Anchorage of Innovations: Assessing Dutch efforts to use the greenhouse effect as an energy source

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Abstract

To analyse and understand transitions and system innovations various scholars use the so-called ‘multi-level perspective’ (MLP). The two key levels in the MLP are the ‘socio-technical regime’ (an existing system) and ‘technological niches’ (a breeding ground for alternatives to the system). The interactions between niche and regime, however, are not well understood. We need what Smith (2007) calls a ‘theory of linking’. Building on Loeber (2003) we use the concept of ‘anchorage’ to analyse this interaction.

Our case study concerns the Dutch glasshouse horticulture sector which is responsible for 10% of the country’s natural gas consumption. Various developments resulted in internal as well as external pressures to bring this down. This has led to a variety of ‘alternative energy approaches’ for the sector, some internal, some seeking to create new links with other sectors which makes this case very suited to study processes of anchorage.

We conclude that the concept of anchorage provides a useful tool to study the interaction between niche and regime and the crooked pathways of ‘innovation in the making’. It appears that what we call ‘hybrid actors’ and ‘hybrid forums’ play a crucial role in bringing about forms of anchorage. Furthermore, we show that within an ongoing process it is difficult to distinguish between developments leading to ‘incremental’ innovation and those having a potential of contributing to ‘radical’ or system innovation.

Keywords: System innovation, Anchorage, Glasshouse horticulture, Energy transition, CO_2 reduction

1 Introduction

The ‘multi-level perspective’ (MLP) has become an important analytical tool for understanding processes of transition and system innovation (e.g. Geels, 2002 and 2005; Berkhout et al., 2004, Geels and Schot, 2007). The perspective suggests that radical innovation emerges from complex interactions between processes occurring at three levels: socio-technical regimes (the meso level), technological niches (the micro-level) and socio-technical landscapes (the macro-level). This perspective has been used effectively by innovation scholars to analyse historical processes of radical change. Given the time frame considered, such descriptions and analyses necessarily abstract from the messy dynamics that occur within and between projects and networks of actors that are involved in innovation processes. As a result the processes through which practices at niche level interact with those at regime level and gradually shift dynamics in the direction of system innovation are not well understood. (Smith, 2007)

In this article we set out to increase our understanding of such interactions by analysing an ongoing process of change in glasshouse horticulture that has recently picked up speed and has become recognized as an example of ‘system innovation in the making’. First, we point to the need of having a better analytical framework for looking at linkages between niche and regime dynamics, and suggest that it is useful to think of the multi-level perspective in a less hierarchical manner. Building on Loeber (2003) we propose the term ‘anchorage’ as a useful analytical notion in this regard and distinguish between various aspects of it. Subsequently, we identify episodes of anchorage at the interface between niche and regime in the case-study which centres around efforts to transform glasshouse horticulture into an energy supplying sector instead of a major energy consumer.

We conclude that our perspective on anchorage yields meaningful insights in the interaction between niche and regime and the capricious pathways of ongoing system innovations. Our analysis of the case-study shows that what we call ‘hybrid actors’ and ‘hybrid forums’ play a crucial role in bringing about forms of anchorage. Moreover, we demonstrate that within an ongoing process it is difficult to distinguish between developments leading to ‘incremental’ innovation and those having a potential of contributing to ‘radical’ or system innovation, which has sobering implications for those aiming to support transition and system innovation processes.

2 Enriching the multi-level perspective on system innovation

2.1 The System Innovation challenge

Modern societies face structural problems in several sectors. Animal farming, for instance, suffers from manure problems, ammonia emissions and diseases like BSE and Foot & Mouth Disease. In the energy sector there are problems related to oil dependency, reliability, and CO_2 and NO_x emissions. The transport system suffers from problems like congestion, air pollution (particulates, NO_x), energy use and CO_2 emissions. These problems are deeply rooted in societal structures and activities.

In the past two decades much effort has put in solving such problems with product innovations. Cleaner products and environmental technologies have been developed and end-of-pipe solutions have been introduced. Sometimes these product innovations have led to substantial improvements in environmental efficiency (e.g. automobile catalysts which greatly reduced tailpipe-emissions of pollutants). The focus of these efforts was on the technological artefact.

According to a Dutch study substantial improvements in environmental efficiency (factor 2 as a general average) may still be possible with incremental innovation. (Weterings et al, 1997) But larger jumps in environmental efficiency (possibly a factor 10) may be possible with system innovations. The promise of transitions to sustainability via system innovations is schematically represented in Figure 1. Such system innovations not only involve new technologies, but also new markets, user practices, regulation, infrastructures and cultural meanings.

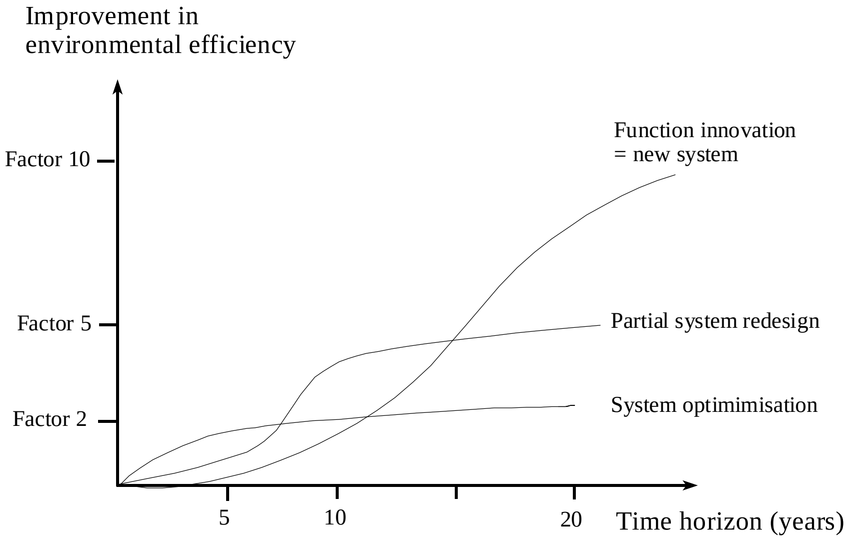

Figure 1. System optimisation versus system innovation (Weterings et al, 1997)

Because of its sustainability promise there is increasing interest from policy makers, NGO's and large firms in transitions and system innovations (see e.g. American National Research Council, 1999; VROM, 2001; Raskin et al. 2002). Also the academic interest in system innovations and developing strategies to induce them within a sustainability framework has grown rapidly over the past few years. A variety of scholars is working on these issues which has lead to a growing body of edited volumes, journal articles and Books. (e.g. Rotmans, 2003; Elzen et al., 2004 and 2005; Olsthoorn and Wieczorek, 2006; Loorbach, 2007; Loorbach et al., 2007)

2.2 The multi-level perspective for understanding System Innovation

To analyse and understand transitions and system innovations various scholars use the so-called 'multi-level perspective' (MLP). This perspective distinguishes three levels (Kemp, 1994; Schot, Hoogma and Elzen, 1994; Kemp, Rip and Schot, 2001; Geels, 2005):

1. The meso level of 'socio-technical regimes' (S-T regimes) which denotes an existing socio-technical system that is embedded in society and links together a wide variety of societal actors (e.g. companies, public authorities, users/consumers). Regimes change continuously but the change, technical as well as societal or behavioural, is of an incremental nature, building further upon an existing socio-technical configuration.
2. The micro-level of 'technological niches'. This denotes protected spaces in which radical innovations are developed. Niches are important as a learning space on issues like technology, user-preferences and -practices, regulation, etc.
3. The macro-level of 'socio-technical landscape'. This denotes the 'external environment' and consists of factors that not only affect the regime under analysis but a variety of other regimes as well.

The relation between the three concepts can be understood as a nested hierarchy, which implies that regimes are embedded within landscapes and niches within regimes. (Figure 2) The linkages between the elements of existing socio-technical regimes provide them with stability, and make it hard for niche developments to be taken up within the regime. However, under specific circumstances, e.g. landscape pressures that make a regime loose its coherence, these novelties may link up to the regime and become a (small) part of it, e.g. in de form of market niches. From there the share of these novelties may start to grow and gradually transform the regime, a process that may include the development of new infrastructures, new institutions and rules, etc. The end result over several decades may be a system innovation.

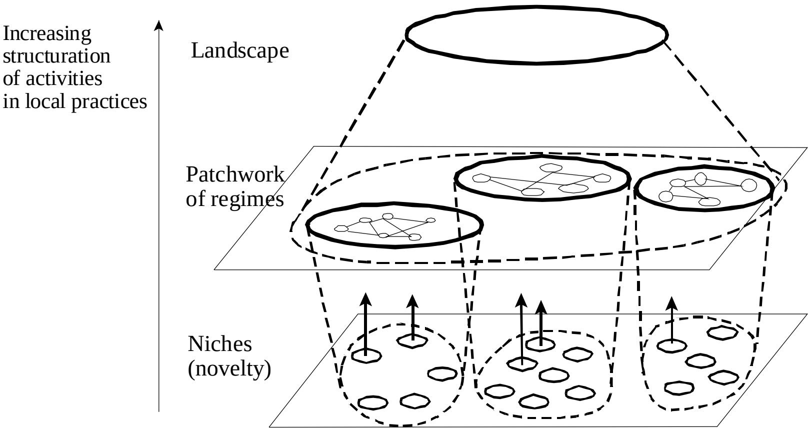

Figure 2. Multiple levels as a nested hierarchy (Geels, 2002)

2.3 Towards a theory of linking

The multi-level perspective has been convincingly used to describe, reconstruct and analyse historical processes of system innovation (E.g. Geels, 2002, 2006). Moreover, it has inspired practitioners to initiate and work on niche experiments. The challenge for them is to develop novelties and learn on how they can be made to work in practice by involving ‘real life’ stakeholders in pilot and demonstration projects. How to do this systematically is elaborated by the approach of ‘Strategic Niche Management’ (SNM). (Kemp et al., 1998, Hoogma et al., 2002, 2005, Van Mierlo 2002) In historical studies, details of the interaction between niche and regime dynamics remain under-exposed due to the long time horizon under consideration, whilst in practical experiments the interaction with the regime is an everyday reality, which however is not usually analysed and theorised. Smith hit the nail right on the head when he wrote in a recent publication (2007, p.431):

> “… the precise relations between niche and regime still requires further analytical attention. Niche practices link up with regimes under stress, resolve bottlenecks and lead to reconfigurations. … However, linkage is understood in the literature to be ‘haphazard and coincidental’. [references to Geels, 2002: p. 29; Schot, 1998] We still do not have a theory of ‘linking’.”

Smith himself made an attempt at filling this theoretical void. One of his starting points is that he sees linking as a two-way influential process. MLP studies typically focus on how a niche influences a system (not out of principle but because of analytical choice). Smith stresses that the influence of regime on a niche is equally important to understand linking. Bos and Grin also stress the importance of analysing how “the regime talks back”. (2008, p. 484) Smith argues further and demonstrates that linking rarely means that elements from a niche are simply adopted but that some form of translation takes place to make this possible. His main argument is that “a focus upon the translation of socio-technical practices between niche and regime will further help theory development. In addition to identifying opportunities for niche-regime connections, we need to understand the connecting processes how these reconfigure developments in niche and regime.” (Smith 2007, p. 431; emphasis in original)

Thus, linking is an active process (involving translation) and not a matter of simply adopting elements from a niche in a regime or vice versa. This may then blur the distinction between niche and regime which has implications for the MLP model. To quote Smith (2007, p.447):

> “Whilst this multi-level model has heuristic value, in practice niche-regime distinctions are rarely so clear cut. Distinctions soon break down, as socio-technical elements, but not entire alternative practices, translate from niches into regimes and components of each appear in the other. (…) Without rejecting the multi-level model, the findings here do stress the need for closer attention to relations and translations between levels.”

We agree with Smith’s conclusions. Moreover, in line with Giddens’ (1984) ideas about structuration, we suggest that, at a certain level (e.g. the niche level), influences from other levels (e.g the regime and/or the landscape level) do not somehow operate ‘behind the back’ of people, but in one way ore another must be brought into the interaction by active human agents who represent (or give representations of) what happens and/or is relevant in other spheres, and translate this into action. (see also Knorr-Cetina, 1988) Thus, different levels and spheres can be distinguished analytically, but from the perspective of interacting agents it may not always be evident whether they operate in the niche, the regime or in both. In order to do justice to this, we propose a new representation of the multilevel model that satisfies the following demands:

- niches and regime overlap to some extent;
- landscape pressures affect niche as well as regime;
- niches, regimes and landscapes are not hierarchically ordered;
- leave intact the overall multilevel heuristic idea.

The result is depicted in Figure 3 which provides an alternative sketch of a multi-level configuration, indicating how the three ‘levels’[1] may influence each other in various ways.

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[1] Since we present a less hierarchical version of the model the term ‘level’ seems less appropriate but we continue using the term to be able to relate our work more easily to the existing literature.

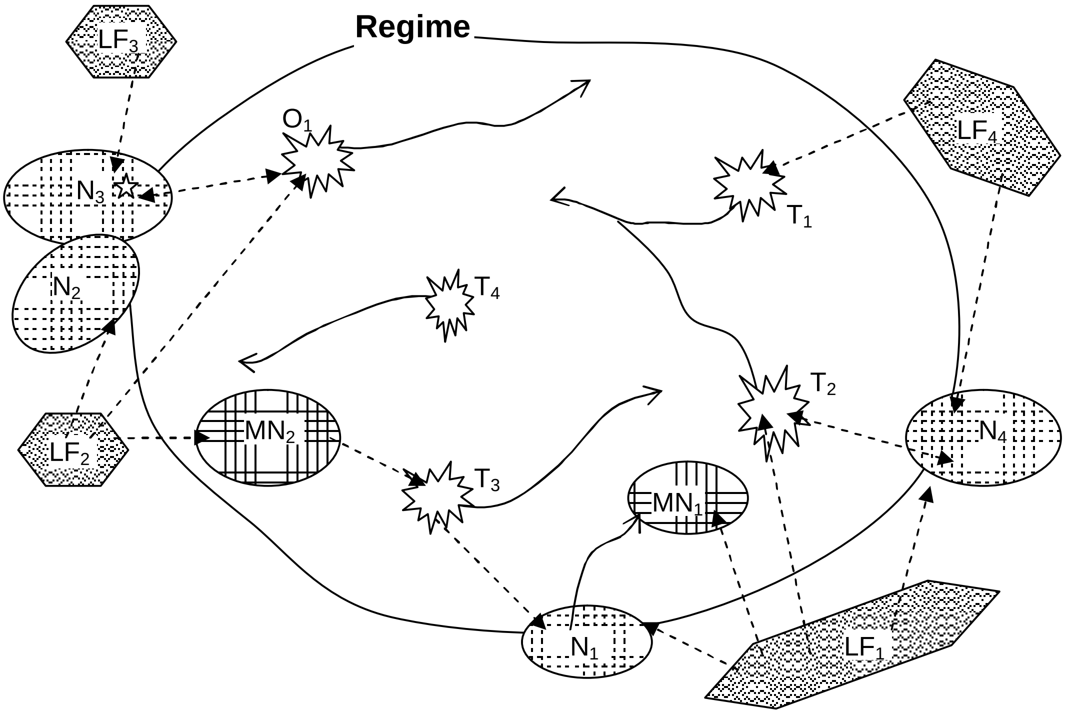

Figure 3: Multi-level processes in system innovation.

In figure 3, the area within the drawn line represents the incumbent regime. At the edges of the regime, several niches are indicated by the small ovals N_1 - N_4. They typically have a partial overlap with the regime (e.g. by using shared technical elements or through actors that operate in the regime as well as in a niche). Some niches may have a partial overlap with each other (e.g. N_2 and N_3). A niche may also transform into a market niche (MN_1, MN_2) meaning that it can survive as a subsection of the regime without protection.

Various landscape factors are indicated by the hexagons LF_1 – LF_4. Although they are all hexagons they have different shapes to indicate they can be varied in nature. Landscape factors are 'floating all around' (suggested by the wave-like shading) and may influence the regime, various niches or the linking process between niches and regimes. Niches and the regime may also influence each other as indicated by various dashed arrows.

As is represented by multi-pointed stars (T_1 – T_3), landscape influences and developments in niches may create tensions or opportunities (O_1) in the regime. Tensions can also emerge internally within the regime (T_4), or in niches (see the small star in N_3). From the tensions and opportunities new developments start as is indicated by the bended arrows. The bended shape indicates that the developments are not straightforward although there is a sense of direction due to path dependencies, at least in the short term. Some developments may 'link up', e.g. the developments emerging out of T_1 and T_2 in the figure.

With this figure the process of linking refers to what happens at the area of overlap between a niche and a regime. We see linking as a micro-level process that initially leads to small changes that may be more or less durable. Because of our interest in system innovation we are especially interested in those links that are sufficiently permanent to start off development in a direction different from the existing dynamic in the regime and may eventually lead to major changes at the macro level.

We will use the term *anchorage*[2] (Loeber, 2003, Grin and Van Staveren, 2007) to express such forms of linking. Anchorage is related to terms like 'institutional' or 'societal' 'embedding' which are used in literature on Strategic Niche Management (e.g. Hoogma *et al.*, 2002). However, we use the term anchorage to express that a new link has some durability but that the link can also be broken again. Thus, anchorage is more vulnerable and can be seen as a kind of pre-stage that may or may not lead to wider change.

2.4 Exploring anchorage

Before using anchorage to analyse interaction between niche and regime dynamics in the context of system innovation, it is helpful to first develop some sensitising notions on possible forms of anchorage. We will do so by taking Geels' (2004, pp. 902-903) three general dimensions of innovation processes as a starting point. These dimensions are (1) socio-technical systems, (2) human actors, organisations, societal groups, and (3) rules and institutions. Anchorage, we suggest, could take place on either of these dimensions. By rephrasing these dimensions somewhat we will distinguish between three forms of anchorage, notably technological anchorage, network anchorage and institutional anchorage. These are discussed briefly below.

We will speak of *technological anchorage* when novel technical artefacts, concepts and practices in relation to the technology that are worked on in niches become more defined and take shape for the actors involved. Parts, that were separated before, may become linked to form a new configuration. These may subsequently become linked to other configurations and artefacts to make up new systems, possibly also linking up to new infrastructures.

Network anchorage means that the technology or concept becomes accepted (e.g. by producing it, using it or developing it further) by a wider range of actors. Besides simple expansion of the network, there are also other indications of network anchorage. These could include an increased involvement of regime players in niche activities, a strengthening of the coalition which is supporting the innovation process, intensified contact and exchange among actors within the network involved, and/or a formalization of the network (e.g. in terms of professionalization, commitments, degree of organisation, etc.).

Institutional anchorage of a new technology refers to a broad range of (still vulnerable) changes relating to institutions in a more sociological sense, i.e. with changes in the formal and informal rules and arrangements that orient human behaviour and (inter)action. Different categorizations of institutions exist. (e.g. Scott, 1995) Cognitive or *interpretative institutions* relate to how people make sense of themselves and the world around them. This includes, for example, the causal beliefs, visions, and problem views (as related to social values and interests) to which they orient their behaviour and actions. Also the identity that people ascribe to themselves and others can be seen as an interpretative institution. Translations as mentioned by Smith (2007, see previous section) can be seen as a shift in the interpretative rules applied to a situation. A second broad category includes *normative institutions*, which in our view includes *regulative* institutions. Here we speak of the translation of societal values into normative rules and aspirations (i.e. formal or informal rules about what is desirable and what not) that can be embedded in laws, regulations, policies and ethical standards. Finally, we can add *economic institutions* which include the rules and arrangements that govern economic activities and transactions connected to scarce resources. These encompass the way in which property and markets are organised and regulated, as well as the mechanisms and infrastructures through which exchange of goods is facilitated. Institutional anchorage then

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[2] The Dutch word 'verankering' (meaning anchorage) is used in these sources. In the Netherlands, this term is often used in writing and presentations to describe these processes but it has not been elaborated systematically.

means that developments within a niche are translated into new or adapted (interpretative, normative or economic) rules that play a role, at least temporarily, in orienting the activities of both niche and regime actors.

The distinction between different forms of anchorage are analytical and in practice they may be difficult to disentangle. We expect, for instance, that technological anchorage will often be accompanied by network and/or institutional anchorage. We will analyse this further on the basis of a case study on energy use in glasshouse horticulture in the Netherlands to provide further insights into the processes of anchorage. We will thus explore whether this approach provides a productive inroad towards developing the theory of linking that Smith called for.

Concerning our case study, the Dutch glasshouse horticulture sector is responsible for 10% of the country's annual natural gas consumption. This has led to internal pressures (because of rising energy prices) as well as external pressures (to conserve energy and reduce CO_2 emissions) to bring this down. In recent years, this has led to a variety of 'alternative energy approaches' for the sector, some internal, some seeking to create new links with other sectors. This variety in linkage attempts makes this case very suited to study processes of anchorage.

Our case description is structured in the form of different episodes. At the end of each of these we will highlight the various forms of anchorage that took place, indicate how they related to each other and how this affected the niche-regime interactions. These analyses form the basis for the concluding section where we will generalise our findings from the emirical sections and present the contours of a theory of linking.

The case study is based on various technical and economic reports from research institutes and sector organizations. Since some of the developments analysed are quite recent and not yet documented we also rely on info from websites from the parties involved. This was supplemented with eight semi-structured interviews with representatives from growers (LTO-Glaskracht), project leaders, Horticultural Product Board, Agricultural Ministry, and academic research. These interviews were recorded and transcribed *verbatim*. This especially provided information on the reasons behind the developments described in written sources.

3 Towards an energy efficient glasshouse horticulture

3.1 Energy use in the glasshouse sector

After the traumatic experience of the 'famine winter' in the last year of the World War II the Netherlands developed strong agricultural policies to avert this risk for the future. One focal point was the development of a glasshouse sector to become less dependent on the often unreliable klimate to grow especially vegetables. This policy was so successful that the sector grew beyond what the country needed for its own supply and the Netherlands have become an exporter of vegetables as well as flowers and plants grown in glasshouses. (Wijnands et al. 2003)

Glasshouses convert sunlight into heat. During summer, when the air inside a glasshouse gets too hot, ventilation windows in the top are opened to get rid of excess heat. During winter, glasshouses also warm up on sunny days but on cloudy or cold days additional heat is needed to make the interior warm enough for plant growth. Furthermore, most crops don't grow in winter because there is not enough light and to enhance growth huge light installations are used. This may also be applied during dusk and night.

Glasshouse heating installations in the Netherlands are fueled with natural gas. The sector also uses gas during spring and summer because of the CO_2 that results from burning gas. Plants 'inhale' CO_2 and 'exhale' oxygen (the opposite of the process in humans and animals) in a process called photosynthesis. In a glasshouse, growth is enhanced by feeding plants with extra CO_2, the same substance that is the main contributor to global warning. Gas is also burned in the fall, in this case to drive out excess humidity. (Interview Poot) Thus, the glasshouse sector uses gas year-round and in total the sector is responsible for about 10% of the Dutch natural gas consumption as well as 3% of its electricity use. In 2005, the sector emitted 6.1 Mtonnes of CO_2, about 3% of the Dutch total. (Van der Velden 2007; Koelemeijer and Kruitwagen, 2007)

The total area of glasshouses has grown to about 10 000 ha., a figure that has been relatively stable over the past decades. (LEI Data)[3] But under this constant figure major changes have occurred. On the international market, Dutch horticulturalists face competition from southern countries that are in a more favourable climatological position which requires less heating of the glasshouses. Especially with rising gas prices this became a significant factor in the past two decades. The Dutch have been able to remain competitive by continuous innovation in optimising the conditions for growth for a variety of crops and using advanced technologies to control the climate in a glasshouse. (AVAG, 2004; Vermeulen and Poot, 2008)

3.2 Aligning forms of anchorage in the regime: CHP

During the 1960s, after the discovery of huge national gas reserves in the north of the Netherlands, a nationwide grid for national gas was created. Since, natural gas has become a relatively cheap primary source for heating for housholds and industry, including the glasshouse horticulture (GH) sector. (Correljé and Verbong 2004) After the oil crises of the 1970s, however, oil and gas prices went up considerably which stimulated growers to start saving energy or find other ways to tackle the situation.

One option to do so sort of indirectly presented itself. In the 1980s, seeking to expand their business, glasshouse floriculturists started to grow flowers year-round. As winter light is insufficient for plant growth this required huge lighting installations, raising electricity needs and, hence, energy costs. To cut these costs, floriculturalists started to install ‘combined heat and power’ instalations (CHP) from the mid 1980s. (Van Vliet 2006)

This is a sort of mini-powerplant that burns fuel (in the Dutch case natural gas) to produce heat as well as electricity, both of which were used by the sector. Such installations were initially developed and used by large industries and further application was stimulated by government policies seeking to make more efficient use of energy. A 1989 electricity law allowed small producers to supply electricity to the grid and a dedicated programme to stimulate CHP was implemented which provided investment grants and a lower gas price for CHP. (Raven and Verbong, 2007)

This offered new opportunities for the GH sector. In the warmer and lighter months, their CHP installations sat largely idle but with the option of selling electriciy and stimulated by the government programme several growers started to supply electricity to the grid during summer. Initially, lighting in winter using CHP was applied mainly in the floristry sector but because of international market developments it also spread to vegetables in the late 1990s. UK supermarkets, for instance, used to buy their tomatoes from the Netherlands during summer and from Spain during winter but to keep up quality standards they preferred to work with the same supplier year-round. This stimulated Dutch horticulturalists to apply lighting to grow other crops in winter as well which, in its turn, stimulated the use of CHP. (Interview Poot)

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[3] ‘LEI data’ refers to data are taken from the LEI website. See references.

The liberalisation of the utility sector since the 1990s gave an enormous boost to this process. One effect of liberalistation was that new markets developed for buying and selling energy where horticulturalists could negotiate longer or shorter term contracts for buying gas and selling electricity. Many horticulturalists were quite good at this new game and in recent years quite a number of them have made more money in trading energy than from selling crops. (Interviews Smits and Van der Valk) An attractive condition for CHP was that the price received for electricity compared favourably to what horticulturalists paid for natural gas, the so-called ‘spark spread’, which stimulated further investments in CHP systems. In 2006, the sector became a net producer of electricity and early 2007, the total electric capacity of the CHP installations in the sector was about 1.7 GW, supplying some 10% of the country’s total use. (Van der Velden and Smit, 2007)

In terms of our analytical framework, this episode firstly shows the *technological anchorage* of CHP installations. For the floriculturists, lighting became linked to their traditional heat production through CHP, constituting anchorage within the regime. Later, CHP became also linked to the national electricity system by integrating these systems in the national grid constituting a form of technological anchorage between regimes. This was largely stimulated by a form of *normative institutional anchorage*, notably government regulations that made possible and stimulated selling electricity to the grid.

This episode also shows different forms of *network anchorage*, first between the CHP installation world and the floricultural world. Once the floriculturists had used it successfully, other horticultuists also applied CHP which constitutes a further form of network anchorage within the regime. When the sector at large started to supply electricity to the grid the network further expanded to include the electricity world.

Following that, a gradual change in identity took place on the side of growers. They saw that they could make a lot of money from the energy they produced and developed energy production as a second business, i.e. a form *interpretative institutional anchorage* acompanied by *economic institutional anchorage*. What we thus see in this case is that all different forms of anchorage aligned and reinforced one another which led to CHP becoming a standard part of a horticultural enterprise.

3.3 Institutional anchorage of landscape pressure: ‘sustainability requirement’

During the 1990s, sustainainable development became a rising public and political issue. Various sectors, including the GH sector, came under pressure to do something about emission of polutants, energy use, use of raw materials, use of pesticides etc. Attempting to achieve this in a coherent and non-disturbing way, voluntary agreements were concluded between government bodies and representatives from various sectors. These agreements specified targets for the future (e.g. 2010) providing room for businesses to work on various issues in succession rather than on everyting at the same time.

Thus, in 1997 the GH sector concluded a voluntary agreement with provisions for the use of minerals, crop protection, energy efficiency and the use of sustainable sources of energy. A steering committee by the name of Glami[4] was created that should help realise the targets. (Interview Smit) Glami expressed a need to change the rules applied to the GH sector (to produce not only in a cost-effective way but also in sustainable way) which constitutes a form of normative institutional anchorage.

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[4] Glami = Glastuinbouw en Milieu (Horticulture and Environment). Specifics can be found at: http://www.glami.nl/

In 2002 the Glami agreement was followed by policy regulations (Besluit Glastuinbouw, 2002) that set standards for each area (energy, minerals) for individual companies for successive years. Energy reduction targets were defined via an energy efficiency index that was set at 100 in 1980. By 2010, this should be reduced to 35, 4% of which should be generated from sustainable sources, implying a reduction of 65% over a period of 30 years. In the year 2000, the realised index was 56 and in 2005 it was 46 meaning that the reductions achieved in practice were more or less on schedule. (Van der Velden and Smit, 2007)

In the late 1990s, the need to reduce CO_2 emissions became a rising star on the sustainability agenda. The Dutch government has set a national target of 30% reduction of CO_2 emissions by 2020 compared to 1990. (Koelemeijer and Kruitwagen, 2007) The glasshouse sector was also expected to contribute its share which started a variety of new developments. One of the most important changes is that horticulturalists themselves have started to recognise the need to reduce energy use and CO_2 emissions. (Interviews Maters and Van der Valk)

It is evident that the need to save energy is large stimulated for economic reasons because of rising gas prices but according to several interviewees the need to reduce CO_2 emission is also clearly acknowledged in the sector. Thus, *economic institutional anchorage* and *normative institutional anchorage* seem to reinforce one another although it is difficult to disentangle them.

3.4 Aligning forms of anchorage in a niche: semi-closed glasshouse

3.4.1 Semi-closed glasshouse

In the period 1984-1992, inspired by plant-growth reasons, scientists had been working on the concept of a closed glasshouse. Keeping a glasshouse closed helped to keep insects out and CO_2 in which enhanced plant growth. However, it appeared too difficult to cool a closed glasshouse in summer and the development was stopped. (De Gelder and Kipp, 2005) In the late 1990s this work was picked up again for energy reasons by linking it to developments in the building sector.

In the 1990s, the building sector started to use a combination of heat exchangers with underground heat and cold storage. A heat exchanger is a device with tubes through which water is pumped. Doing this with cold water in a warm atmosphere in summer resulted in cooling down the air and warming up the water. This warm water was stored in underground layers called aquifers. During winter, the warm water was pumped up for heating purposes. In the same way cold water was stored in winter and pumped up in summer for cooling. (Verbong 2001)

In the late 1990s, scientists at WUR[5] (Wageningen University and Research Centres) sought to apply such a scheme to a glasshouse. They teamed up with Ecofys, a large consultancy firm that specialised in renewable energy and energy saving. Ecofys had no experience in the glasshouse sector but wanted to move in that direction and created a subsidiary, Innogrow, to develop a working prototype. This led to a design that used a large central heat exchanger placed in the front of the glasshouse and a ventialation system with hoses that led the warm or cool air through the glasshouse. This ‘Glasshouse of the Future’ was exhibited at the 2002 *Floriade* world horticulture fair, a large prestigeous exhibition visited by the public as well as stakeholders from the sector. (Van Gelder and Kipp, 2005, p.11)

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[5] Wageningen University has traditionally specialised in agriculture and animal husbandry sectors. In The Netherlands, these are large economic sectors and next to the university there were a variety of more specialised research centres with a more practical orientation. In 1998 the university and these research centres merged to form WUR.

This raised considerable interest and the following year a practice demonstration was carried out. In 2004, the results were promising enough to stimulate one grower to install it in his own glasshouse. The first technical results indicated that this system allowed a considerable amount of energy conservation while there was also some rise in productivity because of higher CO_2 levels. Articles on these results appeared in business journals and meetings were organised to inform growers. This stimulated interest from horticulturalists as well as suppliers of technology who started to develop and offer new variations. As a result, about a dozen horticulturalists started with some form of (semi-) closed glasshouse concept in 2005-2006. A government programme to stimulate energy conservation provided subidies that lowered the investment costs. (PT and LNV, 2006)The remaining costs would have to be recooped by lower energy costs and higher productivity.

Innogrow's initial design was a 'Closed Glasshouse' which they registred as a trademark. Such a glasshouse still gets too hot in summer (due to the inefficiency of catching and storing heat) and requires an additional cooling system which adds to te costs. A cheaper variant was to allow for some ventialation although far less than in a conventional set-up. Such designs are called 'semi-closed glasshouses' (SCG). (Innogrow, 2005)

In analytical terms, we initially see a form of technological anchorage when a heat exchanger becomes linked to a glasshouse energy system to define a closed glasshouse. This was accompanied by network anchorage, initially between scientists and an engineering company in a niche. The network then expanded to include half a dozen growers and suppliers of glasshouse installations who also became part of the niche because they relied on protection in the form of government subsidies. This niche expansion enhanced the possibilities to learn about whether and, if so, how the concept could be made to work in practice.

3.4.2 Energy producing glasshouse

Concurrently with the development of the semi-closed glasshouse a more radical variant was also developed. In the late 1990s, the Dutch national advisory council for agricultural research (NRLO) carried out various desk studies on what was called a "climate neutral glasshouse horticulture". In 2000 the NRLO was succeeded by an organisation with a more developmental than advisory character called in short the *InnovationNetwork*. At the same time the sector's branche organisation *LTO* (later *LTO-Glaskracht*) saw a need for major innovation in the sector to tackle competitive and energy challenges and created a programme and organisation by the name of SIGN (the Dutch acronym for Foundation for Innovation in the GH sector). (Grin and Van Staveren, 2007, Ch.3)

Early 2001 SIGN and the InnovationNetwork organised a joint meeting to develop an innovation agenda for the GH sector. They developed a long-term programme by the name "Glasshouse Horticulture 2020" and identified five themes to work on, one of which was energy. The people responsible for this theme were not afraid to think radical and started with a paradigm shift: rather than seeing the GH sector as an enormous consumer of energy they saw it as a 10 000 ha. big solar collector. Using heat exchangers combined with heat and cold storage as in a semi-closed glasshouse would make it possible to harvest enormous amounts of heat during summer, store it underground to be used in winter. (Roza, 2006)

In 2001, the programme managers talked to a variety of actors in the sector to gain support for their ideas. Stakeholders from various corners of the sector lend a willing ear but were quite unanimous in their judgements: "It's nonsense." (Van Oosten and Koehorst 2007; Interview Van Oosten) The only positive responses came from outside the GH sector, one from an Akzo Nobel employee who worked on a new type of heat exchanger by the name of *Fiwihex* which he thought would be perfectly suited for the purpose. A representative from KEMA, a Dutch research organisation for the electricity sector, also responded positievely. They became part of the programme team to develop the concept further, using the Fiwihex as a central element. (Roza, 2006)

WUR scientists calculated that this could result in a net-production of energy on a year-round basis. (De Zwart and Campen, 2005) For that reason it was called the Energy Producing Glasshouse (EPG). Various scenarios were developed on how to use the energy produced by the glasshouse. In some of these, the energy was used within the sector but in the most radical scenario the heat was used to warm nearby houses. The glasshouse would thus become part of a broader local system of use and supply of energy called an *Energyweb*. Later studies within the programme suggested that a 1 ha. glasshouse could warm a hundred houses. (Roza, 2006, p.26) With a total GH surface of 10 000 hectares the theoretical capacity would be to warm a million houses, over 10% of the Dutch stock.

On the technical side, in contrast to the semi-closed glasshouse where a large central heat exchangers was used, a Fiwihex was a small device of which a large number (about 250 per ha.) would have to be placed in a glasshouse. The advantage was that no hoses would be needed to pump the warm or cool air through the glasshouse. In 2003, after some small scale tests and further developmenent, WUR scientists considered this a promising concept. Their positive report was important to secure further funding. (Grin and Van Staveren, 2007, pp. 41-42)

The next step was to demonstrate the concept on a larger scale. After some internal deliberations it was decided to go directly to a real life size pilot, notably 5 000 m^2, i.e. 0,5 ha. Since this was larger than existing research facilities the pilot was carried out in an existing business owned by an interested horticulturist. This project started in 2006. (Roza, 2006, p.31)

In analytical terms, we initially see a form of technological anchorage in which the Fiwihex heat exchanger becomes linked to a glasshouse energy system which subsequently became conceptually linked to an energyweb. Network anchorage of sector actors, however, appeared quite problematic, with various stakeholders rejecting the concept. Eventually, one grower became linked who, because this was realised via subsidy protection, became part of the niche.

3.4.3 Research programme and actionplan

During the early 2000s, the concept of transition management became quite popular in the Netherlands. The general idea is that in many sectors system innovations are needed to achieve sustainability which should be stimulated and guided by specific forms of governance. This was also taken up for the GH sector. Around 2005 representatives from the Ministry of Agriculture as well as from the sector concluded that a variety of new initiatives were germinating and that some sort of co-ordination would be needed to reap the full benefits of this for the sector as a whole. To facilitate this, the ministry together with the Horticultural Product Board established a programme by the name “Kas als Energiebron” (“Glasshouse as an Energy source”; hereafter called GaE programme) and provided substantial funds, € 5.6 million in 2007. (PT and LNV, 2006)

The programme defined six so-called transition paths, including solar energy (using heat caught by glasshouses and production of electricity), biofuels, energy efficient crops and growth strategies, light (efficient use of daylight and energy efficient lamps). (PT and LNV, 2006, p.3) These examples reflect a broad portfolio of possible solutions for two reasons. The first is that it was still unclear what the practical potential of each option was. The second is that the managers of the programme did not think there would be one solution. The glasshouse sector is quite varied with thousands of companies growing hundreds of different types of crops, plants and flowers and various concepts would have to be tailored to specific needs to satisfy this diversity. (Interview Smits)

The programme makes a distinction between what are seen as forerunners and the sector as a whole, in 2007 some 5 000 businesses. Until that year, some 15 of them had started with different variants of semi-closed glasshouses, all of which used heat exchangers combined with heat and cold storage in aquifers. There was a considerable interest in the sector as appeared from the 60-70 applications for an investment subsidy in 2007. The rapidly rising gas prices in 2006 are likely to have stimulated this interest. Applications were for the construction of 140 ha. of new glasshouse surface, all of which were awarded. (PT and LNV, 2007, p.6) Sector representatives considered this a high interest given that about 400 ha. is renewed each year. (Interviews Smits and Van der Valk)

In further developments, the sector representative *LTO Glaskracht* and the *Stichting Natuur en Milieu* (Nature & Environment Fund) became also linked to the semi closed glasshouse. In the mid-2000s they had started to interact on issues related to the environmental impact of the GH sector which, in 2007, led to a joint ‘Actionplan for a climate neutral glasshouse horticulture’. The plan specifies a ‘transition package’ including the target of a 45% reduction of CO_2 emissions by 2020 compared to 1990. For 2010, the plan specifies that 400 ha. of glasshouse (i.e. 4% of the total surface in the Netherlands) should be ‘semi-closed’. (SNM and LTO Glaskracht, 2007)

3.4.4 Synergie businessplatform

In the Netherlands there are several national programs that seek to combine scientific research on innovation processes with practice oriented programmes to induce system innovations towards sustainability. Within these programs there are various projects dealing with more specific topics. One of the national programs, Transforum, deals with the agricultural sector and within this one concrete project by the name of *Synergie* (the Dutch writing of ‘synergy’) targets the GH sector. Synergie is linked to the ‘Glasshouse as an energy source programme’. (Boonekamp, 2006)[6]

The platform aims to bring together scientific knowledge developed in research institutions with knowledge developed in practice by the horticulturalists. This is a challenge in itself because these two groups partly speak different languages. A horticulturalist may say that he can see that a plant doesn’t feel happy or describe that a leaf feels crispy but that’s not the kind of information that a scientist can work with. These differences in language are one of the reasons that the links between research and practice leaves much to be desired. (Interview Maters)

The platform started early 2006. Horticulturalists working with new energy systems started to meet regularly with researchers and discuss their experiences and various other issues. Gradually, they have learned to speak each other’s language and come to a fruitful exchange. Meeting each other regularly was also important to build confidence between growers and researchers. Especially since a (semi-) closed glasshouse allows to control various relevant parameters (temperature, CO_2 level, humidity, light) it was considered important that horticulturalists work closely together with scientists to find new optimal growth conditions. Suppliers are also part of the platform to ensure that new technologies can indeed be produced at a price that makes it interesting for a wider group of followeres to acquire these installations. (Synergy website; Interview Maters)

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[6] Detailed info can be found at the Synergie website: http://www.synergieplaza.nl/

3.4.5 Aligning forms of anchorage in the niche

Through the GaE programme the network related to semi-closed glasshouses expanded further to include regime actors such as the Horicultural Product Board and the Ministry of Agriculture while the 'Actionplan' further enrolled *LTO Glaskracht* and the *Nature & Environment Fund*. Still, the SCG development took place within a niche as its survival was dependent upon various forms of protection such as subsidies. The *Synergie* business platform not so much expands the niche but strengthens co-ordination within it which, as we have defined it in section 2.4, also contributes to network anchorage.

The GaE programme, the Actionplan as well as the business platform provided a specific way of framing future development that became more widely shared in the sector (given the large number of subsidy applications), which constitutes an example of interpretive institutional anchorage in our analytical framework.

Thus, several forms of anchorage (technological, network and institutional) were starting to align although the semi-closed glasshouse was still supported by subsidies and, therfore, this contributed to niche development rather than regime development. It seems that to achieve the latter one important form of anchorage, economic institutional anchorage, was still missing.

3.5 Anchorage opening up new possibilities: adiabatic cooling

The GaE programme explicitly targets a system innovation, with the goal that after 2020 all newly built glasshouses will be climate neutral. Interestingly, after the semi-closed glasshouse had anchored on several dimensions this started new developments that could also be used in existing installations which might compromise the system innovation ambition.

One example is adiabatic cooling. In a closed glasshouse, the heat caught in summer is stored in an aquifer. In practice, however, these glasshouses still get very warm necessitating some sort of ventilation or cooling. As in the new thinking ventilation was not attractive (which would necessitate continuous CO_2 feeding to enhance growth) there was a search for effective, inexpensive forms of cooling. An interesting option apeared to be to make use of so-called adiabatic cooling. In this approach, small droplets of water are sprayed into the glasshouse creating a light mist. Due to the high temperature these droplets vapourize quickly which has a cooling effect, so-called adiabatic cooling. This increases the humidity in the glasshouse but this might even benefit growth as it does in a rainforrest. (Cli Mate, 2008; Interview Smits)

Thus, adiabatic cooling was initially applied to compensate for the lack of ventilation in a semi-closed glasshouse but once demonstrated it appeared to have more general advantages in the sector. Such a mist installation has a relatively short payback time and various horticulturalists have started to install it in a conventional glasshouse. Thus, a development that was initially started as an overall concept targetting system innovation led to the technological anchorage of a 'spinn-of' that can be seen as a form of incremental innovation. Network anchorage followed quickly when it was picked up by various growers in the regime. (Interview Smits)

But this incremental step does not mean that the possibility of a system innovation has evaporated because a higher level of humidity contributes to another development path. A closed glasshouse makes it easier to control CO_2 levels and, hence, plant growth. However, there are various physical parameters that affect growth, the most important of which are light, temperature, CO_2 concentration, and relative humidity. A closed greenhouse with a mist installation, initially intended for cooling, makes it easier to control all these parameters. At present, growing crops is based on practical experience on what the optimal combination of these parameters is but it is now possible to stretch these parameters considerably further than in a conventional glasshouse. With these new technological options horticulturalists may have to learn anew how to grow crops. (Dieleman et al., 2007)

3.6 Anchorage between systems – Energywebs

The Energy Producing Glasshouse project suggested the possibility of using heat generated in glasshouses to warm houses. In analytical terms this would imply linking two systems that hitherto were separate. In 2001, when the EpG programme managers tried to get support for their ideas, including heating houses via so-called energywebs, they were turned down by all sector actors. One of the arguments from the ministry was that the glasshouse sector was about producing crops, not about producing energy. (Interview Van Oosten)

Although initially turned down by the sector, the energyweb concept came back on the agenda via the semi-closed glasshouse route. It appeared that these glasshouses provided more energy in summer than was needed in winter. One of the first applications was in the sector itself. In 2006, Prominent, a group of 22 growers, built 9.3 ha. of new glasshouses of which 3.4 ha. used the Innogrow Closed Glasshouse concept and the other 5.9 were conventional ‘open’ glasshouses. Excess heat stored in summer from the 3.4 ha. was used to heat the whole 9.3 ha. area in winter. (SenterNovem, 2006)

Other growers, however, started to look for possible external users for their heat. In 2006, two horticultural enterprises teamed up with Volker Wessels, a large construction and infrastructure company, to make an offer for heating 2 800 new houses in the village of Waddinxveen in the western part of the Netherlands. (InnovatieNetwerk, 2007) The outcome on the bid at the time of writing was still unsure. In Venlo, in the south of the Netherlands, a project did take off. A tomato grower built a new glasshouse by the name of Greenport which, as of 1 January 2008, warms a nearby nursing home. (SunnyTom, 2007)

These initial moves open up a range of new possibilities. Firstly, the managers of the GaE programme have raised their ambitions: by 2020 the glasshouse sector should not only supply sustainible electricity but also sustainable heat to other sectors. (PT and LNV, 2007, p.3) But this line of thinking can also be reversed. The sector could also use heat generated elsewhere to warm glasshouses. Various industries now have excess heat that is discharged as warm water into rivers or canals or via cooling towers into the atmosphere. (Interview Smits) Thus, the energywebs have come back on the agenda.

This is not only a thought exercise because the first moves in such a direction have already been made. In 2007, plans were being developed for the region of the ‘Westland’ between Rotterdam and The Hague, that has the highest concentration of glasshouses in the Netherlands, to develop a variety of smaller energywebs which, in a later stage, might be linked to create larger webs. The city of the Hague, for instance, is developing plans to use geothermal heat to warm houses and such a scheme might later be connected to a developing grid in the Westland. (interview Smits)

Thus, initial technological anchorage that links glasshouses to wider energywebs has taken place. A growing variety of actors is tinkering with this concept constituting also network anchorage. This is accompanied by interpreative institutional anchorage in which the glasshouse sector is no longer seen as self supporting but part of a wider system of producing and supplying energy. Admittedly, the links in this developing niche at the time of writing were quite weak but the interesting point about this episode is that it shows that anchorage that initially fails (when the ideas of the EpG people were turned down) may find other routes that are more successful.

4 Conclusion

In this section we will systematise and reflect upon the findings that were presented and evaluate the usefulness of our perspective on niche-regime interaction and anchorage. Furthermore, the emphasis on ongoing innovation processes allows us to draw some general conclusions on possibilities to stimulate system innovation. These will be addressed in the final part of this section.

4.1 Crooked pathways of anchorage

In section 2.4 we proposed several forms and expressions of anchorage to characterise interactions between niche and regime. We distinguished between technological anchorage, network anchorage and various forms of institutional anchorage (interpretative, normative and economic). We have seen that it is indeed possible to describe the recent history of events and the progression in the innovation process in terms of these different forms of anchorage as we demonstrated technological as well as network and institutional forms of anchorage.

More important than signalling that different forms of anchorage can indeed be identified is that our description of different episodes of anchorage results in a meaningful story. This story shows that different forms of anchorage are closely intertwined and logically connected and that an earlier episode of anchorage creates the conditions for later forms of anchorage. This is not to say, however, that such trajectories are intentional or amenable to deliberate planning and design. At the beginning of the journey, for example, we see that for cost-reduction purposes some growers were already using CHP technologies. This coincided with a dynamic in the energy regime towards liberalising the energy market which, in turn, resulted from a ‘landscape’ level international trend towards market liberalisation. The interaction between this technological and (economic) institutional dynamic resulted in a situation that was conducive to growers starting to look at themselves as energy producers, a shift in identity that can be seen as a form of (interpretative) institutional anchorage. Although this was not initially associated with the later notion of ‘glasshouse as an energysource’, this identity change certainly helped to pave the way at a later stage.

In the empirical description several of such interdependent sequences can be discerned. This is represented in Figure 4 which builds on Figure 3 and zooms in to the area where one niche intersects with the regime. In Figure 4 we attempt to visualise the various forms of anchorage, the ‘locations’ of anchorage and the most relevant influences and pathways. What the figure basically shows is that various forms of anchorage may follow one another via very crooked paths.

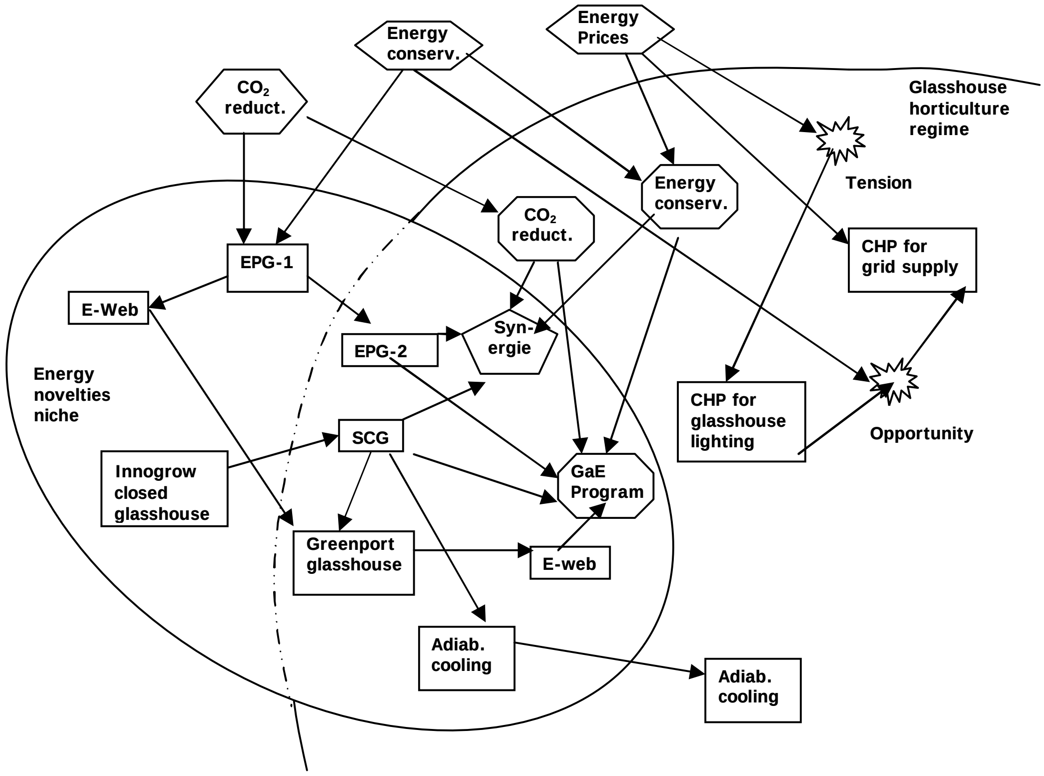

Figure 4. Processes of anchorage. The rectangles denote technological anchorage, the pentagons network anchorage and the octagons institutional anchorage. As in figure 3, the hexagons denote landscape pressures.

What emerges from the above is that different forms of anchorage occur in a relatively capricious pattern, where one form of anchorage (or the lack or failure of it) offers opportunities for subsequent dynamics to occur. In line with earlier work on MLP, our case-study suggests that landscape pressures play an important role in inducing niche- as well as regime developments. Growing political and societal awareness that CO_2 emissions must be reduced, for example, has affected virtually all developments described, on the niche as well as the regime level. Thus, landscape pressures can set things in motion but that is not yet anchorage. Anchorage implies that different actors link up to a novelty and that this link has some durability. The case provides a variety of instances of this happening. Building further on some of the examples mentioned in the previous paragraphs we can see patterns like:

- *Translation*: e.g., of Innogrow closed glasshouse into semi-closed glasshouse. Also translation of semi-closed glasshouse (SCG) into a more radical concept (EpG) with the addition of the concept of energyweb. The latter initially refuted but later linked to SCG. This coroberates Smiths' findings on translation referred to in section 2.3.
- An '*opportunity*' that presents itself after a previous anchorage, e.g. to sell electricity after installing CHP, initially for internal use. Subsequently growers find out they can also supply to the grid making many of them energy-converters (gas into electricity) and traders.
- *Internalisation*: The need to reduce CO_2 emissions and the ambition of climate neutrality first were an *outside pressure* that was put on the agenda primarily by outsiders and affected niche developments like EPG. In the early 2000s it became internalised within the regime and since it has clearly anchored there.

- *Alignment* of various forms of anchorage seems to enhance durability. In the CHP case, all forms of anchorage aligned and it became a standard part of a horticultural business. In the case of semi-closed glasshouses, only one form is missing, notably economic institutional anchorage. This has led to a variety of activities in the niche but it is not (yet) picked up in the regime at large.

This limited summing up already suggests that processes of anchorage can follow a variety of crooked paths. The research challenge in further work is to find some order in this and possibly distinguish a limited set of characteristic patterns but this can only be done on the basis of a wider variety of case studies.

One thing that we do want to stress is that anchorage can take place under a variety of pressures and tensions as well as *opportunities* (e.g. selling electricity once CHP has anchored). The initial MLP studies typically stress (landscape) pressure only but in Figure 3 we acknowledge this duality by seeing both tensions (T) and opportunities (O) as a possible starting point for change and and our empirical study gives various examples of the latter as is also indicated in Figure 4.

4.2 Locating anchorage: critical role of hybrid forums

The relatively positive dynamics in this case may be related to the fact that we are not just dealing with the horticultural regime, but also with the energy regime. In terms of the actors and networks involved, therefore, we are likely not only to encounter ‘insiders’, but also ‘outsiders’. Various studies have stressed that radical innovations usually come from outside the regime and are initially developed by entrepreneurs and pioneers. (e.g. Constant, 1980; Utterback, 1994) Van de Poel uses the term ‘outsiders’ for these actors who feature two main characteristics: (Van de Poel 2000, p. 384)

1. They are outside or at least marginal to the regime;
2. They do not share some of the relevant rules with respect to technical development.

When looking at the actors that played an important role in furthering the radical innovation process in our case-study the following categories stand out:

1. Suppliers of glasshouse installations. Because they also operate in other sectors than the GH sector they are an important channel for introducing innovations from other sectors into the GH sector (e.g. from the building sector);
2. ‘Pioneer-growers’: they are definitely regime actors who want to make a profit from growing crops but they are at the same time prepared to take risky, innovative steps to satisfy societal concerns;
3. Horticultural Product Board. They clearly seek to guard the vital interests of the sector but are at the same time very sensitive to societal concerns, and actively stimulate innovation through programmes such as SIGN;
4. The semi-governmental innovation intermediary *Innovation Network*, which is affiliated to the Ministry of Agriculture and who introduced the vision of an Energy Producing Glasshouse.

These actors clearly do not satisfy both of Van de Poel’s criteria. They are anything but marginal to the regime and/or they do share (some of) the relevant rules. On the other hand, they also have a deep commitment towards the realisation of (radical) change to satisfy societal concerns. Interestingly ‘real’ outsiders such as players in the energy sector proper do not play a very active and prominent role, even if (economic and legal) institutional developments in the energy sector are of critical importance in the background.

To account for this we define an intermediary category which we call *hybrid actors*. They form a category between insiders and outsiders, displaying some important characteristics from each of them.

Coming back to anchorage, then, it is exactly these *hybrid actors* that play a crucial initiating role. They operate at the intersection between niches and regime in figure 4. In this case, they do so in various network settings, e.g.

- several pilot projects;
- the ‘Glasshouse as an Energysource’ programme;
- meetings between the *Nature & Environment Fund* and *LTO Glaskracht* that have led to the ‘Action programme for an energy neutral GH sector’;
- *Synergie* businessplatform.

All these activities take place within the overlapping area between niche and regime. (cf. Figure 4) These settings are characterised by relatively stabilised networks (i.e. forms of network anchorage) and take the form of forums where regime and niche developments come together at the most concrete level. We will call these networks *hybrid forums*.

With reference to the different forms of anchorage discussed, this case-study suggests that both technological and institutional anchorage seem to go along with, and is in most cases are preceded by, network anchorage. This is not all that surprising as network formation has been often identified as a critical process in bringing about innovation (Callon et al., 1986; Leeuwis, 2004). This study specifies that further by suggesting that hybrid actors which operate in the context of stabilised hybrid forums play an important role in stimulating anchorage and radical innovation.

In addition, the hybrid forums are of interest in that they can be seen as a specific ‘location’ where anchorage takes place. When distinguishing niche, hybrid forums and the regime, anchorage can in principle take place in either of these. Our study provides some indication that anchorage in a hybrid forum can be an important intermediary step in moving from niche to regime.

4.3 Multi-regime dynamics

This study shows that landscape factors like the need to reduce CO_2 emissions and energy consumption have an impact on the dynamic in the niche as well as the regime. This has been acknowledged in the MLP literature right from the beginning but the model with the three levels (figure 2) obscures this important feat. Similarly, in the original MLP model, the energy consumption by the GH sector would be seen as a regime feature while the overall dynamic of the energy sector would be seen as a landscape factor since it affects a broad variety of regimes. This study shows, however, that the dynamic in the energy sector and that of the GH sector have become much more closely interlinked as increasing numbers of growers became suppliers as well as buyers of energy.

In analytical terms we suggest that the these developments take place at an intersection between two regimes, the GH regime and the electricity regime. Each of these regimes largely has its own dynamic but there is an overlapping section where they influence one another. Thus, we are looking at interactions between two regimes.

There are only a limited number of studies that describe and conceptualise such ‘multi-regime’ dynamics (e.g. Raven and Verbong, 2007; Van Mierlo, 2002). Van Mierlo focuses on one specific aspect, notably how the confrontation of actors from different regimes who cooperate and have conflicts within pilot projects stimulates niche branching. In our analytical terms this would constitute a breaking up of anchorage but our case study (out of analytical choice) provides hardly any examples of this.

Raven and Verbong analyse multi-regime processes at a rather high level of aggregation and have developed a typology in which they distinguish four different interaction patterns between two regimes, notably: (1) competition (2) symbiosis (3) integration, and (4) spill-over. With our interest in processes of anchorage, however, this model is too crude. By zooming in to a more micro level we see different dynamics and patters occurring at different moments in the process. E.g. we see competition (between growers and utilities both supplying electricity) as well as integration (e.g. via energywebs). It would be interesting to explore in further work how processes of anchorage could help to understand multi-regime dynamics, also looking at breaking up of anchorage and relating this to Van Mierlo's work.

4.4 Distinguishing incremental and radical innovation

Our study of anchorage also sheds some further light on the distinction between incremental and radical innovation, at least when looking at 'innovation in the making'. In a rather simplistic distinction between the two, incremental innovation takes place in a regime, gradually transforming the technical side but hardly affecting the institutional side. In early MLP studies it was argued that system innovation largely comes from radical alternatives in niches breaking through in the regime, transforming not only the technical dimensions but also the institutional dimensions and the actor-configurations. (E.g. Geels, 2002, 2005). Geels and Schot (2007) have shown, however, that this distinction is too simple. By analysing a variety of cases on system innovations (or transitions) they present a typology of four what they call 'transition pathways'. In one of these pathways, niches play no or only a minor role and a pattern of system innovation largely develops within the regime.

Geels and Schot provide useful insights into different patterns of system innovation but they do not question the distinction with incremental innovation. This is probably the result from looking at very long-term processes leading to clear distinctions after leaving out various micro-level developments. If we zoom in to this micro level and ongoing processes, however, the distinction is less clear. Let us highlight some examples from our case.

The concept of semi-closed a glasshouse had explicit system innovation ambitions. The general idea was to use glasshouses to catch and store energy in summer for later use in winter rather than finding ways to get rid of excess heat. To be able to do so, some additional form of cooling appeared necessary leading to the development of adiabatic cooling. The latter concept, however, appeared to be of use in a conventional glasshouse as well as it allowed keeping windows shut and provide for more 'controlled' growth. Thus, a development, that started with clear system innovation ambitions became modified (translated, in Smith's terms) into a system with incremental ambitions notably to enhance plant growth.

Another example shows the reverse process. CHP was initially used in the floriculture sub-sector with incremental ambitions, notably to reduce the electricity bill. Subsequently, the electricity was supplied to the grid and provided an extra source of income. The liberalisation of the energy sector offered new possibilities to play with gas and electricity prices and several growers became energy traders as well and thus became players in a regime different from their traditional one. Building further on this, various sector-actors have started explorations to create energywebs, a concept that was rejected only a few years before. These developments clearly reflect a process of system innovation with changes in technology as well as institutionalisation.

These examples illustrate that a development that starts with system innovative ambitions can be transformed into an incremental path of change and *vice versa*. Apparently, it is very difficult to distinguish between the two when one is in the middle of it. This not just a matter of having insufficient overview of what is happening, but also related to the fact that unforeseen dynamics and coincidences occur, which fundamentally reduces the feasibility of predicting the direction that developments will take.

4.5 The meaning of projects and intervention

The realization that what turns out to a system innovation can only be identified *ex-post* is perhaps an open door. Nevertheless our observations are relevant for practitioners and project funders who frequently make early judgements and claims about the nature of innovation efforts that they are involved in. It contains a warning that one should not be overtly optimistic about the scope for planning and controlling system innovation processes. However, this does not render deliberate intervention and projects meaningless. In fact, we see that the pathways outlined involve and weave together a range of networks (including hybrid forums) and developments that are somehow part of (pilot) projects, programmes and interventions. Some of these are indeed directed at stimulating Energy Producing Glasshouses, while other building blocks derive from (simultaneous or past) developments and projects in other domains and spheres. Interestingly, also projects that were in their own time looked at as a 'failure' may have positive spin-offs and be brought back into the lime light. An example of this are past projects aimed at building 'closed glasshouses' as a strategy to manage pests and diseases and prevent air pollution. These goals were not achieved at the time, but the glasshouse designs developed for these purposes have at a later stage inspired and influenced the development of glasshouses with heat storage systems.

Thus, we can say that projects and interventions matter, albeit at times - and perhaps quite often - in ways that were not intended or anticipated. (Elzen et al. 2004). They are part of a complex (selection) environment in which actors act, strategise and take initiatives, which results in the development of elements and building blocks that may become linked and which offer opportunities for change. This is in line with both evolutionary understandings of innovation (e.g. SNM; Hoogma et al., 2002) and approaches which build on theories about complex dynamic systems (Prigogine & Stengers, 1984; Loorbach, 2007; Leeuwis & Aarts, 2008). In the Western context, 'projects' are a dominant mode of sourcing resources, action and energy, and without them it is doubtful that much effort would be invested in re-organising the glasshouse horticultural sector.

4.6 Epilogue

What we set out to do in this paper was to argue that in order to understand system innovations better we need to take a closer look at what happens at the area of overlap between niche and regime. We agreed that we need what Smith calls a 'theory of linking'. Inspired by Loeber (2003) we have used the term anchorage, and explored the usefulness of several forms of it in analysing an ongoing system innovation trajectory. We concluded that the analytical concept helps in identifying pathways and patterns of anchorage, and was instrumental in signalling the significance of *hybrid actors* and *hybrid forums* in fostering anchorage at the area of overlap between niche and regime. Moreover, the analytical framework resulted in a new and less hierarchical representation of the multi-level perspective, which proved helpful in mapping and visualising the messy dynamics of innovation trajectories. Thus, we argue, we have made a useful next step towards the theory of linking that Smith called for. In further work, a wider variety of cases would have to be anlysed to systematise patterns of anchorage and the role of hybrid actors and forums therein.

The work presented is not only of academic relevance. In the introduction we started by pointing to the widely shared ambition to induce system innovation to contribute to sustainability. To be able to do so, we argued, we need a better understanding of system innovation and, especially of what happens at the intersection between niches and regimes. For practitioners, the important role that hybrid actors and forums seem to play could inspire the development of future interventions and projects. Moreover, the demonstrated messiness of innovation trajectories might inspire practitioners to rethink the scope and nature of projects required (e.g. more variety, less predefined outputs, more realistic expectations) and the way in which they are evaluated and monitored.

Finally, after zooming in on the intersection between niche and regime, the subequent challenge, of course, is to zoom out again and understand how anchorage can eventually contribute to system innovation. That challenge is far beyond the scope of this article but with this analysis we have sought to provide some useful analytical tools for ourselves and others to take up that challenge.

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