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Niche accumulation and hybridisation strategies in transition processes towards a sustainable energy system: An assessment of differences and pitfalls

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Abstract

This paper assesses two patterns in transition processes for using them as strategies towards a sustainable energy system, i.e., niche accumulation and hybridisation. Both play important but different roles in transitions. The expected success of these strategies depends on the innovation's history and the innovation context. The different strategies are illustrated with several examples from the energy domain.

Keywords: Transition strategies; Niche accumulation; Hybridisation

1. Introduction

Many sectors in modern societies face structural problems. The energy sector for example faces problems related to oil dependency, security of supply and climate change. Although the environmental performance of the energy sector has greatly improved over the past 30 years (e.g., reduction of SO_2, NO_x, dust), policy makers increasingly acknowledge the limitations to end-of-pipe solutions and the need for more structural change. This has facilitated the emergence of 'transition thinking' among scientists, policy makers, and increasingly also industry.[1]

Transitions refer to the shift from one stable 'socio-technical regime' to another in such a way that the structure of that regime in the way it fulfils a certain societal function (e.g., mobility, energy supply) has fundamentally changed. Sustainable transitions also include a normative aim, i.e., a radical jump in environmental performance. A transition implicates that a change occurs in the basic elements that constitute the nature and working of the regime including technological, institutional and social (network) changes. But this is a long-term and complex process, because regimes tend to be stabilised and resist to any fundamental change. Institutional structures (both formal ones like public financing schemes and informal ones like cultural values) are often very rigid, preventing the breakthrough of alternatives (Jacobsson and Lauber, 2006). Total energy subsidies in the European Union in 2001, for example, have been estimated to be 29.1 billion, of which the majority was still directed towards coal (13 billion) and oil and gas (8.7 billion).[2] Actors and social networks represent 'organisational capital', which make them blind for alternatives and lead them to support the old system even when alternatives have improved societal or environmental characteristics. And artefacts and

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[1]Transitions and transition management were first mentioned as policy approach in the fourth Dutch National Environmental Policy Plan (NMP4). Since then the transition approach has been adapted by various groups of actors in the energy domain, the agricultural domain and the mobility domain. More information on the Dutch energy transition approach can be found on http://www.senternovem.nl/EnergyTransition/.

[2]Remaining amounts were directed towards nuclear (2.2 billion) and renewables (5.3 billion). Although these financing schemes might seem strange from an environmental perspective, proponents use other arguments such as the security of supply, economic benefits for certain sectors and employment and social benefits (European Environment Agency, 2004).

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infrastructure give certain 'hardness' to a system, which often represent large vested interests of incumbent actors (Walker, 2000).

So institutions, social networks and technologies are sources for path dependence and stability in regimes. But this stability is dynamic. Within socio-technical regimes there is still innovation through variation and selection processes (evolution). Because of internal stability, however, this innovation is often incremental, building upon dominant designs and old practices. So once established, regimes tend to develop along specific technological trajectories—thereby effectively locking out alternatives. Electricity regimes, for example, have been developing along incremental trajectories towards ever-larger power plants, mainly based on fossil fuels, and connected to nation wide AC grids. Institutional arrangements and ever-growing demand for power were important drivers in that process. This has led to carbon lock-in of electricity regimes (Unruh, 2000). Only since the 1970s and 1980s this development process has been increasingly criticised and arguments and advances have been made towards alternative, more environmentally sound (and often decentralised) electricity regimes.

This paper discusses two patterns that are put forward in transition literature as typical in transitions and assesses the potential of such patterns to be used as strategies for dealing with the lockout of alternatives. This first strategy is to apply the innovation in niche markets and improve and build up internal momentum through a process of niche accumulation. The second strategy is to start more closely to the existing regime and opt for a radical transformation through a process of hybridisation. Both strategies are seen as promising, but limited work has been done on assessing the differences and the potential for success. This paper aims to fill that gap.

The next section discusses a multi-level perspective that has been developed to understand how transitions come about. Section 3 continues with discussing both strategies. Section 4 discusses if and how a single actor can choose a certain strategy. In Section 5, I end with summarising conclusions.

2. Radical change in niches and the role of external factors: a multi-level perspective on transitions

Historical cases show that established regimes are sometimes overthrown. Examples are the rapid introduction of natural gas in the UK and the Netherlands, taking over dominant positions from coal and oil (Winskel, 2002; Coreljé and Verbong, 2004), and the transition from horse-drawn carriages to automobiles (Geels, 2002). These scholars and others (e.g., Rip and Kemp, 1998) have developed a multi-level perspective on transitions based on insights from evolutionary economics and sociology of technology. In this perspective radical transformation of *regimes* (the first level) starts in *early niche markets* (the second level): distinct application domains where users have different preferences than mainstream users.[3] Many historical examples support this assumption such as the application of solar cells in space travel and mobile phones for business people. These early adopters are often willing to pay a higher price, because of particular benefits they gain from the innovation. For sustainable innovations, however, early niche markets often do not exist (benefits are at the collective level of societies; no individuals are willing to invest) or are too different from mainstream markets (e.g., solar cells for space travelling). Markets for sustainable innovations have to be created: market and technology develop in a process of co-evolution. By actually using an innovation, users create or learn about new needs, policy makers create regulatory frameworks that fit the innovation and industrial actors learn to improve the innovation and reduce costs. Scholars have called these special niche markets *technological niches*. Technological niches are made operational through (a series of) protected test beds such as pilot- and demonstration plants where technologies are applied in a societal setting for the first time. In evolutionary terms these test beds form a bridge between the variation and selection environment (Kemp et al., 1998; Hoogma et al., 2002; Raven, 2005).

The third level of the perspective is called 'socio-technical landscape' and highlights the role of events and developments in the exogenous environment: developments and events that cannot be controlled by regime or niche actors. It is a rather descriptive concept that refers to broad societal trends such as macro-economic developments (e.g., recessions, global oil prices). But the concept is also used for referring to rapid historical shocks and events (e.g., the Chernobyl explosion) that put pressure on existing regimes and create windows of opportunities for radical innovations.

This model of transitions emphasises multi-level and multi-actor dynamics of transitions. Transitions (such as the one towards a sustainable energy regime) do not occur as simple (economic) substitution processes in which one dominant design is overthrown another. Instead, transitions occur as a result of complex interaction patterns between all levels and a range of actors. Established firms, new (innovative) firms, users, governments (local, national, supranational), scientists and NGO's have strategies, interests and motivations (often conflicting). The innovation patterns that develop out of their interactions often have an emergent rather than a planned and structured character.

According to this model managing transitions towards a pre-defined goal (e.g., sustainability) is very difficult and, for a single actor, even impossible to pursue, because of the

[3] In early transition research based on this model only a single storyline was developed, in which transitions always start in niches. Recently this storyline has been criticised for being too much technology push and bottom–up oriented and transition researchers have come up with more sophisticated models of transitions. See for example, Smiths et al. (2005) who propose four different transition contexts.

interdependence between multiple actors and the role of autonomous developments in the socio-technical landscape. Recent attempts to formulate guidelines for transition management therefore try to take into account the contingencies created by multi-level developments and aim to facilitate multi-actor processes in so-called arena's (Kemp and Loorbach, 2006). In arena's many heterogeneous actors develop a shared vision on, for example, a future energy regime and discuss possible pathways to realise that vision. Subsequently, experiments within each pathway are set up to learn about feasibility and desirability. Ideally, the experiments are fully monitored and lessons learned are then used as input into a new cycle of strategic vision making and experimenting. Although transition management is a promising concept, it has proven to be difficult to apply the principles in practice (Dignum, 2006). An important difficulty identified by practitioners is to link the strategic level of vision making and planning with the operational level of experimenting. Actors at the operational level argued that they were often missing a clear framework for experimentation. And at present no monitoring occurred to feed lessons from experimentation back into the strategic level.

This article aims to contribute to these attempts by discussing two patterns described in historical case studies as possible *strategies* to pursue by transition practitioners and discuss differences and possible pitfalls. These transition strategies should not be understood as traditional planning strategies that see strategy formation as a formal, prescriptive process. Rather transition strategies should be seen as what Mintzberg et al. (2005, p. 6) call learning strategies: "For the learning school, the world is too complex to allow strategies to be developed all at once as clear plans or visions. Hence strategies must emerge in small steps, as an organisation adapts, or learns". Learning strategies have an emergent rather than a deliberate character. While the latter implies that strategies are about control and making sure that managerial intentions are realised in action, the first implies that strategies are about understanding what those intensions are in the first place through the taking of actions. The learning strategy is in particular relevant for transitions, which are characterised by actor interdependence and multiple, often diverging intensions. No single actor is able to enforce its will and intensions upon all others. But in the process of interaction a pattern can develop that can eventually become a strategy when firms, users, policy makers, NGO's and other actors increasingly develop consensus through conflicts, mutual adjustment and interactive learning processes. A transition strategy is thus a collective strategy rather than an individualist's strategy. The 'strategist' is the collectivity rather than an individual (Minztberg et al., 2005).

3. Transition strategies towards sustainability

Two general strategies can be distinguished when it comes to attempts to induce transitions (Geels, 2005b). The first—niche accumulation—starts as a radical distinction from the current regime (in terms of markets, technologies, actors involved, institutional arrangement) and aims to prevent too early rejection through smart experimentation in niche markets. The second—hybridisation—starts close to the existing regime, but aims to diverge along the road and bend existing trajectories towards more desirable ones. Table 1 lists the main differences between the two strategies, which will be discussed in this section. The table should be read as two theoretical extremes on a gradual scale. Any transition strategy in practice will often be a mix of hybridisation and niche accumulation. For example, a transition can start out as a niche accumulation process, in which a technology is applied in various niche markets, and later also form hybrid combinations with the dominant design.

Table 1
Difference between niche accumulation and hybridisation

	Niche accumulation	Hybridisation
Description	Radical innovation improves and stabilises in multiple niche markets until it can invade mainstream market	Innovation starts close to existing regime, but lures mainstream actors into perusing alternative trajectory
Type of innovation	Radically different from regime technology	Add-on to regime technology
Market focus	Niche markets	Mainstream markets
Niche–regime relationship	Competitive	Symbiotic
Driving actor	Small innovative firms (or other regime outsiders like NGO)	Incumbent firms (+outsiders?)
Main rationale	Great potential for learning about new market/technology combinations	Easy integration in existing regime (infrastructure)
Pitfalls	Dividing resources across technology/market combinations can result in insufficient momentum for any of the combinations	Danger of getting stuck into existing regime without radical transformation
	Exchanging lessons between combinations can be difficult	Regime optimisation hardens competition for other alternatives
	Danger of remaining stuck in small market niches	

3.1. Niche accumulation as a transition strategy towards sustainability

Niche accumulation refers to the application of a technology in different niche markets so that technology/market combinations become robust. In such a process a novelty starts out as a radical deviation from the dominant design, e.g., in terms of technical characteristics (radical new design) or institutional arrangement (e.g., new forms of organisation). The innovation still survives because of the characteristics of the niche market. For example, consumers outside the reach of electricity grids are willing to invest in decentralised systems in order to benefit from access to electricity supply. Also protection (e.g., tax exemptions, investment grants, strategic firm investments) can prevent a too quick rejection by mainstream market selection criteria. The innovation can then move from one niche market to another ('niche branching'). This improves the fit between technology and markets and increases internal momentum so that a new regime emerges: the new technology is now embedded in institutions and social networks and is able to better compete with the old technology on mainstream markets.

For example, in the Netherlands the implementation of Combined Heat and Power (CHP) technologies started in the 1970s in markets with a large heat demand such as large industries (e.g., chemical industry) and the emerging district heating market. Electricity was only a by-product. Gradually CHP moved towards other markets as technology companies developed and tested different prime movers (the energy producing part of the plant). In the early 1990s, CHP emerged in the markets for horticulture and services (large building heating), using small gas turbines instead of steam turbines. Electricity production now became equally important for the construction of CHP. Protection in the form of favourable feed-in tariffs for electricity supply back to the grid and investment grants made electricity supply in CHP plants more profitable. In the early 2000s several companies are involved in experimenting with CHP technologies in yet another market, i.e., micro-CHP for individual households. Such a local market for electricity generation in houses does not exist yet. The participants in the projects are therefore not only discussing technological issues, but also aim to align user preferences and regulations. A new niche market is being created (Raven and Verbong, 2006).

Hendry et al. (2006) foresee a similar pattern for the fuel cell. Fuel cells have yet to achieve commercial viability, but have been seriously experimented with in a variety of niches since the 1960s, in particular space travelling and the US army and navy. Technology developers that want to promote fuel cells can continue with small scale applications such as portable electronics, move on to the stationary market for electricity generation in households, then move on to the market for decentralised CHP, and finally move to large-scale generation. The innovating company may also consider a different domain, e.g., transport, and develop fuel cells for vehicles (public transport, private cars, taxi, etc.).

All these markets have different characteristics and set different requirements for the new technology. For example there are differences in performance, size and weight requirements. But also market circumstances are different such as the performance characteristics of the dominant design that a fuel cell has to compete with or the power and resources of the social network that is supporting the 'old' technology. Applying a fuel cell in different markets can lead to the emergence of new social networks supporting the fuel cell (including producers, scientists, user organisations and policy makers) and the formulation of institutions like safety standards and design requirements. This improves the social robustness of the fuel cell and its competitive position compared to the internal combustion engine or fossil fuel power plant. This process has for example been observed in the case of biomass combustion in Denmark. Biomass was first applied in district heating markets, then moved to decentralised biomass CHP plants and finally the mainstream market of large power plant. These markets set different requirements for the technology, which resulted in a steady increase in steam temperature and efficiency and reducing the gap with fossil fuel-based systems. Also the market for biomass supply benefited through formalisation of contracts and quality control in reaction to a growing demand for biomass (Raven, 2005).

The rationale for a niche accumulation strategy is that it potentially offers a great opportunity for learning about technology and markets. Technological design can be gradually optimised and fitted for use in different markets so that the technology becomes more robust. But the technology developer can also learn from feedback from various users or other relevant actors and verify assumptions about perceived user needs or societal context. Lynn et al. (1996) have identified such a pattern of market application and learning in non-energy domains. They argue that in particular for radical innovations conventional market research techniques such as customer surveys are not sufficient, because customers often have difficulty expressing needs for technologies that are not yet existing or fully developed. Lynn et al. therefore argue that there is a need for a different strategy, i.e., a 'probe-and-learn strategy'. Initial market application is input for subsequent market application in order to improve the innovation and learn about market characteristics. This is shown in Fig. 1 for the case of the Corning Company, which developed optical fibers by 'probing' in various markets such as picture phones, cable TV and finally home application over a period of more than 20 years. Markets are not so much picked on the basis of expected profits, but rather on the basis of learning potential.

Leonard (1998) adds that such a strategy may take different forms (see Fig. 2). In the case of parallel experimentation a single company experiments with different technology/market combinations at the same

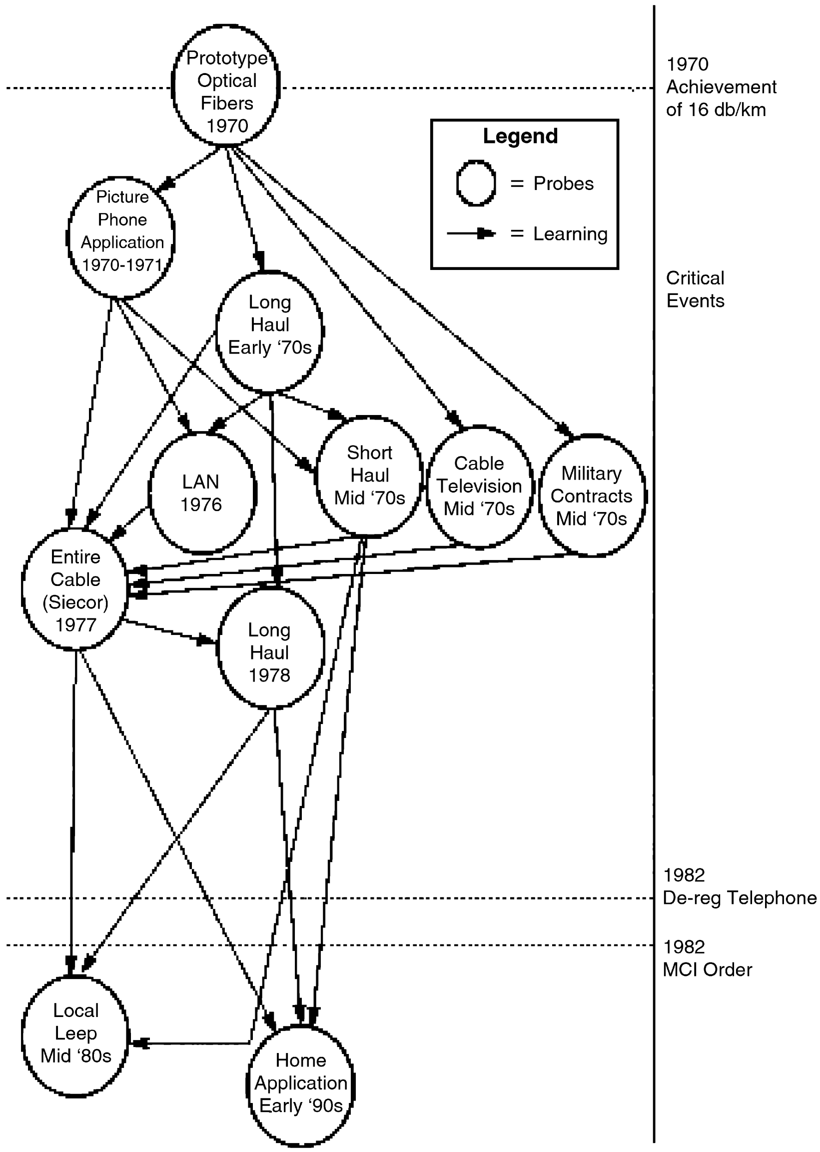

Fig. 1. The probe and learn process for optical fibres (Lynn et al., 1996).

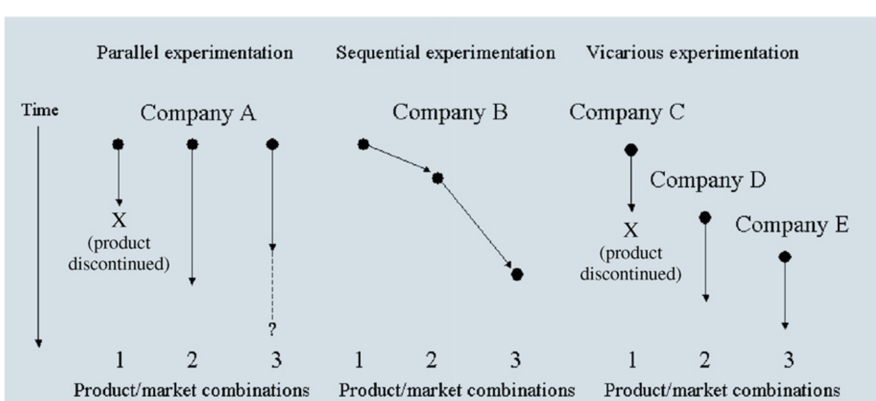

Fig. 2. Different experimentation strategies for radical innovations. Adapted from Leonard (1998).

time. Such a strategy is in particular feasible in the case of small-scale technologies with limited investment requirements for R&D and production. Leonard, for example, argues that in particular Japanese companies are well known for their "product churning" and she gives the example of soft drinks: "about a thousand new soft drinks are brought out annually in Japan, although almost all of them fail within a year'' (Leonard, 1998, p. 209). Large technologies such as power plants are more likely to follow a sequential experimentation strategy, in which a single company takes a more step-wise approach, or a vicarious experimentation strategy, in which multiple companies experiment with different technology/market combinations. The latter has for example been observed in the case of solar cells and wind turbines in Germany. In the 1970s and 1980s, 39 firms and 12 research institutes received funding for solar cell development. At least 14 wind turbine suppliers received funding for 124 wind turbines and ''a range of firms and academic departments began a process of experimentation and learning. Small niche markets were formed and a set of firms were induced to enter'' (Jacobsson and Lauber, 2006).

An example of sequential experimentation comes from Denmark in the case of biomass combustion (Raven, 2005). In this case it was not so much a company, but rather the Danish government who was the driving force in this transition strategy. The Danish use of biomass started rather spontaneously in the market for small district heating systems. Many if these district heating systems had been fuelled with biomass, but had shifted towards inexpensive oil in the 1960s. When the oil prices started to increase in the 1970s some of these plants turned back to biomass. In the 1980s, the Danish government tried to stimulate further expansion by targeting a number of subsequent niche markets for heating. The aim was to convert as many conventional plants as possible to CHP plants and introduce biomass fuels. The strategy was successful and the number of district heating plants using biomass increased from three in 1984 to about 100 in 1999. Also a new niche market for power generation emerged: in 1998 seven CHP plants combusted straw, while twenty CHP plants used biogas from manure digestion (Centre of Biomass Technology, 1998).

The Danish government continued their strategy with the introduction of biomass in the market for mainstream electricity generation. In 1993, the Danish government realised a new agreement with the opposition, which obliged the electricity utilities to buy 1.4 million tons of biomass in the year 2000. Although met with opposition from the utilities this agreement pushed biomass into the mainstream market. The utilities could build upon previous experiences with biomass combustion, e.g. through co-operation with boiler suppliers. By the year 2000 the utilities had constructed co-firing plants equivalent to 173.3 MWe biomass capacity. Although this was not yet sufficient for reaching the goals from the biomass agreement, the companies had made major investments in R&D and plant (re)construction.

A possible pitfall of the niche accumulation strategy is that resources can become scarce quickly. The niche accumulation strategy is rooted in evolutionary theories and the strategy's advocates therefore often make pleas for variety stimulation instead of 'picking winners' in technological development (Raven, 2005). In practice, however, there is a limit to how much variety can be stimulated due to limited resources of firms and policy makers. Dividing resources across many different technology/market combinations may dry up resources quickly or niche markets may lead to low returns on investment. This is in particular relevant in the case of radical innovations, which often require long-term experimentation strategies in order to develop into a robust innovation. And in the case of energy innovations this might be even more difficult due to size and complexity of energy plants. Another pitfall is that this strategy requires a great deal of work of aligning lessons and experiences from different locations. A platform or forum needs to be created for sharing experiences. But in particular when multiple firms are involved exchanging lessons and experiences can be extremely difficult because of strategic reasons. A third pitfall is the danger of an innovation becoming stuck into small markets. In cases where there is harsh competition with dominant designs (e.g., in the case of private cars), it may be insufficient to only build up internal momentum in various early market niches. Although many companies have carried out pilot projects with electric vehicles in various niche markets since the 1980s, electric vehicles remained a niche product, while the internal combustion engine has continued to improve (Hoogma, 2000).

3.2. Hybridisation as a transition strategy towards sustainability

Hybridisation refers to the process were 'new' and 'old' technology hook up to form some kind of a hybrid technical design. For example a technology developer can try to link an innovation to a specific problem in the dominant regime. He can try to enrol regime actors to adopt the innovation as an add-on element to the dominant design and aim to supply to mainstream markets. An example is the introduction of gas turbines in the electricity regime. Gas turbines were initially used for peak demand in the electricity system, but took over the dominant position from stream turbines through a process of hybridisation, which eventually let to the development of combined cycle power stations (Islas, 1997). In the first combined cycles the gas turbine was only an auxiliary device used to improve the performance of the steam turbine, but in the 1960s and 1970s large electrochemical companies and large boiler companies developed combined cycles in which the gas turbine was the main component and the steam turbine took the role of auxiliary device.

Also the transition from sailing ships to steam ships shows a process of hybridisation (Geels, 2005a). Steam engines were initially add-on elements in sailing ships for situations when there was no wind. In the 1840s and 1850s, hybrid ships were built using wind and steam as equal forms of power source. Eventually (after a long period of hybridisation) the new technology (in this case the steam ship) might become the dominant design, while the old technology continues to exist as an auxiliary device for the new technology, moves to niche markets (e.g., for pleasure cruises), or distinct completely.

The rationale for applying a hybridisation strategy is that a technology developer can circumvent harsh competition with the established regime. In particular in cases where a 'hard' infrastructure is a crucial aspect of the functioning of the regime, hybridisation can be an important strategy, because these are often tightly coupled regimes that create a high threshold for new technologies (Kaijser, 2003). Technologies like power plants only work when there is an infrastructure available (electricity grid). New technologies that require a different type of infrastructure therefore have a disadvantage when coming to the market since there is not yet an infrastructure in place. By making hybrid forms users can still use the innovation in cases where there is already a new infrastructure in place, but fall back on the old technology when there is not. So by making hybrid technologies the 'fit' between innovation and infrastructure (and the existing regime in general) is improved. The innovation can build upon "the widely spread technological trajectories developed out of the past" (Fuchs and Arentsen, 2002).

The challenge is then to slowly diverge from this trajectory into directions more desirable. An example of such a process is the development of co-firing technologies in the Netherlands (Raven, 2006). In the early 1990s, Dutch electricity production companies started to experiment with replacing part of the coal with organic sources like sewage sludge and demolition wood. Waste often came with a negative price and policy makers actively stimulated biomass combustion with research programmes and subsidies. But the companies hardly had any experience with biomass combustion and they did not want to put power plants at risk. Hence the companies only replaced minor amounts of coal with biomass and did not make any real technological changes to the plant. In the late 1990s an emerging 'green electricity' market stimulated an increase in co-firing activities. To enable more biomass to be co-fired most companies now moved from 'direct co-firing' to 'indirect co-firing', i.e., they implemented special equipment for mechanical pre-processing the biomass before combustion. In the early 2000s, a covenant between government and electricity companies to reduce CO2 emissions from power plants pushed the companies' ambitions even further. While in earlier experiments utilities had only replaced up to 5% of the coal, they were now forced to replace up to 20% in the short term and even 40% in the mid-term (10–15 years). One company began the operation of an advanced gasifier plant, which formed a hybrid with an existing coal combustion plant (gas produced in the gasifier was co-fired with coal powder in the existing boiler). Other companies investigated similar options such as hybrid forms of gasification and pyrolysis of biomass with existing coal fired power plants. The expansion of co-firing also required the large-scale import of biomass. The companies began to import biomass from Eastern Europe, Canada, Southern America and Indonesia. And also emission standards were adjusted to the new situation (and aligned with European frameworks). Biomass co-firing grew quickly to become one of the largest renewable energy technologies in the Netherlands.

A similar process of hybridisation might be seen in the case of electric vehicles. An electric engine can initially take the form of an add-on device to the internal combustion engine, making use of the existing infrastructure for gasoline (e.g., Toyota Prius). This also 'solves' the limited technical performance of electric vehicles, e.g. in terms of axiradius. When the number of users increases, it becomes more attractive for fuel suppliers to set up 'fuel stations' for electric power. Technological improvements in various sub-components like storage may then result in a lesser need for the internal combustion engine from a performance perspective, or only for specific circumstances (e.g., fast acceleration on high ways). Now also other actors may become attracted to the hybrid forms, e.g., service stations or consumer organisations, and start promoting the novelty. Eventually the internal combustion engine might no longer be seen as necessary at all or disappear to special market niches like car racing.

A hybridisation strategy can be described as a 'fit-stretch pattern' (Hoogma, 2000). In a fit-stretch pattern, the innovation starts out as a close fit to the existing regime (both in terms of technology and markets), but gradually stretches into a more radical innovation. Three sub-strategies can be distinguished (see Fig. 3). One strategy is to opt for market differentiation (A): companies explore new markets, while technical design does not change. Only later the design becomes adjusted to the new market circumstances. Leonard (1998) gives the example of fish locators used by sport fishermen. This technology (underwater sonics) was developed by the military to spot submarines. The first fish locators were simply a copy of the original underwater sonics. Only later the product was adjusted and a whole new branch of products emerged from there. A second strategy (B) is to opt for stretching technological design (leapfrog design for substitution). New markets and functionalities are only explored later in the process. Leonard refers to the example of gas chromatography developed by HP. HP realised a huge jump in the price/performance curve, which engineers described as 'not just a local enhancement of the current chromatograph'. Initially HP targeted only existing customers, but because of lower costs the technology later branched towards new application areas. Finally, technology and markets can emerge in a process of co-evolution (C): changes in technological and market elements gradually build upon each other. Many historical cases show this pattern of co-evolution of technology and market (Geels, 2005b).

A possible pitfall of the hybridisation strategy is that it presupposes pro-active cooperation from regime actors, which might not always be the case. Regime actors often have large vested interests in factories, infrastructures, etc.

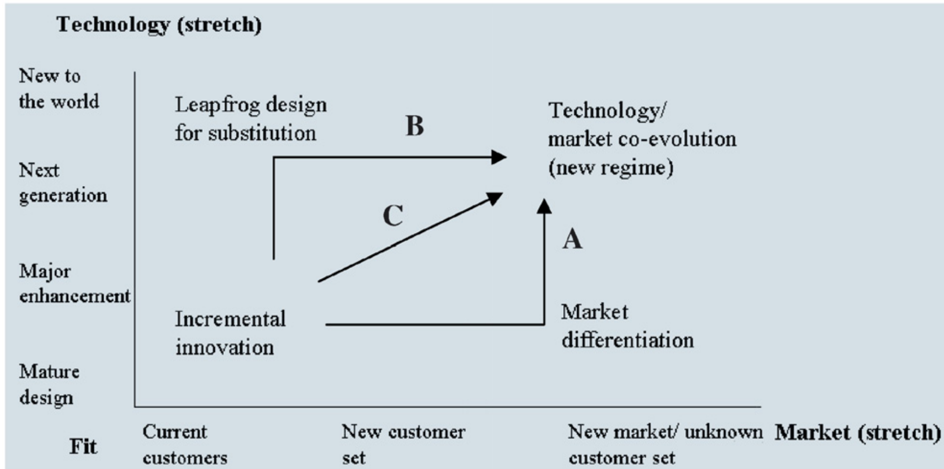

Fig. 3. Hybridisation strategies. Adapted from Hoogma (2000) and Leonard (1998).

This may cause them to actively hinder the hybridisation of 'their' system, or only half-heartedly participate in the process. For example, in the case of the Californian mandate for electric vehicles, several opponents—including the oil industry—began to lobby against the mandate and some car producers participated only to block other's progress (Hoogma, 2000).

Often regime actors are not acting intentionally against new technology, but because they are cognitively and institutionally locked in to the old technology and be blind for certain advantages of technology or market stretch. So the innovation gets stuck into existing designs and markets without radically transforming the regime. The regime only changes incrementally. This may even result in a disadvantage for other potentially radical innovations: they now have to compete with an improved system (the so-called sailing ship effect, or shooting at a moving target). For example, in the case of co-firing biomass in the Netherlands it is still questionable whether co-firing will result in a transition towards sustainability. Investments in advanced co-firing technology are still limited and various stakeholders oppose the co-firing of organic waste in power plants in fear of environmental and health damage. Also liberalisation and changing policies (in particular related to feed-in policies for renewable energy) have led to hesitation among energy companies to invest in risky projects. Also, co-firing does improve the environmental performance of the electricity regime, thereby hardening the competition for other alternatives (e.g., decentralised gasification systems or PV systems), because these alternatives loose some of their relative advantages. So hybridisation can be a fruitful strategy to induce transitions, but can also have adverse effects and be a strategy for regime actors to deliberately frustrate transition processes.

4. Discussion: choosing strategies

Discussing emergent strategies like the ones in this paper justifies the question if and how a single actor can choose between strategies. Is a single actor able to define a strategy ex ante instead of ex post? If we take an extreme position, one would argue that an emergent strategy literally means unintended order, not driven by conscious thoughts of any actor (Mintzberg et al., 2005). So strategies would only be identifiable ex post. But instead of taking such an extreme position a more moderate approach is to focus on learning and mutual positioning as means to determine one's strategy. Determining ones strategy then becomes a continuous process of learning-by-doing in which an individual actor can pursue a strategy in reaction to another one's.

Douthwaite et al. (2001, 2002) have developed a model that shows how such process takes place. Building upon Kolb's (1984) experimental learning model and empirical research on agricultural technology, these scholars developed a learning selection model that places individual learning within a social context (see Fig. 4). In Kolb's original model an individual's learning curves exists of four (cyclic) stages. The cycle might start when an actor has a certain *experience*, e.g., a car producer who notices a decrease in car sales. The producer reflects on this experience from different points of view to give it *meaning*. For example, the company realises that oil prices have increased and are likely to continue to increase in the future. The company than draws *conclusions* and decides that developing a multi-fuel vehicle is a reasonable strategy for dealing with decreasing car sales. When the company translates this conclusion into *action*, a new cycle of experience, sense making, drawing conclusions and learning is set in. Douthwaite et al. make Kolb's model social by linking individual actions and experiences with other's. Learning not only emerges from personal learning action and experience, but also in interaction with other actors.

Douthwaite's model suggests that determining ones strategy requires sensitivity for (a) an innovation's history and (b) the innovation context. The innovation history refers to past projects with similar technologies and markets (either projects carried out by the actor that is

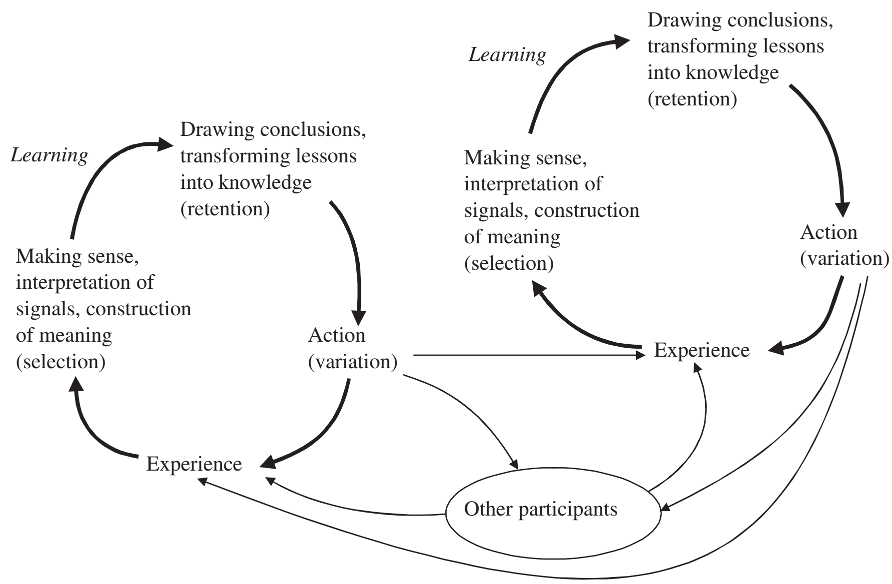

Fig. 4. The learning model by Douthwaite et al. (2001, 2002).

determining a strategy, or by other actors). An innovation's history is important to position oneself against others and learn from previous experience. Engwall (2003) rightfully argues that "no project is an island", meaning that every project occurs within a certain context and history. Instead of taking a 'project management textbook' procedure for granted, a company's strategy would be "most effective when striking a balance between what measures would instrumentally be the most rational for the individual project and which measures would be legitimate to undertake, given the interests of the key players of the environment and the project's historical and organisational context" (Engwall, 2003, p. 805). Jolivet et al. (2002) make a similar plea for the role of history in determining one's innovation strategy. These scholars developed the Socrobust methodology for managing breakthrough innovations (Socrobust), arguing that the first step is to develop a narrative on the project's past and defining the critical moments in history. Similarly, the approach of Strategic Niche Management has been successfully used as a method for determining strategies for regional policies regarding biofuels on the basis of analysing past experiments in other regions (Van der Laak et al., 2006).

The innovation context is equally important for determining a strategy. The innovation context refers to the wider developments in relevant regimes and the socio-technical landscape. Regime characteristics and dynamics in the socio-technical landscape determine to a large extent the frames within which a single actor can operate on the short term, while on the longer term the frames themselves are likely to shift (Van der Vleuten and Raven, forthcoming). One example comes from the implementation of biogas technologies in the Netherlands and Denmark. Both Dutch and Danish farmers started to digest animal manure in the 1970s in reaction to increasing oil prices and emerging environmental awareness. Albeit minor differences, both country strategies were equal: farmers developed small biogas plants on single farms. In the late 1980s, however, strategies started to diverge due to different regime and landscape dynamics. First, global oil crisis collapsed in the late 1980s. But while the Dutch government embraced lower prices to relax energy intensive industry expenses in a period of limited economic growth, the Danish government introduced high taxes on fossil fuels to improve the competitive conditions for domestic energy sources and stimulate the development of new industries. These regime changes benefited the Danish biogas innovation journey, while in the Netherlands regime changes complicated the journey. Second, the Netherlands were facing a huge manure surplus problem in the late 1980s, causing a shift in the perception of biogas plants from an energy producing plant to animal processing plants. Environmental problems in Denmark were less severe (although still very much present) and biogas plants became seen as a multi-functional technology addressing environmental problems in both the energy and agriculture regime. The resulting strategies were completely different in both countries. The Dutch applied a breakthrough approach with large, complex technologies for manure processing, while the Danes applied a bricolage approach consisting of taking small steps, focus on network building and learning by experimenting in both the markets for energy generation and manure processing, and later even in the market for waste management (Raven 2005; Raven and Geels, 2006).[4]

An emergent strategy thus depends on the historical and context conditions of an innovation journey. They define the space for a single actor (firm, policy maker) to manoeuvre strategically. But how can insight in historical

[4]Garud and Karnø (2003) have observed a similar pattern for wind turbines when comparing Denmark and California.

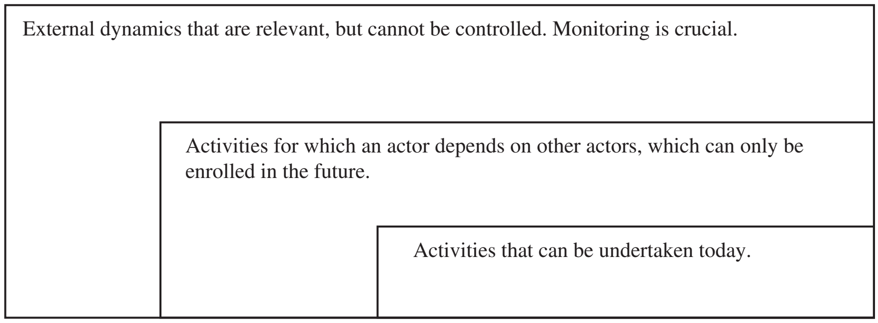

Fig. 5. A boundary map (or nested diagram) for defining strategic activities.

and context conditions be translated into strategic activities? This question is currently researched in the context of an ongoing EU project that builds upon the Socrobust project with a particular focus on societal acceptance (CreateAcceptance). In the project a first attempt has been made to investigate the space for strategic manoeuvring in concrete projects and develop managerial advice to project managers involved in renewable energy projects. In the project several methodological steps are taken to develop a 'boundary map' (see Fig. 5).[5] A series of structured interviews with innovator and relevant stakeholders of a renewable energy project provide the input for filling the boundary map. The map distinguishes between three levels of strategic activities. The first level refers to the activities that a certain actor can undertake immediately. This may include the identification of relevant niche markets to set up a project or contact regime actors for participation. The second level refers to activities for which the actor depends on other actors, which can only be enroled in the future. This for examples includes the advice to establish a platform with allies to negotiate about and lobby for changes in the institutional environment. The third level refers to the monitoring of those developments that are relevant but cannot be controlled by the actor. Here an example is to monitor activities from competing actors.

The map gives a visual representation of the short- and long-term activities that are possible and desirable for a single actor in such a way that those activities fit the innovation journey's history and the context in which the innovation journey takes place. This methodology is still in development, but will be tested in five energy projects in five European countries (including a wind project in Hungary, a biomass project in Germany, a solar project in Italy, a hydrogen project in Iceland and a carbon capture and sequestration project in the Netherlands).

5. Conclusions

This article has assessed differences between niche accumulation and hybridisation patterns in transition processes towards sustainability. The following summarising conclusions can be drawn.

First, both patterns occur in reality and are relevant for determining transition strategies towards sustainability in the energy regime. These patterns can be seen as emergent strategies, in which there is no complete control and planning by a single actor. Instead, the strategy unfolds at the collective level through a process of conflicts, mutual adjustment and interactive learning.

Second, although both strategies are seen as promising, they both have pitfalls that are important to recognise. The niche accumulation strategy offers a great potential for learning about new market/technology combinations, but has the pitfall of getting stuck in small niche markets. The hybridisation strategy offers the potential of an easier fit with existing regimes (in particular in cases of infrastructural regimes), but has the pitfall of getting stuck into the existing regime without a radical transformation of that regime towards sustainability.

Third, while the definition of strategies as emergent at the collective level seems to fit observations in historical case studies, it leaves a single actor in the dark on pursuing his own strategy. However, recent insights from innovation studies suggest that insight in the innovation's history and the innovation context are crucial in determining one's strategy. The development of a concrete management methodology for this purpose is still ongoing in the Create Acceptance project.

[5] A similar map was originally developed by the Energy research Centre of the Netherlands (ECN), and in particular Ruth Mourik, as an addition to the Socrobust methodology. For more information see http://www.createacceptance.net.

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