From 'Alternative' to 'Advanced': Mainstreaming of Sustainable Technologies

Knut H. Sørensen

This paper revisits some technologies that, in the 1970s, were considered as 'low-tech' alternatives to mainstream versions, but more recently have been developed using high-tech elements. This change from alternative to advanced is analysed as a process called sociotechnical mainstreaming, whereby technologies are transformed by the dominant R&D institutions and/or industry. The paper aims to clarify what is involved in such processes of mainstreaming, and how they affect the fate of the alternative technology legacy, not only in terms of being ecological but also their production being craft-based, decentralised and with some form of local control. This is explored through three examples: wind turbines, electric cars, and ecological architecture. Four mainstreaming processes are identified: pragmatic, expansive, dominant design, and conceptual. More empirical research is called for to further develop the concept of mainstreaming.

Keywords: alternative technology, mainstreaming, sustainable transitions

Introduction: A Point of Departure

Most of today's sustainable energy technologies have in some way emerged from what used to be thought of as alternative technologies in the 1970s and 1980s. While they still are alternatives to the entrenched, fossil fuel based technologies, the dynamics of their development have changed. It was expected that alternative technologies would be made differently from the dominant industrial regime with its emphasis on advanced design, mass production and centralisation. Alternative technologies were supposed to be based on low or intermediate technology elements and designs developed outside the industrial and technological centres. In contrast, present-day efforts make use of advanced elements and designs and take place at the very centres of technological development. This paper uses the concept of mainstreaming to help understand and describe this change.

What perception of technology was characteristic of the alternative technology discourse? Langdon Winner (1977) chronicles the many roots of critical appraisal of technology, in particular the idea of an autonomous technology developing from its own logic, more or less out of control of humanity. This admittedly pessimistic outlook was supported by observations that industrial technologies were endangering, even destroying the conditions of human life through massive pollution and reckless exploitation of natural resources (see, e.g., Dickson, 1974). The interest in alternative technologies emerged from these fears, as a strategy to regain human control of technology as well as achieving more environmentally friendly designs. In addition, a concern for third world countries' need for cheaper and locally manageable designs was important.

At the heart of the argument was technological determinism: the idea that technology represents a force developed outside of society with the ability to reshape social relations. The fear that advanced technologies would increasingly display unwanted but unavoidable properties was used to support the alternative technology agenda. However, as Stewart Russell (1993) noted, technological determinism is difficult to reconcile with a critical or alternative technology policy. To accept determinist arguments limits strategic choices to two main options: either to protest against the hegemonic technological regime and dismiss new technologies, or to try to create protected spaces where alternative technologies may be developed. The 1970s and 1980s saw examples of both – for example industrial actions to stop new technologies and efforts to create alternative life styles. Though the strategy of simply dismissing new technologies attracted little political support, ideas of fostering alternative technologies were more popular (Winner, 1986). The radical social movements of the period engaged in resistance, as well as making efforts to modify proposed technological projects.

As we shall see, what was usually understood as alternative technology grew out of a belief that the dominant trajectory of technological development could not help to solve social and environmental problems. How could the hegemonic technology be used to manage the problems that it had produced itself? Thus, the interest in alternative technology was linked to the perceived possibility of making artefacts that were environmentally friendly and socially desirable, without being caught in the wheels of advanced engineering embedded in large-scale, wasteful and alienating industry.

We now observe that alternative technologies seem to be appropriated by advanced engineering; what has happened? An interesting line of inquiry is suggested by Winner (1979). He made an early attempt to take stock of the achievements of alternative technologies and argued that developing new assessment criteria was more important than constructing new technologies:

> [T]he ultimate promise of alternative technology has little to do with the new hardware that it may happen to develop. Indeed, if the success of the field is to be measured solely in terms of new inventions to solve the energy crisis, then it will have done little that is significantly new. [...] A sign that alternative technology has reached a meaningful point of sophistication would be its ability to move logically from a set of critical, evaluative principles towards specific criteria of technological design. (Winner, 1979: 83)

Consequently, mainstreaming of alternative technology could be understood as the application of its design criteria in a high-tech context; what were these criteria?

What Was Alternative Technology?

As Winner (1986) argued, the roots of the alternative technology movement are found in a complex combination of the politics of the period, diverse theoretical sources and practical experiments. Dickson (1974) describes the ambitions as characterised by utopian thought, to break with established patterns to seek new principles for development and use of technology. The main idea was that the alternative technology should be 'soft', environmentally friendly and economical with respect to resources:

> [Alternative technology] should function most effectively at the lowest level of society; [...] the poorest people should be able to use it; [...] it should be based primarily on ecological and social considerations, rather than those of economic efficiency; [...] it should allow the possible evolution of small, decentralized communities; and [...] it should require relatively small amounts of resources (Dickson, 1974: 101).

Thus, it was important to transcend the dominant industrial regime that emphasised large-scale design and standardisation as keys to growth and efficiency. E. F. Schumacher, one of the best known spokespersons at the time for a different way of developing technology, formulated the alternative in a simple and rhetorically effective manner – 'Small is Beautiful':

> The system of mass production, based on sophisticated, highly capital-intensive, high energy-input dependent, and human labour-saving technology, presupposes that you are already rich [...]. The technology of production by the masses, making use of the best modern knowledge and experience, is conducive to decentralisation, compatible with the laws of ecology, gentle in its use of scarce resources, and designed to serve the human person instead of making him the servant of machines. (Schumacher, 1973: 143)

Clearly, Schumacher's approach to alternative technology was based on a critique of then current big industrial technology as wasteful, hostile to the environment, and alienating. At the same time, he linked the need for alternative or intermediate technology particularly to developing economies as a corrective to the dominant approach to technology transfer as based on advanced, industrially oriented solutions.

Dickson (1974) perceived alternative technology as a socialist strategy, as a way of building a different type of society. Schumacher (1973) was more pragmatic and saw 'intermediate technology' as a realistic, preferable option of reforming technology transfer. It is important also to note that he specified alternative technology as something in-between the advanced and the primitive. Intermediate technology should be an improvement to already existing artefacts but at the same time be manageable in local communities of developing economies.

Jéquier (1976) proposed a distinction between three varieties: (1) low cost technology, (2) intermediate technology, and (3) appropriate technology. The third of these labels seems to have been the most widely used (Carr, 1985). This reflected the emphasis placed upon the need for new technologies to be adapted to local conditions:

> Appropriate technology [...] represents what one might call the social and cultural dimension of innovation. The idea here is that the value of a new technology lies not only in its economic viability and its technical soundness, but in its adaption to the local social and cultural environment. (Jéquier, 1976: 19)

The argument that technology should be appropriate gained some support in the discussions about transfer of technology to developing economies. However, the idea that technology should be locally manageable was seen as important also to industrialised countries (Dickson, 1974; Winner, 1986). Regardless of the actual interpretation of the concept, alternative technology discourses stressed the importance of increasing the possibility for decentralised local communities to develop their own technologies according to local skills and local resources. Ideally, it should be possible to make the technologies locally; at least their running should be manageable for local people.

Underlying this view was the presumption that local communities engaging with alternative technology would encompass a fairly broad share of the population. Equally, innovation competence should be more evenly distributed. The communities pursuing alternative technology were believed to need a relatively high general level of mechanical skills and proficiency with machines. Accordingly, we find a comprehensive engagement with practical technological possibilities in books on alternative or appropriate technology (see, e.g., Carr, 1985; Darrow & Saxenian, 1986).

The idea that technologies should be locally embedded and with broad public participation signalled the need to break with the universalising approaches of the hegemonic engineering sciences. At the same time, the concept of intermediate technology emphasised that alternatives did not need to be primitive or low-tech – they should just not be 'advanced' according to the dominant premises of the engineering sciences.

In the early 1980s, the alternative or appropriate technology movement more or less disappeared (Pursell, 1993), although the concept of appropriate technologies has continued to play a role in technology transfer and technology dynamics in developing countries (Kaplinski, 2011; Murphy et al., 2009). Winner (1986) also noted the demise and thought that the enduring legacy of the appropriate or alternative technology was in the making of some of its concepts like sustainability more of a commonplace to planners, engineers, and the public; this assumption is also found in approaches like ecological modernisation (Mol et al., 2009).

What were the main ideas of the alternative technology movement? Adrian Smith (2005) suggests four requirements: (1) craft-based, (2) local participatory control (3) small-scale and decentralised, and (4) ecologically sound. To what extent have these criteria been taken on board in the mainstreaming of alternative technology? When studying this issue, we are warned by Winner (1986: 73) that "the set of criteria upon which this vision of good technology rests […] may not be compatible. Hence, it is not obvious that decentralised technologies are necessarily sound". In addition, the criteria are not unambiguous: even with respect to ecological soundness or sustainability, assessments may be framed in different ways (see, e.g., Jørgensen, 2012; Skjølsvold, 2013).

The paper does not address the latter problem. Primarily, it explores some efforts to mainstream alternative technologies, and if and how the four above-mentioned criteria have been part of the transformation process, but not whether the outcome may be considered environmentally friendly. Additionally, the paper examines if there are clear links between the original alternative technology ideas and the more high-tech outcomes of the transformation.

Mainstreaming Alternative Technologies

Evolutionary innovation theory puts learning – in a variety of articulations – at the centre of technological change (Lundvall et al., 2002). This includes standard-setting and other forms of regulatory actions that may mediate between, for example, environmental concerns and innovation efforts. At an abstract level, we might see influence from alternative technologies as related to some form of learning, perhaps through search processes initiated as a response to environmental regulations. However, we need more knowledge about this, including conceptual development.

Inspired by Berker (2010), the processes through which alternative technology ideas are integrated into mainstream technological development is referred to here as mainstreaming. Berker borrows this concept from the literature on gender equality, where gender mainstreaming denotes a strategy to transform organisational processes by introducing concern for gender equality as a mandatory consideration (see, e.g., Benschop & Verloo, 2006). He contrasts mainstreaming to substitution as a strategy of implementing sustainable energy technologies. Substitution designates a top-down approach of 'creative destruction' where new, science-based designs replace existing technologies. Mainstreaming, according to Berker, involves bottom-up, incremental improvement of compatible technologies.

There are other approaches that may be used to study such transformations. For example, David Hess (2007) puts social movements at the centre of the making of alternative pathways for scientific and technological development. He differentiates between industrial opposition movements, which aim to stop a particular technology, and technology- and product-oriented movements that work to develop alternative systems of technology and products. With some reserve, Hess (2007: 236) argues that "agents of social change often find, to their chagrin, that they have made history, but not exactly according to their original vision. Rather than achieving a full victory, they usually become caught up in a more complex dance of partial success and co-optation".

This view raises questions about the nature of co-optation processes and their outcomes. Hess (2007: 237) describes the potential successes of the technology- and product-oriented movements as related to the incorporation and transformation of ideas by established industry: "as the mainstream industry shifts from resistance to incorporation, the companies may acquire the innovating entrepreneurial firms or develop new product lines, and they often redesign alternative technologies". However, the problem with concepts like co-optation is the underlying suggestion that when alternative ideas, actors or social movements gain influence, they usually are modified to become less radical or even rendered harmless. 'Mainstreaming' does not make such presumptions, although co-optation may be a form of mainstreaming.

Another approach that focuses on the way environmental concerns are made to shape modern societies is ecological modernisation. Here, the focus is on environmental reform to make such ideas mainstream in industry, government, etc. Thus, policy-making is given particular attention (see, e.g., the contributions in Mol et al., 2009). My emphasis in this paper is on the role of sociotechnical transformations, which means that the ideas that are to be mainstreamed, in addition to catering for environmental concerns, also may include suggestions regarding other aspects of design, such as size, shape, and resources. This is different from the more general environmental criteria promoted through ecological modernisation and also in approaches like clean technology or clean innovation (see, e.g., Markusson, 2011).

The idea of moving environmentally friendly innovation into mainstream development is also important in the 'multi-level perspective' on sustainable transitions. This approach distinguishes between three levels: (1) niches, where innovations may be nurtured and protected; (2) sociotechnical regimes, that refers to the rules that shape development of technology; regime is the mainstream of development of technology; and (3) socio-technical landscapes, which represent contexts beyond the direct influence of niche and regime actors, like macro-economic or macro-political developments (Geels, 2002; Verbong & Loorbach, 2012). From the multi-level perspective, sustainable sociotechnical transitions mainly take place when sustainable innovations make their way from the niche to the regime or mainstream level. This may happen through different pathways that are produced through different forms of interaction between the three levels (Geels & Schot, 2007). Smith (2005) proposes that alternative technologies like wind power or local organic food may be niches that make their way into the mainstream regimes.

The multi-level perspective has gained considerable popularity as a way of studying sustainable transitions, possibly due to its rather formulaic features. However, its proposal to study sustainable transitions as produced through the interaction of the three levels creates analytical difficulties: first, there is the issue of how to distinguish empirically between the three levels; second, the underlying systems approach tends to give actors and action less attention. This has resulted in oversights with respect to the role of political and other controversies as well as a lack of consideration of the strategies of involved actors. Geels' (2014) effort to remedy some of the problems by indicating how politics and power may be analysed at the regime level illustrates the difficulties with the idea of system-generated transition pathways.

The mainstreaming concept avoids some of the problems with the multi-level perspective, because it uses a 'flat', action oriented approach. The advantages of this way of thinking are argued by Latour (2005) in a general sense and Jørgensen (2012) specifically with respect to sustainable transitions. Rather than seeing sustainable transitions as results of niche innovations being nurtured to grow into the mainstream regime, mainstreaming of alternative technologies is viewed as a co-production of niche and mainstream developments. What needs to be clarified is the nature of such co-productions and the role and effect of alternative technology criteria, including the strategies of participating actors and the conflicts that may take place.

The analysis here starts from an assumption that mainstream technological development is embedded in technologically advanced engineering. This is not to say that this development is science driven but that it draws upon scientific insights and new artefacts that are made from such insights. Thus, mainstreaming is seen as a process where ideas and concepts from the alternative technology tradition are used to change the direction of mainstream technological development. For example, the alternative idea of using wind rather than fossil energy has been picked up by companies that use their competence in making technology for offshore production of oil and gas to contribute to the design of offshore wind parks (Steen & Hansen, 2014).

However, alternative ideas and concepts themselves change through mainstreaming, and over time, some aspects of the alternative thinking may become less important or even disappear. For example, within the field of new renewable energy sources, it is mainly the ideas about alternative energy sources that are retained, while the first three characteristics identified by Smith (2005) – craft-based, local participatory control and small-scale decentralised – tend to fade out of sight.

Cases and Method

The remaining part of the paper explores the ability of 'mainstreaming' to make sense of the transition from 'alternative' to 'advanced' by discussing three cases: wind turbines, electric cars, and ecological architecture. These have been selected in order to look for diversity in mainstreaming processes. Wind turbines were considered an alternative technology, but have become a well-established concern of a technologically advanced industry as well as public R&D institutions. Electric cars were for a long time a marginal phenomenon, a technology for those with particular interests and developed by actors outside the established automobile industry.[1] Ecological architecture is a field with considerable technological diversity, but where particular ideas have played an important and controversial role in the development of strategies for sustainable buildings.

The three cases are based on re-analysis of secondary sources; most of them published scientific studies. The wind turbine case is focused on Danish experiences, which have been considered particularly important in the development of wind turbine technology and so have been quite widely studied. The electric car case is mainly concerned with developments in Denmark (Munch, 2002) and Norway, in particular the Norwegian Think efforts (Undheim, 2002; Kårstein, 2010). However, these sources have been supplemented by a search using the news media database retriever.no to update the information about Think. The case of ecological architecture is based mainly on Norwegian publications (especially Ryghaug, 2003, 2007).[2]

Thus, the three cases are based on sources using different methods. The wind turbine case is based on primarily written sources. In the electric vehicle case written sources using interviews as well as documents are combined with newspaper articles. The ecological architecture case is based on publications using interviews with architects. The case material has been analysed in an 'abductive' manner, which means that the analysis has moved between conceptual deduction and empirical induction (see, e.g., Reichertz, 2007).

The selection of the cases and the data sources raise some issues. First, the three cases clearly differ with respect to their maturity. Wind turbines are fairly well established, electric cars seem to be in the midst of a fairly rapidly changing development, while ecological architecture is less mature, and still on its way to take-off. The analysis has consciously tried to take into account differences in mainstreaming due to differences in the stage of development. Second, the cases involve different types of actors and contexts. However, this allows for analysis of the mainstreaming concept under diverse circumstances. Third, there are in places insufficient original or detailed data to allow a closer study of specific mainstreaming processes. Even so, the available secondary data has allowed for a preliminary comparative analysis.

Wind Turbines: The Alternative Technology that Ousted the Advanced

After the oil crisis in 1973, many industrialised countries began searching for alternative sources of energy. Wind power emerged as one of the most promising options, but it was pursued in different ways.

Industrial communities in Germany and the US thought they could use advanced engineering competence, in particular from the aerospace industry, to design large and light-weight wind turbines. Danish actors followed a rather different development pathway. (Heymann, 1998; Nielsen, 2010)

The German and US efforts met with serious technological difficulties, and after a while they were outdistanced by the Danish wind turbine industry. Danish actors conducted R&D to explore the possibilities of high-tech wind turbine design, but did not follow the trajectory of advanced, science-based engineering. Rather, wind turbines were constructed by a locally embedded mechanical industry with a strong craft tradition, and the turbines were largely bought and operated by Danish farmers. Thus, initially, wind turbine development was characterised by small enterprises and local ownership. This facilitated close interaction between users – mainly farmers – and the emerging wind turbine companies. In turn, this meant that the industry could make use of user experiences to improve the products (Jørgensen & Karnøe, 1995).

Garud and Karnøe (2003: 296) described the Danish development of wind turbines as a bricolage-like approach "that begins with a low-tech design but ramps up progressively". This contrasted with the strategy pursued by the German and US actors – aimed at a high-tech breakthrough by providing a completely new design, linked to industrial, large-scale production of electricity. Thus, the Danish experience appears to be an example of how technological innovation based on an alternative path may outstrip and substitute high-tech engineering science – at least for a while. The alternative technology criteria (Smith, 2005) were in the Danish case met through reliance on intermediate technology solutions: use of local resources and local embedding of the activity. However, Garud and Karnøe (2003) show that this is only part of the story. Gradually, some companies began to construct wind turbines for export, particularly to California; these companies grew larger, and the local foundation of their operation became weaker. Increasingly, the technological development of wind turbines became based on high-tech engineering science. Today, to characterise the Danish wind turbine industry as low or intermediate technology would be very misleading.

Kemp et al. (2001), working from a multi-level perspective, interpret Danish wind turbine development as a result of policy interventions. Clearly, policy was important, not the least the introduction of a fairly generous feed-in tariff, technological standards and, later, investment subsidies. In addition, the planning system was beneficial (Buen, 2006; Munksgaard & Morthorst, 2008; Petterson et al., 2010). Jørgensen and Karnøe (1995) also remind us that the political climate was favourable, not the least through support from the anti-nuclear movement. The mainstreaming of the alternative wind turbine technology was facilitated by the political and administrative context. However, it is unclear how important this 'landscape effect' actually was.

When we analyse the Danish wind turbine story as a mainstreaming narrative, there are some other striking features. It begins as an account of the strength of alternative technology relative to more high-tech efforts, not least through the pragmatism of alternative technology actors. However, its continuation shows the unfolding of a high-tech mainstreaming. When Danish companies reached a share of 40% of the world market of wind turbines it was because they had been at the technological forefront for some time (Nielsen, 2010). The path of development has become unequivocally high-tech.

The mainstreaming was therefore a co-production of the niche of wind turbines as alternative technology and mainstream engineering, merging into the present-day high-tech wind turbine industry.

The early stage of the Danish development of wind turbine technology arguably satisfies all four of Smith's (2005) criteria. However, after the mainstreaming process, the Danish wind turbine industry at best meets only the fourth criterion, of ecological soundness; none of the other three are met today. Standard wind turbine technology is not simple and craft-based, it cannot easily be made anywhere, and its design and development is embedded in high-tech engineering science. Interestingly, the rapidly growing wind turbine industry in India and China today follows a high-tech track, not an intermediate strategy (see, e.g., Lewis, 2007).

To summarise, the development of wind turbine technology during the last 3–4 decades began when the use of an alternative technology approach in the context of Denmark provided a fruitful point of departure for designing robust, functional turbines with a stepwise innovation strategy. The subsequent further development of larger and more efficient turbines was increasingly supported by R&D and high-tech engineering, resulting in technologically advanced products from a technologically advanced industry. Is this a typical path for alternative technologies if they extend beyond their alternative niche?

Electric Cars: Alternative Technology or Alternative Mobility?

Electric cars played a prominent role in the early development of modern mobility (see, e.g., Mom, 2004). However, they were outstripped by combustion engine cars in the early 20th century. When they re-emerged as a concept in the 1970s, it was more as a curiosity and a special niche vehicle than a real challenge to the standard automobile (Fogelberg, 2000). Thus, the electric car of the 1970s and 1980s was an alternative technology, satisfying the criteria of being small-scale, decentralised, ecologically sound, maybe also craft-based, but without local participatory control. The cars were made in small numbers by small companies, and they differed from standard combustion engine cars not only in terms of the motor, but in the whole design. This meant not only that they were more environmentally friendly, but also that they were based on an alternative concept of mobility, namely short distance driving in and around cities. Thus, electric cars were an urban niche phenomenon.

Increasingly, however, the large automobile manufacturers are offering electric models as alternatives to combustion engine cars. The number of electric cars in the streets still remains relatively small, but the sociotechnical context of the development is radically different. When the concept of electric cars re-emerged in the 1970s, most efforts to design and build them came from actors outside the automobile industry (Maruo, 2000). The Norwegian inventor Lars Ringdal is a typical example. Ringdal was primarily engaged in making of plastic boats but in the wake of the so-called oil crisis of 1973, he developed a conceptual design of a small car, cast in plastic and running on an electric engine. This idea was picked up later by a small Norwegian company Pivco in their construction of an electric car that eventually became Think. (Undheim, 2002)

Developments in Denmark and Norway illustrate particular features of the niche-like development of electric cars, in terms of how they were manufactured, and their patterns of use.[3] In Denmark, several models of electric cars, meant for short-distance, city driving, were produced in the 1970s and

1980s. However, none of the models of this generation of electric cars were produced in more than 50 units. The total production increased somewhat in the next decade but never became large. The most popular model of the 1980s was the Ellert, which was marketed more extensively than the previous models, but sales were no more than around 700 vehicles. (Munch, 2002)

We may safely characterise the Ellert as an alternative, intermediate effort. It was relatively environmentally friendly, and the production was substantially based on locally available resources and skills. Moreover, electric cars in the Danish context were made for a particular group of users (public institutions), for a particular purpose (driving short distances in cities), and with a different design (small, lightweight vehicles with relatively low top speed). Thus, it was made for an 'alternative' audience, which remained small.[4]

To what extent do we observe mainstreaming efforts? In the early 1990s, new ideas emerged about how to design electric cars and how they could be marketed. In Denmark, the electric Kewet Citi-Jet car was made to be as much like a normal car as possible. Its maximum speed was 75 km/h, and the range was 80 km (Munch, 2002). The Kewet Citi-Jet represented a break from the idea that this alternative technology should be linked with alternative mobility – driving short distances only. Even more important was the shift in thinking about what should be demanded from users:

> The putative users of a Kewet were ordinary people who wanted a well-functioning, easy to drive, noiseless vehicle, performing so similarly to a conventional car that they did not have to make major adjustments of their driving patterns and practices (Munch, 2002: 74).

The Norwegian company Pivco used the conceptual drawings of Lars Ringdal as a basis for designing an electric car with an all-plastic vehicle body, eventually called Think. The name was chosen because the car was promoted to represent an alternative form of mobility – meaning less driving – while a lot of effort was put into the design of the car body to give it a suitably 'alternative' look. Even if the body was made of plastic, neither the car's technology nor its production was alternative in the sense that it was low or intermediate technology. Think was a professionally constructed car with some high-tech qualities, and its maximum speed and range was about the same as the Kewet City-Jet (Undhjem, 2002). It could be considered as a niche product in an early stage of sociotechnical mainstreaming, with a goal of being environmentally friendly.

The detailed story of Pivco and Think is fairly complex, with multiple bankruptcies, shifting ownership and discontinued strategies (Kårstein 2010). A couple of observations will have to suffice here. Most striking was the fact that one of the world's largest automobile companies, Ford, became a majority owner of Pivco and Think in 1999, in response to California's Zero Emission Vehicle (ZEV) policies (see Hoogma et al., 2002). When Ford's CEO at the time, Jack Nasser, announced the transaction, he stated that:

> This car not only will give us immediate access to a whole new market niche, it will provide a wealth of new ideas for us to develop. We are particularly interested in new concepts in the use of plastic body components, as well as low-volume and flexible manufacturing. (Quoted from Hoogma et al., 2002: 84–85)

Ford helped to accelerate the mainstreaming process of Think, and thus of the electric car; between 1999 and 2003 Ford invested around 200 million dollars to develop a production line for a new model, Think City, which was more similar to combustion engine cars than the previous model. However, Ford sold off Pivco soon after California modified their ZEV policy in 2003, stating that they rather would explore options related to hydrogen and fuel cells. Nevertheless, the mainstreaming of Think's design continued with new owners. Their new concept car, Think Ox, signalled that the original ideas of Pivco to make Think a car for alternative, mainly urban, mobility had been abandoned.[6] Mainstreaming resulted in efforts to make the electric car more like conventional cars. While Pivco learnt from Ford, it remains unclear whether Ford learnt from Pivco, as Nasser intended.

Compared to the wind turbine case, the mainstreaming of electric cars was more complex, with greater uncertainties. The development received little or no support from any social movement. Pivco began by providing something that definitively was an alternative car, technologically as well as with respect to use. It was marketed as a new form of mobility, as a lightweight vehicle with limited range, to be leased to companies and public institutions. Pivco was a small company located in a fairly small community some 50 kilometres outside Oslo. Initially, there was local control and a base in craft skills but no participatory interaction with users. In the mainstreaming process, local control was lost, together with most of the alternative design concepts except environmental friendliness. With respect to Smith's (2005) criteria, this is an ambiguous case.

Arguably, the main contribution of Pivco and other actors in their efforts to make electric cars was to revive the concept of electric mobility, emphasising short-range, low emission, low noise, and low speed driving. According to Maruo (2000), several producers of electric cars were acquired by traditional auto companies looking for ideas about how to design electric vehicles, similar to Ford's relationship to Pivco. Furthermore, Sierzchula et al. (2012) argue that the field of such vehicles is transitional, with many new entrants. In some places, like California and Norway, supportive policies are in place (Brown, 2001; Ryghaug & Toftaker, 2014). Overall, it appears that the established automobile industry may be learning from alternative efforts, but the mainstreaming of the electric car seems increasingly to be influenced by the image of the standard automobile with an emphasis on speed and range but also with strong similarities with regard to design. Criteria of craft-based, local participatory control and small-scale decentralised have been lost in the mainstreaming process.

Ecological Architecture: From 'Knitted Houses' to Glass and Steel

While wind turbines and electric cars were alternative products, ecological architecture has been a reform programme in the mainstream building industry rather than an alternative technology, with quite diverse conceptions and pluralist practices (Guy & Moore, 2007). Even so, ecological architecture largely fulfils Smith's (2005) alternative technology criteria. Compared to wind turbines and cars, the building industry is to a greater extent characterised by small-scale, locally controlled activities. Thus, the mainstreaming of ecological architecture could have been less disruptive than the two other examples. In practice, ecological architecture has proven controversial, making mainstreaming difficult.

When it emerged in the 1970s, ecological architecture differed from dominant approaches with respect to design and choice of materials. Ecological buildings were environmentally friendly, preferably built of local resources and using low or intermediate technology elements. However, the majority of practicing architects in Norway perceived ecological houses as badly designed (Ryghaug, 2003, 2007). Ecological buildings were considered personal statements with a home-spun character, associated with the use of 'outdated' building materials like earth or bales of straw. Ecological houses were criticised for looking too much like traditional mountain cottages. The design was described by words like chubby, hairy, dishevelled, organic, knitted, or as having a 'barefoot out in the woods' style. The architects interviewed by Ryghaug criticised the use of many different angles and curved lines in ecological buildings. One architect described the approach in the following way:

> These earthen houses where pee, poop and plugs are recycled and comes out of the kitchen tap [...] after four turns of purification. This is something different, then, like pigs on the roof and goats in the basement. This is the backyard ecology from Berlin in the 1970s that was further developed also in Norway. (Quoted in Ryghaug, 2007: 221, English translation by the author)

The blunt dismissal by the large majority of architects clearly made ecological architecture difficult to mainstream. How then to consider its relationship with the emerging high-tech sustainable architecture? To begin with, this latter effort shares some aesthetical preferences with traditional architecture, but it is at the same time experimental and oriented towards energy efficiency and environmental friendliness, for example by using double glazed facades and complex ventilation systems (Andresen et al., 2007). This also means that technologically advanced ecological architecture is at the research frontier and to a substantial degree shaped by elements made by engineers. Some architects fear that the visual expression of such buildings thus becomes sturdy and boring (Ryghaug, 2007: 222). Nevertheless, this type of ecological architecture is increasingly popular among architects as well as builders, and probably will influence a growing number of new buildings (Kongsli et al., 2008 Hojem et al., 2014).

High-tech ecological architecture shares some features with the traditional ecological approaches, such as local control and an experimental approach. The lack of public standards for ecological buildings in Norway, except with respect to energy efficiency, means that the local contexts as well as the ideas of the project actors are important (Kongsli et al., 2008 Hojem et al., 2014). However, the high-tech architects use advanced technology to signify sustainability in the visual expression of the buildings, rather than organic elements (Kongsli et al., 2008; Hojem et al., 2014).

Has traditional ecological architecture really been mainstreamed? As a reform programme, the original ecological architecture made little impact upon the building industry. As we have learnt, it was controversial and marginalised (Ryghaug, 2007; see also Smith, 2007; Guy & Moore, 2007), and it is still practiced as a fringe phenomenon. Moreover, the local qualities of both traditional and high-tech ecological architecture reflect characteristics of the building industry more generally.

The ideas that buildings should be energy efficient and sustainable have been drivers of the development of high-tech ecological architecture (Andresen et al., 2007. Did this idea come from traditional ecological architecture? Judging from accounts of building industry actors, the idea has mainly been picked up from the general discourse about environmental and climate issues (Kongsli et al., 2008. However, Smith (2007: 106, original emphasis) observes that "green" design of buildings in the UK has been a niche, "likely to be only a source of debatable ideas for mainstream sustainable development, not a model for mainstream transformations". This seems a fair assessment of the Norwegian situation also.

Thus, the idea of traditional ecological architecture that buildings should be sustainable has been mainstreamed, but not the alternative architectural practices. Arguably, a more comprehensive mainstreaming was made difficult by the blunt dismissal by mainstream architects of alternative aesthetics. When mainstream architecture has taken on board environmental concerns, it has done so by going for high-tech solutions. There are also policy issues to consider; with respect to sustainable architecture, new and stricter building codes have not paved the way for traditional ecological architecture, or made it more influential. Rather, new building codes have supported the emerging high-tech ecological architecture, which draws on traditional ecological architecture with respect to environmentalism, traditional architecture as a source of ideas about aesthetics, and engineering science as a source of new building technologies and new kinds of visual elements. The result, considered attractive by traditional architects and high-tech ecological architecture, may eventually become a new, distinct mainstream.

Conclusion: The Diversity of Mainstreaming

As we have seen, the alternative technology movement of the 1970s and 1980s called for increased emphasis on craft skills, decentralisation, use of local resources, engagement by users and ecological thinking. This paper has examined what may happen to such ideas and related practices when technologies considered alternative are (partially) appropriated by high-tech communities through mainstreaming.

The alternative technology movement did not succeed in achieving a fundamental change away from what was seen as an ecological harmful advanced technology path. Rather, alternative technologies – or at least some of them – have been made advanced in the sense that they have become part of mainstream high-tech paths of development. What was involved in such processes? Following Winner's (1986) suggestion, mainstreaming can be seen primarily as a picking-up of ideas, of alternative design criteria. This would also be in line with the ecological modernisation approach (Mol et al., 2009). Is this a reasonable understanding of the three cases discussed in the paper?

The cases reviewed here suggest that mainstreaming is not just a process where alternative ideas are picked up or co-opted by established industrial or technoscientific communities, but that there is more going on. The cases of wind turbines and electric cars involve alternative technology communities pragmatically integrating high-tech elements into their designs; this may be called pragmatic mainstreaming.[7]

The Danish wind turbine industry then developed into what we may call expansive mainstreaming, and in the process, the once alternative industry was transformed so that the industry lost its anchoring in local skills and engagement and so most of its alternative qualities. However, the process should not be seen simply as co-optation or a transfer of ideas. The 'ramping up' of the Danish wind turbine industry was a process of learning, deeply embedded in what originally was an alternative industry. Moreover, wind power is still generally considered sustainable, even if there are conflicts with respect to some developments.

The case of the electric car is different. Until about 2000, as we saw, production took place in communities outside of the automobile industry. More advanced technological elements were increasingly introduced to extend the range and improve safety and comfort as an instance of pragmatic mainstreaming. The take-over of Pivco by Ford signalled the beginning of another form of mainstreaming where the dominant design (Abernathy, 1978) of the automobile industry became a strong shaping factor. As we observed with the changing design of Think, and even more so with the electric cars that have been produced by the established automobile industry after 2010, the electric car was transformed from an alternative vehicle for urban mobility to become a standard car with a non-standard motor, an example of dominant design mainstreaming.

What we observe here is closer to the notion of co-optation in that the established automobile industry has appropriated the idea of an electric car, and has tried to combine design features important for standard cars, like range, speed and safety, with criteria from alternative electric vehicles (use of electric motors, improved batteries and lightweight bodies). While we do not know the extent to which the established industry learnt from the alternative one, it seems clear that more has been transferred than just going electric.

The case of ecological architecture is more complex, because low-tech ecological architecture continues to co-exist with emerging high-tech practice.[8] The emergence of high-tech ecological architecture seems to have been based on the concept of sustainable buildings and not on any 'ramping-up' in the low-tech community. Thus, we observe conceptual mainstreaming. This is different from dominant design mainstreaming because visually, high-tech ecological architecture is only moderately influenced by traditional buildings, using high-tech building elements to signify environmental consciousness (Hojem et al., 2014). Further research is needed to examine how different this is from more traditional aesthetics.

Thus, we can identify four types of mainstreaming: pragmatic, expansive, dominant design, and conceptual. They may be combined – probably in more ways than we have seen in this paper – and there is no reason to believe that these four are the only ones possible. This conceptual plurality suggests a diversity of mainstream logics. Berker (2010) proposes two logics: bottom-up approaches and incremental improvements. While incremental improvements seem to be a feature of all four types of mainstreaming, the bottom-up logic is only seen in pragmatic and expansive mainstreaming, not with dominant design and conceptual types. Other suggested logics to be observed in the three cases in this paper include environmental criteria, efficiency, and hybridisation; more work is needed to identify and elaborate such logics.

Should we rather have considered the three cases as processes where we see transition pathways produced through systemic interaction, on the lines suggested by Geels and Schot (2007)? Already suggested difficulties implementing the multi-level perspective appear to be supported by the cases covered in this paper. For example, how to empirically distinguish between the niche, the regime and the landscape level? What constituted the regime level in the case of wind turbine development? In the case of electric cars, can we really identify a transformative niche innovation that made its way into the automobile industry? By comparison, the mainstreaming concept facilitates observations of actor strategies and conflicts in sociotechnical transformations – the co-production and the acting-out of mainstreaming logics.

One weakness could be that mainstreaming needs better conceptual explanation. Do we need ecological modernisation or the multi-level perspective for this purpose? Clearly, the kind of mainstreaming studied in this paper happens in a favourable context of increasing demand for sustainable technologies. Still, it remains a matter of controversy which transitions actually are sustainable, which technologies should be preferred and how such preferences should be established (see, e.g., Jørgensen, 2012). At least, more empirical work is needed to see how mainstreaming is supported.

The exploration of mainstreaming in this paper has been based on revisiting a set of studies of past developments conducted by many authors with different goals and foci. To carry the analysis and understanding further it is desirable to undertake primary research directed towards explicating detailed mainstreaming processes. This would provide an opportunity to address issues such as the interactions and learning between traditional and high-tech approaches. Such research may also lead to the discovery of other types of mainstreaming and mainstreaming logics.

Acknowledgements

A first version of this paper was presented at "Symposium to celebrate the contribution of Dr. Stewart Russell", March 30, 2012, at The University of Edinburgh. The present version has benefitted from valuable comments from participants at that symposium, Heidrun Åm, three anonymous reviewers, and the editors of this special issue. The work has been supported by grant #185397 from Research Council of Norway.

References

Abernathy W (1978) *The Productivity Dilemma*. Baltimore: Johns Hopkins University Press.

Andresen I, Kleiven T, Ryghaug M & Malvik B (2007) *Smarte energieffektive bygninger.* Trondheim: Tapir Academic Press.

Benschop Y & Verloo M (2006) Sisyphus' sisters: Can gender mainstreaming escape the genderedness of organizations? *Journal of Gender Studies* 15(1): 19–33.

Berker T (2010) Dealing with uncertainty in sustainable innovation: mainstreaming and substitution. *International Journal of Innovation and Sustainable Development* 5(1): 65–79.

Brown MB (2001) The Civic Shaping of Technology: California's Electric Vehicle Program. *Science, Technology, & Human Values* 26(1): 56–81.

Buen J (2006) Danish and Norwegian wind industry: The relationship between policy instruments, innovation and diffusion. *Energy Policy* 34(18): 3887–3897.

Carr M (1985) (ed) *The AT Reader: Theory and Practice in Appropriate Technology.* New York: Intermediate technology development group of North America.

Darrow K & Saxenian M (1986) *Appropriate Technology Sourcebook: A guide to practical books for village and small community technology*. Stanford CA: Volunteers in Asia.

Dickson D (1974) *Alternative Technology and the Politics of Technical Change.* Glasgow: Fontana.

Fogelberg H (2000) *Electrifying visions: The technopolitics of electric cars in California and Sweden during the 1990's.* Gothenburg: Section for Science and Technology Studies, Gothenburg University.

Garud R & Karnøe P (2003) Bricolage versus breakthrough: Distributed and embedded agency in technology entrepreneurship. *Research Policy* 32(2): 277–300.

Geels FW (2002) Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research Policy* 31(8–9): 1257–1274.

Geels FW (2014) Regime Resistance against Low-Carbon Transitions: Introducing Politics and Power into the Multi-Level Perspective. *Theory, Culture & Society* 31(5): 21–40.

Geels FW & Schot J (2007) Typology of sociotechnical transition pathways. *Research Policy* 36(3): 399–417.

Guy S & Moore SA (2007) Sustainable Architecture and the Pluralist Imagination. *Journal of Architectural Education* 60(4): 15–23.

Hess D (2007) *Alternative pathways in science and industry: Activism, innovation, and the environment in an era of globalization.* Cambridge MA: The MIT Press.

Heymann M (1998) Signs of Hybris: The Shaping of Wind Technology Styles in Germany, Denmark, and the United States, 1940–1990. *Technology and Culture* 39(4): 641–670.

Hoogma R, Kemp R, Schot J & Truffer B (2002) *Experimenting for sustainable transport: The approach of strategic niche management.* London: Spon Press.

Hojem TSM, Sørensen KH & Lagesen VA (2014) Designing a "green" building: expanding ambitions through social learning. *Building Research & Information* 42(5): 591–601.

Jéquier N (1976) The major policy issues. In: Jéquier N (ed) *Appropriate Technology: Problems and Promises.* Paris: OECD, 15–112.

Jørgensen U (2012) Mapping and navigating transitions – The multi-level perspective compared with arenas of development. *Research Policy* 41(6): 996–110.

Jørgensen U & Karnøe P (1995) The Danish wind turbine story: technical solutions to political visions? In: Rip A, Misa TJ & Schot J (eds) *Managing Technology in Society: The Approach of Constructive Technology Assessment*. London: Pinter, 57–82.

Kaplinski R (2011) Schumacher meets Schumpeter: Appropriate technology below the radar. *Research Policy* 40(2): 102–203.

Kemp R, Rip A & Schot JW (2001) Constructing transition paths through the management of niches. In: Garud R & Karnoe P (eds) *Path dependence and creation.* London: Lawrence Erlbaum, 269–299.

Kongsli G, Ryghaug M & Sørensen KH (2008) Miljøarkitekten: Dirigent eller deltaker? *Nordisk Arkitekturforskning* 20(3): 7–20.

Kårstein A (2010) 'Th!nk'. Unpublished paper. Trondheim: Department of interdisciplinary studies of culture.

Latour B (2005) *Reassembling the Social: An Introduction to Actor-Network-Theory.* Oxford: Oxford UP.

Lewis JI (2007) Technology Acquisition and Innovation in the Developing World: Wind Turbine Development in China and India. *Studies in Comparative International Development* 42(3–4): 208–232.

Lundvall BÅ, Johnson B, Andersen ES & Dalum B (2002) National systems of production, innovation and competence building. *Research Policy* 31(2): 213–231.

Markusson N (2011) Unpacking the black box of cleaner technology. *Journal of Cleaner Production* 19(4): 294–302.

Maruo K (2000) Escaping from the Prototype Trap: EV Venture Firsm and Their Struggle for Survival. In: Cowan R & Hultén S (eds) *Electric Vehicles: Socio-economic prospects and technological challenges.* Aldershot: Ashgate, 101–135.

Mol APJ, Sonnenfeld DA & Spaargaren G (eds) (2009) *The ecological modernisation reader: Environmental reform in theory and practice.* London and New York: Sage.

Mom G (2004) *The Electric Vehicle: Technology and Expectations in the Automobile Age.* Baltimore: The Johns Hopkins University Press.

Munch B (2002) Wish You Were Here – Users, Producers, Politics and, Electric Vehicles in Denmark. In: Elzen B, Jørgensen U, Sørensen KH & Thomasssen Ø (eds) *Tackling Transportation Problems around the World.* Twente: University of Twente, 57–80.

Munksgaard J & Morthorst PE (2008) Wind power in the Danish liberalised power market – Policy measures, price impact and investor incentives. *Energy Policy* 36(10): 3940–3947.

Murphy HM, McBean EA & Farahbakhsh K (2009) Appropriate technology – A comprehensive approach for water and sanitation in the developing world. *Technology in Society* 31(2): 158–167.

Nielsen KH (2010) Technological Trajectories in the Making: Two Case Studies from the Contemporary History of Wind Power. *Centaurus* 52(3): 175–205.

Petterson M, Ek K, Söderholm K & Söderholm P (2010) Wind power planning and permitting: Comparative perspectives from the Nordic countries. *Renewable and Sustainable Energy Reviews* 14(9): 3116–3123.

Pursell C (1993) The rise and fall of the appropriate technology movement in the United States, 1965–1985. *Technology and Culture* 34(3): 629–637.

Reichertz J (2007) Abduction: The Logic of Discovery of Grounded Theory. In: Bryant A & Charmaz K (eds) *The SAGE Handbook of Grounded Theory.* Los Angeles: Sage, 214–228.

Russell S (1993) Writing energy history: explaining the neglect of CHP/DH in Britain. *British Journal of the History of Science* 26(1): 33–54.

Ryghaug M (2003) *Towards a sustainable aesthetics: Architects constructing energy efficient buildings.* PhD Thesis, Norwegian University of Science and Technology, Norway.

Ryghaug M (2007) Miljøarkitektur: Fra grav til vugge? In: Aune M & Sørensen KH (eds) *Mellom klima og komfort. Utfordringer for en bærekraftig energiutvikling.* Trondheim: Tapir Akademiske Forlag, 217–232.

Ryghaug M & Toftaker M (2014) A transformative practice? Meaning, competence, and material aspects of driving electric cars in Norway. *Nature and Culture* 9 (2): 146–163.

Schumacher EF (1973) *Small is beautiful: A study of economics as if people mattered.* London: Blond and Briggs.

Sierzchula W, Bakker S, Maat K & van Wee B (2012) The competitive environment of electric vehicles: An analysis of prototype and production models. *Environmental Innovation and Societal Transitions* 2(3): 49–65.

Skjølsvold TM (2013) What we disagree about when we disagree about sustainability. *Society & Natural Resources* 26(11): 1268–1282.

Smith A (2005) The Alternative Technology Movement: An Analysis of its Framing and Negotiation of Technology Development. *Human Ecology Review* 12(2): 106–119.

Smith A (2007) Governance Lessons from Green Niches: The Case of Eco-Housing. In: Murphy J (ed) *Governing Technology for Sustainability*. London: Earthscan, 89–109.

Steen M & Hansen GH (2014) Same Sea, Different Ponds: Cross-Sectorial Knowledge Spillovers in the North Sea. *European Planning Studies* 22(10): 2030–2049.

Undheim TA (2002) Think Electric – A Successful Branding of Sustainable Mobility? In: Elzen B, Jørgensen U, Sørensen KH & Thomassen Ø (eds) *Tackling Transportation Problems around the World*. Twente: University of Twente, 155–178.

Verbong G & Loorback D (2012) *Governing the Energy Transition: Reality, Illusion or Necessity?* London: Routledge.

Winner L (1977) *Autonomous Technology: Technics-out-of-control as a theme in political thought*. Cambridge, MA: The MIT Press.

Winner L (1979) The Political Philosophy of Alternative Technology: Historical Roots and Present Prospects. *Technology in Society* 1(1): 75–86.

Winner L (1986) Building the Better Mousetrap. In: Winner L (ed) *The Whale and the Reactor. A Search for Limits in an Age of High Technology*. Chicago: The University of Chicago Press, 61–84.

Notes

1 Recently, the latter industry is increasingly offering such cars but the links to alternative actors are more obscure than in the case of wind turbine technology.

2 In the two latter cases, I was familiar with the most frequently used sources because they have been produced through research in which I have participated.

3 The development of EVs did not follow a strategic niche pattern (Geels & Schot, 2007) but took place in a setting outside of competition from the established automobile industry due to special interests of the producers and a small number of customers.

4 In addition, Munch (2002) points to safety rules as a special challenge. The Danish electric cars were usually made from lightweight materials, like plastic, their top speed was low, but they were still considered to be dangerous with unacceptably inadequate levels of safety.

5 An update is found in 'Eventyret endte i tragedie' (The adventure ended tragically), Adresseavisen, October 24, 2012, p. 18.

6 See, e.g., 'Denne bildesignen er ekte norsk' (This car design is genuinely Norwegian), Verdens Gang, November 29, 2010.

7 Pragmatic mainstreaming may also have happened with respect to ecological architecture, but this is not clear from the evidence reviewed here.

8 The extent to which low-tech ecological architecture has engaged with pragmatic mainstreaming need to be further studied.

Knut H. Sørensen
Department of Interdisciplinary Studies of Culture and Centre for Sustainable Energy Studies (CenSES)
Norwegian University of Science and Technology (NTNU)
Dragvoll, 7491 Trondheim, Norway
knut.sorensen@ntnu.no