MODIFYING ACTOR-NETWORK THEORY TO ANALYSE THE GERMAN PROJECT OF PHOTOVOLTAIC ELECTRICAL ENERGY GENERATION

by

RAY GALVIN

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RAY GALVIN
UNIVERSITY OF EAST ANGLIA
r.galvin@uea.ac.uk

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ABSTRACT

German state subsidies for photovoltaic (PV) electricity generation now amount to over 200 million euros per month. Yet PV in Germany is only 30% as economically efficient as wind power, while up to 19 times as much energy would be saved if the same funds were used to thermally renovate homes. The generous subsidy has led to increasing demand for PV units and an annual increase in subsidies of around 50%. This study investigates why these subsidies were instigated and why they continue. Because both material and social factors appear to play a role, a composite analytical framework is developed, using actor-network theory (ANT) and policy discourse approaches. This is achieved through discarding ontologically unsound concepts of radical human/non-human symmetry in ANT, while re-materialising the concept of discourse, and theorising how to test the veracity of strands in discourse which make truth claims about the material world. The result shows that the German PV subsidy system can be explained in terms of various interplays of material and discursive factors which have held sway in it at crucial times, from its inception to the present day.

Key words: photovoltaic, Germany, actor-network theory, discourse

INTRODUCTION

The federal German state spends over 200 million euros every month subsidising a renewable energy technology which by all practical measures is a failure[1]. The best photovoltaic cells, in German sunshine, produce less than a third of the electrical energy that wind turbines produce in German wind, per euro invested. The subsidies amount to about eight times the price per kilowatt hour that conventional electricity is sold for on the German spot-market. Because the subsidies are so generous, a mass-market has developed for photovoltaic panels, which is steadily expanding, so that the subsidies are rising by around 50% each year. If the current subsidies were spent instead on thermal refits of old homes, the return, in terms of energy saved, would be up to 19 times as high[2]. Even if the law were changed so that no new photovoltaic installations were subsidised, current subsidy commitments would last for up to 20 years and cost at least a further 20 billion euros (Frondel, et al. 2008).

[1] The figures in this paragraph are based on statistics in German federal documents FME (2007) and VDN (2007), plus studies by Frondel, et al. (2008); de T'Serclaes (2008) and Enseling and HInz (2006).

[2] Enseling and Hinz (2006:15) show that renovating existing homes to the minimum federal standard results in energy savings that amount to a cost of 2.99 eurocents per kilowatt hour saved. This compares with state payouts of up to 57 eurocents for each kilowatt hour of energy produced by PV.

From the purely pragmatic perspective of wanting to import less fuel and reduce CO2 emissions, this project would seem to be not only of little use, but actually counterproductive, as it diverts money and technological expertise from energy saving projects which can give far higher returns. It appears to subvert green aims, not further them. Yet it is widely applauded throughout Germany, while NGOs such as Greenpeace, and at least one newspaper, the *Guardian* relentlessly press the UK government to emulate it (SolarCentury, 2009; Seager, 2008).

All this makes the project an interesting subject of analysis. Why is it permitted to continue, and indeed to continue to grow? Why is it so widely applauded? Why does a country with low levels of sunshine invest so heavily in a technology which is of little use even in areas like Texas, with much higher levels of solar insolation? In a land where engineering is highly valued, why are so many engineers engaged on this project rather than more productive ones?

This paper reports on a preliminary analysis of the German project of promoting and subsidising photovoltaic electrical energy generation on a mass scale (hereinafter called 'the German PV project'), asking why it continues despite its failures and shortcomings. In Section 1 a conceptual framework is developed for analysing large, complex socio-technical systems such as this. This framework is designed to trace two quite different types of influence within and upon such a system: (a) the human/technological interactions resulting from the peculiarities of the material realities in the system and how they interface with people; and (b) social influences arising out of relevant discourse. These two types of influence are seldom traced simultaneously in studies of socio-technical systems, so the framework developed here is something of a pioneering effort. It is offered for wider scrutiny and possible use in examining other socio-technical systems where explanations of just one type or the other are unsatisfying.

In Section 2 this framework is applied to the German PV project, based on preliminary empirical research carried out in 2008. This consisted of examination of policy documents and the history of the German PV project; discussions with personnel in the PV industry; visits to the sites of many PV installations throughout Germany; and a period of more intensive research on PV promotion and action in a 'leading' PV municipality, Freiburg, in the German state of Baden-Württemberg.

1. DEVELOPING AN ANALYTICAL MODEL

The German PV project can be perceived in two distinct ways, each corresponding to a popular analytical framework. Firstly, it can be seen as an 'actor-network', in which human and non-human elements 'act' upon each other and are mutually formative of each other's contribution to the system. Alternatively, it can be seen as a product of policy discourse, formed and shaped by the influence of human beings acting in response to socially constructed views of the world.

The first approach, known as 'actor-network theory' (ANT) or the 'sociology of translations', focuses on the hybrid human/non-human products of the interactions between all the relevant entities within the system (Latour, 2005; Callon, 1991; Law,

1989). It is attentive to the ways human and material entities interact to produce novel forms, which then impact on other things within the system, producing larger units of influence, all of which together determine how the system works. This approach seeks explanations for the system's stability or instability, successes or failures, within this broad 'co-constructivist' picture.

The second approach focuses on the socially constructed views of the world that sit somewhat outside or alongside technological and other systems, and how these impact on policy development, which then determines how the system functions (e.g. Hajer, 1995). It has roots in postmodern approaches, in which interest centres on the range of different world-views that people construct through discourse (Berger and Luckmann, 1984). In many of these approaches there is little interest in the question of whether or how well these world-views correspond to the way the world actually is (e.g. Kuhn, 1970). Rather, these approaches are concerned to see how a community's world-views influence its actions. In the policy discourse realm, interest is on the ways various discourses compete against each other to achieve dominance among policymakers so that their particular world-view becomes the one best represented in the actions of the state (Torfing, 2005; Howarth, 2005; Hajer, 1995; 2005).

On the surface, it would seem, both these approaches have something to offer for an analysis of the German PV project. The German PV project can well be conceived as an actor-network. It consists of such entities as federal, state and local politicians, bureaucrats and technologists; PV and electrical materials and their manufacturers and installers; banks and their balance sheets and loan rules; the energy of the sun falling on Germany; roofs and other surfaces and their owners; the people who pay the subsidies for PV owners; PV research establishments; the electricity grid; NGOs; associations of PV promoters and manufacturers; suppliers of materials for PV panels, and so on. Much of what goes on in the project can be understood in terms of the interactions between these entities, and the larger hybrid human/non-human complexes these interactions produce.

Yet this cannot explain everything about the project. As we shall see, the project is subverting rather than fulfilling the government's aims of furthering Germany's energy saving and climate change mitigation goals, and this could have been easily predicted from its inception. Why set up such a system in the first place? Why not unwind it rapidly, now that its failures have become so glaringly obvious? I will argue that the system was put in place partly because certain world-views became dominant in the policy sphere, and these world-views are among the things that keep it going. Hence a policy discourse approach could be useful for analysing it.

At first sight it might be thought appropriate to do an analysis from both perspectives, and add up or combine the results to get a fuller picture, as Murdoch (2001) comes close to suggesting. But the situation is more complex. Advocates of both these approaches accuse the other of not just giving merely a partial view of the world, but a wrong view. ANT co-founder Latour (2004; 2005) claims the idea of a purely human social reality made up of discourse is an illusion, with no explanatory power (2005:1-9). He also argues that such a view is self-contradictory, and that to argue on the basis of it is to render one's own account valueless (2004:163ff). Meanwhile social constructivist Bloor (1999a; 1999b) argues that ANT's abstract, 'symmetrical' treatment of human and non-human entities bears no relation to the way the world is,

and merely introduces confusion. If the critiques of both approaches are substantially valid, trying to do a combined analysis might land us with two sets of worthless results. A better strategy would be to examine the weaknesses and strengths of both approaches, exploring the critiques in depth, and see whether there is a way forward for either or both of them in the light of these critiques.

This section seeks to tease out the aspects of these two approaches that withstand critique, and that therefore can be relied upon. It also identifies the aspects that do not stand up to critique. It then goes one step further, showing how a bridge can be built between the two approaches if a more rigorous, materially grounded understanding of discourse and of the social milieu is developed.

1.1 ANT as an Analytical Framework

A key principle of ANT, which it shares with some related approaches to analysing socio-technical systems (STSs), is to reserve judgement, at the outset, as to whether the influences in a system are coming primarily from human or from non-human elements. Both these are seen as mutually formative of each other. 'The point is that whilst technology is a thoroughly social construction, society is a technological construction as well' (Kirsch, 1995: 531).

Approaches differ, however, in the way they perceive non-human entities to be acting. For want of an existing framework for discussing these, I will address them using the terms 'the hard stage' and 'the radical stage'

The 'hard stage' involves treating non-human entities solely according to their natural attributes and characteristics. Non-ANT[3] examples of this approach are Hughes's (1983; 1987) study of the development of electricity infrastructure, and Fallows's (1985) exploration of why the US Army persistently deployed the vastly inferior M-16 rifle in Vietnam. ANT studies along these lines include Cowan's (1989) account of the history of heating and cooking stoves in the US, and Star's (1991) discussion of the ubiquity of onions in fast-food meals. In these, non-human things are treated as 'hard' (my terminology) in that their specific, natural characteristics are invoked to contribute to the explanation of how and why the system works the way it does. At the same time, the things people do, think, say and envisage are also treated as 'hard', in that they, too, exert influence on technology, though of course in their peculiarly human ways.

Law's (1989) study of Portuguese maritime and commercial expansion into the Indian Ocean in the 15th century can also be seen as a 'hard stage' study. His concern is to ask 'How do objects, artefacts, and technical practices come to be stabilised? And why do they take the form that they do?' The 'actors' in his account include geographical distance, ocean currents, stars, wind and weather patterns, foreign naval vessels, weapons, navigational equipment and charts, training schools, timber

[3] There is discussion as to what constitutes an 'ANT' approach (e.g. Latour, 2005:10-11). For simplicity, here I am using the term 'non-ANT' for approaches to STS which emphasise both human and non-human influences but do not claim to be in the tradition of ANT.

and ships. Law maintains that the social '… should not … be pictured as standing by itself *behind* the system being built and exercising a special influence on its development (p. 113). Rather, '… *the stability and form of artefacts should be seen as a function of the interaction of heterogeneous elements as these are shaped and assimilated into a network'* (p.113, emphasis in original).

The strength of these accounts is the attention they pay to the formative influence of both human and non-human 'actors' on the performance of a STS. They can also reveal how non-human things can determine power relations, either by design or default. Winner (1986) illustrates how the height of a bridge, set by ruling authorities to obstruct bus transit, can serve to exclude certain social classes from access to a desirable public area. With regard the German PV project, the direction a roof is facing can determine whether a homeowner can install PV panels and thereby gain generous financial subsidies.

A weakness of these approaches, however, is the limited way in which human influence is conceived. Only direct human actions within the system are considered. There is no place for the influence of a domain of socially constructed beliefs, values and habits of action which might have their provenance quite apart from the system, but which nevertheless influence the way people behave within the system. Hence, Fallows does not explain why a handful of middle-ranking staff in the Army Ordnance Corps were able to set the agenda for frontline weapons procurement despite a chorus of protestations right through the ranks, from battlefield soldiers to the President himself. Cowan does not explain why people wanted cast iron stoves. Star does not explain why raw or half-raw onions, which upset the digestion of huge numbers of people, are ubiquitous in restaurants – and not only those of the fast-food variety. Law does not explain why the Spanish government became deeply committed to sea trade into the Indian Ocean despite huge obstacles. In these cases, one is led to ask whether there were socially constructed domains of belief, which had some influence on the construction or maintenance of the system. However, Latour (2005:4) maintains that 'there is no social dimension of any sort, no "social context", no distinct domain of reality to which the label "social" or "society" can be attributed …'

'Radical stage' approaches erase the dividing line between human and non-human entities, and conceive of non-human entities as acting in ways that go beyond their normal, natural characteristics. Where this approach is found, there are often also features of the 'hard stage', and it is important to tease out the differences.

The 'radical stage' is seen in Latour's (1983) study of Pasteur and the anthrax bacillus, in which he depicts Pasteur and the bacillus as cooperating together to co-construct the new hybrid reality 'Pasteur-and-the-bacillus.' It is not that Pasteur discovers or identifies the bacillus, but that he and it are engaged in a process of it becoming visible in the laboratory. In later reflection on this study, Latour says they 'mutually exchange and enhance their properties' (1999a:125).

The 'radical stage' is overtly and consistently maintained in ACT studies by Callon (1980; 1986; 1991), and his reflections on these (Callon, 1989). The first is an examination of attempts by engineers in Electricité de France (EDF) to develop and popularise an electric car, the VEL, in the early 1970s (Callon, 1980). The project

failed because (in prosaic, non-ANT terms) the car batteries did not work. But Callon reflects:

> The proposed associations, and by consequence the project itself, would hold together only if the different entities concerned (electrons, catalysts, industrial firms, consumers) accepted the roles that were assigned to them. (1989:93)

Such anthropomorphisms are typical in Callon's accounts. In his exploration of the failed attempt to domesticate scallops in St Brieuc Bay, Callon (1986) notes the 'refusal' of the scallop larvae to 'cooperate' with the scientists, together with fishermen breaking ranks and prematurely trawling the bay. In his (1991) exploration of the processes of social and technical change in 'techno-economic networks', inanimate things 'make', 'seek', 'rework', 'test their identities,' and 'are not as dumb as we think' (pp.135-136). A nuclear power station has the 'right' to be an actor (p.141), and it is 'increasingly difficult to distinguish between humans and non-humans' (p.139) There is also a blending of fully inanimate objects, and texts written purposively by human beings (pp.135-136). These expressions demand we conceive of inanimate things as quasi-human realities, and at the same time dumb down the intentionality and freedom of human beings.

Ironically, we do not need this 'radical' symmetry in order to conclude that human/technological interfaces create strange and novel realities that constitute a form of hybrid human/non-human 'society', which continually creates new, unpredictable expressions. A 'hard stage' analysis, treating humans and non-humans strictly according to their prosaic, natural characteristics, will do this job just as well. Examples of such hybrid elements are 'horse-and-rider', 'pony club meet', 'man-wearing-clothes', 'pilot-and-aircraft', 'old-man-and-walking-stick', 'software-engineer-at-computer', 'US Army', 'household-with-grid-connected-PV-panels.' Each of these has characteristics that are more than the simple sum of its parts. This does *not* mean, however, that a 1 metre wooden pole 'co-operates', 'enrols', 'attempts', or in any other way acts as something other than wood when it is taken and used as a walking stick. It is just wood acting as wood.

Further, a 'hard' view of the interaction between humans and non-humans has 'ontological' implications, in that it is a claim about the way the world is, and not simply a convenient way of picturing the world, or a useful 'lens' (Cordella and Shaikh, 2003) through which the world can be analysed. The 'hard stage' of ANT makes the (reasonable) claim that the influences which determine the way human beings live in the world are not merely person-to-person connections and discourses. Instead, they are influences which come into being through the peculiarities of how human and non-human entities interact. This does not go as far as Law's (1989) more 'radical' claim that: '… entities take their form and acquire their attributes as a result of their relations with other entities'. There is no evidence that the form of, say, a guitar changes when it is held and played by a guitarist. It is the same 'thing' as before, and it has the same attributes. However, the human/non-human hybrid 'guitarist-playing-guitar' is a novel element which influences other entities (such as a 'bassist-playing-bass) in a way that the neither the guitarist alone, nor the guitar alone, could achieve.

Hence a 'radical' type of claim can hold true for human/non-human *hybrids* but not for inanimate *objects*. A guitar is just a guitar, and cannot be made to do anything that a

plain prosaic guitar cannot naturally do. A composite entity made up of two or more inanimate things (such as PV panel and a roof) is just the same. Even though the two together may produce novel effects that neither can produce alone, these effects are grounded in the plain material characteristics of the constituent entities. It is only when human beings get attached to things that the resultant human/non-human hybrids can behave in unexpectedly novel ways - such as 'PV-panel-and-roof' combining with 'MPs-passing-laws' to result in 'homeowner-getting-rich'.

There is no logical or empirical basis for arguing that guitars, electrons or PV panels 'enrol' or 'co-operate with' people in any literal sense. The 'radical stage' of ANT does not stand up to critical analysis. At best it is a poetic, metaphorical flourish; at worst a piece of misleading fantasy, '… a formula for imposing confusion on ourselves' (Bloor, 1999a: 97). Because inanimate things do not behave this way, no dependable explanatory power is likely to come from imagining that they do[4].

Further, in erasing the distinction between human and non-human entities, the 'radical' form of ANT tends to deny the reflexivity and intentionality of human beings (Hacking 1999a: 105; 1999c). The ability to reflect upon options, make free choices and invent new ones, is seen as an essential feature of humanity, at least in much philosophy and psychology (e.g. Sartre, 1958; Harré and Gillett, 1994). Yet ANT either suppresses it, transfers it to inanimate objects, or treats it as an irrelevance, in order to maintain consistency it its view the world.

Further, Miettinen (1999) observes that ANT does, actually, preserve the notion of human reflexivity, but removes it from the human actors within the network while focusing it all in the 'heterogeneous engineer' who runs the system. This leads to 'a Machiavellian analysis of innovation in which the contribution of designers, users, and non-human entities remains marginal' (p.170). All the real decision-making power and competence are in the hands of the person running the system. There is no place for the intentionality and competence of other humans. Again this is an ontological claim. Yet it runs counter to the commonsense notion that human beings in their workplaces are a mixed offering of creativity, conformity, good judgement and mischief, simultaneously influenced by the social rules and beliefs they identify with.

1.2 Policy Discourse Approaches

Policy discourse approaches are social constructivist, rather than human/non-human co-constructivist. Their tacit assumption is that non-human entities are a backdrop to, and a consequence of, those human interactions which are designed to achieve policy change. A significant contribution for the present study is that of Hajer (1995, 2005), who relates this approach to the technological project of ecological modernisation (Mol and Sonnenfeld, 2000). His view is broadly situated within the social constructivist tradition of Berger and Luckmann (1984 [1966]), Kuhn (1970) and Giddens (1979; 1984), and the social-political theorising of Foucault (e.g. 1968; 1976), but is also informed by the 'realist', psychology-based social constructivism of Harré (1980), Billig (1987), and Davies and Harré (1990).

[4] See also critiques along these lines in Collins and Yearly (1992), Elam (1999), Knorr-Cetina (1985), Shapin (1995) and Murdoch (1997).

For Hajer there are always two sides to the analysis of discourse: the statements made by people, and the context in which the statements are made and into which they are directed. Hence Hajer's definition of discourse is:

> … a specific ensemble of ideas, concepts, and categorisations that are produced, reproduced and transformed in a particular set of practices and through which meaning is given to social realities. (p.44).

Hajer sees discourse as the key element in what gives institutions their power, noting that '…institutions are only powerful insofar as they are constituted as authorities *vis-à-vis* other actors through discourse' (p.51).

Policy change, in Hajer's view, is 'the outcome of struggles among political decision-makers to achieve "discursive hegemony" i.e., to get their construction of the environmental problem and its proper solution adopted as public policy' (Lundqvist, 2000:21). When a new or emerging discourse reaches a certain level of appeal within a policy domain, the actors within that policy domain have to adopt it to remain credible. Following Giddens (1984), Hajer calls this 'structuration'. If this discourse gets translated into policy and institutional arrangements, it has achieved 'institutionalization.' A discourse that has achieved both structuration and institutionalization is now 'hegemonic in a given domain' (Hajer, 1995:59). The key players have adopted it as their view of the world, and have devised laws, regulations, bureaucracies and enforcement agencies to put it into practice.

In order to achieve structuration, a discourse must win *cognitive* acceptance. It must appear to fit the facts, hold together as a consistent 'story-line,' and appeal intellectually to a 'coalition' of supporters who might be coming at the issue from different perspectives. It must also be *positionally* acceptable: it must offer its potential proponents real advantages in the physical world.

There are two main weaknesses of policy discourse approaches such as this. Firstly, policy change often occurs *without* its corresponding discourse becoming structurated – i.e. it can happen even if the discourse does not win the public over. Britain joined in the invasion of Iraq because it was the Prime Minister's will, not because the pro-invasion discourse won the arguments (Kramer, 2003; Hoggett, 2005). Sweden adopted a policy of ecological modernisation (EM) largely because the Swedish Prime Minister wanted it, well before EM discourse had become structurated (Lundqvist, 2000). Further, factions with more material things at their disposal (such as oil companies) can have an edge in getting their chosen policies adopted, regardless of discourse (Salomon and Siegfried, 1977; Mommer and Araque, 2002). More brutally, at times policy change occurs simply because the people who want it have control over guns, tanks and air forces - as in military coups, revolutions and invasive wars.

Secondly, even if structuration does occur, institutionalisation might be impossible if material factors prevent it. Germany's aspirations to phase our nuclear power are hindered by (a) physical limitations on renewable energy development, (b) objections to increased fossil fuel consumption, and (c) continued high demand for electrical energy (Rüdig, 2000; Nill, 2003). The material realities (a) and (c) prevent it

embracing a policy of immediate phase-out of nuclear power, no matter how the discourse debates turn out.

Both these weaknesses have to do with materiality, and both factors are better explained by ANT analysis, which takes full account of non-human, material influences.

But even if Hajer's approach does not provide a complete explanation, it does describe significant aspects of what influences what in policy formation, change and stability. This is because its motive power, discourse, is 'real', in that it influences people's actions. To more fully understand this 'discursive social reality', as I will call it, we turn to the field of philosophical social psychology, where it has been carefully investigated.

Early empirical investigations of discursive social reality were made by Vygotsky (1978), based on Saussure's (1974) semiotic understanding of language and Voloshinov's (1973) application of this to social theory. The linguistic philosopher Harré[5] develops these ideas more formally and rigorously (e.g. 1980; 1983). His 'discursive psychology' explores how human beings freely and intentionally pick meaningful units out of the chaos of their sense experiences, and use language to negotiate the meanings of these units with other people. Together with neurosurgeon and philosopher Gillett (Harré and Gillett, 1994), he develops a model of the human mind based on discursive skills and their application to everyday living. The mind is a discursive phenomenon rather than the disembodied medium of Cartesian dualism (p.77) or merely a concomitant of cause-and-effect processes in the physical brain (p.78).

The acquisition of language – i.e. discursive skill - enables a child to convey to another person an experience she has had of the world around her. This enables the child and her speech partner to find their way in the physical world of people and things, but only to the extent that they develop the skills to produce language that corresponds more or less to the way the world actually is.

The images so conveyed can be passed on through long chains of speakers and listeners, who 'see' the original speaker's experience through the effect of words. However, some of the things that impact upon people do not correspond to straightforward sense experience, but to more abstract things, such as 'hooliganism', 'communism', or (recently) 'quantitative easing'. There is indeed a spectrum of things constructed or construed in discourse. At one end of the spectrum are 'concrete' realities such as trees, CO2 levels, screws, fasteners, and measurements of energy produced by a PV cell. At the other end are fantasy and religious objects such as goblins, ghosts and gods. In between is a range of objects which either do not yet exist, or which are several levels removed from simple sense experience. These include: what the climate will be like in 2050; the effects of quantitative easing; and the value of ecological modernisation.

[5] Harré is also prominent in the philosophy of science.

All these things can be ‘real’ to interlocutors in that the force of the words about them conjure up images and feelings which impact upon the interlocutors. But the further such utterances move away from the ‘concrete’ end of the spectrum, the more likely there is to be a range of different, and perhaps competing, constructions or construals of the way the world is.

At this point some social theorists, such as Bloor (1973; 1999a) or Kuhn (1970) prefer to perform social analyses from a position of agnosticism as to which construal of the world is nearest to the way the world actually is. Hajer (1995) also appears to take this position, along with others such as Torfing (2005). Latour (2004; 2005:100ff) criticises it fiercely. The core of his argument is that if a sociologist proclaims that we must be agnostic about the truth or falsity of, say, a physicist’s beliefs about the world, then we must also remain agnostic about the truth or falsity of the sociologist’s conclusions about the physicist. What is good for the goose is also good for the gander. This is a central reason Latour rejects the notion of a ‘social’ reality, i.e. a domain composed of the world-views of the people being studied by sociologists.

However, the circularity of this ‘agnostic position’ can be broken if we consider what I will call ‘the descriptive elements of discourse’. Almost every discourse contains some reference to aspects of the physical world which can be tested, to see how well that aspect of the discourse lines up with the way the world is. Generally, the closer a discourse topic is to the first (‘concrete’) type, the easier it is to put the veracity of the discourse’s statements to the test. The statement, ‘PV cells in German sunshine produce far less energy per euro invested, than do the latest wind turbines’ can be tested quite simply. Other statements, such as ‘the arctic icecap will have disappeared by 2050’ are harder to test because they refer to the future. However, such statements depend on an array of supporting claims, and some of these can be tested. Even apparently ‘moral’ statements such as ‘PV is an ethically sound investment’ have to be backed up by more prosaic claims (such as the rate of return of a particular PV installation), which are amenable to testing. That such tests are possible is discussed by Latour (2005), who points out that laboratory scientists generally have rigorously upheld processes designed specifically to avoid conclusions being drawn for social or non-scientific reasons.

It is important, therefore, to tease out the descriptive elements within discourse, and put them to the test if this is practically possible. Based on Bhaskar’s (1989) ‘critical realism’, Sayer (2000) develops a detailed approach to identifying such elements and seeing how they stand up to scrutiny.

Hence there are two senses in which ANT’s explanations could become fuller. Firstly, ANT studies could take account of the impacts, within its networks, of the discourses which the people in its networks hook into – regardless of how well these discourses line up with the way the world is. Even unsupportable world-views are ‘real’ in the sense that the beliefs influence the believers.

Secondly, ANT researchers could put the descriptive elements in relevant discourses to the test. This would throw light on the question as to whether unfounded beliefs are causing a system to fail, or to run sub-optimally.

1.3 Drawing ANT and Policy Discourse Approaches Together

We can now bring several elements together to form a model which can be used to analyse a failing socio-technical system, such as the German PV project. To begin with, the model can be broadly based on the 'hard stage' of ANT. In this, we will be attentive to the ways in which relevant human and non-human elements interact, to form hybrid human/non-human elements. We will also be open to seeing influences from both human and non-human sources, without any pre-judgement as to which type is dominant. However we will rigorously keep to explanations grounded in the natural, prosaic properties of non-human entities, while allowing the full range of intentionality and reflexivity to human beings.

We will also investigate how these hybrid elements form and re-form each other as they interact together. Because such hybrids could act in unexpected ways, we will be open as to what sort of peculiarities they might display.

Secondly, we will be attentive to elements of discourse among the human actors within the network. Some of these might be extremely extensive geographically or temporally, going beyond the boundaries of the system being investigated. For example, discourse which applauds the value of green 'demonstration projects' could be infiltrating, as it were, the German PV project and weakening attempts within it to judge its success or failure on its actual performance.

Thirdly, we will seek out the descriptive elements within discourses that are impacting on the system, and put these to test where possible. One possible candidate might be the discourse that asserts that PV will increase its economic efficiency 4-fold or more, provided the current system continues. This would lead us to seek evidence of potential increases in PV economic efficiency, to see whether there is a reasonable basis for the truth-claim in the discourse, If not, we might conclude that part of the explanation for the system's obduracy is this particular piece of misinformation.

As a convenient shorthand, and to distinguish this approach from other forms of ANT, I will call it 'discursive actor-network theory enterprise' (DANTE).

2. INVESTIGATING THE GERMAN PV PROJECT

The most economical PV units cost around 5,000 euros per kilowatt-peak[6] (kWp), and produce about 900 kilowatt hours (kWh) of electrical energy, in German sunshine[7], for each kWp installed. If a PV unit lasts 20 years it will therefore produce 18,000 kWh for each kWp, at the cost of 28 eurocents per kWh. Electricity sells on the German spot-market for less than 7 eurocents per kWh, so that electricity from

[6] kWp is the maximum power (energy per unit time) a unit can produce under ideal conditions.

[7] PV panels in Germany work best when facing directly south at an angle of around 60 degrees from the horizontal. People whose roofs are so oriented have an economic advantage as the panels do not need angle-brackets.

the best PV units is four times as expensive as the going rate[8]. The most economical wind turbines can produce electricity for around 8 eurocents per kWh, and are therefore about 3 ½ times as economically efficient as PV[9]. PV was previously even less economically efficient, but costs fell from the 1950s to the 1990s due to improved design techniques and mass production efficiencies. However, costs have remained static since 2003 (FME, 2007:14).

There are two basic, material/mathematical reasons why PV cannot compete with wind power. Firstly, wind speed increases markedly with height above ground, and the power produced by a wind turbine varies with the cube (the third power) of the wind speed. Doubling the wind speed gives 8 times as much power; tripling it gives 27 times as much. By contrast, the intensity of solar radiation falling on Germany can never get above its mid-summer, midday level. Hence the ceiling on raw energy potential for PV was reached when PV was first invented, but it gets higher every year for wind power, as turbines get taller. Secondly, the power produced by a wind turbine is proportional to the square (second power) of the diameter of the rotor blades[10], whereas with PV it is proportional to the area of the panels. This gives wind turbines an extra potential economic advantage since you can increase the power by a factor of 9 by using not much more than three times the amount of blade and associated material, but with PV you have to use 9 times the amount of material to get 9 times the power. These advantages are offset to some extent by higher turbine costs associated with metal stress on the parts, but in general the theoretical limits are far more open, with wind power, than with PV (DWIA, 2009).

On their own, these 'hard' material facts would deter potential customers and thrifty governments from widespread commitment to PV. However there has long been a prevalent discourse in Germany applauding renewable energy sources in general and PV in particular. One Freiburg interviewee, a municipal engineer, said PV is '… the only way forward, the only truly green energy source.' The city's tourist literature promotes it as 'the new leading energy' (Freiburg, 2008:3). An oft-repeated discourse, is that PV is 'small and beautiful': it produces electricity locally, using small units, and is seen as less subject to corporate control than enormous wind power turbines (cf. Byrne and Toley, 2006). However the descriptive element in this discourse is problematic, as 99.9% of German PV is connected to the national grid, via converters (JRC, 2009), because power from PV varies with sunshine. Nevertheless the discourse survives and acts in support of the system.

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[8] Because solar energy peaks around midday and is intermittent due to clouds, a house cannot be powered effectively by PV panels alone. Hence most PV units are coupled to 'converters', which change PV's low voltage direct current into higher voltage alternating current and feed it into the grid.

[9] Of all the renewable energy sources in Germany, wind power is 'the closest to being competitive' (FME, 2007: 9)

[10] The power of the wind passing perpendicularly through a circular area is:

$P = 1/2\ \rho\ v^3\ \pi\ r^2$

Where P = the power of the wind measured in W (Watt).
ρ = (rho) = the density of dry air = 1.225 measured in kg/m 3 (kilogrammes per cubic metre, at average atmospheric pressure at sea level at 15° C).
v = the velocity of the wind measured in m/s (metres per second). π = (pi) = 3.1415926535...
r = the radius (i.e. half the diameter) of the rotor measured in m (metres).

Further, many interviewees said that wind power's aesthetics were *'problematisch'*, *'hässlich',* or *'eine katastrophe'*[11]*.* By contrast, the tens of thousands of glossy black PV panels adorning Freiburg's medieval skyline were consistently storied as 'cool and sexy', 'pleasing to the eye' and 'symbolic' of a 'green future'. These or corresponding discourses were evidenced throughout Germany. For many, PV is an 'emblem' (Hajer, 2005:308) of a green, sustainable future.

The beginnings of the German PV project can be traced to the small town of Hammelburg, in northern Bavaria, in the early 1990s. There, in 1991, Hans-Joseph Fell, later a federal Green MP, became one of the first Germans to install a PV panel on the roof of his home (Laudatio, 2006; and interviews with Hammelburg residents). Fell conceived the 'feed-in tariff' (FIT), a state subsidy for renewable energy generation. The level of the FIT would be set so as to ensure that those who installed renewable energy generating devices would have their investment paid back within about 15 years, and thereafter make generous profits. Fell set up a pilot PV programme in the Hammelburg municipality, which paid a FIT of 2 Deutschmarks per kWhr (Laudatio, 2006, Fell, 2008). As a federal Green MP, together with his parliamentary assistant Volker Oschmann, Fell worked toward having the FIT established at national level. When the Greens and Social Democrats formed a coalition government under Gerhard Schröder, this was achieved, with the passing of the Renewable Energy Sources Act *(Erneubare Energien Gesetz – EEG),* which came into force in April 2000 (see EEG, 2004).

The FIT is paid by electricity grid operators, out of a national fund collected through a surcharge on the power bills of every German electricity consumer. Hence it is not a direct government subsidy but an indirect one, as it functions like a tax on electricity usage. By 2006 the FIT for all renewables amounted to a surcharge on German electricity bills of 4% (FME, 2007: 9), of which a quarter was due to PV (FME, 2007: 7), but this share is climbing every year.

The EEG was amended in 2004 (EEG, 2004), increasing the levels of the FIT (see Chart 1).

[11] 'problematic', 'ugly', or 'a catastrophe'

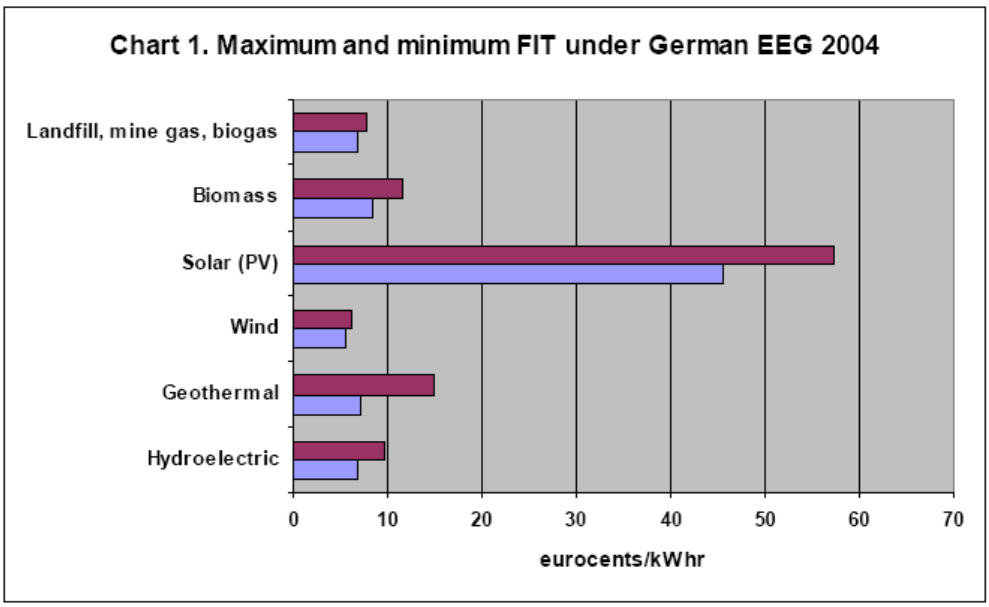

Chart 1. Maximum and minimum Feed-in tariff for renewable energy sources in Germany. Source: EEG (2004).

Because PV is far less economically efficient than other renewable sources covered in the legislation (hydroelectric, wind, biomass, geothermal, and waste and sewage incineration – see UO, 1998), the level of FIT payments for PV were set an order of magnitude higher than for other renewables. The 2004 FIT was set at 45.7 eurocents/kWh for ground-mounted PV systems and 57.4 eurocents/kWh for installations on buildings. It is paid at these rates for 20 years to PV operators who began to generate in 2004. The starting rate for new operators in subsequent years is tapered, reducing by 5% each year. So, for example, an operator starting in 2005 receives 51.7 cents (95% of 57.4) per kWh for 20 years. The reasoning behind the taper is to spur manufacturers to progressively reduce the cost of PV units. This is based on another prevalent discourse: that mass-production and deployment of PV, together with research, will lead to production efficiencies which will bring costs down, so that within a few years PV energy will be as cheap as fossil fuel energy. This discourse was evidenced among almost all interviewees, including engineering and bureaucratic staff. Since this discourse has descriptive features, it could be put to the test, by asking interviewees which particular material improvements to PV would bring costs per unit down to 25% of those at present. None were able to give a convincing answer. There was often an angry or flustered response when it was pointed out that costs had not come down at all since 2003.

The installed capacity of PV in Germany increased by 55% per year from 2003-2007 (FME, 2007). This unrelenting demand for PV panels can be explained in terms of the financial returns coming from the FIT. Using the above figures of 5,000 euros per kWp and 900 kWh per kWp installed, a FIT of 50 eurocents per kWh for 20 years equates to an annual return of 9% on one's investment, and free money thereafter if the panels outlast their expected lifetime. Since PV customers can get a loan from the German Development Bank (*Kreditanstalt für Wiederaufbau*[12] - KfW) at 2.46%

[12] The KfW is a federal funding agency primarily for energy-efficient building projects and renovations. Interest rates for loans for PV installations are given on its website. See http://www.kfw-

interest, installing a PV unit is actually a way of getting free money from start to finish. This is sufficient to explain its growth and popularity.

This growth, however, has led to a massive increase in the cost of the FIT. The cumulative installed capacity of 3,862,000 kWh in 2007 required a PV FIT of 1.9 billion euros (VDN, 2008). This will have approached 2.9 billion in 2008. If capacity continues to increase by 55% per year the 2009 PV FIT will be 4.5 billion euros. Frondel et al. (2008) developed a model based on modestly increasing sales of PV in Germany and a steadily increasing spot-price of wholesale power. They calculated that, even if the FIT were to be phased out as from 2010, the cumulative FIT for PV would amount to over 30 billion euros. Without such a phase-out, the Rhein-Westfalen Economic Institute calculate that the cumulative PV FIT will run to at least 120 billion euros in real terms, i.e. translated into 2008 purchasing power (cited in Waldermann, 2008).

Projections such as these partly explain why the Conservative-Social Democrat government made changes, albeit modest, to the EEG in 2008. As from 1 January 2009, the annual taper (i.e. reductions in subsidy for new installations) will go from 5% to 8-9%, depending on the level of PV installed. The remainder of the explanation is that the Greens are no longer part of the governing coalition, so that their discourses no longer need to be heeded.

However, the *modesty* of the changes is explained by a material factor: the momentum of the infrastructure of manufacture and deployment of PV units throughout Germany. For example, the world's largest PV manufacturer, Q-Cells, is in Wolfen, near Leipzig, and employs over 1,000 people (www.q-cells.com). In all, about 27,000 people are employed in the German PV industry (FME, 2007: 7). If a decision were made to stop subsidising new installations (but to continue with those currently subsidised), the entire domestic base of this industry would be threatened, since the financial incentive to install PV panels would be gone. This brute material reality serves to lock the government in to the PV subsidy system, even though the discourse behind it is no longer 'structurated'.

3. CONCLUSIONS AND DISCUSSION

We have identified the logically and philosophically defensible features of ANT and policy discourse analysis, brought these together, and extended them with the critical realist insight that descriptive elements within discourse can be tested. This framework ('DANTE') has enabled us to perform a preliminary analysis of the German PV project, and provide explanations for its peculiarities. These explanations can be summarised as follows:

1. As a means of producing renewable electrical energy, PV cannot come anywhere near competing economically with wind power. Further, the money spent manufacturing and installing it would save far more energy if invested in relatively low-tech projects such as thermal renovation of existing homes.

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foerderbank.de/DE_Home/Umweltschutz/Programme_ab_2009/KfW-Erneuerbare_Energien/index.jsp Accessed 15 April, 2009.

2. PV has become massively popular in Germany because of the FIT and the KfW loans, which make it a guaranteed source of free income for anyone with a south-facing roof.

3. The FIT was established as a consequence of the structuration and institutionalisation, within the Red-Green Schröder government, of discourse which applauds the moral value of PV and claims its economic efficiency will dramatically increase. The strategy for institutionalisation of this discourse is closely associated with the political career of Green MP Hans-Joseph Fell. This discourse continues to provide support for the PV FIT system among many groups in Germany.

4. The main descriptive element in this discourse, i.e. that PV will soon become cost-effective in German sunshine, does not appear to have a sound basis. In any case, nothing can make the PV panels that are already installed, and receiving subsidies, become more economically efficient.

5. The demise of the Red-Green government has enabled this discourse to de-structurate from within the federal policymaking system. This has provided the opportunity to begin to reduce the FIT.

6. However, the material reality of a large PV producing infrastructure, together with the jobs it provides, prevents the new government from stopping the FIT for new PV installations.

What can be done about this? It would be unfortunate if tens of billions more euros were spent subsidising a renewable energy technology that has failed. One way ahead would be to undertake a detailed study of how the PV industry in Germany could be scaled down such that jobs and technical ability could be diverted to more promising energy-saving technologies. Simultaneously there needs to be more open and honest discussion in Germany on the shortcomings of PV. This should also happen in countries that have copied Germany's PV subsidy scheme, such Spain, Italy and Greece. Meanwhile the UK government, which is under pressure to adopt the FIT for PV, needs to look more critically at it and speak back more directly to NGOs and others who advocate it so assiduously.

With regard to DANTE, this approach is offered for others to critique and, if it stands up to scrutiny, to test out in the analysis of other socio-technical systems.

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- 'Kommentar zur Jahrestagung des FVS Dez 2007' (Comments on the annual meeting of the FVS, December 2007)
- 'Die Voreingenommenheit internationaler Energieinstitutionen '(The biases of international energy institutions)
- ''Energiepolitische Halbzeitbilanz der Großen Koalition' (The grand coalition's energy policy at half-time)
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