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The sun also rises in Norway. Solar scientists as transition actors

Abstract

This study contributes to transition studies through an empirical analysis of scientists at the Norwegian Research Center for Solar Cell Technology. From a policy perspective, this research center is a concrete undertaking within transitions politics. How do solar energy scientists make sense of this mission and what strategies do they adopt? The analysis adopts a bottom-up perspective focusing on the politics involved in actor-networks constructing and empowering sustainable innovations. I suggest the micro/macro divide characterising transition studies may be discarded, if we recognize that actors operate both on niche, regime, and landscape level. Instead of presuming a multi-level perspective, transition studies could analyse the multi-actor politics of translations in arenas of development. Adopting this approach, I argue that solar scientists pursue mainly two lines of activities: improving efficiency (translations to fit and conform) and challenging negative hegemonic representations of solar energy (translations to stretch and transform).

1 Introduction

To mitigate climate change and to meet future energy demand, many countries adopted policies to stimulate sustainable energy transitions. Despite its renewable hydropower, oil-producing Norway was no exception. This shaped Norwegian policy approaches to renewable energy technologies (Sørensen, 2007; Karlstrøm & Ryghaug, 2014). For example, a central rationale behind much of the Norwegian policy for new renewables was that climate policy also should be economic policy (Regjeringen, 2011; Karlstrøm, 2012). Consequently, research and technology development (R&D) featured prominently in Norwegian climate policy. For example, the Norwegian climate strategy included an effort to increase spending on sustainable energy research by NOK 600 million (ca. 75 million Euros) in 2008-2010

(Meld. St. 21, 2012:183). Much of this money funded the establishment of eleven Centres for Environment-friendly Energy Research (CEERs) with the goal of developing new Norwegian industry. This fits well with the international tendency to complement climate political instruments, such as quotas and fees, with technology development so that climate policy becomes innovation policy (Kasa, 2011). Indeed, the arrival of the transition idea on a policy level often parallels a renewed interest in mission-oriented, state-led innovation policy (Steward, 2012:333).

Thus, the establishment of the CEERs can be interpreted as a concrete undertaking within transition politics. The research communities were endowed with the mandate to play a role as transition actors. In this paper, I analyse how one CEER, the Norwegian Research Center for Solar Cell Technology (hereafter FME Sol),[1] enacted this mission. FME Sol aimed to gather the major research groups and companies in the field of Norwegian solar cell technology to develop internationally ranking competence, to promote the Norwegian solar industry and to help make solar energy a significant source of renewable energy (FME Sol, 2009:3)—in other words, clearly combine climate policy and industry development.

FME Sol lends itself to study what Genus and Coles call the 'complexity and ambivalence of the messy reality of case studies of transition' (Genus & Coles, 2008:1442). Not least because the country has a cold climate and little winter sunlight, solar energy highlights the paradoxes of Norwegian renewable energy politics. R&D was funded, whereas no public funds were directed toward increasing public deployment of photovoltaic (PV) technology. While it had been difficult to include solar energy in the country's energy mix, Norway actually had a strong export-oriented solar industry until 2007/2008. That Norway hosted a globally lucrative PV industry without a home market was in itself puzzling, and significant research attempted to explain this phenomenon (Hanson 2008; Klitkou & Coenen, 2013; Klitkou & Godoe, 2013; Koesah, 2013; Ruud & Larsen, 2006). Since 2007, however, the Norwegian solar industry has been severely troubled.

Key questions, then, are how solar energy scientists made sense of their work in this challenging situation and what strategies they adopted in their work as transition actors. To answer these questions, I conducted a series of in-depth interviews with 17 solar energy scientists with diverse disciplinary backgrounds. My research adds to transition studies that demand a more detailed analysis of actors, to account for strategies and collective sense-making activities in the construction of sustainable niches (Farla et al., 2012; Smith & Raven, 2012; Verhees et al., 2013; Jørgensen, 2012). In general, transition scholarship's interest in the solar energy quandary has recently surged (Klitkou & Coenen, 2013; Klitkou & Godoe, 2013; Moosavian et al., 2013; Choi & Anadón, 2013; Liu & Shiroyama, 2013; Dewald & Truffer, 2012). Many of these papers analyse the success of PV policies, accounting for factors such as regional differences, network formations, and infrastructure issues. My work complements this literature with an empirical study of the role and forms of agency of scientists. If transition management—as a kind of reflective governance—wants to provide

[1] Since the Norwegian Research Center for Solar Cell Technology has no official English abbreviation, in the following I use the common Norwegian abbreviation, FME Sol.

navigational support to actors on how to reach sustainable transitions, we first must understand *existing* actor strategies.

2 What if levels would not direct the analysis?

How can we theorize research on solar technology within a transition context? Currently, the multilevel perspective (MLP) dominates transition literature. Originating in the works of Rip and Kemp (multilevel model of innovation) and of Schot and Geels (evolution and pathways), the MLP framework differentiates between three levels of transition—the sociotechnical landscape, the regime, and the niche (Geels 2002:1260f, Kemp & Loorbach, 2006:108; Voß et al., 2009:283). 'Landscape' refers to the "broader societal patterns and developments that provide structural gradients of possibility for socio-technical change" (Voß et al., 2009:283). Incumbent 'regimes' denote the hegemonic socio-technical set-up (ibid.) in terms of research, development, production, infrastructure, use, or regulation. 'Niche' signifies the protected space in which sustainable innovations can grow. Generally, the problem for sustainable innovations is that extant regimes too often are difficult to break through. This seems to be the case with solar energy; it must assert itself in a regime where other energy sources dominate. In the literature on MLP and strategic niche management, the argument is therefore that sustainable innovations need to develop in a protected space (Smith & Raven 2012)—a niche—that shields them from market pressures until they are strong enough to compete with existing energy sources. From a MLP perspective, the niche could thus be seen as an apt theoretical concept in the study of FME Sol.

As the name implies, transition studies are concerned with a *change* toward more sustainable development. Stability is ascribed to incumbent regimes that frame actors by forcing them into certain paths of development. Changes derive in this framework either from niche developments or from transformations at the landscape level (Jørgensen, 2012:996). Questions of how and when a niche becomes larger and more robust and how niches, regimes, and landscapes interact are therefore critical (Smith, 2007). Smith & Raven (2012) suggest that niches can promote transitions because processes of niche development fulfil three functions: shielding, nurturing, and empowering. The niche *shields* innovations against regime selection pressures; *nurtures* those innovations through strategies such as technical improvements, socio-technical expectations, or network building; and *empowers* innovation through the participation of niche-actors in the discursive politics concerning the potential of the niche. The last function of empowerment addresses a gap in transition studies: the ontology of the field has yet to account for the interaction of interpretations in the transition process, such as conflicts over definitions of current situations and future scenarios.

How do actors shield, nurture, and empower? This question implies setting aside the widely accepted idea of transition management studies that analysts should focus on systemic-level governing rather than on individual components of the regimes (Kemp & Loorbach 2006:109). Several recent papers express the need for more actor-oriented approaches to transition and for analytical perspectives that improve understanding discursive dynamics in transitions (Smith & Raven, 2012; Jørgensen, 2012; Farla et al., 2012; Smith, 2007; Raven et al., 2011; Späth & Rohracher, 2010). Though agency has always been present in MLP (Geels, 2011:29f), these recent calls for actor orientation might be understood as suggestions to refocus methodologically on actors and their transition practices. Smith and Raven 2012 is particular fruitful. They suggest adopting a bottom-up perspective on processes of niche development as "potentially emerging through the agency of advocates of a 'niche'" (Smith & Raven, 2012:1034). In a bottom-up perspective, analysts need to shift the focus to "the politics involved in actor-networks constructing, maintaining, and empowering contested protective spaces, with a particular focus on the role of narrative" (ibid.). In these politics, niches innovations can be nurtured to become competitive under conventional, incumbent regime terms—what Smith and Raven call for "fit and conform empowerment". Or, advocates of niches can engage in re-structuring mainstream selection environments favourable to the niche—what they call "stretch and transform empowerment" (ibid.:1030).

Smith and Raven's (2012) suggestions are an important step towards linking the regime and niche level—a step that could be taken even further concerning MLP's separation of levels. For example, who and what exerts pressure when "landscape developments exert pressure on regimes" (Geels 2011:32), and how does this happen? If "each 'level' refers to a heterogeneous configuration of elements" (ibid:26) in which macro is more stable than micro "in terms of number of actors and degrees of alignments between the elements" (ibid.), then why not also address landscapes and regimes from a bottom-up perspective? Immediately this raises methodological questions about where to start—if landscapes and regimes are addressed from the bottom up, these "macro-actors" suddenly might appear quite micro, of vast quantities, and difficult to a priori ascribe to one 'level' (Callon & Latour 1981).

Hence, if we recognize that actors operate also at the regime and landscape levels, refocusing on actors contributes to linking levels so that levels do not need to direct the analysis. The concept "arena of development" (Jørgensen & Sørensen, 2002; Jørgensen, 2012) allows for following actors without defining a priori what level they belong to, using a flat ontological and methodological approach. In arenas of development, "actors operate in networks that involve institutions, technologies, visions and practices" (Jørgensen, 2012:997). The boundaries of such arenas are in flux. I suggest adopting Smith and Raven's bottom-up perspective focusing on the politics of actor-networks in constructing or maintaining even bigger actor-networks. By following Jørgensen's arenas of development suggestion, the micro/macro divide characterising transition studies may be discarded. This is not to suggest that different sizes or inertia from regimes don't hinder sustainable solutions from catching on. Indeed, by solely focusing on the assembling of one actor network, actor-network theorists might spuriously disregard the continuous unfolding of other entangled actor-networks. My proposition is rather to vest less energy into keeping these levels *analytically* separate—for example, one can re-interpret niches as being flat. Instead of moving from one level to the other, the analysis then focuses on processes of growing in which micro-actors become macro-actors. How could one study these processes?

A key concept in actor-network theory (ANT; on which the concept of arena of development is based) is 'translations'. The concept is also used in transition studies (Smith, 2007; Raven et al., 2011). An ANT-perspective considers as a macro-actor those actor-networks that successfully have assembled other actors by translating their will into a single will for which they speak (Callon & Latour 1981). ANT studies generally find that the mere existence of methods or knowledge does not lead to anything, but that scientists must interest others in their enterprises in order to be successful. Research collectives as well as arenas of development thus meet similar challenges: they have to *enroll* others (consumers, ministries, industries, electricity suppliers, etc.) in their activities. *Translation* probably has an important function in shielding, nurturing, and empowering 'niches' or 'arenas of development'. It denotes the establishment of relationships between heterogeneous elements (Callon, 1986b:26, see also Law, 1999:8). The concept of translation is that, in assembling actors (e.g., persons, things, practices, ideas), the actor-network changes. Thus, a (trans)formation is taking place when something is translated, actor-networks are in constant development, and outcomes are uncertain.

According to Callon (1986a), translation encompasses four moments: *Problematization* denotes the process of defining the problem at hand and actors involved. During *interessement*, new actors are recruited to stabilize the problematization. In *enrolment*, allies define, accept and coordinate roles. *Mobilising* considers that some actors take on the role of spokespeople in order to make others do things. While Callon (1986a) suggests that these moments are successive steps, they seem to overlap to the extent that they rather should be seen as different shades of translation processes. Latour's (1987) typology, different from Callon's, exemplifies this. It focuses on translating interests that "means at once offering new interpretations of these interests and channelling people in different directions" (Latour, 1987:117). He distinguishes five ways of translating interests that each describe different persuasion strategies. Translation then is "the interpretation given by the fact-builders of their interests and that of the people they enrol" (Latour 1987:108).

By focusing on translations, the task of the analyst becomes shedding light on how associations that foster a transition to sustainable development are built (or not built). Which elements are important in these processes? How do solar scientists try to interest others in their work in order to assemble wider actor worlds? Grounding my decision to interview solar energy scientists in the actor orientation outlined here, I now describe methodological aspects of my study.

Method

A narrow focus on PV technology R&D in Norway is methodologically suited to a detailed study of the efforts of actor networks in arena development. Specifically, I analyse the dynamics of FME Sol by focusing on the "insider ontology" (Smith & Raven, 2012:1031), acknowledging that agency ultimately "results from sense-making advocates" (ibid.). As I was working on an integrated project with material scientists who were developing new materials for solar cells, my collaborators suggested most of the 20 interviewees I contacted in spring 2012. The interviews consisted of five blocks of questions: personal background and current project, innovation, transition strategies, risks, and public and media. Questions read as such: "What is your strategy to achieve that your research leads to innovation?" or "What do you think contributes to or hinders that solar energy becomes a major renewable energy resource?” Obviously, both questions directly refer back to the theoretical ideas of translation. Coincidentally, when the interviews took place in April 2012, one of the major Norwegian solar companies (REC) announced closure of all its manufacturing sites in Norway. This culminated a five-year economic crisis that caused solar panel prices to plummet, with inexpensive Chinese panels saturating the market, all topics raised by interviewees, some of whom had projects with REC.

Finally, the 17 semi-structured in-depth interviews were analysed, informed by a Grounded Theory approach, and coded using Atlas.ti software. Such analysis implies that sense-making is foregrounded, to emphasise respondents’ interpretations of their actions and of the events they have been involved in (Charmaz, 1990:1161). Although I conceptualised my study as being about arena development (which is operationalised by interviewing the scientists as actors within an arena of development), a grounded approach does not bring to the interview subjects and the research field an operationalised set of hypotheses about the research problem at hand. That is, while the formulation of research questions is theory-guided (exploring strategies of actors), such research approaches proceeds in a constant alternating between qualitative induction and abductive reasoning (Reichertz, 2007).

During coding, I determined which qualitative features appeared across data. This coding process soon showed that efficiency and costs are keys in gathering actors in solar technology development. Other consistent themes were debates on new materials or silicon improvements and worries about future funding when the solar industry in Norway was closing. In this process of qualitative induction (Reichertz, 2007:219), coding orders the data on a more abstract level. This process becomes interesting when the analyst discovers “combinations of features for which there is no appropriate explanation or rule in the store of knowledge that already exists” (ibid.). This occurred during my work when some interviewees—after first drawing on the usual repertoire of efficiency and costs—began to question the assumption that efficiency is the sole goal. Within discussion of new materials that have problems catching on, more nuanced explanations of why solar energy hasn’t become popular often emerged. These alternative narratives mitigated the dominant economic and technical explanations and pointed to a lack of political decisions supporting solar energy. Some interviewees then mentioned that solar energy actually already was a cost-efficient technology. They cited as example the fall in prices. These solar scientists opened the otherwise unquestioned black box of cost-efficiency assumptions.

Such surprise responses trigger abductive efforts—a search for new rules or suitable types that fit the surprising facts (Reichertz, 2007). The end point of this search is a (verbal) hypothesis that must be checked (deducing predictions form the hypothesis, which are then re-tested by searching for facts to verify or falsify the assumption) (ibid., 222). In this latter search for facts, I extended my interview data with media reports featuring catch words such as solar energy, FME Sol, and the names of interview partners in order to learn whether the actors engaged in opening the black box of how solar energy is represented in Norway in contexts other than my interviews. I used the media database retriever.no to access newspaper articles in Norway.

I now turn to my analysis. First I address the scientists' strategies to nurture the arena of solar technology development. I then shed light on their efforts of empowering.

3 Translations to fit and conform: Improving efficiency

Approaching the field from a translation perspective, I assumed that solar energy scientists must interest others in their work in order to translate their research into innovation. Indeed, Norwegian solar technology research had considerable experience in building alliances and in rendering itself interesting to industry. Studies showed that innovation played a significant role in the growth of the Norwegian PV industry, contributing to its status as a major global player (Hanson, 2008; Klitkou & Coenen, 2013; Klitkou & Godoe, 2013; Koesah, 2013; Ruud & Larsen, 2006). But R&D from research institutions and university departments played only a minor role during the rise of the solar industry (Koesah, 2013:71/108); only later did cooperation with industry and R&D institutions become more significant. Seeing that their expertise could be relevant to PV technology (Grimsrud after Koesah, 2013:70), many research groups tried to sell their work to these companies. A two-way actor enrolment occurred: First, external research convinced industry that their work was relevant for industry processes. Second, industry mobilized human resources through these collaborations. Subsequenty, the Norwegian solar industry and R&D institutions established tight links (observable in the case of FME Sol; see also Koesah, 2013: 52; Klitkou & Coenen, 2013). Accordingly, the interviewed scientists were part of networks encompassing universities,[2] independent research institutions, and industry.

Exploring strategies employed in nurturing the Norwegian PV arena (e.g., technical improvements, technical expectations, and network building) revealed the key strategy to be improving efficiency. Scientists or industry actors refer to the percentage of solar radiation converted into electricity as the efficiency of solar cells. Many of the interviewees were motivated to increase such efficiency. Simultaneously, this interpretation of efficiency was frequently intertwined with that of cost efficiency. Indeed, a common thread throughout the interviews was that solar energy was about costs. PV was considered uncompetitive on the electricity market because of its costs. This is the first chain of translations on which the key strategy of improving efficiency rests: If solar cells use solar radiation more efficiently, fewer or smaller solar cells are needed, reducing production, price, and instalment costs. Improving efficiency becomes thus tightly linked to demands for material improvement. With this problematization (Callon, 1986a), solar scientists render themselves indispensable for solar energy growth. This translation strategy also accommodates demands that climate policy be economic policy in Norway.

Efficiency supplies meaning to the entire arena of PV technology development and mobilizes it in the challenging Norwegian solar energy situation. One might say that efficiency is the device of interessement for solar actors such as scientists, industry, energy providers,

[2] Mainly the Norwegian University of Science and Technology (NTNU), the University of Oslo (UiO), and the University of Agder.

imagined future consumers and research funders. For example, when interview partners summarized their research projects to me, a layperson, they would often boil down the entire process to a description such as this:

> "I work on quantum dots. We use nanomaterials [to make] solar cells that are more efficient." (Solar energy scientist 16)

This interviewee, like others, did not try to explain the role of nanomaterials in solar cells, but she considered the result—that solar cells were more efficient—as sufficient definition of her work.

In sum, the scientists shaped expectations about future performances of solar cells in terms of efficiency, cost reductions, and material improvements. Increased efficiency, together with reduced costs, would make PV a competitive energy source within the incumbent electricity system. These interviews, and other studies on solar energy, showed strong orientation toward the future. Solar energy systems are often discussed as energy systems for the future (Henning 2000:3). The scientists engaged in the interviews with an outward-oriented representation of solar technology development (Smith & Raven, 2012:1032) in which they suggested a linear translation of innovation that led to cost efficiency, which led to competitiveness, which would increase solar energy use. This translation activity accepts the original problematisation that renewable technology development must be economic development.

Nevertheless, solar energy technology in general is a radical innovation.[3] Therefore, "improving efficiency" might be an insufficient strategy for successfully implementing solar technology: What else were solar scientists doing to assert themselves in the context of an incumbent fossil energy system?

4 Translations to stretch and transform: Mobilising interpretations of reality

This paper presupposes that solar energy scientists must interest other actors in their activities. I have already shown how solar energy scientists attempted to inscribe themselves in a network of industrial actors, energy providers, and energy consumers by setting out to improve efficiency. They tried to build alliances, particularly for their own research projects, by establishing good communication with the industry. This section concerns the politics of empowering the arena of development to secure the commitment of actors in the wider social world (Smith & Raven, 2012:1031). Smith and Raven conceptualize this process as a primarily discursive one in which narratives of empowerment play a major role (2012:1032). To be sure, empowerment was also implied in the material translations on efficiency, when solar scientists tried to convince others that PV could become a competitive energy resource. But this was *fit and confirm empowerment* (Smith & Raven, 2012), which did not challenge the problematization that climate policy must be economic policy, and in this section I discuss

[3] In general, a sharp distinction between radical and incremental innovations is difficult. Although slow, incremental change can imply radical change over the long term, how radical an innovation is depends on which beginning an analysts sets for a particular transition path (Genus & Coles, 2008:1440).

efforts to *stretch and transform* this problematization—such efforts necessarily imply contestation.

Transition processes are often characterised by “conflicts over the fundamental constitution of the problems and visions that inform the directions and initiatives taken” (Jørgensen 2012:997). My analysis has so far shown that solar scientists’ sense-making activities reflected existing configurations, for example when they tried to conform to the hegemony of economy by focusing on cost-efficiency. But I also identified elements in existing configurations that some solar scientists interpreted differently. I turn to these elements now.

Conflicts over interpretations concerned, for example, existing representations of solar energy and its use—representations that some solar scientists wanted to dissociate. This must be seen against the background that doing solar research in Norway could be a discouraging business. The dominant mood in Norway was that solar energy meant nothing for the country. The troubled solar industry situation was conflated with an energy policy discourse that had never been positive toward solar energy use. Internalizing this mood, the pervading opinion of the interviewees was that solar energy was not for Norway. They frequently joked that, in order to use solar energy in Norway, one should move the country south. However, some interviewees were frustrated by the current negativism:

> “I think people in Norway currently think that the time for solar energy is over. That we have discovered it is too expensive to make solar cells and to produce electricity. *Which is totally different from what is actually going on*. There is still an incredible growth in sales of solar cells. It has been increasing EVERY year for the last 10 to 15 years with growth rates of 40 – 60%. […] Often, when solar cells are presented, people use cost numbers from perhaps five years back. But the cost perspective has completely changed. *We need awareness that solar IS actually becoming a cost-efficient technology.*” (Solar energy scientist 8)

This interviewee was appalled by the dominant public conception of solar energy. He and other interviewees claimed that the performance of solar panels was much better than their reputation purports and that although solar technology had indeed improved, the way in which it was presented had not changed accordingly. Simply being aware of this problematic negative hegemonic situation definition, however, was not enough.

Further into the interviews, some scientists reflected on and questioned whether fostering solar energy was primarily a technical question (revolving around technology development and increasing efficiency). If one takes the position that technical improvements are *not* essential, then making this arena of development grow becomes a political question. This shift in problematization demands institutional reform. As one interviewee put it,

> “Using solar energy does not depend on material improvements. Efficiency is low, but the force of the sun is high … I mean, we don’t need to use more than a very small fraction of that energy. The technology IS there. What we need is a political decision.” (Solar energy scientist 13)

As I show below, some solar scientists who questioned the economy-policy problematization and who aimed to mobilize actors tried to stretch and transform it.

4.1 "Typical" stretch-and-transform narratives

The objective of stretch-and-transform empowerment is to "convince the wider social world that the rules of the game need to be changed" (Smith & Raven, 2012:1033). Empowerment narratives featured strongly in the interviews: the scientists articulated positive expectations, presented solar energy in a favourable light, and argued for niche-friendly institutional reforms. The scientists presented these narratives in varied outlets: in funding proposals, at solar energy conferences, while teaching, at public science days, and in media reports. For example, interviewees highlighted the advantages of maintaining a solar industry in Norway: They maintained that Norway should use the available industrial infrastructure and skills, research competence, and resources (i.e., silicon, inexpensive green electricity for production), and that setting the nation's sights on green industry would furthermore generate future jobs.

The interviews showed that the solar energy scientists wanted to bring a larger actor-network into position. They foresaw affiliated actor worlds that included architects, regulations, funding for energy users, infrastructure, and storage technologies. Intermediaries (e.g., plumbers, pipers, architects) were also considered crucial—but currently absent. Overall, the interviewed scientists pointed to a range of nontechnical conditions that should be in place to realise more widespread distribution of solar energy.

4.2 Enacting solar into being

Considering the difficult situation of the Norwegian solar industry and the energy situation in Norway, the solar scientists most engaged in translation activities fought against the hegemonic perception of the situation that solar energy was not appropriate for Norway and that the time for solar energy was past[4]. To call into question existing definitions of reality, they adopted the task of showing that many public and political debates operated with old numbers. This opened a space for interesting others in the possibilities of solar energy. They seemed aware that, in order to sustain and nurture their arena of development, not only must scientists carry out good research, but their activities must also become more comprehensive. They fought the hegemony of the negative situation definition, which could prove fatal because governing discourses provide conditions of possibility for further action. Solar energy scientists concurred that solar energy *would* contribute to the future energy mix. Although

[4] This is not true of all of the interviewees. Broadly delineated, I observed two types of researchers: For the first type, solar technology is just one of many areas in which their research can be applied; for these researchers, solar energy is primarily a suitable area to receive funding for what they actually want to do. The second type of respondent researchers presented themselves as genuinely dedicated to solar energy; improving solar energy is what they want. In the literature on transition studies, idealistic enthusiasts are revealed as key to successful niche development (Smith, 2007:427). My analysis in section 4 therefore focuses on this second type, who take on a role as transition actors. Be that as it may, we must bear in mind that these scientists might not see themselves as transition actors. That scientists do not necessarily see that they can make a difference is true not only for sustainable technology but also in other areas, such as the nanosciences (Swiestra & Rip, 2007:8). More central actors, such as firms or government agencies, are seen as carriers of agency (ibid.). Indeed, the question "do you consider yourself as bearing a role in societal aims to move towards a transition to sustainable energy?" triggered nothing more than awkwardness in interviewer/informant relationship (for a methodological discussion of such issues, see Yanow, 2003), so I removed it from the interview guide. The question was 'meaningless' to this group, who framed their activities in a completely different way.

they disagreed about how, how much, and where solar energy would contribute, their research was sustained by a vision that solar energy would be important in the future. What remained was to persuade others of this fact. I experienced their persuasion efforts during the interviews and found it also in other outlets, as exemplified by two instances below.

The first is a commentary by two solar scientists published in a Norwegian newspaper (Nordam & Reenaas, 2013). The article responds to conservative Norwegian journalist Jon Hustad's article, "Green Naiveté and Idealism." Hustad claims that fossil fuels contain much more energy than any renewables. Even if 5% of Great Britain were covered by solar panels, he argues, the energy produced would hardly be sufficient to fuel all British cars. Nordam and Reenaas contest this assertion by revealing that Hustad's calculations use a low future conversion efficiency of solar cells (10%); overlooking expected efficiency rises. Furthermore, they note that solar radiation in southern Great Britain is stronger than Hustad estimated. The two scientists conclude that covering 5% of Britain with solar panels would meet two-thirds of Britain's entire energy demand. Typically, arguments about the future of solar energy were carried out at this level of detail.

The second instance involves a research project at the University of Agder in Kristiansand, Norway. The research group was engaged not only with solar energy in general, but specifically with the use of solar energy *in Norway*. They worked with measuring solar radiation and PV performance in southern Norway. One of their researchers explained:

> "We would like to properly document, measure, and prove the actual force of solar energy use in Norway. In the southern part and up the Oslo Fjord, we should have as good conditions as in northern Germany, which has widespread application of solar energy." (Solar energy scientist 14)

These researchers assumed an important role, because such work is performative: the possibility of solar energy in Norway remains unreal until it is enacted into being. Such performances of engaged actors are crucial for restructuring or extending arenas (Jørgensen, 2012:1001). Interviewees employed complementing arguments, such as that the angle of the sun in northern countries is better for capturing solar energy and that, during the summer, northern Norway receives direct sunlight 24 hours a day. Another project, Northsol, aimed to demonstrate that solar energy could be used effectively both at high latitudes and in cold climates. Such projects might provide the technological foundation for a national solar energy policy that would make the Norwegian solar industry less dependent on international markets (Klitkou & Godoe, 2013:1592).

These examples show how some solar scientists engaged in an implicit struggle over solar energy and its potential by producing scientific—and thereby authoritative—evidence to redefine the public image of solar energy. Their counter-facts were often represented in numbers and curves that inscribed price development, costs, measured solar radiation, and efficiency rates of solar cells. These new representations could be transported, reproduced, and diffused in the politics of empowerment. Some solar energy scientists assumed the task of speaking for solar energy. An important spokesman for solar energy was the head of FME Sol, Erik Marstein. In newspaper articles, he championed solar energy in Norway and evoked the competences united in the arena of development around FME Sol and the benefits of solar technology development in Norway.

In sum, scientists committed to solar energy engaged in a struggle of defining the potential of that energy: they "sold" solar. They—in addition to their research activity—actively engaged in negotiations about the presence and future of solar energy use. This is not typical of scientists working with environmentally friendly energy (see, e.g., Klimek and Sørensen, forthcoming; Heidenreich, forthcoming). I use the concept "transition actor" to refer to those change agents that are "trying to influence a situation in which actors' thoughts and actions are constrained by incumbent institutions" (Raven & Smith, 2012:1032). Nevertheless, some solar scientists acting as transition actors were also discouraged to be the only ones lobbying for solar:

> "The public needs more awareness about solar energy. Actually, what we do—working on material sciences—is not related to energy use and the end consumer … teaching society how solar cells work … I wouldn't expect that from researchers in positions like mine. We are NOT the right people to do that. BUT we can do that. And we ARE doing that somehow, because there are not so many other actors." (Solar energy scientist 8)

In this section, we have seen that, for their research to be well received, solar energy scientists first had to lay a foundation that was amenable to that research.

4. Discussion

What does the analysis reveal about building associations that foster a sustainable transition? Focusing on solar scientists in Norway, the paper shows how scientists sought to translate other actors into their preferred actor-world, mainly by pursuing two lines of activities: increasing efficiency and challenging negative hegemonic representations of solar energy.

In their first activity, they engaged in different moments of efficiency translations to interest others in their work. Efficiency was an interessement device (within promises of a sustainable future) and additionally constituted a material achievement of the research. The objective of this *fitting-and-conforming* (Smith & Raven, 2012) strategy was to articulate the arena of development in conformation with the problematization suggested in climate policy being economy policy: solar energy should become competitive.

The second activity was a translation to represent solar energy as worthy of pursuit. The question is how to make sense of this activity theoretically. It obviously has features of "conventional" *stretch-and-transform narratives* (Smith & Raven, 2012) that aim at institutional reform. However, this paper shows that those solar scientists who took on a role as transition actors went beyond addressing institutional reform. They understood that they had a *co-production* challenge: in the case of alternative energy sources—as with any radical innovation, it was shortsighted to interest others solely in individual research projects. If no one considered solar energy as a significant alternative energy source, then even the most advanced solar technology was useless. Scientists who took on roles as spokespersons attempted to represent solar energy in a favourable light by, for example, transforming solar radiation into numbers that rendered solar power tangible. These numbers then circulated as part of the politics of empowerment. This highlights the constitutive role of (socially produced) evidence in empowering.

The analysis also showed that interpretations of existing and future situations play an important role in these processes. In interpretation, the notion of translation and Smith and Raven's (2011) politics of empowering come together. All interpretations act upon actor-networks; they perform and transform forces (Callon & Latour 1981:297). Examples of interpretations that have an effect include visions, scenarios and perceptions of reality. Advocates of development arenas share their favourable interpretations of the arena's future to enlist a broad network of actors (Farla et al., 2012; Smith, 2007; Verhees et al., 2013). Expectations can be performative in attracting necessary allies (Borup et al., 2006:289). They are significant elements of producing sustainable innovations because "the products of sciences, both cognitive and material, embody beliefs not only about how the world is, but also how it ought to be. Natural and social orders, in short, are produced at one and the same time—or, more precisely, coproduced" (Jasanoff, 2005:19).

Thus, in the 'expectation work' that the actors engaged in pursuing systemic changes (Farla et al., 2012:995), solar scientists not only participated in shaping expectations in PV development and projected future imagined worlds, but they also addressed and tried to disassociate currently collectively imagined social orders. Academic system builders that ignore the necessity of engaging in the reframing of energy realities may lack a common ground for long-term, radical transitions, which is a prerequisite for generating interest. If expectations are performative in attracting the interest of necessary allies, the opposite is unfortunately also true: negative expectations can disinterest actors (Nerlich & Halliday, 2007). The expectations work and R&D of the Norwegian solar scientists were mutually dependent, because in order for the innovation to succeed, practical and material considerations must play along with the discursive shaping of the future (Brown & Michael 2003:7). My study thus takes an important step toward studying the making and unmaking of rules constraining or enabling actions and the reproduction of practices central to transformation that have not yet been an explicit object of systematic study in MLP research (Genus & Coles, 2008:1442).

5. Conclusion: From a multi-level perspective to a multi-actor politics of translation

This article departs from the argument that exploring the politics involved in actor-networks constructing, maintaining, and empowering contested protective spaces (Smith & Raven 2012) helps us to understand how sustainable technologies may grow. From the perspective of translation, sustainable technologies increase their significance through processes of associating. In addition, the concept of translation opens up for analysing contestations of meaning and disassociations because in the enrolment of actors continuous negotiations occur. Such struggles of meaning are central in translation processes. This acknowledgement of multiple realities is an important insight that translation offers to transition studies.

In terms of theory development, I have shown not only that the inventory of translation strategies employed by solar scientists aims toward technological development and institutional reforms, but that solar energy scientists who act as spokespersons try to change the representations of solar energy at what MLP would call the 'regime' or 'landscape level.' This study confirms that it is difficult to distinguish between the theoretical concepts of landscape and regime when confronted with empirical data and that actors cannot analytically be attached to levels (Jørgensen 2012:1000). That solar scientists tried to shape and change elements at the landscape level challenges the foundational logic of this level (ibid.). Transition processes are multi-actor and multi-sited, thus any containment into levels will necessarily result in overflows. To account for this, I considered Jørgensen's 'arena of development' a more useful concept than 'niches.' Instead of the levels of MLP, transition studies could analyse the co-production of arenas of development, which is a more fluid concept. Smith and Raven have provided a useful framework to study actor strategies in niches' growth that may be applied independent of whether one talks about niches or arenas of development.

More case studies are needed that study the multi-actor, multi-sited politics of transitions. This paper applies the translation approach to a limited study of one actor group. Future studies should include more actors and sites and attend to aspects of representation, translation, and ordering and to how representations may become hegemonic or not. This study has shown that solar energy scientists do not react only to their contexts. Much of their work suggests this, like their preoccupation with efficiency that mirrors the hegemonic economic cost-benefit logic in the sustainable energy field in Norway. But they also exhibit attempts to redefine current modes of representation (Gottweis, 2003:261) and through this the problematization in which their work is situated.

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