 2012; Cheon and Urpelainen, 2013; Hess, 2013). In order to shed light on the politics of protective space, the propositions adopt an actor-oriented perspective (Ferguson et al. in press; Farla et al., 2012) focussing on the strategic work that technology advocates undertake when attempting to construct, maintain and expand protective spaces. As such, we address the following research question:

How do technology advocates attempt to create, maintain and expand protective space for developing their path-breaking low-carbon technologies?

Published research provides a conceptual approach to this issue (Smith and Raven 2012), and some isolated case studies have explored it empirically (Verhees et al. 2013; Smith et al. 2014; Walter, 2012; Boon et al., 2014; Kern, et al. 2014a; Kern et al., 2014b; Verhees et al., 2014). As yet, however, there has been little synthesis across individual cases that might provide a more robust basis for understanding the dynamics of 'protective space'. To address this gap we conduct a meta-analysis of case studies of three different types of low carbon electricity-generating technologies in two jurisdictions committed to energy transitions. The technologies are solar photovoltaics (PV), offshore wind (OSW), and carbon capture and storage (CCS). The jurisdictions are the UK and the Netherlands. The methodology section justifies these choices.

The paper begins in section 2 with a discussion of protective space and develops three propositions about the role of technology advocates. After outlining the methodological approach in section 3, the paper continues in section 4 with the analysis reviewing the propositions against evidence from the case studies. The paper ends with conclusions and implications for research in section 5.

2. Protective space and low-carbon technology advocacy: three propositions

In their review of the niche literature, Smith and Raven (2012) focused specifically on the concept of protective space. Here we provide a brief summary of the conceptualisation of protective space arising from this literature review. The summary informs three propositions that better allow the framework to be confronted with empirical evidence across multiple case studies. We note here that the propositions are used to guide our comparative research through pattern matching similar to ways suggested by Yin (1994) and to provide lenses for interpretative analysis (Stake, 1995). Given the qualitative, historical nature of the case studies, we do not undertake statistical analysis. The methodology section further explains how the propositions were used in the comparative analysis.

Smith and Raven found that the literature emphasised two out of three features of protective spaces important for the development of low-carbon technologies. These functional features were *shielding* and, in particular, *nurturing*. A third function, that of *empowering* the niche innovation, was less developed in the literature. The propositions in this paper focus on the least developed parts of the framework, i.e. shielding and empowerment. Propositions on nurturing have already received substantial attention across cases and empirical domains (Schot and Geels, 2008).

2.1 Shielding

Shielding is defined as "processes that hold at bay certain selection pressures from mainstream selection environments" (Smith and Raven, 2012: 1027). As such, niche spaces are shaped through a variety of measures and mobilisations that provide sites for technological development relatively free of selection pressures prohibiting such activity more generally elsewhere. These regime selection pressures are multi-dimensional rather than merely economic and arise from industrial structure, technologies and infrastructures, knowledge base, markets and user practices, public policies and political power, and the cultural significance of the regime form (Geels 2002; Rip & Kemp 1998). Therefore, shielding can take multi-dimensional forms too.

Shielding can be passive in the sense that favourable spaces already exist before and independently of the strategic action by technology advocates, such as off-grid settings (Verbong et al., 2010) or environmentally concerned communities (Truffer, 2003). Protective spaces can also be created more actively, through the purposeful provision of facilities like demonstration programmes (Kemp et al., 1998) or strategic firm investments (Pinkse et al., 2014; Sushandayo and Magnussen, 2014).

Because path-breaking technologies will have little support initially (Aklin and Urpelainen, 2014), advocates will have to take advantage of pre-existing passive spaces that afford some limited shielding from selection pressures and offer resources and conditions that enable some kind of innovative development to the technology. Where those developments show promise, then technology advocates are eventually able to enrol others into the active construction of further strategic spaces for more dedicated, active forms of protection of the technology such as policy programs (Lovell, 2007; Diaz et al., 2013; Raven et al., 2011).

In sum, shielding can be achieved by technology advocates through mobilisation of passive spaces such as geographic locations (e.g. off-grid sites), generic innovation schemes or cultural milieus (e.g. environmentalists) or through more active measures such as technology-specific public policies, strategic industrial research, market subsidies, and political support (see Smith and Raven 2012, Table 1).[1] These observations lead us to formulate the following proposition:

P1: Technology advocates initially use pre-existing passive spaces for technology development before strategically creating dedicated active spaces.

The next section discusses how protective spaces enable nurturing of path-breaking innovations. Given that most studies on niche development focus on nurturing, we do not develop a proposition in this section, but only briefly synthesize previous studies.

2.2 Nurturing

The mobilisation of passive spaces and creation of active spaces for innovative activity contribute to the second feature of protective spaces, which are the processes for nurturing the innovation. Analysis of nurturing is the most developed aspect of the strategic niche management literature. Nurturing consists of interacting processes for social learning, articulating technological expectations, and social network development. The niche

[1] It is important conceptually to see these measures as contributing to protective processes evolving over time, rather than seeing them as distinctive events that can be categorised as shields, nurture, or empowerment.

literature suggests that: (a) expectations contribute to successful technology development when they are robust (shared by many actors), specific, and of high quality (substantiated by ongoing projects); (b) social networks contribute when their membership is broad (plural perspectives) and deep (substantial resource commitments by members); and (c) learning processes are broad, covering issues on a variety of socio-technical dimensions, not only accumulating facts, data and first-order lessons, but also generating second-order learning about alternative ways of valuing and supporting the niche (Schot and Geels, 2008).

Nurturing processes develop iteratively across located socio-technical experiments and through an emerging institutional field at the 'global niche' level that is constituted by networks of intermediary actors, such as industry platforms, user-groups, policy bodies, business and NGOs, and others (Geels and Raven 2006; Geels and Deuten 2006).

2.3 Empowering

The way shielding and nurturing processes are complemented by empowerment of low-carbon technology advocates is least developed in the literature. Empowerment is recognised as an important feature (Jacobsson and Lauber 2006, Avelino and Rotmans 2009), though there remains some confusion as to the mechanisms through which an innovation becomes more competitive vis-à-vis the incumbent regime. Smith and Raven (2012) draw a conceptual distinction between 'fit-and-conform' empowerment and 'stretch-and-transform' empowerment. Empowerment consequently denotes two conceptually distinct developments of a niche innovation that, in practice, can be present simultaneously.

'Fit-and-conform' empowerment is defined as processes through which low-carbon technologies become "competitive with mainstream socio-technical practices in otherwise unchanged selection environments" (Smith and Raven, 2012: 1030). Fit-and-conform strategies involve advocates improving the socio-technical competitiveness of their technology along conventional regime lines. That is, it will perform profitably in existing markets, and does not require far-reaching changes to institutions, infrastructures, skills and knowledge bases, and so forth. It involves advocates demonstrating codified performance to audiences consisting of existing standards agencies, consultancies, industrial bodies, sponsoring government departments, institutional investors, and so forth. Technology advocates promoting fit-and-conform strategies try to convince these audiences on the basis of the same assessment criteria as those currently used by these audiences. Shielding measures are seen only as temporal, which will be removed after the development of the low-carbon technology has converged with price-performance levels of the incumbent technologies.

In contrast, 'stretch-and-transform' empowerment is defined as processes through which mainstream selection environments are changed in ways that make them more amenable for the niche innovation. Stretch-and-transform empowerment seeks to reframe the rules of the game, and reform institutions that influence prevailing performance criteria. Shielding measures will come to be seen as new norms for sustainability, for example, and the kinds of criteria that count will become more aligned with the advocated technology. An example of this is to evaluate electricity-generating technologies not just according to costs per KWh produced, but also based on the associated emissions of each KWh produced. The audience for this kind of work is more likely to operate in opinion forming arenas in civil society, politics and business (Smith & Raven, 2012: 1033).

Technology advocacy of a stretch-and-transform kind not only requires narratives to be persuasive to these wider audiences (Hajer and Versteeg, 2005). Technology advocates also need to be politically powerful to stretch-and-transform regime-structures, and this power rests on resource attributes, experience, institutional positions, and connections with other influential actors (Cheon and Urpelainen, 2013). Stretch-and-transform empowerment is more difficult than fit-and-conform, because "(…) acceptance (…) is more likely when the innovation is perceived to meet the goals that are consonant with already widely accepted goals (Johnson et al., 2006: 72). As such, we propose that:

P2: Fit-and-conform strategies are more prevalent than stretch-and-transform strategies.

2.4 The socio-political empowering of low-carbon technology advocates

Conceptualising protective spaces in the form of shielding, nurturing and empowering relates niches to the evolutionary requirements of a developing low-carbon technology (variation, selection and retention). However, these features, if they arise at all, are shaped by technology advocates attempting to construct supportive actor networks and mobilise institutional and infrastructural opportunities (Phillips et al., 2004). Smith and Raven suggest that for empowerment in particular, narrative work and networking undertaken by technology advocates is central. Networks are built and institutional opportunities for empowerment developed through arguments about the past performance of the technology, the current realities, and future improvement possibilities.

These narratives need not only portray technological performance as positive, but also make sense of the technological implications in relation to broader social, political and economic agendas (Geels and Verhees, 2011). Successful narratives bridge positive expectations about the technology, drawing upon inward-oriented nurturing work, with outward-oriented problematisations of incumbent regimes and identification of institutional opportunities. These outward-oriented, socio-political narratives are directed, for example, to arguments about the employment and potential industrial opportunities of the technology, or how it can address carbon emissions or energy security concerns (Garud and Gehman, 2012; Smith & Raven, 2012: 1032; Benford and Snow, 2000).

As such narratives are strategic devices for technology advocates that gain legitimacy only when they succeed in framing the developing technologies as solutions to specific regime problematisations (Jensen, 2012). Often those who need to be enrolled are not directly or deeply involved in the actor networks developing the low-carbon technology, nor are they particularly interested in their details (Law and Callon, 1994). Yet often these actors have incumbent regime positions with decisive control over institutional and infrastructural adjustments necessary for stretch-and-transform empowerment. So there is work to be done in committing them, which often involves contestation and conflict (Jorgensen, 2012), as well as finding mutual ground for aligning diverse interests behind the technology in order to change the regime selection environment.

The ability to craft credible and valid narratives about the technology in terms meaningful to powerful socio-political actors and their agendas, increases the technology's legitimacy in the eyes of those actors, and thereby the chances of changing regime selection environments in ways beneficial to the niche innovation (Suchman, 1995). This leads us to the following proposition.

P3: To achieve empowerment technology advocates will attempt to link socio-technical narratives to prominent socio-political agendas.

In the following section we will discuss the methodological approach taken in this paper.

3. Methodology

One of the methodological weaknesses of the sustainability transitions field is the high reliance on single technology, single country case studies (Geels, 2011). This paper has adopted a different approach, namely a meta-analysis, which utilises six case studies in two countries in order to confront our propositions with empirical evidence and thereby contribute to the further development of the conceptualisation of 'protective space' in a systematic and empirically validated way. Meta-analyses are often used to synthesise insights across a variety of quantitative studies in fields like medicine, education and psychology (Borenstein et al. 2011), but its main logic can also be applied to qualitative work (Weed, 2005): namely that single (case) studies taken in isolation can be misleading and therefore a systematic approach to synthesise insights is desirable (Petticrew and Roberts 2008).

Our aim is to confront the three propositions with the six cases, thereby offering systematic and empirically-based insights into creating, maintaining and expanding protective space. Our approach follows Eisenhardt's (1989) suggestion of finding generic patterns and mechanisms by constantly comparing the data and theoretical constructs articulated in the propositions in an iterative process. Table 1 shows the key theoretical concepts, their definitions and examples of the kind of evidence used.

Table 1. Operationalisation of key-concepts

Concept	Definition	Examples
Technology advocates	Individuals and organisations who speak or write in favor of the development and/or deployment of a technology.	Developers of the technology, industry platforms and other lobby organisations, consumer representatives and other intermediaries, supportive regulators and political representatives, environmental NGOs, academics and other knowledge actors in favor of the technology

Passive spaces	Generic sites for technology development that pre-exist deliberate mobilisation by advocates of specific innovations, but who exploit the shielding opportunities they provide.	Geographical locations such as off-grid settings, existing market segment such as environmentally concerned consumers, generic institutional arrangements such as R&D facilities
Active spaces	Specific sites for technology development, which are the result of deliberate and strategic creation by advocates of specific innovations to shield regime selection pressures.	Technology-specific policies such as investment subsidies or private initiatives such as technology-specific incubator programs or collective buying cooperatives
Fit-and-conform strategies	Actions from technology advocates aimed at making low-carbon technologies more competitive with mainstream socio-technical practices in otherwise unchanged selection environments.	R&D efforts or public policies targeting lower costs and performance improvements
Stretch-and-transform strategies	Actions from technology advocates aimed at changing mainstream selection environments in ways that more amenable for the niche innovation.	Public or private institutional reforms such as changes in regulatory frameworks or organizational networks, infrastructural changes
Socio-technical narratives	Stories about the past, present and future performance of a technology	Entrepreneurial articulations of benefits and implications of the technology, media exposures, political statements about the technology
Socio-political agendas	A set of social issues, their relative priority and associated supportive policies that are prominent in a specific temporal and spatial context	Articulations of ‘what matters’ in political party documentations or in speeches of leading public figures, in prominent media debates, etc

We position our research design and use of propositions within the interpretive social science tradition (Stake, 2010). Propositions are not used for articulating causal relationships between dependent and independent variables, but to provide guidance for the researchers to collect and explore data, and shape meaning about processes and patterns found across cases. Propositions are thus part of the theoretical perspective, a way to refine the research question and a focal instrument to the researcher, rather than statements that will be tested, falsified or verified. In sustainability transitions research, propositions have been used in similar ways by for instance Geels and Schot (2007). As such, in the results section, we explore how the cases speak to the propositions in qualitative ways. In the concluding section we develop an interpretation of how the evidence compares to each proposition across all six cases.

Technology-based cases were selected on the basis of maximum variation (Flyvbjerg 2006), but within a similar regime-context, which is to say we chose technologies whose characteristics differed markedly from each other, generating a rich variety of empirical information such that any patterns emerging across that variety suggest generic features of protective space (see table 2). We reflect in the discussion on the limitations of choosing cases within the same empirical domain.

Table 2. Variety of case study technologies

	CCS	**Offshore wind**	**Photovoltaics**
Principal technology advocates	Government, oil and gas sector, international organisations like IEA, utilities.	Some energy companies, utilities, government, equipment manufacturers, and Environmental NGOs.	New energy SMEs, green consumer-producers, Environmental NGOs, government.
Form of technology / niche-regime relation	End-of-pipe treatment of centralised fossil fuel electricity generation, close to prevailing regime	Medium scale (several 100MWs), intermittent supply to the grid, niche-regime hybrid	Micro-scale, intermittent supply to households and local networks, also MW scale solar farms, potentially disruptive to prevailing regime
Status of technology	Basic building blocks tested or in	Several large commercial	Diffusing rapidly, but from a very small base.

	commercial application already (e.g. stripping CO_2 from natural gas); Some pilots but very few to no larger integrated demonstration projects in the UK and NL so far. No real commitments to large-scale, commercial projects.	developments in operation; many more planned and currently being built in the UK.

A key criterion for selecting these cases is their relative 'distance' to the existing electricity regime, i.e. the necessary adaptations in the electricity regime for empowering these technologies is *potentially* largest for solar-PV. CCS arguably requires the least far-reaching changes, whilst offshore wind energy is in the middle. However, it should be noted that there may be substantial diversity in the actual socio-technical forms that materialise through long-term niche developments. Solar-PV may materialise as a roof-top, community-owned energy technology shaping substantial changes in energy markets and infrastructures, but it can also come in the form of utility-owned, large scale 'solar farms'. CCS, on the other hand, was not understood initially by its technology advocates to be very disruptive to the incumbent electricity regime (rather as an end-of-pipe technology leaving intact most of the existing infrastructures, institutions and actor constellations), but as we will show in our analysis CCS turned out to be more disruptive in terms of the required knowledge-base and cultural acceptance. The disruptiveness of these technologies needs to be assessed through analysis rather than assumed from the beginning as the ongoing socio-technical configuring shapes the relative distance or disruptiveness vis a vis the regime, as seen in the PV example above.

Each of the case studies used for this meta-analysis was conducted by the authors of this paper and followed the same methodology. A longitudinal, qualitative case study approach was used that allowed us to reconstruct the processes of development of each technology (Yin 1994, George and Bennett 2005). The case studies gathered evidence from documentary sources (policy and stakeholder documents, other grey literature, news articles, company announcements, existing academic literature, etc), data on deployment, R&D funding, pilot or demonstration schemes, and semi-structured interviews with stakeholders involved in the development of the technology (drawn from academia, policy makers, firms, green NGOs). All material gathered was coded for evidence of our preliminary concepts in our analytical framework. Detailed descriptions of individual case study methods and more detailed analysis of actor strategies and agency have been documented elsewhere (Verhees et al., 2013; Smith et al., 2014; Kern et al., 2014a).

Figure 1 shows the variety in terms of installed capacity: while in the 1990s Dutch deployment of PV and OSW was in the 10s of MW, with very little deployment of either in the UK, the second part of the figure shows that deployment of PV and OSW is now in the GW range. It is in the 100s of MW for both technologies in the NL. There are no large-scale, fully-integrated CCS plants in either country.

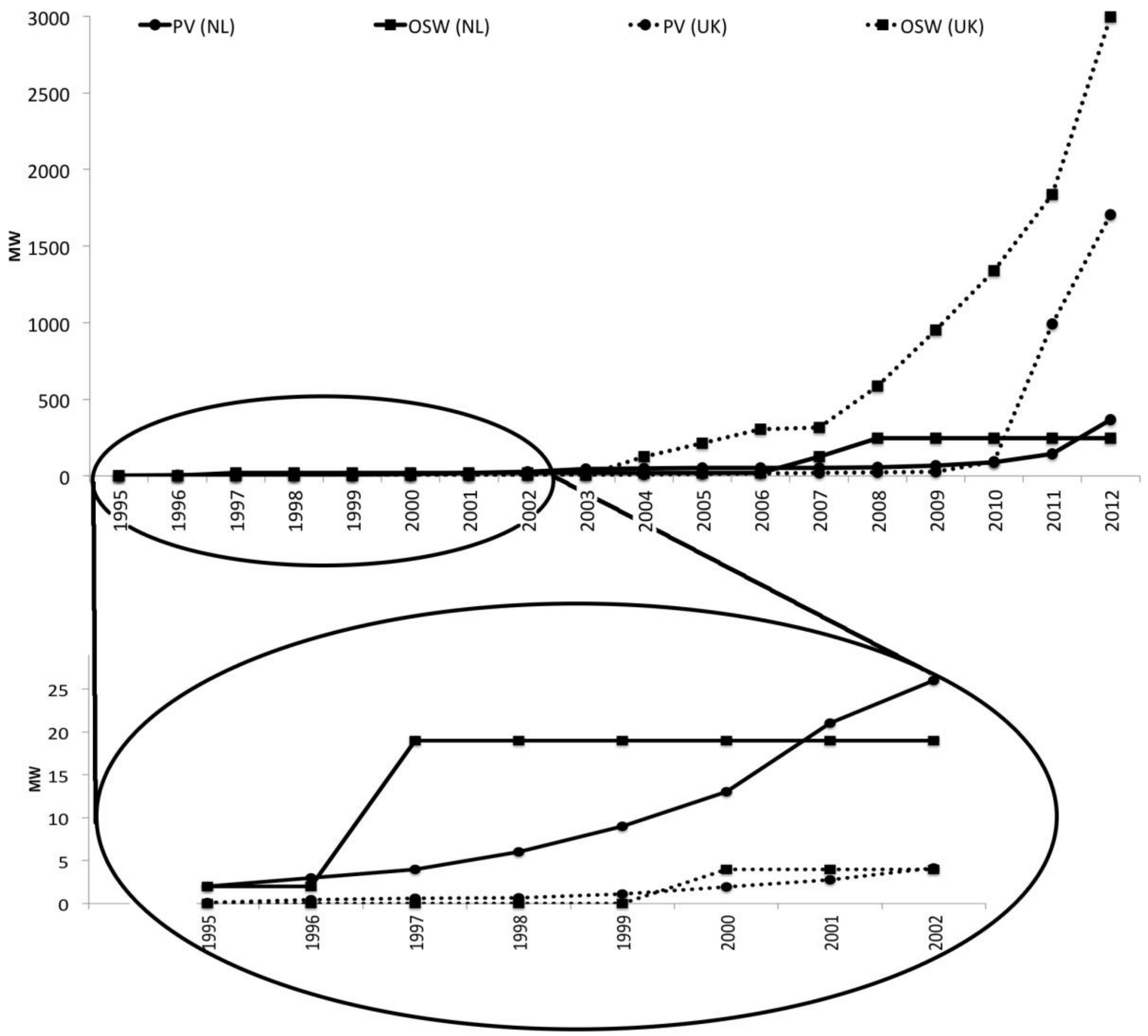

Figure 1. Total installed capacity of offshore wind and PV in the Netherlands and the UK (in MW). The top graph shows the deployment of PV and OSW in the Netherlands and the UK between 1995-2002. The bottom graph zooms in on the early years. Note that CCS is not covered in the graphs as there are no integrated CCS plants operating on a commercial scale power plant in either country. Sources: LORC Offshore Wind Farms List,DUKES, National Survey Report Photovoltaics, the Netherlands.

4. Analysis: confronting the propositions with empirical evidence

This section systematically confronts the propositions introduced in section 2 with the empirical evidence from the six case studies.

4.1 Proposition 1. Technology advocates initially use pre-existing passive spaces for technology development before strategically creating dedicated active spaces

Initially, in both countries solar PV was predominantly shielded passively: it was developed making use of pre-existing budgets in materials science (basic research) and the space sector (applied, as a power source for artificial satellites as part the 'Space Race'). For terrestrial applications, Dutch and UK PV advocates also sought out passive protection in the form of small commercial niche markets (such as low power needs in recreation vessels, buoys, etc.) and projects in the developing world or remote locations: a form of geographic shielding (as no grid connection was available in these locations). Once the latter proved successful, more active shielding was increasingly provided in both countries in the form of dedicated solar PV research programmes, funding for pilot and demonstration projects, and later subsidies to incentivise roll-out. Large energy companies like BP and Shell also took an interest in the technology at times and provided space for further developing PV (e.g. through setting up BP Solar in the 1980s) which created positive expectations about the future prospects for the technology among policy makers and other decision makers. Although the process was less linear than the proposition suggests (i.e. some active shielding in the early stages, some passive shielding in the later stages, and some degree of overlap in between) Dutch and UK PV developments clearly show a shifting *emphasis* from passive to active shielding.

Dutch OSW research goes back to the mid-1970s, at which time its advocates managed to secure some active shielding (of marginal scale) through energy research programmes, but their efforts were mostly ignored. Interest in OSW intensified as a result of societal controversies surrounding the planned roll-out of *onshore* wind in the early 1990s. The 'flight offshore' can thus be interpreted as an attempt to secure a passively protected space for wind power: a location where antagonistic residents could not delay or halt construction. However, from the late 1990s onward, active shielding was sought and found as well (e.g. the first large-scale pilot project was initiated and partially financed by the government; differentiated production subsidies with a relatively high rate for OSW were provided; new offshore rules and regulations were made to facilitate deployment).

In Dutch OSW development both passive and active shielding have clearly played prominent roles at various times. Although the process has been somewhat more complex than the purely sequential process ('from passive to active') suggested in the proposition (e.g. some minor active shielding has been present from the beginning, and passive protection continued to play a role), a shifting emphasis from passive to active can be detected.

Dynamics in the UK show a similar pattern: while there was initial interest in offshore wind in the 1970s, there was little to no earmarked research funding nor other active shielding until the mid-1990s/beginning of the 2000s. Similarly to UK PV developments, OSW advocates for a long time had to rely on generic, pre-existing passive spaces (e.g. generic research council funding; tax credits) and only the increased public interest in climate change mitigation, a need for rapid renewable energy deployment and the contestation of onshore wind developments provided a window of opportunity to obtain more active spaces.

Dutch and UK interest in CCS only emerged in the late 1990s and early 2000s. In the Netherlands, its development was mostly actively (rather than passively) shielded by the government in the form of dedicated CCS programmes (e.g. CRUST, CATO), earmarking clean energy budgets specifically for CCS development (e.g. the Borssele covenant), and subsidising pilot projects. Currently, with the technology's socio-political legitimacy being very low, its advocates are attempting to move storage offshore. While offshore locations to some extent provide passive shielding (e.g. absence of the forms of local protests which scuttled several onshore pilot projects), advocates are seeking out new sources of active shielding to finance such projects (e.g. funds from the European NER300). The near-complete emphasis on active shielding seems to indicate that the proposition does not hold for Dutch CCS development. The same is also true for UK CCS developments. While there was some pre-existing legacy of clean coal programmes and a unit within government responsible for them (shaping the government's early thinking about CCS), the technical, political and social issues with CCS are quite distinct from the technologies covered by these earlier programmes, which meant that advocates from the beginning were trying to obtain CCS-specific active spaces. They were successful in this endeavour (as evidenced by the setting up of initiatives like dedicated CCS research networks, providing pilot and demonstration project funding, R&D investments, incentives for deployment through the Electricity Market Reform, cost reduction taskforce, etc).

In sum, in most of the cases technology advocates have made use of pre-existing passive spaces initially, and early attempts to create more active spaces failed, whilst they managed more successfully to create active spaces for furthering the development of their technology in later stages. CCS, however is - within our limited case study selection - a notable exception in both countries, where much of the shielding has been of active forms from the beginning.

In sum, compared with case study evidence, the original proposition is ambiguous and needs to be nuanced: the relationship is much less linear than the proposition suggests. Analysis of the CCS cases suggests that some technology advocates are able to create active shielding very early on. This might be the case because of strong international support for CCS (e.g. through the IPCC special report, G8, and IEA) as well as support by powerful incumbents (see P3 below).

4.2 Proposition 2. Fit-and-conform strategies are more prevalent than stretch-and-transform strategies.

During the development of Dutch solar PV advocates have mostly implemented fit-and-conform strategies aimed at enabling solar PV to compete with mainstream electricity generation technologies after shielding is removed. In the mid-1970s, they only spoke of PV in terms of the dominant electricity generation paradigm (large-scale centralised) but because it failed this comparison on price, advocates searched for new passive spaces (e.g. autonomous systems in the developing world where PV was argued to be an economically and technically viable alternative for diesel generators). When the successes of these projects changed the government's opinion about PV in the late 1980s, advocates started articulating the expectation that price drops and efficiency improvements would render PV competitive. In The Netherlands as well, a similar fit and conform view was prominent in the 1990s. There is also some evidence of stretch-and-transform strategies such as opening up tax proceeds for subsidising PV purchase, but most were terminated in the early 2000s (Verhees, Raven et al. 2013). Only recently, PV has started to witness more intensive growth in the Netherlands, mostly constituted by a new cooperative movement and a number of successful collective buying initiatives. Most of these initiatives still occur within unchanged selection environments, but it is increasingly recognised that the future perspective of this movement depends on stretching and transforming institutional contexts, e.g. by allowing cooperatives to become real producers rather than a collective customer for existing energy utilities, or allowing PV owners to place panels on roofs they do not own. Such changes have been promoted by PV advocates in the context of the 2013 national Energy Agreement. However, it still has to be seen how this agreement will play out in practice.

UK PV patterns are relatively similar. Especially from the 1970s to the 1990s, many technology assessments by governments and incumbents constantly compared PV in techno-economic terms to conventional generation which PV of course failed. Off-grid applications were promoted as niches where PV was already or could become competitive. Also later on PV advocates mostly focused on arguing for policy measures to help PV achieve 'grid-parity' with conventional generation and the debate was mostly about when such a point could be reached. In terms of stretch-and-transform strategies advocates argued for and achieved minor institutional changes such as making retrofitting PV an allowed development not requiring planning permission and the introduction of a FIT for small-scale generation including PV, and which enabled some deployment. However, also this policy was conceived of as a temporary fix to help PV become competitive in an otherwise unchanged (electricity) selection environment. Attempts by PV advocates to reframe building-integrated PV as a building material that also produces electricity and to integrate it into normal housing developments (i.e. changing the building regime) were unsuccessful.

In the development of Dutch OSW, advocates have largely employed fit-and-conform strategies as well, e.g. arguing that OSW will be competitive under conventional criteria and that no radical changes to current electricity systems are required for offshore wind to 'work'. Studies concluded that 'fitting' the target of 6000 MW of offshore wind capacity into the existing grid would not be prohibitively expensive. The sector's framing of government support as temporary resulted in a step-wise, 'no-regrets' approach to subsidising the implementation of the 6000 MW target, which could be halted if costs would not go down sufficiently. This occurred in 2010 when the government decided to support roll-out only for the cheapest renewable technologies – removing OSW from the scheme. Subsequently, OSW advocates successfully lobbied for the inclusion of OSW in a new innovation policy paradigm (i.e. government facilitation of industry initiatives in pre-defined 'top sectors'). The OSW sector promised to focus on cost-reducing innovations in return for government support. Attempts to materialise stretch-and-transform strategies were unsuccessful (e.g. the choice of licensing OSW farms on a first-come-first-served basis proliferated above a more encompassing institutional reform based on a concession system). Hence, costs rather than broader sustainability criteria determined the fate of Dutch OSW.

In the UK OSW advocates employed both fit-and-conform and stretch-and-transform strategies. OSW has been pushed as a large-scale, low carbon technology which fits well into the existing electricity system but is currently too expensive and therefore requires temporary protection. However, alongside financial support for R&D, testing infrastructure and pilot projects to make the technology more competitive, a coalition of large business actors, public bodies and policy makers were successful in significantly shaping the selection environment to make it more amenable to OSW. This includes the Electricity Market Reform which changes the selection environment for new investment in generation capacity in favour of low carbon technologies, a change of rules implemented under the EU Third Energy Package which allowed the 'generator-build option'[2] addressing industry concerns, and altering planning rules to make it easier for developers to obtain consent. Also in terms of assessment criteria, OSW is no longer required to become competitive with conventional generation but the government talks about a 'low carbon technology race' in which OSW needs to become competitive with other low carbon technologies such as nuclear and carbon capture and storage. These examples show that powerful technology advocacy can successfully adopt a stretch-and-transform strategy to achieve significant changes in the selection environment.

Dutch CCS advocates have mostly pursued fit-and-conform strategies as well. Advocates argued that CCS was a proven technology (in the oil sector) that would be competitive under conventional economic criteria because of knowledge spill-overs from other sectors and the presence of depleted gas fields. Moreover, no radical changes to the existing system would be required: CCS would be an end-of-pipe solution. These fit-and-conform narratives resonated politically. Although the government initially (~2003) saw CCS as a 'backup plan' which would not be essential for meeting Kyoto obligations, it quickly (~2005) came to be seen as a necessary bridge to a renewable energy system, and later (~2010) as inevitable for achieving post-2020 emissions objectives. Nevertheless, this political support has so far not resulted in deployment, as pilot projects became heavily contested at the local level. Counter-narratives employed framed CCS as producing unknown environmental risks

[2] Under this model, the OSW developers build the transmission infrastructure as part of the overall project and then sell off the asset once the OSW farm is up and running.

(instead of addressing known ones), as uneconomical (because of high infrastructure costs and indefinite monitoring), and as blocking renewables (instead of bridging to them). By successfully *attacking* the fit-and-conform essence of the pro-CCS narrative arguing that CCS would require stretch-and-transform of the existing electricity system, CCS became politically less attractive.

In the UK CCS advocates mainly utilised fit-and-conform strategies, too. The most commonly used argument in favour of CCS is that for climate change reasons there is no alternative to using it because of the necessity of the continued use of fossil fuels for energy security and cost reasons. In this logic CCS fits well into the existing fossil fuel based, centralised electricity infrastructure so no radical change is required. However, like in the Netherlands this fit with the existing systems is also a liability politically with the public and NGOs who are not keen on CCS as part of an energy transition. The legitimacy of CCS rests on achieving cost reductions and there is a variety of government initiatives to foster these (e.g. cost reduction taskforce; £125m CCS innovation programme). Advocates promote the narrative that CCS will be competitive with other low carbon technologies by the early 2020s. However, there are also significant attempts at stretching and transforming existing selection environments. The Electricity Market Reform is a significant shift in the institutional framework of the utility industry, which is meant to incentivise CCS investment (alongside nuclear and OSW). Also internationally there have been important rules changes which UK CCS advocates have lobbied for and tried to shape so that they enable CCS deployment such as the EU CO_2 storage directive (to provide clarity on and limit liabilities) and the change of the London Convention (to allow sub-seabed storage of CO2).

Overall, in relation to the proposition we conclude that we observe attempts at both strategies for all cases, but also find that fit-and-conform strategies enrol establiashed interests more easily. We argue that this is because fit-and-conform is likely to be the more strategic choice by niche advocates when convincing powerful actors to provide the niche with the necessary resources whereas stretch-and-transform requires political power to re-frame dominant assessment criteria and to institutionalise new rules. The UK OSW case shows how a coalition of influential actors was actively supporting OSW and successfully pursued both fit-and-conform and stretch-and-transform strategies which led to a rapid growth of the niche.

4.3 Proposition 3. To achieve empowerment technology advocates will attempt to link socio-technical narratives to prominent socio-political agendas.

Empirical evidence shows that in all cases, advocates have attempted to secure resources by constructing narratives that link 'their' preferred technologies to broader socio-political agendas, and 'performing' these before an 'audience' of resource controllers. All technologies in both countries have been linked to agendas around energy security, climate change mitigation and job creation through narratives that articulate how the technologies will contribute to these socio-political goals. However, the cases also show that a narrative which resonates with broader agendas does not always result in the mobilisation of significant resources. In all cases, we see that success or failure also depends on the composition of the networks articulating the (same) narratives, i.e. not just 'what is said', but also 'who is saying it'.

Narrative resonance

In the case of UK OSW, narratives were created that resonated well with the government's wider agenda of re-balancing the economy away from finance towards manufacturing sectors, building on existing offshore-engineering skills and the prospects of attracting large-scale inward investments (in this case by international turbine manufacturers) which would boost job creation and economic growth in a recession. In the Dutch OSW case, too, advocates' narratives have shifted around 2010 to emphasize the sector's job potential in response to the government's more market-oriented policy style and its withdrawal of support for OWS, which it (at that point in time) viewed primarily as a 'too expensive emissions mitigation option'.

But whereas offshore wind ticks all the boxes in terms of aligning socio-technical narratives with wider socio-political agendas (climate change mitigation, renewable energy targets, and jobs), it is more difficult to make such a case to the same extent for CCS. Both in the UK and The Netherlands, supportive narratives for CCS refer to preserving existing jobs in the fossil fuel industry and portray the technology as a central contribution to climate change targets given the continued reliance on fossil fuels, but obviously CCS does not help either nation's government in achieving the EU 2020 renewable energy targets – unless CCS would become seen as a renewable energy technology much like organic waste was re-framed as a renewable energy source in the mid 1990s (Raven and Verbong, 2007).

Also for PV, both in the UK and in The Netherlands, advocates proved capable of articulating plural narratives in flexible ways appropriate to circumstance and audience. Over a 40 year period they had to interpret shifting energy (policy) contexts and represent PV in favourable terms, such as providing solutions to new policy priorities, e.g. as an alternative form of energy after the oil crisis in the 1970s or as a solution to climate change from the mid-1990s onwards. Nevertheless, certainly in the UK case, resonance of pro-PV narratives with wider socio-political agendas was lower than it was for OSW. Given the high costs of PV compared to conventional electricity, narratives about job creation have long been used to promote the technology (like OSW) but mostly with very limited results (unlike OSW). One reason is that the majority of jobs created from a PV roll-out mainly concerns installation rather than manufacturing jobs as PV modules are traded globally and are now mainly manufactured in China[3] – which does not have the same appeal to policy makers compared to the promise of turbine factories located in deprived areas in the North of England and Scotland in the case of OSW.

Enrolling powerful actors

The Dutch PV case shows that enrolling powerful actors into these narratives is crucial as well. Although over time the PV narrative in The Netherlands has been quite flexible, it did not change significantly between the early 1970s and late 1980s, at which point the Dutch government nevertheless suddenly ‘switched’ to a view of solar PV as a realistic option. This was in large part due to the fact that several early PV advocates had risen into influential positions by then, and that Shell had entered the solar PV sector, as many of its foreign competitors had done (Verbong et al, 2001). Recent developments in the Dutch OSW case show a similar dynamic: while its advocates have created a compelling narrative about the sectors job potential, the fact that this narrative was articulated by a consortium that included some very large offshore construction contractors and energy companies was a key factor in the recent uptake of offshore wind into the Dutch top sector policy (a policy

[3] Even in the earlier period when Sharp started to produce solar modules in the UK in 2004, most of the modules were exported to Germany and Spain as the domestic market was very small because of the absence of deployment incentives. Solar advocates struggled to gain acceptance of the claim of job benefits in the UK because policy at the time was still very much focused on ‘cheapest mitigation’ technologies and market driven policy frameworks (Kern, Kuzemko et al. 2013).

paradigm initiated by a government that had previously withdrawn support for OSW rollout).

Also in the UK OSW case, we see that after smaller and less powerful actors struggled for years to mobilise resources (mainly small, engineering-based companies), this only became successful in the mid-2000s when OSW became a joint project of a variety of powerful actors who each came to see OSW as being in their interest, including turbine manufacturers, utilities, energy companies and large institutional investors. But most notably is the role of a mandate to the Crown Estate to develop profitable investments for the seabed. The Crown Estate has taken up this role in a very pro-active manner bringing together different actors along the value chain by creating industry platforms, and though orchestrating the development of OSW parks; without either, little development would have taken place. We argue that it was the resonance with wider socio-political agendas *and* the powerful advocacy behind these narratives that led to the UK becoming the world leader in OSW deployment.

In the Dutch CCS case the composition of the network articulating narratives (and counter-narratives) proved decisive as well. The technology was pushed mainly by the national government and the oil sector, but lacked support from electricity utilities and environmental NGOs. Local authorities opposed a large onshore demonstration project, successfully enrolled local citizens and eventually regional authorities into a network of opposition, and voted against the project. Although initially overruled by the national government, a subsequent media controversy called into question the societal legitimacy of the technology, which led to the government's decision to abandon first the demonstration project and later the whole concept of onshore CCS for lack of societal support.

In the UK, CCS is supported by a more diverse network of actors from the oil and gas industry, utilities, the UK CCS Association, equipment manufacturers and technology providers, networks of academics, and public sector organisations. Nevertheless, implementation has been slow in the UK as well: despite government support, utilities have so far refrained from committing substantial resources to building large-scale integrated demonstration projects. This poses political legitimacy problems (rather than societal legitimacy problems as in The Netherlands), undermines narratives about the UK being a world leader in CCS, and might eventually affect the availability of resources for further niche development.

Overall, in relation to the proposition we conclude that whilst evidence clearly shows that advocates indeed articulate socio-technical narratives in relation to socio-political agendas, we suggest an important additional qualification. Successful strategic alignment of socio-technical narratives with prominent socio-political agendas depends on the composition of the technology advocacy network.

5. Conclusions

This article contributes to the socio-technical transitions literature by building on the concept of protective spaces and shedding light specifically on the dynamics of the advocacy of low-carbon technology advocates. Our research question was: How do technology advocates attempt to create, maintain and expand protective space for developing their technologies? This question has been answered by reviewing three propositions against evidence from six cases. Our meta-analysis finds the propositions relevant to an emerging theory of protective space, but requiring finer nuance and further development (see Table 3).

Table 3. Interpretation of case study evidence in relation to the three propositions

Proposition	**PV, NL**	**PV, UK**	**OSW, NL**	**OSW, UK**	**CCS, NL**	**CCS, UK**
P1. Technology advocates initially use pre-existing passive spaces for technology development before strategically creating dedicated active spaces.	Cases suggest a more complex dynamic: less linear than suggested by the proposition				Cases suggest a different dynamic than articulated in the proposition: substantial active protection in early phases	
P2. Fit-and-conform strategies are more prevalent than stretch-and-transform strategies.	Cases provide support for the proposition			Case suggests a more complex dynamic: substantial presence of stretch-and-transform	Cases provide support for the proposition	

P3. To achieve empowerment technology advocates will attempt to link socio-technical narratives to prominent socio-political agendas.	Cases suggests a more complex dynamic: the cases demonstrate the additional importance of the composition of the actor network articulating the narratives

The cases suggest that proposition 1 needs reconsideration. The PV and OSW cases demonstrate a shifting emphasis from passive to active shielding, but the relationship is less linear than suggested by this proposition (some active shielding in the beginning, some passive shielding in later stages). The CCS cases even suggest an opposite pattern as articulated in the proposition, i.e. CCS was actively shielded from its inception. Notably, in the Netherlands, social struggles in later phases pushed CCS back into more passive shielding, resulting in a 'move offshore', and demonstrating the opposite development as suggested by the proposition. It seems the mobilisation of passive and construction of active spaces follows a much more non-linear pattern, which is dependent on broader levels of social and political legitimacy (see proposition 3).

In relation to proposition 2, we conclude that whilst evidence reveals attempts to stretch-and-transform throughout the entire case study periods, fit-and-conform has been the dominant narrative. A notable acceptation is the UK OSW case. UK OSW advocates employed both fit-and-conform and stretch-and-transform strategies equally. Interestingly, this was the case in which deployment rates have been largest, which suggests that empowerment of niche innovations cannot occur without stretch-and-transform strategies – a finding that echoes some of the findings of earlier niche-studies (Hoogma et al., 2002). Nevertheless, the UK CCS case has demonstrated that although the basic legitimacy of CCS rests on achieving fit-and-conform cost reductions, arguably there have been significant attempts to stretch-and-transform as well, but without leading to substantial deployment. The Dutch CCS case suggests a key-mechanism in the complex relationships between narratives and successful deployment. While our methodology mostly focussed on narratives of technology advocates, the Dutch CCS case shows how anti-narratives successfully attacked the fit-and-conform nature of CCS arguing that CCS would require stretch-and-transform of the existing electricity system, making CCS politically less attractive. We suggest that the interplay between narratives and anti-narratives deserves more attention in future research.

Our research has further nuanced proposition 3. Case study evidence suggests a more complex relationship between socio-technical narratives and socio-political agendas. Notably, in all cases we found narratives emphasising similar claims such as benefits for the climate, jobs, energy security, national industrial and export opportunities, and technological efficiency improvements leading to future cost reductions. It is striking just how similar these narratives are across cases and countries. Moreover, our cases suggest success or failure also depends on the composition of the networks articulating these narratives, in particular the participation of legitimate actors (as in the eyes of the resource providers) is suggested to be critically important.

We also note the following methodological limitation. All cases are from the energy domain and only two jurisdictions, which suggest one should be careful about generalisation to other empirical fields. Arguably the energy domain has some specific features. Energy is in most countries a key topic of national policy interests, because disruptions in energy provision can have major social consequences. For example, public actors often own technical networks, which are core to the operation of the system. In many countries, such as in the Netherlands, energy provision makes a major contribution to the national treasury. These features suggest that changing energy systems inherently requires substantial infrastructural, institutional and policy reforms, which makes it a case-in-point for studying socio-political work of technology advocates, but essentially limits its generalizability to empirical fields with substantially different features. Future research could investigate protective space dynamics in other empirical fields and different jurisdictions.

Although our immediate conclusions are about the three propositions, the broader aim of this paper was to investigate technology advocacy in making, maintaining and removing protective space. Although we were not able to produce a definite solution to this issue, we argue that our findings nevertheless have important implications, especially for niche-based transition approaches such as strategic niche management. Our findings highlight the importance of broadening the framework's analytical focus from the three niche-internal processes around the development of expectations, actor networks and social learning processes that nurture technological development within those spaces, to include those more *outward-oriented* processes by which the spaces in which such nurturing occurs are constructed in the first place and how they are deconstructed (if at all). By broadening the scope from 'nurturing' to 'shielding, nurturing and empowering', and being more sensitive to the socio-political strategies of technology advocates, we believe we have contributed to the emergence of a more comprehensive understanding of niche development patterns.

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