5 The psychology of expectations in sociotechnical systems

Introduction

This chapter illustrates how social psychology can add to existing, functional accounts of expectations in sociotechnical, specifically energy, futures. It is closely connected to the previous chapter, drawing in part on the same study. Again, the aim is not simply show the relevance of psychological theory and empirics for sociotechnical transitions perspectives of energy system change and stasis, but to show how these may be closely connected in ways that provide a fuller account of topics of interest to energy transitions processes.

In innovation studies and, more recently, sociotechnical transitions literature, what are described as 'expectations' play an important role (van Lente, 2012). 'Expectations' include all types of visions, scenarios, roadmaps and other depictions of the future, whether private or public, individual or collectively produced, formal or informal (ibid.). In general, expectations are viewed as directing attention (positive and negative) to future options, helping to direct and legitimise interest and investment (Borup *et al*. 2006; van Lente 2012). While innovation studies and the sociotechnical transitions literature tends to look at expectations through a functional lens, that is, at what expectations *do*, here we are more interested in their nature as a psychological phenomenon. We therefore define expectations as *beliefs about the future* and show how, interpreted in this way, expectations can be connected to one of the most well-known psychological models of behaviour – the theory of planned behaviour (TpB) – and hence can help to explain why individuals act positively on some expectations and not others.

Although the sociology of technological expectations literature primarily focuses on the social dynamics of expectations – such as how they circulate, compete and are involved in the 'hype' of changing levels of societal attention towards particular technologies (e.g. Alkemade and Suurs 2012) – the same literature also implicitly acknowledges their psychological dimensions. For example, those studying expectations have observed that one feature of foresight and road-mapping exercises, that is, formalised

scenario processes usually involving a range of stakeholders, is the tendency to generate rather unoriginal visions of the future, perhaps in part due to those involved drawing on pre-existing cognitive repertoires of possibilities for that future (Jacobsson and Johnson 2000; Unruh 2000, cited in van Lente 2012). As these cognitive repertoires are both socially shaped and cognitively held, the question is how and why some such ideas and norms are internalised by individuals while others are not, and why some are given a lower degree of personal commitment than others. In both this and the next chapter we reflect upon these questions using different types of psychological theory. In this chapter, we refer to constructs that are common in cognitive, behavioural psychology, while in the next chapter we use the theory of social representations, which relates more directly to the acceptance of ideas.

We begin with a short overview of the literature on the sociology of expectations. We then outline three closely related psychological theories that are in essence refinements of the same proposition, namely, that behaviour follows from the belief that such action will have a desirable consequence for the actor: Vroom's (1964) expectancy theory; the theory of reasoned action (Fishbein 1967); and the theory of planned behaviour (Ajzen and Fishbein 1980). We use these theories to identify psychological constructs that connect the expectations of individuals (and, potentially, groups) to action. This constitutes more of a psychological perspective of what sociologists would describe as connecting agency to structure, and here more specifically to sociotechnical structures. To model these sociotechnical structures and processes we use the multi-level perspective (MLP) (Geels 2002), around which so much of the sociotechnical literature has coalesced (Sorrell 2018).

As illustrative case material, we use data from the same interviews with the European hydrogen innovation systems' actors referred to in Chapter 4, again specifically those involved with the use of hydrogen as a fuel and hydrogen fuel cell (HFC) electric vehicles. Thus, the empirical data for this study was collected as part of the same case, and analysed using the same methods described in Chapter 4.[1] In this chapter, however, we focus more specifically on *expectations* among the informants, and we show how the policy environment in which the informants are integrated interacts with those expectations as psychological constructs.

As caveats, our purpose is not to evidence this interaction in depth, but rather to show that we can look at sociotechnical expectations from long-standing psychological perspectives and to argue that this is likely to add to our understanding of the processes involved. Similarly, as the data available to us stops short of the level of detail required to connect specific behaviour to the psychological constructs that we identify, we have to be content here with setting out the rationale for a direction for further research. The chapter again draws upon on the study by Dütschke *et al.* (2017) and the interpretation of Upham *et al.* (2017). We begin with an overview of how technological expectations are usually considered.

The sociology of technological expectations

Within the literature on the sociology of shared expectations, such expectations are believed to help to co-ordinate action within and between organisations, acting as a 'constitutive force', particularly in the early stages of the social embedding (uptake and use) of an innovation. This is especially the case when different technology options (e.g. different types of energy supply etc.) are competing for investment and attention (Borup *et al*. 2006). It has been argued that shared expectations help to connect different groups within and between organisations (ibid.). In relation to one of the functions of innovation systems, this includes guiding the search for emergent technology selection[2] (Bergek *et al*. 2008; Hekkert and Negro 2009). Hence, facilitating shared expectations has become an important feature of "communication and interaction across institutional and epistemic borders" (Borup *et al*. 2006, p. 286), where the latter refers to the distinctions between different types of knowledge or knowledge domains, within or between organisations. Berkhout (2006) describes expectations as strategic "bids" for possible futures, highlighting their often competitive nature, especially at the early stages of sociotechnical development before major commitments to investment have been made.

Expectations are found everywhere. For those involved in formal, institutionalised visioning (typically well-resourced scenario production), Van Lente (2012) highlights some of the dilemmas posed by what he describes as a "sea" of informal expectations. Formal plans and visions for the future, such as roadmaps, scenarios and foresight activities take place not in a space empty of expectations but, conversely, in social environments in which a sea of expectations already exist, circulate and compete. If sociotechnical emergence from a niche requires the development of aligned and strong networks of actors, visions of the future that deviate substantially from each other may disrupt and eventually shape those networks.

With the above in mind, and thinking in terms of connections to psychological constructs, we suggest that expectations can be treated as *beliefs* about the future. Hence, to hold an expectation relating to, for example, hydrogen fuelled vehicles is to hold a belief about the future of those hydrogen fuelled vehicles. To view this expectation positively is to hold a positive *attitude* towards it – or the contrary. The *strength and the direction* of the attitude may be influenced by personal and social *norms*. The likelihood of acting in a way that assists the realisation of that expectation (belief) is considered the function of an *intention* to act.

Hydrogen fuel cell electric vehicles (HFCEVs) and hydrogen fuel cell applications in general are subject to what has been described as "arenas of expectations" (Bakker *et al*. 2011), where different actors promote and assess competing claims as to which technological option will

succeed in the market (ibid., p. 55). As Bakker *et al.* (2011) emphasise, this process is collective, social and competitive at the same time, and it takes place in many different fora that include a wide variety of actors (industry actors, practitioners, policy makers, lobbyists, NGOs, end-users, news media, scientific conferences and journals, research funding agencies and so on). All of this activity taken together comprises an expectations dynamic that, assessed over time, can provide an indication of the future fortunes and prospects of particular technologies (Alkamade and Suurs 2012). HFCEV technologies have been described as being particularly subject to a 'promise–requirement cycle'. This means that performance-related promises (e.g. specific expectations regarding range, speed, safety and costs) with a specific time horizon (e.g. ten years) have become performance requirements as a condition for public and commercial investment (Van Lente 1993, 2000; Van Lente and Bakker 2010). In other words, product expectations that become product requirements are more likely to receive funding and investment and thus to become a reality (Upham *et al.* 2017).

Psychological theory and expectations

The range of theories that employ constructs directly relevant to psychological theories of expectations is rather small, although these theories are very commonly used. In particular, they are Vroom's (1964) expectancy theory and the related theories of reasoned action and planned behaviour (Fishbein 1967; Ajzen and Fishbein 1980).

Expectancy theory holds that the behavioural choice of an individual is a function of strength and direction of their attitudes (valence) and the perceived likelihood of a desired outcome following from that behaviour. Contemporary research using expectancy theory investigates the influences on valence and the anticipated outcomes of actions in, for example, organisational contexts. This could be the relation of employee work activities and associated organisational or employee goals (Chen *et al.* 2016).

The *theory of reasoned action* (Fishbein 1967) hypothesises that behavioural *intentions* are the best predictor of actual behaviour, and views those intentions as a function of the same core variables: attitudes to perceived action outcomes and the perceived likelihood of those outcomes being realised. The theory of reasoned action also takes into account social norms, e.g. societal beliefs about a behaviour.

The *theory of planned behaviour* adds the variable of perceived behavioural control. This includes factors that are both endogenous and exogenous to the individual, i.e. the locus of control as perceived by the individual may be seen as either internal or external to that person (Ajzen 2002). In the theory of planned behaviour, personal norms are regarded as differentiated from social norms (see Box 5.1).

Box 5.1 Theory of planned behaviour

The theory of planned behaviour (TpB) aims to predict how individual behaviours form, given the specifics of time and space, and to this end the theory emphasises the importance of motivation and abilities in determining behaviour. The theory identifies three main constructs that jointly contribute to determining the degree of control people have over their behaviours. These are: behavioural beliefs, normative beliefs and control beliefs. These overarching constructs and their subcategories refer both to societal norms and values *and* to the potential influence on/interpretations of these by the individual actors that ultimately 'do the behaviours'.

Behavioural beliefs refer to the attitude towards the act or behaviour; to the individual's assessment of how certain behaviours might ultimately become either a positive or a negative contribution in the life of that individual; to the consequences of actions. *Normative* beliefs focus on what is around the individual actors and, in this respect, to the normative expectations of others. For example, social groups and networks, cultural norms and group beliefs may influence individuals and their actions. Individuals may consider what peers and social network would think about doing something or about some action, and this again will influence the eventual behaviour. *Control* beliefs refer to how hard or how easy individuals believe it may be to do or display certain behaviours or agency, and thus these refer to beliefs about various factors that may either hinder or facilitate behaviours. Such assessments are inherently dependent on the specifics of time, place and context, and thus individuals can have very differing perceptions of their behavioural control given the particular situation.

Considering the impact of these constructs together, TpB predicts that a positive attitude towards the act or the behaviour, favourable social norms and a high level of perceived behavioural control are the best predictors for forming a behavioural intention, which in turn leads to a displayed behaviour or act. This is less like if any of the constructs prove less favourable (Ajzen 1991, 2006).

In Figure 5.1, key constructs are summarised and the model therein sets these in relation to the basic elements of the MLP of sociotechnical change (Geels 2002). As stated in Chapter 1, drawing on various literatures relating to technology development, the MLP posits that transitions come about through different types of interaction between processes at three levels: via *niche*-protected innovations gradually becoming more powerful; via *landscape*-level change that pressures the sociotechnical regime; and/or via destabilisation of the *regime*, enabling niche-innovations to gain their own momentum (Rip *et al.* 1995). At the micro level, niches are the location at which path-breaking innovations emerge – protected spaces that policies may passively or actively protect, nurture, empower or hinder (Smith and Raven 2012). At the macro level, the landscape is conceived of as an exogenous environment that is beyond the direct influence of niche and regime actors, including macroeconomics, deep cultural patterns and macro-political trends (Geels and Schot 2007) (see Box 5.2).

The model in Figure 5.1 depicts precisely the more individual level processes within the framework of the MLP, and it does so focussing on some of the most important variables considered in the theory of planned behaviour (Ajzen and Fishbein 1980). However, beyond simply depicting the psychological, social and sociotechnical processes in mutual

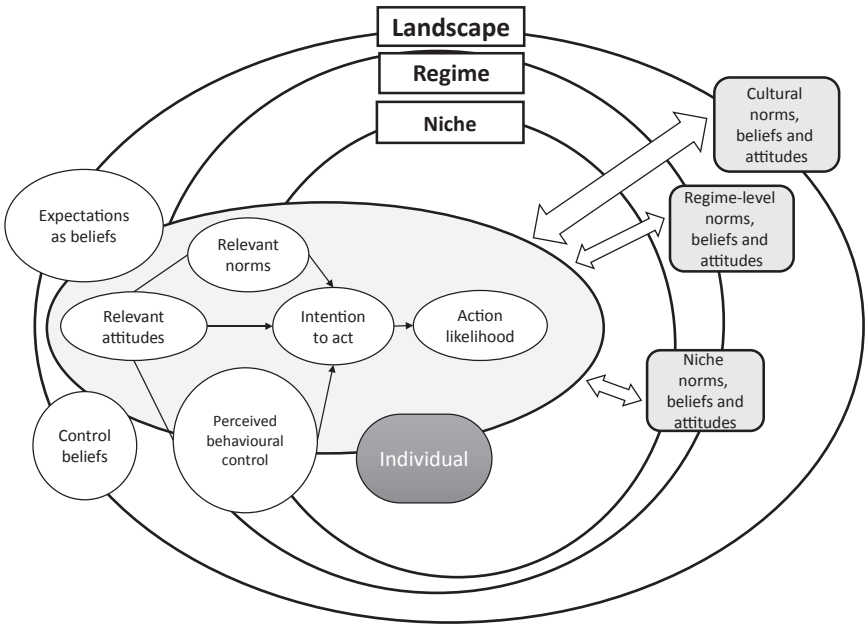

Figure 5.1 Basic components of individual psychology in relation to Geels' (2002) multi-level perspective of sociotechnical transitions.

Box 5.2 Exemplar reference to norms in the sociotechnical sustainability transitions literature

The multi-level perspective (MLP) recognises norms, beliefs and attitudes as operating at the niche, regime and landscape levels. For example, Elzen *et al.* (2011) discuss the role of normative contestation in transitions in relation to system innovation in pig husbandry. The authors describe how niche-level normative pressures from social movements for increased animal welfare in the Netherlands led to varying responses by some regime-level farmers, who then tested different pig husbandry designs.

In the MLP ontology overall (i.e. categorisation of phenomena at three levels), slow-changing social norms and values that are taken for granted are generally regarded as part of the 'landscape' level (Geels 2002). There is little intra-individual consideration of norms, values or attitudes within the transitions literature.

relationship, Figure 5.1 also implicitly connects the psychological aspects of expectations with the different levels of the *structuration* that underpins the niche, regime and landscape processes in the MLP (Geels and Schot 2007). Thus, the model also conveys psychological constructs and processes: (a) at levels beyond the individual, i.e. in different forms of collective organisation; (b) in relationships of mutual influence across these levels; and (c) in relationships of mutual influence with the systems that the individuals are part of. Importantly, in all of these processes *expectations* function as specific forms of belief. Overall, this connection of psychological and structuration processes helps to overcome the limitations of psychological perspectives that privilege a more individual level focus (see Batel *et al.* 2016), and at the same time it enriches the structure-focused accounts of change and resistance to change (Stones 2005).

Several further points can be made. First, following from the model, hope and fear are potential correlates of expectations. This is because expectations are often affectively engaged constructs, with emotional attributes. In this respect they differ from predictions per se (Castelfranchi 2005) – although one may also have hopes and fears about a prediction. Second, as humans are capable of abstractions, expectations involve cognitive representations of the future (ibid.). Third, and importantly, it follows from the model that not all expectations will lead to action. In this case, the main form of action would be efforts towards resource mobilisation, but a strong intention to act would also require sufficient strength and congruence among relevant attitudes, beliefs and norms of the actor(s) (see Castelfranchi 2005). In particular, one of the main implications of the TpB is that agents are less likely to act if they believe their actions will not have desirable consequences (Batel *et al.* 2016).

In the next sections we briefly describe the following: the policy context of our illustrative case; how the individual expectations of hydrogen and HFCEV stakeholders were elicited and analysed; and how these stakeholders' expectations illustrate the value of viewing expectations as future-oriented beliefs that interact with individuals' attitudes and norms. As we suggest, this is particularly important when seeking to understand the relationship between expectations and agency/action in sociotechnical contexts.

European policy context for HFCEVs

In the European Union, Directive 2014/94/EU on the deployment of alternative fuels infrastructure supports the development of low carbon transport. Here, alternative fuels are defined as: electricity, hydrogen, biofuels, synthetic and paraffinic fuels, natural gas (including biomethane), in gaseous form (compressed natural gas or CNG), liquefied form (liquefied natural gas or LNG) and liquefied petroleum gas (LPG) (Miguel *et al.* 2016). The Directive sets out minimum requirements for the development

of alternative fuels infrastructure, and these minimum requirements include recharging points for electric vehicles and refuelling points for natural gas (LNG and CNG) and hydrogen, common technical specifications for these recharging and refuelling points, and user information requirements. Specifically, Article 5 of the Directive, "Hydrogen supply for transport", requires the circulation of hydrogen-powered motor vehicles within national transport networks with cross-border links by 31 December 2025. Deciding on the appropriate number of hydrogen refuelling stations to achieve this is left to individual member states (Miguel *et al*. 2016).

As mentioned in Chapter 4, in order to span high, medium and low HFCEV innovation activity in this study, five European countries are considered here: France, Germany, Slovenia, Spain and the UK. Among these countries, only Germany has a dedicated national hydrogen implementation plan. The German National Hydrogen and Fuel Cells Innovation Programme, managed by the National Organisation for Hydrogen and Fuel Cell Technology (NOW GmbH), is a public–private partnership spanning several ministries and regions with an initial, planned budget of 700 million euro from both government and industry (1.4 billion euro in total). A further initiative launched by NOW GmbH specifically for fuel cells transport application is H2Mobility, the first broad European plan to build a hydrogen refuelling station (HRS) network for HFCEVs (Miguel *et al*. 2016).

France has the strongest level of financial support from the State, particularly through the Hydrogen Mobility France initiative, a European financed project also involving four other countries. Partners in this project include the French government; energy companies; hydrogen and hydrogen refuelling producers; vehicle, fuel cell and electrolyser providers; research organisations; several regions; and EU and French associations. Key targets through to 2020 are to: create transnational corridors to Germany and Belgium for hydrogen vehicle use and refuelling; deploy HFCEV technology in clusters, i.e. so that specific regions are served; and to deploy extensive fleets of HFCEV vans, trucks and 15–20 hydrogen refuelling stations on selected road networks. The estimated funding needed until 2030 to implement the approximately 600 hydrogen refuelling stations and more than 800,000 HFCEVs necessary to achieve the longer-term goals of the programme is about 586 million euro (Miguel *et al*. 2016).

The UK, Spain and Slovenia all have project-based hydrogen and HFCEV activity, but there is less national programmatic support. In terms of project examples, in the UK, London had eight HFC buses under the Clean Hydrogen in European Cities (CHIC) project and Aberdeen had ten in 2016. This made Aberdeen's hydrogen bus fleet the largest in Europe at the time (Miguel *et al*. 2016). Through the multisector consortium UKH2Mobility in the UK, a national 2030 roadmap for HFCEVs has also been formulated.

All of the countries referred to here have forms of subsidy, tax incentives and related measures at the consumer level for low emission vehicles in

general, though sometimes (as in Spain) only in certain regions. However, in terms of *national* private and/or public sector commitments to financial investment and infrastructure deployment relating to hydrogen applications, Germany's initiatives are the most substantial, while France has significant commitments too. It seems that where there are no nationally coordinated programmatic activities relating to hydrogen applications (as in Spain and Slovenia), initiatives such as hydrogen bus operations tend to cease as soon as the European funding expires (Miguel *et al.* 2016). While such project expiry applies to programme-funded activities too, individual project funding outside of programmes is usually on a more temporary basis. As we show via the presented data, such national policy differences do play a role in the psychology of the expectations of interviewees.

Individual stakeholder expectations

Below, we first provide an overview of some of the expectations that we identified among the informants and, second, we show how three psychological constructs – negative control beliefs, positive control beliefs and social norms – can help us to characterise and understand those expectations, both in and of themselves and in relation to anticipated action or agency. We now turn to an illustrative discussion of these expectations. Figures 5.2 and 5.3 show the expectations themes as identified among the interviewees; the figures illustrate the number of times each theme was mentioned by the countries studied.

The key expectations for hydrogen supply and use (independent of application) among the informants were generally positive, with market development expected in the relatively near term. Nonetheless, many of the interviewees did expect national differences in the way that supply and use of hydrogen will develop. Many informants expected the prospects and uses of an expanded hydrogen supply to be contingent on key decisions taken in the vehicle, heat and power sectors, but they also expected those decisions to be influenced by decisions taken outside of these sectors. In this regard, some informants mentioned the ongoing tightening of environmental legislation.

Many interviewees from across the five countries referred to Germany as most likely to be at the forefront of HFCEV developments due to its dedicated national hydrogen innovation programme and the substantial auto-manufacturing sector. French respondents were particularly confident of the prospects for hydrogen itself, perhaps because of a focus on (apparently successful) hydrogen trials in the professional transport sectors with light duty vehicle fleets fitted with a battery as a range extender. These offer the advantage, over the individual consumer sector, of the need for fewer refill points. That is, vehicles owned by professional fleets have shared and hence fewer home bases than is the case with individual owners – and fewer home bases means the need for fewer individual refill points.

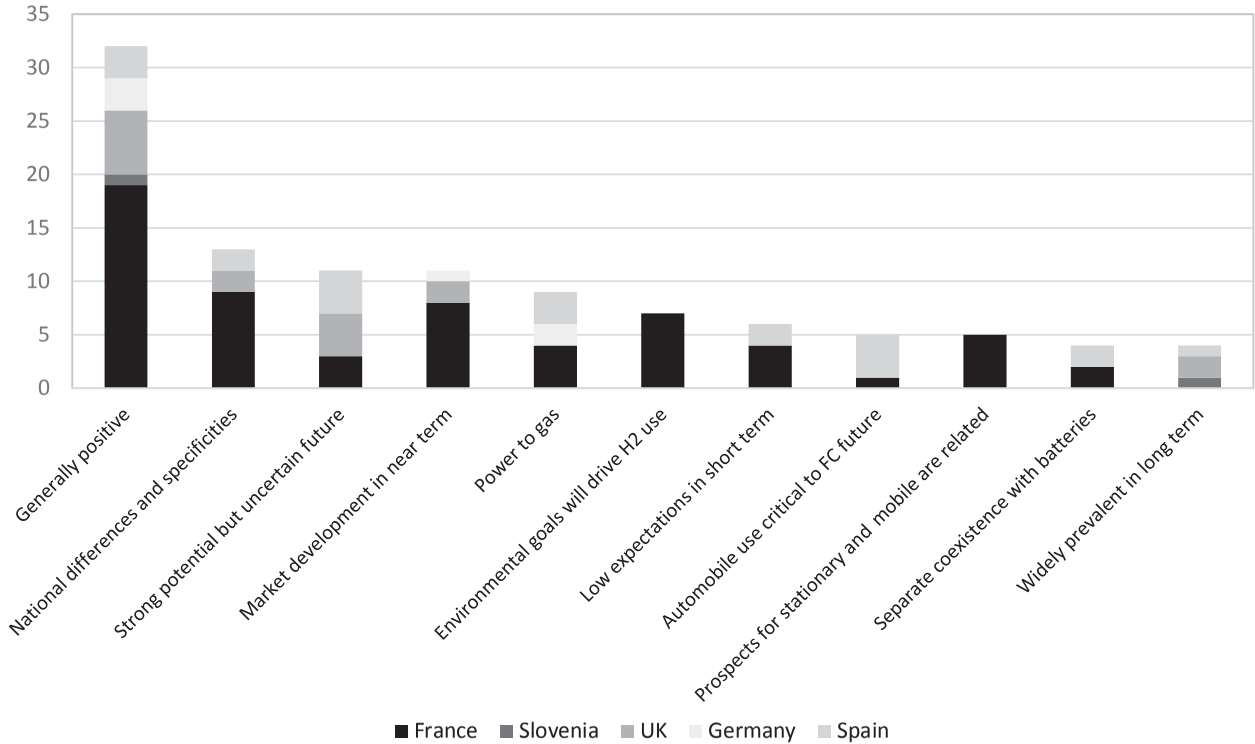

Figure 5.2 Hydrogen supply and use: expectations count.

Notes
1 H2 – hydrogen; FC – fuel cell.
2 Thirteen expectations expressed by 1–2 people per item have been omitted so that the figure legend remains legible.

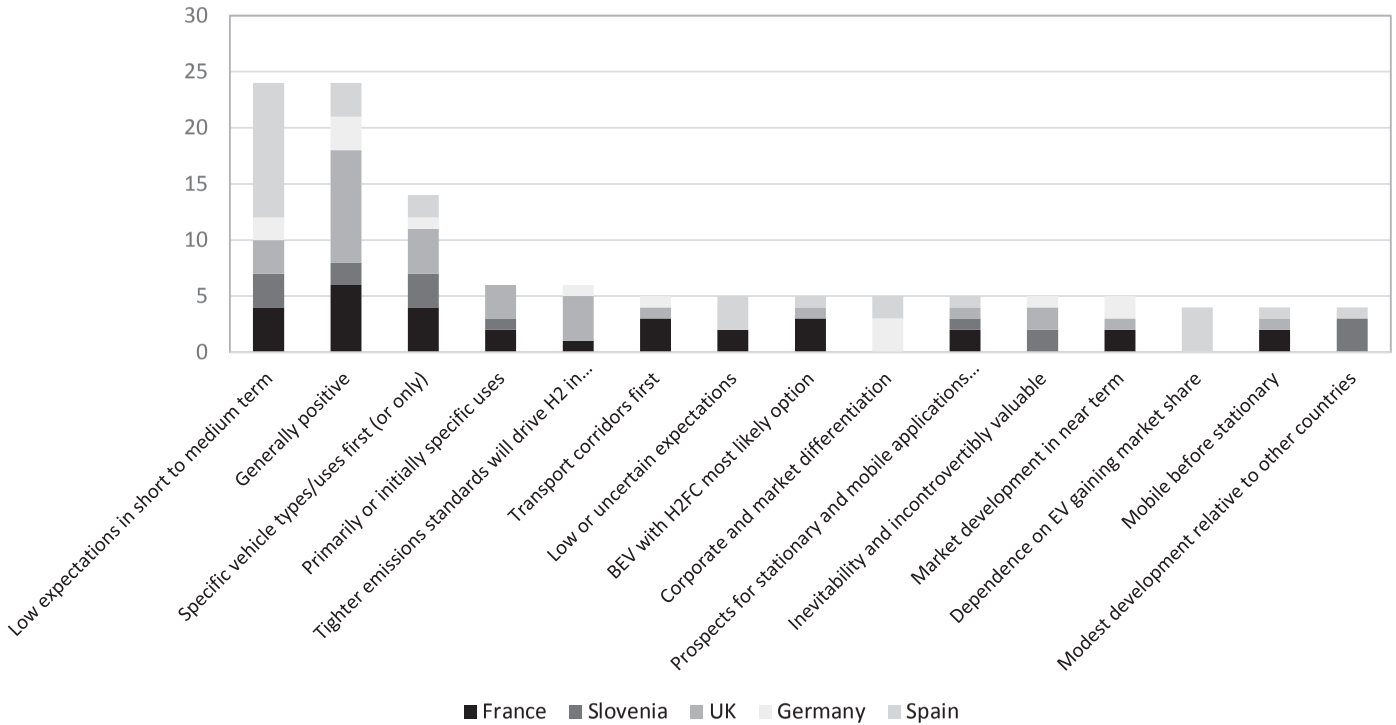

Figure 5.3 Hydrogen fuel cell electric vehicles: expectations count.

Notes
1 H2 – hydrogen; EV – electric vehicle; BEV – battery electric vehicle; H2FC – hydrogen fuel cell.
2 Thirteen expectations expressed by 1–2 people per item have been omitted so that the figure legend remains legible.

Overall, interviewees were very aware of their national and regional economic contexts and of the role and value of hydrogen supply not only for HFCEVs, but also the wider value of new regional economic clusters and connections with oil and gas industry expertise. The French interviewees were probably the most unequivocally optimistic about the prospects for hydrogen (see Figures 5.2 and 5.3).

For many interviewees, financial and cost-related matters in relation to HFCEVs were expected to be severely constraining on the further development of the technology. Generally, the financial instruments and forms of policy support intended to bring down the relative costs of hydrogen and HFCEVs (see e.g. OECD/IEA 2015) were seen as desirable possibilities, but they were also seen as unlikely in the short term. Hence, few expected HFCEVs to be deployed at any significant level in the short term. Rather, there were expectations of: HFCs and electric batteries being mutually supporting within individual vehicles; battery electric vehicles dominating in the short to medium and/or longer term; and hydrogen being blended with methane for compressed natural gas engines,[3] rather than used for HFCEVs. More positively for HFCEVs, some stakeholders expected the trend of electrification in transport to assist HFCEVs – which use electric powertrains – by making the latter and their supporting infrastructures more prevalent. In other words, more manufacturing capacity for suitable electric motor systems requires correspondingly skilled workforces, component supply chains, standards and, ideally, per unit lower costs. Hence, although battery electric vehicles were expected to compete with HFCEVs in the short to medium term, electrification pathways (consisting of all of the wide variety of actions necessary to transition from fossil-fuelled mobility to electric-powered mobility) would be established that would help HFCEVs in the long term (Kemp *et al.* 1998; Geels 2002; Geels *et al.* 2012; see Figures 5.2 and 5.3).

Psychological dimensions of expectations

In the next sections, we show how the basic psychological constructs of positive and negative control beliefs and social norms have the potential to help to explain how interviewees' experiences with hydrogen and HFCEVs influence their expectations of these and their propensity to act on those expectations, recommend action or expect action by others. This is not only likely to facilitate a richer characterisation of the position of agents than is usually found in literatures relating to technological expectations, but may also reveal some details about the nature of those expectations and their propensity for future material influence and change. We illustrate this with a number of interviewee quotations below; the selected quotations are categorised by type of psychological construct. As stated earlier, the data we have available can only take us so far in making the argument and it remains for further work to trace in empirical detail the connections we map out.

Negative control beliefs regarding hydrogen and HFCEVs

Many of the interviewees' responses relate to the control beliefs referred to in Box 5.1. Self- and response-efficacy are, respectively, the beliefs that acting/doing something will make little difference, either because of one's own limited capacity for action (self-efficacy) or because of the inconsequential nature of such action (response-efficacy). For the Spanish and Slovenian stakeholders in particular, negative control beliefs reflect limited government and/or commercial interest in hydrogen and HFCEVs at the national level.

The Spanish stakeholders referred to a lack of national governmental support for the sector:

> I do not have a crystal ball … [but] what is clear is that Spain is not in the game. When we want to do it, it will be already done. Germans and others will have already done it … It will happen as in the automotive sector, we are only good component manufacturers.
>
> (Spain, private sector employee)

Slovenian respondents also had limited expectations of the success of hydrogen and HFC technologies relative to other countries. For example:

> I estimate the role of this technology in Slovenia will be somewhat less than in the neighbouring countries (Austria, Germany etc.), but much stronger than in the south-eastern parts. Let's say we will be at about 50 per cent of the level achieved in Germany.
>
> (Slovenia, university employee)

However, German respondents too, had doubts about the *near-term* prospects for HFCEVs and the associated effectiveness of current R&D efforts:

> On … the supplier side of the technology we do not have the necessary capacity that is needed. One major company is now consequently following this path, and they expect it to be relevant in the medium term, but many others are still playing on a low level. You cannot make billions from it at the moment. The time span is more towards 2030.
>
> (Germany, state research organisation employee)

In fact, this was the dominant message of all those interviewed, despite decades of investment in the sector to date. Apart from the currently very high cost of HFCEVs, many of the informants saw one of the key reasons for doubting the near-term effectiveness of R&D investments in HFCEVs and their associated technologies as the existence of alternatives that satisfy the same environmental and service provision objectives.

> In the short to medium term, the EV [electric vehicle] is going to prevail. For road transport, I think [in the form of] liquefied natural gas. As an alternative to conventional fuels, I see more possibilities in EV because now there is more supply of vehicles and the cost of the recharging infrastructure is much more affordable. Manufacturers, due to the issue of CO_2 emissions, are positioning themselves in favour of electric vehicles. It is the most immediate.
>
> (Spain, public sector employee)

Other informants expressed more confidence in non-fuel cell uses of hydrogen, however:

> When we talk about hydrogen today, we always think about fuel cells. This is fine, but there are still very few HFCEVs, there is still no solution for heavy vehicles, etc. … So then, we want to resume the tests done years ago to mix hydrogen and methane … you can propel a bus running on natural gas with a mixture of 20 per cent hydrogen, you can reach even 25 to 26 per cent, and the rest natural gas.… The hydrogen field always seems to be in the skies, far away … but with this process [mixing hydrogen with methane in natural gas vehicles], we are not talking about the future. We have a lot of faith in this strategy.… In the end, no one thinks that all cars will go with hydrogen, CNG [compressed natural gas] may be an alternative and, in the end, I think there may be room for hydrogen and natural gas.
>
> (Spain, private sector employee)

Among all the informants, national governments were consistently seen as the most powerful actors in the sector, mostly due to their control over the national policy environments and hence fiscal measures, investment and various aspects of regulation.

> A key question here is what level of importance will governments attach to moving towards low carbon technologies? The cheapest option is to continue with modern technology diesel cars etc. If we want to see decarbonisation of the transport sector it will be driven by governments which will see quicker roll out of low carb technology.
>
> (UK, hydrogen partnership stakeholder)

> I would see it [hydrogen technology] commercialising within ten years, that would be the hope, but that relies on what [governmental] policy support it secures.
>
> (UK, public sector employee)

Positive control beliefs towards hydrogen and HFCs

Nonetheless, positive control beliefs were also expressed, particularly among the French informants. Implicit in many of the views expressed is the belief that ongoing investment is worthwhile, in that it will have a positive outcome – the latter is a core premise of the TpB and its antecedent theories:

> As this is a new technology, its costs are very high. Over time, these will decrease and it will become accessible to everyone.
>
> (France, public sector employee)

Sometimes, positive control beliefs were intertwined with positive beliefs about economic opportunities.

> I think there are opportunities for the countries that lead on these technologies. We see Germany going for hydrogen in a big way. Scotland has also done that. We've got clusters in Aberdeen, Orkney and Fife. We are placing ourselves well. There will be jobs created and opportunities for providing services and exporting as well. These are all opportunities that will come.
>
> (UK, private sector employee)

> I think the energy sector, the people who install the hydrogen equipment, and people who design it, designers, installers and manufacturers will have the most opportunities. It is the case that the electrolysers in our project are imported from Canada, so we need to grow a UK supply sector as far as we can. There are opportunities for UK companies to grow their businesses.
>
> (UK, non-profit organisation employee)

Additionally, positive control beliefs among interviewees from several countries were the result of – and associated with – the setting of realistic, achievable targets. For example:

> We have to start with the big vehicles: the buses.… Buses are big in consumption, intensity of use and they depend on one decision taker. Here is the issue. Then we will reach the passenger cars.
>
> (Spain, private sector employee)

Positive control beliefs are also associated with – and encouraged by – past experience:

> When I give a conference [paper] I have a presentation with one slide about the main car companies that in 2000 had planned to introduce

> fuel cell vehicles. They had planned that in 2015 they would sell the first commercial hydrogen vehicles. And it has happened. It seems that the automotive industry has achieved what they had proposed. That's where there are more expectations, the introduction of hydrogen from the automotive sector; from there, hydrogen will begin to raise.
>
> (Spain, foundation employee)

For several informants, positive control beliefs extended into a perception of the inevitability of the widespread use of hydrogen technologies in the long term:

> Of course, the costs of the vehicles are still too high. Sure, there are a lot of problems to solve regarding the infrastructure (reliability, operating costs, the technology itself).… But in the long run there is no alternative, in my view.
>
> (Germany, private sector employee)

Social norms, hydrogen and HFCEVs

Some interviewees referred to anticipation of positive attitudes and implicitly congruent social norms regarding the use of hydrogen and HFCEVs among the wider population, though this was seen as contingent on government support:

> The consumer will positively welcome this type of technology if the governments encourage its use.
>
> (France, private sector employee)

> …there is European legislation around emissions, and the more that those emissions regulations are tightened and enforced the more it's going to make it more attractive for people to be operating zero emission vehicles, be this hydrogen or battery electric vehicles.
>
> (UK, public sector employee)

Moreover, some of the visions among interviewees of changing social norms for use of these technologies where quite detailed:

> I think there will have been a consistently growing intensity of regulations in city centres and a big drive to reduce emissions affecting urban populations. Initiatives for the development of hydrogen will have been in place, but by 2050 they will have been removed. Hydrogen will be a key part of the wider energy infrastructure which will not only include refuelling for different vehicles, but also a key part of storage and an appropriate use of local production of energy.
>
> (UK, multisector partnership stakeholder)

> Cars will probably have moved to a car share and car clubs basis, and people will have changed their attitude to car ownership. Any safety concerns will have been long addressed. Local governments will play a key role in the provision of hydrogen and shaping public attitudes supported by national governments and major companies.
>
> (UK, multisector partnership stakeholder)

The results show how expectations of the future for HFCs also influence attitudes towards these technologies among the informants. In the data, control beliefs, and more overarching social norms regarding energy transitions, are shown to be of particular relevance. Both control beliefs and such social norms are strongly connected to sector developments at the system level; these connections are discussed in more detail below.

Connections to the multi-level perspective of sociotechnical change

In the case above, we have seen how individual-level processes interact with regime and landscape processes. The landscape as the domain of slow-moving change is expected by stakeholders to be supportive of hydrogen and HFCEVs in the long term, but less so in the short and medium term. As the data shows, this expectancy of change among informants is not simply in terms of the technology per se, but is also related to a change in attitudes towards and beliefs in factors such as climate change and the need for transitions to sustainability in general. Hence, pressures for an adequate response to climate change are expected to deepen over time, driving technological change in mobility beyond electric batteries and towards hydrogen, be this via fuel cell (and electric motor) or combustion (standard engine) technologies. Indeed, the view that this technological development was a 'natural' progression over time was expressed by some of the informants. Moreover, regulatory initiatives that have the aim of securing the quality of air locally were seen as another driver.

Such pressures may reflect shifting values or norms relating to environmental concerns, perhaps reframed in terms of societal well-being. In the psychological literature, norms tend to be defined as relating to what is understood as socially acceptable in terms of behaviour, and multiple behaviours may be consistent with a particular value (or attitude). Hence, at the landscape-level in the MLP, the widely shared value of protecting human health may be seen as consistent with a wide variety of social norms relating to sustainable mobility. Thus, for hydrogen and/or HFCs to benefit from the stronger commitment to mitigating climate change and improving local air quality that a number of interviewees expect, hydrogen technologies would also need to be perceived as a feasible and effective response to those climate change challenges.

Discussion

Using the same study discussed in Chapter 4, we have shown in this chapter how stakeholder expectations of a set of technologies can be understood in relation to some constructs that are widely used in variable-based environmental and sustainability-related psychology. In this way, we aim to contribute to the case for studying the connections between individual-level psychological processes and sociotechnical system-level dynamics. Here, those systems dynamics have been represented by the MLP (Geels 2002). We make a number of further observations below.

First, we note that while variable-based sustainable behaviour psychology (for want of a better term) by definition analyses in terms of separate psychological constructs and quantitative question scales, here we have used the same constructs to interpret and discuss qualitative data. Both approaches (quantitative and qualitative) are possible and, indeed, are likely to be complementary.

Second – as we reiterate throughout this book – we are not arguing for an exclusive focus on psychology, and this applies also to understanding the relationships between expectations and action. Some actors have more power than others and this has practical implications. Hence Stones' strong structuration referred to in Chapter 4 has often been combined with accounts of 'position-practice' (e.g. Coad and Glyptis 2014) – an approach that has been used to illustrate the influence of organisational role (position) in decision-making and outcomes. Moreover, actors may take into account and weigh up multiple, different expectations. The expectations of the informants interviewed here often referred to the strategic positioning and anticipated actions of other actors, something also highlighted in other studies of expectations (Budde *et al*. 2012).

More generally, the way in which technological expectations are socially situated is also emphasised by Berkhout (2006, p. 300): "… private expectations are to a large extent shaped by socially distributed rhetorics about the future, as well as by the inertias represented by material conditions". In our case, such socially distributed rhetorics can be seen as some of the shared expectations for the future of hydrogen and HFCEVs. These shared views and future expectations are, in a sense, illustrated in Figures 5.2 and 5.3. Here, each column represents a common view or expectation related to hydrogen and HFCEVs as shared across countries. As Berkhout also states (2006, p. 304):

> Regime members will align themselves to visions of the future that are aligned with their interests, and which they believe they have the resources to achieve (or which they believe they can convince other powerful actors to achieve with them).

Indeed, our interviewees often gave most weight to what was perceived as feasible in the present but, at the same time, they had an eye to the future. Indeed, several stakeholders did view a hydrogen focused future as inevitable – given time.

Conclusions

We argue that an individual-level psychological perspective, using even basic psychological constructs, can help to characterise salient aspects of actor expectations in relation to energy system change and stasis (and, indeed, other systems). This characterisation can contribute to a wider understanding of both individual-level expectations vis-à-vis particular technologies and the relation between these expectations and the more structural-level dynamics within sociotechnical systems. In the case examined above, different types of expectations of the future of hydrogen and HFCEV technologies can be understood as positive and negative control beliefs about the technologies – beliefs that may also include ideas of present and future social norms.

The beliefs held by the actors are the outcome of many influences, including national policy support as well as beliefs about the actions and nature of others, notably consumer-citizens. In this way, we have viewed sociotechnical expectations as involving both intra-individual (defined as psychological) and more inter-individual (defined as social) factors. By viewing expectations as beliefs and – in particular – beliefs that are associated with ideas of control and effectiveness, we add an extra dimension – a psychological dimension – to our understanding of the role of expectations in energy-related sociotechnical futures.

In the next chapter, we show the value of a different type of psychological approach, one which spans both psychological and sociological perspectives: Moscovici's (1984) theory of social representations.

Notes

1 For a detailed description of the methods used in this chapter, see Chapter 4.
2 An innovation system is an analytical construct for thinking about the relationships between actors and emerging technologies. The direction of search refers to the attention given to a wide range of factors, including future expectations and signals, that influence the propensity of a company to invest in the given area or product (Bergek *et al*. 2008).
3 For example, Nadaleti *et al*. (2017) model the environmental benefits of replacing diesel in city buses in Brazil with a blend of renewable hydrogen and biogas. The hydrogen would be produced through electrolysis when hydroelectric reservoirs are emptied for dam cleaning or water level control; and the biogas would be collected from city landfills. Using the biogas or hydrogen alone in combustion engines would be enough to replace the diesel fuel used by buses in the 27 states considered, and one could argue for a transition simply to waste biogas as being advisable. While it is still not economically feasible to store very large amounts of

hydrogen, a blend (e.g. 20 per cent hydrogen from waste hydro-electric energy) would extend the total fuel quantity and reduce hydrocarbon (HC), caron monoxide (CO) and CO_2 emissions from individual bus engines relative to biogas alone, but it would increase nitrogen oxide (NOx) emissions due to higher temperature combustion. All of this raises many more interesting issues for consideration, regarding priorities and trade-offs, but they are not our main focus here!

Bibliography

Ajzen, I. 1991. "The theory of planned behaviour". *Organizational Behavior and Human Decision Processes* 50:179–211. doi:10.1016/0749-5978(91)90020-T.

Ajzen, I. 2002. "Perceived behavioral control, self-efficacy, locus of control, and the theory of planned behavior". *Journal of Applied Social Psychology* 32(4):665–83.

Ajzen, I. 2006. "Behavioral interventions based on the theory of planned behavior". Available at: https://people.umass.edu/aizen/pdf/tpb.intervention.pdf.

Ajzen, I. and Fishbein, M. 1980. *Understanding Attitudes and Predicting Social Behavior*. Englewood Cliffs, NJ: Prentice-Hall.

Alkemade, F. and Suurs, R. A. A. 2012. "Patterns of expectations for emerging sustainable technologies". *Technological Forecasting and Social Change* 79(3):448–56.

Arfken, M. 2015. "Cognitive psychology". In: I. Parker (ed.), *Handbook of Critical Psychology*. Hove, UK: Routledge.

Bakker, S., Van Lente, H. and Meeus, M. T. H. 2011. "Arenas of expectations for hydrogen technologies". *Technological Forecasting and Social Change* 78(1):152–62.

Batel, S., Castro, P., Devine-Wright, P. and Howarth, C. 2016. "Developing a critical agenda to understand pro-environmental actions: Contributions from social representations and social practices theories". *Wiley Interdisciplinary Reviews: Climate Change* 7(5):727–45. doi:10.1002/wcc.417.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S. and Rickne, A. 2008. "Analyzing the functional dynamics of technological innovation systems: A scheme of analysis". *Research Policy* 37(3):407–29.

Berkhout, F. G. H. 2006. "Normative expectations in systems innovation". *Technology Analysis & Strategic Management* 18(3–4):299–311.

Borup, M., Brown, N., Konrad, K. and Van Lente, H. 2006. "The sociology of expectations in science and technology". *Technology Analysis & Strategic Management* 18(3–4):285–98.

Bows, A., with Anderson, K. and Upham, P. 2008. *Aviation and Climate Change: Lessons from European Policy*. London: Routledge.

Budde, B., Alkemade, F. and Weber, M. 2012. "Expectations as a key to understanding actor strategies in the field of fuel cell and hydrogen vehicles". *Technological Forecasting and Social Change* 79(6):1072–83.

Castelfranchi, C. 2005. "Mind as an anticipatory device: For a theory of expectations". In: M. De Gregorio, V. Di Maio, M. Frucci M. and C. Musio (eds.), *Brain, Vision, and Artificial Intelligence. BVAI 2005. Lecture Notes in Computer Science, 3704*. Berlin and Heidelberg: Springer, pp. 258–76.

Chen, L., Ellis, S. C. and Suresh, N. 2016. "A supplier development adoption framework using expectancy theory". *International Journal of Operations & Production Management* 36(5):592–615.

Coad, A. F. and Glyptis, L. G. 2014. "Structuration: A position–practice perspective and an illustrative study". *Critical Perspectives on Accounting* 25:142–61. doi:10.1016/j.cpa.2012.10.002.

Dütschke, E., Upham, P. and Schneider, U. 2017. "Report on results of the stakeholder survey". Deliverable 5.1., Centro Nacional del Hidrógeno (CNH2), Puertollano (Ciudad Real), Spain. Available at: http://hyacinthproject.eu/wp-content/uploads/2017/12/HYACINTH-D5_1-Report-on-results-of-the-stakeholders-survey_v02_DEF.pdf.

EEA. 2017. "Trends and projections in Europe 2017". European Environment Agency, Copenhagen. Available at: www.eea.europa.eu/themes/climate/trends-and-projections-in-europe/trends-and-projections-in-europe-2017 [accessed 26 May 2018].

Elzen, B., Geels, F. W., Leeuwis, C. and Van Mierlo, B. 2011. "Normative contestation in transitions 'in the making': Animal welfare concerns and system innovation in pig husbandry". *Research Policy* 40(2):263–75. doi:10.1016/j.respol.2010.09.018.

Fishbein, M. 1967. "Attitude and the prediction of behaviour". In: M. Fishbein, *Readings in Attitude Theory and Measurement*. New York: John Wiley & Sons, pp. 477–92.

Geels, F. W. 2002. "Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study". *Research Policy* 31:1257–74.

Geels, F. W. and Schot, J. W. 2007. "Typology of sociotechnical transition pathways". *Research Policy* 36:399–417.

Geels, F., Kemp, R., Dudley, G. and Lyons, G. 2012. *Automobility in Transition? A Socio-Technical Analysis of Sustainable Transport*. New York: Routledge.

Hekkert, M. P. and Negro, S. O. 2009. "Functions of innovation systems as a framework to understand sustainable technological change: Empirical evidence for earlier claims". *Technological Forecasting and Social Change* 76(4):584–94.

Jacobsson, S. and Johnson, A. 2000. "The diffusion of renewable energy technology: An analytical framework and key issues for research". *Energy Policy* 28:625–40. doi:10.1016/S0301-4215(00)00041-0.

Kemp, R., Schot, J. and Hoogma, R. 1998. "Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management". *Technology Analysis & Strategic Management* 10:175–98.

Klapper, R. 2005. "The Projet Entreprendre – an evaluation of an entrepreneurial project at a Grande Ecole in France". In: P. Kyrö and C. Carrier (eds.), *The Dynamics of Learning Entrepreneurship in a Cross-Cultural University Context*. Faculty of Education, University of Tampere, Finland, pp. 188–212.

Marcus, George E. 1995. *Technoscientific Imaginaries: Conversations, Profiles, and Memoirs*. Chicago, IL: University of Chicago Press.

Meinshausen, M. 2006. "What does a 2°C target mean for greenhouse gas concentrations? A brief analysis based on multi-gas emission pathways and several climate sensitivity uncertainty estimates". In: H. J. Schellenuber (ed.), *Avoiding Dangerous Climate Change*. New York: Cambridge University Press, pp. 265–79.

Miguel, E., Esteban, D., Rodríguez, L. and Auer, T. 2016. "European projects and policies". Deliverable 2.1 of WP2 Context Analysis, EU FP7 JFCU Project Hyacinth.

Moscovici, S. 1984. "The phenomenon of social representation". In: R. Farr and S. Moscovici (eds.), *Social Representations*. Cambridge: Cambridge University Press, pp. 3–70.

Nadaleti, W. C., Przybyla, G., Belli Filho, P., de Souza, S. N. M., Quadro, M. and Andreazza, R. 2017. "Methane–hydrogen fuel blends for SI engines in Brazilian public transport: Potential supply and environmental issues". *International Journal of Hydrogen Energy* 42:12615–28. doi:10.1016/j.ijhydene.2017.03.124.

OECD/IEA. 2015. "Technology roadmap: Hydrogen and fuel cells". Organisation for Economic Co-operation and Development/International Energy Agency, Paris. Available at: www.iea.org/publications/freepublications/publication/technology-roadmap-hydrogen-and-fuel-cells.html.

Ravasi, D. and Rindova, V. 2008. "Symbolic value creation". In: D. Barry and H. Hansen (eds.), *The SAGE Handbook of New Approaches in Management and Organization*. London: Sage Publications, pp. 270–84.

Rip, A. 1995. "Introduction of new technology: making use of recent insights from sociology and economics of technology". *Technology Analysis & Strategic Management* 7(4):417–32. doi:10.1080/09537329508524223.

Rip, A., Misa, T. J. and Schot, J. 1995. *Managing Technology in Society: The Approach of Constructive Technology Assessment*. London/New York: Pinter.

Schatzki, T. R., Cetina, K. and Savigny, E. V. (eds.) 2001. *The Practice Turn in Contemporary Theory*. London: Routledge.

Seamon, D. 2013. "Place attachment and phenomenology: The synergistic dynamism of place". In: L. C. Manzo and P. Devine-Wright (eds.), *Place Attachment: Advances in Theory, Methods and Applications*. London: Routledge, pp. 11–22.

Smith, A. and Raven, R. 2012. "What is protective space? Reconsidering niches in transitions to sustainability". *Research Policy* 41(6):1025–36.

Sorrell, S. 2018. "Explaining sociotechnical transitions: A critical realist perspective". *Research Policy* 47(7):1267–82. doi:10.1016/j.respol.2018.04.008.

Stones, R. 2005. *Structuration Theory*. Basingstoke, UK: Palgrave Macmillan.

Unruh, G. C. 2000. "Understanding carbon lock-in". *Energy Policy* 28:817–30.

Upham, P., Kivimaa, P. and Virkamäki, V. 2013. "Path dependency in transportation system policy: A comparison of Finland and the UK". *Journal of Transport Geography* 32:12–22.

Upham, P., Dütschke, E., Schneider, U., Oltra, C., Sala, R., Lores, M., Bögel, P. and Klapper, R. 2017. "Agency and structure in a sociotechnical transition: Hydrogen fuel cells, conjunctural knowledge and structuration in Europe". *Energy Research & Social Science* 37:163–74. doi:10.1016/j.erss.2017.09.040.

van der Hoeven, M. 2015. "Foreword". In: "Technology roadmap: Hydrogen and fuel cells". Organisation for Economic Co-operation and Development/International Energy Agency, Paris.

Van Lente, H. 1993. "Promising technology: The dynamics of expectations in technological developments". Doctoral thesis, University of Twente, Enschede, Netherlands.

Van Lente, H. 2000. "Forceful futures: From promise to requirement". In: N. Brown, B. Rappert and A. Webster (eds.), *Contested Futures. A Sociology of Prospective Technoscience*. London: Ashgate, pp. 43–64.

Van Lente, H. 2012. "Navigating foresight in a sea of expectations: Lessons from the sociology of expectations". *Technology Analysis & Strategic Management* 24(8):769–82.

Van Lente, H. and Bakker, S. 2010. "Competing expectations: The case of hydrogen storage technologies". *Technology Analysis & Strategic Management* 22(6):693–709.

Vroom, V. H. 1964. *Work and Motivation*. New York: John Wiley & Sons.