System innovations and Transition Management in Austria: the case of wood-plastic composites and biopolymers

Austria is at the forefront of Europe in terms of innovation in the use of renewable resources for energy supplies. In recent years Austria has also sought to use renewables resources as widely as possible in product manufacturing, though for the moment their adoption is still limited. This paper presents transition field analysis and puts it to the test through a study of the production system for wood and plastic composites and biopolymers in Austria. The intention is to explain how transition field analysis can be interpreted, what impact it has had and how it has influenced governance in the drawing up of a strategy for innovation and technological research policies in Austria.

Austria puntako herrialdeetako bat da Europan, energia hornitzeko baliabide berriztagarriak erabiltzeko berrikuntzaren eremuan. Halaber, azken urteetan, produktuen fabrikazioan baliabide berriztagarriak modu zabalagoan erabiltzen saiatu da Austria, baina mugatuta dago oraindik. Artikulu honetan «Transition Field» izeneko analisia aurkeztu eta probatu da, egur, plastiko eta biopolimeroen konposatuak ekoizteko Austriako sistema aztertuz. Helburua da «Transition Field» izenekoa nola interpreta daitekeen, zein eragin izan zuen eta Austrian Ikerketa, Teknologia eta Berrikuntza politiken estrategia egiteko gobernantzan izan zuen eragina azaltzea.

Austria se encuentra entre los países punteros en Europa en el campo de innovación del uso de recursos renovables para suministro de energía. Asimismo, durante los últimos años, Austria ha intentado utilizar los recursos renovables de forma más extensa en la fabricación de productos, pero su adopción sigue siendo limitada. En este artículo se presenta y se pone a prueba el análisis denominado »Transition Field» mediante el estudio del sistema de producción de compuestos madera y plástico y biopolímeros en Austria. La intención es explicar cómo puede ser interpretado el «Transition Field , qué impacto tuvo y cómo influyó en la gobernanza para la elaboración de la estrategia de las políticas de Investigación Tecnologías e Innovación en Austria.

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1. INTRODUCTION

Austria is one of the leading countries in Europe when it comes to using renewable resources for economic purposes, and this is at least partially a result of favourable natural endowments. This is obvious in the context of energy supply (where Austria can exploit its abundant opportunities for hydropower stations) but also for various products from natural resources (where Austria can exploit its forests). It does thus not come as a surprise that Austria has a strong technology base in many such areas. Major initiatives have been taken to foster the development of new technologies for renewable resources in the context of public research funding programme "Nachhaltig Wirtschaften", which has been dedicating significant resources to areas such as future energy supply, future housing and future production technologies.[1]

The approach pursued in these programmes aims at triggering a far-reaching transformation of the systems concerned (i.e. a "regime shift" in energy supply, housing and production, see

[1] The official English translation of the programme title is "Technologies for Sustainable Development" but it does not fully capture the meaning of the German wording. For further details —in English and German— see the different programme lines at www.nachhaltigwirtschaften.at.

BMVIT, 2004) by way of advancing research and technology development up to a point where major pilot and demonstration projects can serve as "lighthouses" that demonstrate the technical feasibility and economic viability of these novel technologies. The argument behind this approach is that once these lighthouses have been established successfully, the information propagation about their success will not only convince potential adopters but also stimulate the introduction of supportive regulatory and other framework conditions, and thus ultimately lead to an acceleration of the diffusion process. This bottom-up approach of developing new technologies from early and still quite fundamental research to "light-house"-type pilot projects or technological guideposts (Sahal, 1985) is compatible with the approach of Strategic Niche Management (Kemp, Schot and Hoogma, 1998; Weber *et al.,* 1999; Hoogma, 2002) that was developed in the second half of the 1990ies.

However, in spite of these major efforts in Austria, the potential of renewable resource use is far from being fully exploited. This raises the question whether the bottom-up and technology-led approach pursued is actually sufficient to enable wider uptake and move towards a regime shift. Although research over the past ten years has shown in several cases that a purely bottom-up process can indeed be successful if the technology in question develops sufficient momentum to transform or overthrow the dominant regime of production, this is unlikely to be the case if major structural barriers and path-dependencies inhibit the uptake of alternative technologies. A bottom-up, experimental and learning-based approach is a promising strategy for technologies that are in an early phases of development and do not (yet) encounter much resistance. However, a comprehensive approach needs to take account of later phases of development and diffusion as well, and thus of the regulatory conditions (e.g. environmental regulation) and policy measures (e.g. demand-side measures, public procurement, etc.) that influence these later phases. Moreover, the importance of guiding visions and orientations for coordinating the research and innovation activities should be taken into consideration, too.

These insights have been incorporated in the approach of Transition Management (Rotmans, Kemp and van Asselt, 2001), which builds on Strategic Niche Management but puts stronger emphasis on the simultaneous adjustment of wider socio-economic and institutional framework that level shapes the process of moving from technological niches to widespread application in order to achieve a long-term and smooth transition process. In the literature, these frameworks are captured by the notion of 'technological regime'.[2]

Against this background, this paper aims to explore the issue of how to foster innovation and diffusion of technologies based on renewable resources and how to trigger a shift in our production regime. In other words, it tries to provide insights into how a transition of our production systems towards relying on a renewable resource base can be stimulated. This issue is addressed both in conceptual

[2] A technological regime is defined as "the coherent complex of scientific knowledge, engineering practices, production process technologies, product characteristics, skills and procedures, established user needs, regulatory requirements, institutions and infrastructures that makes up the totality of a technology" (Rip and Kemp, 1998).

and empirical terms, and it translates into two main research questions. First of all, the prevailing Transition Management framework has been developed in the Dutch context mainly for infrastructure systems such as water management, energy supply and transport. We want to explore and assess whether this framework is useful to guide policy development to stimulate a transition to a renewable resource base in manufacturing in the Austrian context and therefore propose an adjusted framework which particularly takes into account the specificities of manufacturing industries and value chains.

The second research question deals with the impact of Transition Management-type thinking on policy-making in Austria and more widely on the uptake of new sustainable production technology in general. In other words, we want to know whether the adjusted Transition Management framework has actually contributed to a regime shift in Austria, both in terms of policy-making and in terms of uptake of production technologies based on renewables.

The empirical case on which we draw for this purpose is wood-plastic composites WPC and biopolymers in Austria (Weber *et al.,* 2005). The development and introduction of this technology has been supported in Austria since the late 1990ies, but the longer-term perspectives are still unclear today. Biopolymers are seen as an advanced and longer-term alternative and complement to WPC, which is already comparatively well established. Both technologies have been supported by the Austrian RTD funding programme "Factory of Tomorrow" and are regarded as promising renewables-based technologies for the future.

In methodological terms, we draw on the experiences of a project that aimed at exploring potential future transition scenarios and policies for WPCs/biopolymers and biorefineries by way of interviews and participatory scenario development workshops,[3] as well as on the subsequent influence of this Transition Management experience on policy-making and the uptake of the technologies in question. The transition scenarios developed build on the early experiences with WPC and biopolymers in Austria and aim at exploring more deeply into later phases of diffusion and regime shift.[4] The impact of of this initiative is assessed in several respects. Apart from the immediate influence of project results on the further design and implementation of WPC and biopolymer-related policies, the role of scenario-based and adaptive thinking in spired by Transition Management is analysed both with respect to the programme "Factory of Tomorrow" and the wider govenance practices in Austria. Given that Austria as a small country depends strongly on international developments, an adaptive approach to policy and strategy appears particularly relevant (Eriksson and Weber, 2008). As this project was concluded in 2005, we finally look at the impacts and

[3] The paper draws on research work conducted in he context of the project "Transition to Sustainable Production Systems" that was funded by the Austrian RTI funding programme Factory of Tomorrow. In this project, Transition Field Analyses were conducted for two transition fields, namely one related to biorefineries (led by our project partners at IFZ in Graz) and another one related to WPCs and biopolymers (led by AIT). The conceptual foundations were developed jointly with Ines Oehme, Harald Rohracher and Philipp Späth from IFZ.

[4] More than eighty experts from industry, academia and policy participated in this research. At the workshops scenarios and strategies were formulated for the development and use of renewable resources in manufacturing.

developments in WPCs and biopolymers since then.

The paper is structured as follows. In the next section, the adjusted Transition Management framework for production systems in manufacturing is outlined. This is followed by a brief section on the methodology of Transition Field Analysis, and in particular on the scenario development and assessment method applied The following section describes the scenarios developed and the policy options suggested on their basis. Then, the impact that this process had on policies, on policy-making processes and on the uptake of WPCs and biopolymers will be discussed. Finally, some conclusions will be drawn on the usefulness of the adjusted Transition Management framework and the role and impact of transition policies for the transition towards a renewable regime in production systems in manufacturing.

2. MANAGING TRANSITIONS TO SUSTAINABLE PRODUCTION SYSTEMS

2.1. From transition analysis to Transition Management

Expectations with respect to the role of innovation in society have been rising. Inspired by the perception that our societies are facing major socio-economic and environmental challenges the established orientation towards traditional growth objectives is increasingly questioned. Radical shifts in our production and consumption models towards sustainable development are needed if our societies are to survive. Against this background, transitions are regarded as smooth and long-term shifts of this kind.

Several examples of transitions are known from past history. For instance, the move from a coal-based energy supply system to a gas-based system, or from an industrial to a service economy can be interpreted as transition phenomena. Usually, transitions turned out to be long-term processes that stretch over several decades,[5] and that are characterised by a co-evolution of institutional settings, markets, technologies, cultures, behavioural patterns and policy-making and policy. Often, individual niches are at the origin of regime shifts and further on of changes in the socio-technical landscape in the wider sense.[6] The interactions and interdependencies between these different realms give rise to irreversibilities that stabilise and reinforce the transition path.

Mainly originating from Dutch debates about initiating major shifts in infrastructure system, the concept of Transition Management has been developed as a framework for long-term strategies in innovation policy-making with a view to long-term transitions towards sustainable development.[7] The ability to manage transitions is regarded as an additional key capability that raises specific requirements with respect to innovation policy and its governance. Innovation policy is required to develop capabilities that enable society to address long-term issues and challenges such as climate change, agriculture, mobility, water management, the health systems reform, etc., and to induce corresponding shifts in the technological

[5] Transition processes can thus be interpreted as comparatively smooth transformations, whereas terms like rupture, revolutions or breaks imply a rather fast and abrupt type of transformation process.

[6] See for further examples and and extensive case-study Geels (2002).

[7] See, for instance, Rotmans, Kemp and van Asselt (2001), and Kemp and Rotmans (2005).

regimes that determine innovation processes in such systems.[8]

From a policy perspective, the aim to shape transitions is associated with two questions, namely a) in how far can comprehensive and goal-oriented transformation processes be influenced and guided in a desirable direction at all (i.e. in the direction of sustainable development), and b) what role can and should government actually play in this process.

It is well known that the uncertainty, ambiguity and complexity of future developments prevent any attempt to plan the future in a linear fashion. Consequently, Transition Management is not about the central planning and realisation of future development paths but implies the conscious implementation of structures and collective processes for governing long-term transitions in a goal-oriented and adaptive manner. It is a multi-level and multi-actor learning process in society that aims to integrate the distributed intelligence (Kuhlmann, 2001) of the actors involved in order to improve the co-ordination and coherence of their behaviour. In particular, experimentation and bottom-up learning processes are regarded as key elements of Transition Management in order to maintain the adaptive capacity of an innovation system. Shared problem perceptions, common guiding visions and overarching strategies contribute to orienting the decisions of the different actors towards common goals.

Policy, and innovation policy in particular, is supposed to provide the necessary framework conditions to enable such collective learning and co-ordination to happen. This requires first of all stimulating processes of anticipation and formulation of long-term perspectives that can serve as an orientation and focusing device for the range of actors involved. Secondly, there is a need to monitor continuously the policy actions taken and to adjust them to the evolving visions of the future (see Figure 2). Moreover, conflicts of interest may emerge where government action is needed to mediate between the parties involved. Finally, given the pivotal role played by experimentation, innovation policy can support a transition process by supporting socio-technical experiments that are geared towards the societal goals striven for.

The key difficulty of Transition Management is to ensure the link between open and collective learning and innovation processes on the one hand and the societal goals implicit in the transition concept on the other. In order to operationalise abstract goals such as sustainable development in the context of a Transition Management process, it is useful to differentiate three levels of action. First of all, transition arenas are defined on the basis of comparatively broad problem areas that reflect basic functional needs of society (e.g. energy supply, water supply, mobility, etc.). In a transition arena, government actors, knowledge institutes, businesses, NGOs and consumers interact in order to develop the visions and overarching joint strategies necessary to guide a transition process. Below this strategic level, innovation networks, composed of representatives from the same constituencies, formulate specific transition agendas, define key

[8] In Kemp, Schot and Hoogma (1998) a technological regime is defined as “the whole complex of scientific knowledge, engineering practices, production process technologies, product characteristics, skills and procedures, established user needs, regulatory requirements, institutions and infrastructures”.

projects and experiments, and mobilize, organize and expand multi-actor networks. At the level of the testing grounds, concrete projects and experiments are designed, implemented and monitored in order to put the transition agendas into practice and feed the findings back to the other levels of Transition Management, as inputs to the collective learning process. How these three levels can be interpreted in the context of transitions in manufacturing will be further explored in the next section.

2.2. Adapting Transition Management to production systems in manufacturing

It is still an open question in how far Transition Management, which has been mainly developed in the context of Dutch infrastructure policy, can actually be transferred and adapted to other contexts, be they national or sectoral.[9] It is at least a matter of debate whether so-called "best practices" of policy learning in innovation and technology policy can be sensibly transferred and adapted from one country to another, or from one sector to another. Cultural and institutional settings are recognised today as important factors determining how policy learning actually takes place and how coherent an innovation policy can actually be developed and implemented.

However, one of the aspirations of this paper is to adjust the conventional Transition Management approach in such a way that it becomes useful in the context of manufacturing where specific patterns of production prevail that are substantially systems different from those in infrastructure systems. One of the crucial challenges of applying Transition Management approaches in this context resides in the identification of appropriate intermediate levels of analysis (and policy!), which link broadly defined transition fields to specific technologies. For such an intermediate level useful conceptual building blocks are still lacking in the Transition Management discussion.

When trying to break down the approach of Transition Management to more specific domains than the broadly defined 'production system' as such,[10] it is necessary to specify in more detail the transition fields that shall be addressed by transition policies (e.g. by regulations or research programmes). As a starting point, we take the observation that production is meant to serve certain "needs" and "wants",the fulfilment of these needs and wants is ensured by systems of production. The term production system in manufacturing is hence used here in the sense of a socio-technical system that ranges from the provision of raw materials (including recycling) to service concepts and products for final use and consumption.[11]

[9] In the meantime, the concept of Transition Management in the narrow sense has been applied in a range of different countries, though still mainly in relation to infrastructure systems. For an overview of recent experiences see the KSI Conference 2009 (http://www.ksinetwork.nl/conference2009/). Some of its basic ideas have also been taken up in the context of development studies and industrial development policies, for instance with a view to re-orienting development policies towards a sustainable development (Berkhout, Angel and Wieczorek, 2009).

[10] In line with recent literature, it would actually be more precise to speak of 'systems of production and consumption' because it is increasingly recognised that users —both intermediate and final users— play an important role for innovation and even more so for technological regime shifts. Regime shifts tend to require significant changes both at the supply and at the user side of technology (Tukker *et al.,* 2008).

[11] See for instance the EU-funded project SusHouse where final needs in the realm of the

The more you mov downstream this production chain, the more prominent are the social practices and routines of the users for shaping the technological regime. In further upstream phases, technical design practices are an important social component, while technical considerations play an important role throughout the entire chain.

When looking at production- systems in a more differentiated way, we can thus start with the delimitation of three levels of analysis:

1. *Needs areas:* Final needs and wants of end-users or consumers can be met in different ways. By concentrating on satisfying these final needs and wants, it is possible to overcome the conventional product orientation and think about alternative ways of meeting needs by providing the necessary services and/or products. For instance, the final need of "mobility" cannot only be met by individual car ownership, but also by means of new service approaches such as car-sharing, door-to-door mobility services, etc. Often these alternative concepts are embedded in wider "visions" or "Leitbilder" that capture both these new services and the changes in social, regulatory or organisational practices required. "Sustainable mobility", "sustainable household", "factory of the future" or "green chemistry" are examples in case, often expressed even in terms of concrete performance targets. However, these visions remain at a fairly abstract level. In general, the concept of needs areas can also be applied to other levels of a production system, i.e. also intermediate users (not only end users or consumers) can define a needs area to be addressed by a research programme.

2. *Transition fields:* More specific than the broad-ranging needs areas, transition fields represent the areas where systemic solutions for meeting needs are developed. Transition fields are formed by technologies, actors and their objectives, and they can be interpreted as arenas, where systemic solutions for ensuring the provision of certain functionalities evolve. In other words, it is at the level of transition fields, where specific technologies are tied together with and embedded in social and organisational practices in order to offer an alternative solution for providing a functionality needed. Transition fields are thus an intermediate level, at which the integration of individual technology projects into the provision of needs-oriented products and services takes place, guided by an orientation towards long-term sustainability.[12] For instance, in the case of sustainable mobility, the introduction of an intermodal and integrated mobility service is an example of a transition field. Real-time travel information could be another example, as well as on-line or mobile booking. As an example

household have been analysed and explored in the context of different scenarios (Vergragt, 2000: Green and Vergragt, 2002).

[12] In principle, transition fields can be categorised in different ways. In the case of manufacturing a sectoral differentiation can be useful if this is in line with the production-consumption system under study. "Printing" is an example of a functionality that can be roughly represented by specific industry branches while "dyeing" is scattered over many industrial branches and policy arenas. Alternatively, the resource base (e.g. the use of biomass) can be used to delimit a transition field.

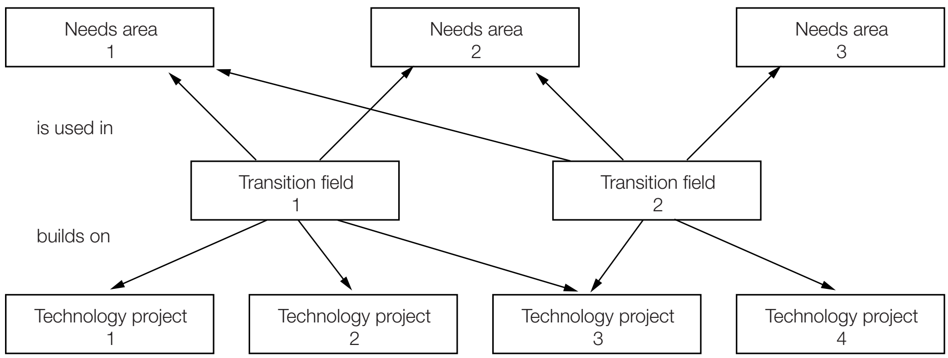
of an intermediate transition field, vehicle maintenance services could be mentioned.

3. *Individual technology projects:* The reality of research activities shows that the individual projects are often realized with focus on specific technologies, without paying particular attention to final needs or social context. In other words, they tend to be conducted in a rather isolated way. What is needed instead from a transition perrspective are technology projects or experiments that take into account user perspectives and that are integrated at the level of the transition fields. In other words, these specific technical solutions need to be contextualised at the level of transition fields in order to enable a wider diffusion. In principle, an individual technology can be applied in different transition fields to meet different functionalities, and correspondingly a functionality can be realised by using different individual technologies. For instance, travel information can be provided in real-time to your mobile phone using GSM, but it can also be transmitted by means of local information terminals or by phone services. Integrated intermodal services can be achieved by standardised integrated ticketing (like in large metropolitan transport system associations") or by means of an electronic bidding service where prices may vary according to demand, etc. Thus, we are particularly interested in new and innovative technologies that have the potential to contribute to a transition to sustainable development.

These three levels of analysis build on each other, thus reflecting the idea of a supply chain from resource extraction to final consumption. However, these chains

Figure 1

Three levels of analysis



Source: Own elaboration.

should not be seen in isolation. Certain functionalities can be useful to serve different needs, just as some technologies have the potential to be applied for fulfilling different functionalities (Figure 1).

2.3. The importance of transition fields as target level of transition policies

From our perspective, the transition fields are clearly the most interesting level of analysis to study. It allows bridging between needs areas and images of the future for certain fields of production on the one hand and concrete technology projects on the other hand. This bridging function between needs and individual technologies makes transition fields a key concept to define and select intermediate transition fields as the core of a policy mix (e.g. comprising research programmes, regulations, procurement initiatives, etc.) that is geared towards sustainability-oriented transitions.

Abstract images of the future are available for many domains as well as individual projects and technologies that are somehow related to these visions. What tends to be lacking, however, is a useful operationalisation of these abstract images at an intermediate level of analysis, i.e. a description that is sufficiently concrete to relate easily to individual technologies, but at the same time sufficiently general to be compatible with more abstract visions of the future at the level of needs areas. Moreover, a transition field should be defined as a sub-field of a production system that is sufficiently coherent and limited in scope to allow specifying a well-defined transition process. In order to reduce the complexity of the scenario development and policy process it appears to be helpful, if a transition field does not consist of too many actor constituencies and if it relates to a limited set of needs areas and technology fields. A certain degree of homogeneity in these areas may be an important argument to select or delimit certain functionalities when demarcating a transition field.

3. TRANSITION FIELD ANALYSIS AS A METHODOLOGY FOR EXPLORING TRANSITIONS IN MANUFACTURING

The above presented framework provides the background for specifying a process methodology that contributes to triggering a transition process in production systems that are characterised by a high degree of heterogeneity as in the manufacturing of specific goods. The intention is to create a context for relevant actors to develop a better understanding of the system and its interdependencies and to reflect on their role within the systemic context in a joint effort. By trying to anticipate systemic effects of individual strategies in the form of scenarios, the process thus shall lead to increased coherence of individual actions and lay the ground for cooperative strategies and policy support. The difference as compared to conventional Transition Management approaches resides in the delimitation of transition fields, and consequently in the range of actors that is contributing to the process.[13] Transition Field Analysis, as our approach will subsequently be called, is particularly

[13] Depending on the complexity of a transition field, and the size of the community concerned —which is rather small in the case of WPCs and biopolymers in Austria— it may be sufficient to involve some 30 to 50 actors in he entire process of Transition Field Analysis.

suitable for areas like the manufacturing of products, which —in contrast to infrastructure systems— are characterized by a high degree of diversification and heterogeneity of the final products and services provided.

In principle, the Transition Management perspective lends itself to a normative approach to scenario-building, where a single desirable scenario or vision of the future is developed (hence normative scenario). As a consequence, a backcasting methodology is applied in order to identify a promising future pathway at the levels of needs areas, transition fields and specific technologies. Such an approach is useful to help clarify goal orientations and desirable future states. However, the realization of any future development path, even the most desirable one, is contingent on many factors that are outside the influence of, for instance, a small country like Austria and a more narrowly defined transition field like WPCs and biopolymers.

The alternative approach – constructing exploratory scenarios which take various possible conditions and frameworks for future developments into account, would not be appropriate to the given objectives, because it does not sufficiently provide orientation with respect to sustainability objectives. What is needed is instead a combined approach, allowing to take into account bottom-up exploratory elements (for instance new technology options, external driving forces) with top-down normative features implied by the sustainability-orientation of future images. Such a combination of exploratory and normative elements is suggested for managing transition fields. Figure 2 gives an overview of the methodology developed for Transition Field Analysis.

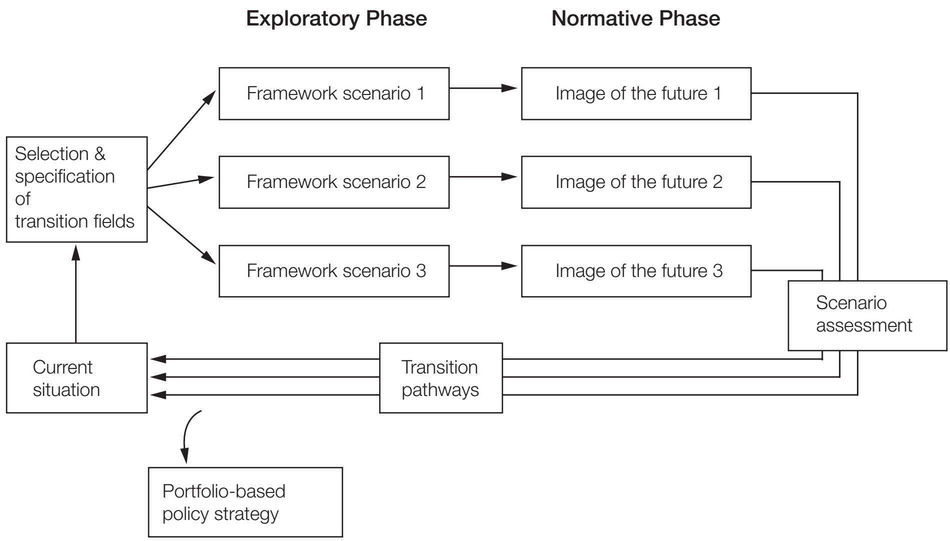
In practice, the methodology can be described by the following five steps. It was implemented in the course of a series of three workshops.

1. *Definition, specification and selection of transition fields:* The initial phase serves to identify and specify the transition field to be subject to the scenario development process. The status quo and current developments within this field are then explored by literature- and internet research and a series of in-depth interviews with key actors from the transition field. It is essential to have a clear understanding of the transition field and how it can be systematically represented in terms of the three levels of analysis (i.e. needs area, transition field, and individual technological experiment).

2. *Scenario development:* The following scenario development process aims to develop first a set of different possible scenarios —basically in an explorative way— asking what is likely to happen in the future, rather than what actors want to happen. Practically, the participants of a first workshop are asked to collect important factors of influence on the future of WPCs and biopolymers. These factors of influence, both external and internal to the transition field, are than combined to generate so-called ‘storylines’, i.e. plausible impact chains and their effects. These storylines re then clustered into consistent groups, thus building the foundation of three different “framework scenarios”. This methodology could be named ‘inductive’ or ‘bottom-up’ scenario development as opposed to the top

Figure 2

Methodology of Transition Field Analysis



Source: Own elaboration.

down deduction of scenarios from a variation of two or three main factors, i.e. the way in which, for instance, the well-known Shell scenarios on the future of energy supply and consumption were developed (Van der Heijden, 2000).

3. *Towards Images of the Future:* In a next step, the three framework scenarios are further elaborated and completed after the first workshop[14]. It is important to ensure that each of the scenarios can not be easily classified as 'desirable' or 'not desirable'; rather each of them should have its positive and negative aspects in order to provide a multi-facetted, plausible and at the same time challenging image of the future. The participants of the process can be involved online and offline into the further elaboration of results. A final discussion and specification takes place at the beginning of the second workshop, leading ultimately to different "images of the future" of the transition field.

4. *Sustainability assessment:* The scenarios will usually differ in terms of their compatibility with sustainability

[14] All three scenarios shared the same structure of nine chapters headed as follows: 1) abstract, 2) nucleus of network development, 3) land use and resources, 4) political context and support, 5) R&D strategy and policy, 6) role of the industry, 7) products and qualities, 8) technological features and scale, ,9) external factors.

objectives. This is intended and useful with regard to the development of policy perspectives, because it allows discussing further on how to move towards a higher legel of sustainability even under detrimental external conditions as reflected in the framework scenarios and images of the future. First trials have shown that initial approach of conducting a quantitative assessment of each scenario along the lines of a set of key criteria was abandoned due to the high degree of uncertainty about future developments. A realistic methodology must restrict itself to what is actually feasible and should not promise results that can not be achieved. Therefore, the assessment methodology suggested and tested in the WPC/biopolymers case aims at identifying 'risks and opportunities' associated to each of the scenarios rather than at providing a seemingly rigorous, but unfounded qualitative or even quantitative assessment[15] Seven dimensions of risk/opportunity assessment are suggested: economy, employment, environment, regional development, knowledge, networks, product characteristics. Obviously, these dimensions may change depending on the specific transition field under study.

5. *Identification of critical developments and actions:* Within each of the scenarios, key actions and conditions are identified which are critical for the future sustainability of the transition field. In addition to these critical issues, further needs for actions can be addressed which are decisive for the realisation of the scenarios and for sustainability potentials. A special focus can also be put on a research agenda and adequate support and network structures to support a specific scenario.

6. *Policy analysis:* This final step draws on these considerations in order to identify potential intervention points with respect to which public policy initiatives promise to be effective for shaping the scenario in a more sustainable direction. In addition to policy conclusions that refer to individual scenarios, it is also important to perform a cross-scenario analysis in order to identify portfolios of policy options that are both robust and adaptive, i.e. they allow to deal reasonably well with different possible futures. Robust policy options are those that would have beneficial impact in all or most of the scenarios, whereas adaptive policy options are an important element of a precautionary strategy that aims to prepare for unexpected negative impacts of single scenarios and to flexibly exploit opportunities opening up at certain development stages. As a precondition for the formulation of robust and adaptive policy options, a cross-cutting assessment of the desirability and the feasibility of the scenarios must be conducted in order to focus on policy options that promise to increasing the likelihood of realising more desirable scenarios, and decresing the likelihood of realising less desirable ones.

[15] In the parallel case of eveloping transition scenarios for biorefineries in Austria, a strict assessment approach was applied, looking at six criteria that were derived from the German Sustainability assessment framework (Grunwald *et al.,* 2001). This approach, however, turned out not to be appropriate and practicable for the purpose of transition field scenario development.

4. THE EMERGENCE AND THE FUTURE OF WOOD-PLASTIC COMPOSITES AND BIOPOLYMERS IN AUSTRIA

In this section, the main results of the Transition Field Analysis are presented, up to the point of highlighting the main cross-cutting policy actions needed to support a transition from the current situation to different future scenarios, and to prevent negative impacts from occurring.

4.1. The current situation in Austria

Wood-Plastic Composites and biopolymers represent a quite heterogeneous set of materials that draw to a significant extent on the use of renewable resources as a substitute for petrochemicals-based materials. WPCs contain usually between 30 and 40 % of wood or other natural fibres, and current research aims at increasing that share well beyond 50% (BMVIT, 2007). The wood particles are usually embedded in a plastic matrix, but in principle also matrices from renewable resources can be used (e.g. based on starch). Biopolymers represent an entire family of materials based on polilactic acid (PLA) and associated polymers. Also some of other substances can be used as starting point for biopolymer material families. Whereas WPCs are used already today for a range of products for internal and external use, often replacing plastic products, biopolymers are mainly of interest to the packaging industry where they are used to produce biodegradable foils. Due to the growing concerns about the availability of oil, the interest in WPCs and biopolymers has been increasing during the past ten to fifteen years, as a building block for moving towards a more sustainable economy, based largely on the use of renewable resources.

Austria has been active in the area WPCs since the late Nineties of the past century. Several innovative products have been launched since then that combine properties of wood and plastics. Several firms are producing and selling WPC-based products in Austria nowadays (BMVIT, 2007). Biopolymers have thus far mainly been used in association with biodegradable packaging foils but major hopes are associated in Austria with the establishment of a lactic acides-based chemical production system that would offer a broad range of materials with different properties, suitable to an equally broad range of applications. For both WPCs and biopolymers to evolve beyond niche technologies, it will be key whether the actors along the entire production chain from resource extraction to consumption will be able to identify benefits in this new option or not.

In general, the conditions in Austria are quite conducive for WPCs and biopolymers. Austria is endowed with extensive forests, it has an advanced wood and plastics industries that is also a target for foreign direct investment, and since the mid-Nineties a significant research capacity has been built up with the help of public funding schemes. In particular the competence centres programmes that aims to foster collaboration between science and industry, and the thematic programme Factory of Tomorrow have been decisive for building up research and innovation capacities and for providing orientating funding for research.

In terms of transition policies, the RTD funding programme Factory of Tomorrow by the Austrian Federal Ministry for Transport, Innovation and Technology (BMVIT) comes close to the conceptual model of Strategic Niche Management. However, due to its focus on RTD-funding, it cannot be considered a Transition Management type framework. In essence, by way of funding consecutively projects ranging from quite fundamental research to visible demonstration projects, it aims at building up in specific fields (e.g. biorefineries, WPCs, biopolymers, and others) the competencies and the trajectories that should culminate in the realisation of large-scale demonstration projects (so-called "lighthouse"-proejcts). These lighthouse projects aims to demonstrate both the technological feasibility and the economic viability of the technologies in question, also with a view to convince innovators, investors, regulators and other relevant policy areas to intensify their efforts to make of the technologies at a larger scale. However, in spite of these efforts, comparatively little progress has been made so far with respect to regulatory initiatives to facilitate the uptake of WPCs and biopolymers and with respect to other policy areas such as agricultural policy, regional policy or environmental policy. This observation is in fact one of the main reasons why the Transition Management framwork is regarded as promising for triggering better coordination with adjacent policy areas and for stimulating the engagement of other industrial and research actors.

4.2. Scenarios on WPCs and biopolymers in Austria

Three main scenarios of future transitions in WPC and biopolymer production systems in Austria are presented. The first two differ because of unlike framework conditions and the degree of novelty of WPCs and bio-polymers. The third scenario emphasises the "lighthouse character" of new applications and products based on the new materials and the importance of demand orientation.

1. *Scenario 1: Substitution pays off – WPCs:* The first scenario is called "Substitution Pays off - WPCs". It is based on the fact that WPCs are already used for some product applications. In the context of this scenario the future potential of the wood plastic composites (WPC) could be used particularly due to rising prices of crude oil. Increasingly, enterprises start to replace conventional plastics by WPCs. Where technical characteristics, weight and geometry are of importance, likewise, wood is substituted in some applications. R&D efforts predominantly concentrate on the development of WPCs to substitute plastic products. To some extent, also wood products are being replaced. The presence of R&D actors, producers, suppliers of equipment and customers in Austria is a reason for the technology leadership. The forging of a coalition of these actors is the result of the publicly funded competence centres Wood K plus, which serves as the main network node.

2. *Scenario 2: Substitution pays off – bio-polymers:* The second scenario "Substitution Pays off - bio polymers" concentrates on the perspectives for bio polymers. It assumes a high level of crude oil prices. The success of the scenario depends on coordinated efforts of agriculture to provide the raw

materials for biopolymers, and their cooperation with the the chemical and plastics industries in particular. In the medium term, a high potential for the use of biopolymers in degradable packaging is exploited. It serves as a basis for a biopolymers-based family of chemical products that represents a credible alternative to petrochemicals-based products. Assuming political support from agricultural policy and environmental policy, the Austrian industry can position itself in global niches. In the long run, however, product properties also gain importance, which cover long-lasting and technologically new products, since the potential for purely biologically degradable bio polymers is limited.

3. *Scenario 3: Lighthouse products with appeal:* In the third scenario "Lighthouse Products with Appeal", which applies to both WPCs and biopolymers, advanced applications of the "new materials" are being developed, that are used in highly innovative products. The success story of the scenario is based on using special characteristics of these materials, and on the buyers' emotional perception of the products. In other words, and in contrast to the two other scenarios, this is a products-based scenario that makes use of the special properties and the special appeal of the WPC- and biopolymer-based products that allows boosting the demand for the new materials.

An assessment of challenges and risks has been conducted for each of the three scenarios and serves as an input to the cross-scenario assessment of desirability and feasibility. Scenario 1 was rated highest in terms of feasibility, followed by scenario 3. The feasibility of scenario 2 was graded much low. The ranking according to the desirability dimension shows a different picture. Scenario 3 was rated as particularly desirable. The almost equally high desirability of scenario 2 stands in contrast to its low degree of feasibility. However, also scenario 1 was rated comparatively high on the desirability scale, showing that the scenario development process delivered as set of well-balanced, but at the same time qualitatively different scenarios.

4.3. Actor strategies and policies

Although suggestions for actor strategies and necessary pathways of action were backcasted for each of the three scenarios, we now focus on the cross-cutting considerations. In the very end, what is needed are the kind of robust and adaptive options that are useful from a policy perspective in order to a) provide support to WPCs and biopolymers under any of the scenarios ("robust options"), and b) to make sure that the most negative impacts of some scenarios are avoided, while the positive repercussions enabled, or at least their potential maintained ("adaptive options").

Further research is needed to analyse the effects of the scenarios on climatic protection goals and the material product life cycle. Here in particular, interdisciplinary research bridging social and natural sciences is of need.

In addition to scenario-specific recommendations, a number of cross-cutting suggestions for action were made:

— Research and development need to be increased and focused on the improvement of product properties such as durability, degradability and hygroscopic characteristics of WPCs and biopolymers.

— Research is needed to analyse the impacts of the scenarios on climat objectives and the material product life cycle. Here in particular, interdisciplinary research bridging social and natural sciences is lacking and .

— While the development trajectory of WPCs is already more advanced than that of biopolymers, the significant potential for synergies between the two should not be overlooked and the advancement of biopolymers by way of R&D funding and pilot applications enhanced.

— Cooperation between research and industry has improved over the past years, but still needs to be further intensified.

— R&D and innovation activities are important to improve the performance characteristics of WPCs and biopolymers, but to enable a transition the wider framework conditions for their diffusion and uptake should receive more attention.

— Activities related to WPCs and biopolymers in Austria need to be better embedded internationally. So far, the perspectives on markets and technologies are too much restricted to the national context, but in view of a wider diffusion of these materials and an associated regime shift, the international developments need to be taken into consideration, facilitated e.g. by collaborative R&D projects at European level or by looking for market developments globally.

— Norms and standards are crucial in all three scenarios to facilitate and orient innovation activities. National interests in this regard need to be fed into international standardisation activities, for instance in the context of construction standards.

— Public procurement practices can exert a significant influence as demand-side factors for innovation, but have not yet been adapted (see also the argument about norms and standards) to enable and facilitate the use of WPCs in particular. With the large volume of public procurement in construction, WPCs could benefit significantly from an adjustment of procurement practices and standards.

Some adaptive options, i.e. options that are specific to certain scenarios for avoiding risks and exploiting opportunities are focusing on the following aspects:

— In Scenario 1, one of the main specific barriers to a transition is the still under-developed cooperation between the wood industry on the one hand and the plastics industy on the other. The respective actors regard each others too much as competitors rather than as potential partners in WPC development and exploitation in their respective markets.

— In Scenario 2, biopolymers are a long-term option, in contrast to WPCs which are already quite advanced. Although there are also some synergies between both trajectories, it would be risky to focus solely on WPCs to the detriment of biopolymers. In order to secure the potential inherent to biopolymers as reflected in Scenario 2, the advancement of this technology should be further supported. Morevoer, biopolymer development would benefit from closer cooperation between the chemicals industry and agriculture; an issue that raises also a need for policy coordination between innovation and industrial policy on the one hand and agriculture policy on the other.

— In Scenario 3, it is essential to maintain the option of launching lighthouse products in the future. As a consequence, it will be necessary to put more emphasis on innovative product development responding to user needs rather than just research-inspired improvements of material properties. In this context, special attention should be put on socio-economic market research to support the realisation of Scenario 3.

5. THE IMPACT OF TRANSITION FIELD ANALYSIS

5.1. The impact of Transition Field Analysis on government policy

Impacts of the Transition Field Analysis and scenario development process can be observed at different levels. As a first level, it is interesting to look at the impacts it had on policies that are directly related to WPCs and biopolymers. The three transition scenarios contributed to shaping of a more comprehensive and realistic perspectives on WPCs and biopolymers because they clearly highlighted the manifold interdependencies and constraints, to which a regime shift towards WPCs and biopolymers is subjected. It became obvious that in addition to the usual technological and economic barriers, several institutional, structural and policy-related barriers have to be considered as well. This implies also looking at the role of adjacent policy areas. In particular, agricultural policy moved into the focus of attention with respect to biopolymers, as well as industrial policy at the intersection of the wood and plastics industries with respect to WPCs. In the context of RTI, the the main thematic funding programme “Factory of Tomorrow” was influenced by the results of the Transition Field Analysis in terms of the definition of priorities for future research, of the need for strenghtening cooperation in several respects, and of intensifying the international embedding of the programme.

At a second level, an influence can be observed on the general approach for designing thematic RTI-funding programmes. It affects not only the specific programme “Factory of Tomorrow” but also other programmes with a similar design, for instance in the field of transport, construction and energy. The prevailing way of building up competencies in order to establish “lighthouse projects” was modified, and the need for a broader embedding of these projects recognised. This concerns, for instance, the role of other policy areas that enable or inhibit the adoption of the regime-shifting technologies, the attention for demand-side factors, and the international perspective on competing technologies and on envisaged markets. Perhaps most important, however, is the joining of forces among Austrian actors beyond the phase of establishing a lighthouse project. By way of creating platforms and networks, further momentum can be generated to prepare the markets, establish standards and common research agendas.

At a third level, it is important to consider the impact that Transition Management-type thinking had on the governance of transitions in Austria more widely. The WPCs/biopolymers case was one of the first attempts of implementing the Transition Management model in Austria, and it triggered novel research, technology and innovation policy models in the areas of energy, transport and production systems. The Energy 2050 strategy process, which was launched in 2007, was at least implicitly inspired by Transition Management thinking and the early experiences with this model in the areas of biorefineries and WPCs/biopolymers. It led to the creation of the Climate and Energy Fund (KliEN) which combines responsibilities for climate and energy-related actions ranging from RTI-funding to investment projects. Even if the implementation of the new fund is not regarded optimal in many respects, it provides an organisation model for realising transition-type policy mixes. More recently and also inspired by the European debates about demand-led innovation policy, public procurement has been discovered as a means to foster innovation and to support transitions. This development is also in line with the "strategic turn in RTI-policy" (Weber 2009), i.e. with explicit efforts to introduce longer-term thinking with a view to societal goals in policy-making; a thinking that is well in line with the approach of Transition Management.

Obviously, these impacts at the second and third are very difficult to trace back causally to specific Transition Field Analysis case on WPCs and biopolymers, but as a kind of pilot exercise it influenced the thinking about how to initiate and accelerate a regime shift by way of RTI-funding in a comparatively small community of programme designers at the ministry in charge of most thematic programmes and of programme implementers at the corresponding funding agencies.

5.2. The impact of transition field analysis on WPCs and biopolymers

Five years have passed since the end of the first experiments with Transition Field Analysis in the field of WPCs and biopolymers. This is still too short a time for really assessing whether we are moving towards a regime change in this transition field. No doubt, further steps forward have been made: WPCs have become more established as an alternative to plastic materials, but also to wood. Research efforts have contributed to further improving the material characteristics of WPCs. The perspectives for biopolymers continue to remain unclear, but the market and the recognition of the alternative chemistry based on non-fossil resources increases. The lighthouse products with appeal have not yet appeared on the market, indicating that scenarios 1 and 2 seem to be more likely to happen. Overall, the Transition Field Analysis gave an important impulse, but at this point of time difficult to assess whether it was the ignition for a regime shift which without doubt will ultimately depend on several of the factors that were elaborated upon in the scenarios.

6. CONCLUSIONS

6.1. Transition Field Analysis as a policy support tool

The concept of transition fields and the scenario methodology of Transition Field

Analysis delivered a number of useful results in the case of WPCs and biopolymers in Austria. As the methodology builds on the general concept of transition fields, which is geared towards transitions in heterogeneous areas such as manufacturing, it has the potential of being more widely applicable to other areas with similar characteristics and of generating similar types of insights for research and technology programmes as well as for technology and innovation policy. As the experiences of the case of WPCs and biopolymers revealed, Transition Field Analysis is particularly helpful in the following respects :

— It delivers orientation and guidance through the formulation of scenarios, but not in a simplistic way of proposing a single 'guiding vision'. By proposing different variants of future developments, it points to the critical issues, joint agenda items and more generally to the "room for manoeuver" to move in an as sustainable direction as possible under the conditions of each scenario. Different types of specific suggestions were developed, both per scenario and across scenarios. The latter suggestions are particularly important for designing a portfolio of robust and adaptive policy options, based on a multi-scenarios perspective on the future.

— It contributes to 'Community Building' and thereby to the establishing of networks and an organisational infrastructure for the respective emerging transition fields;

— It contributes to a broadening of the perspective on the transition field in question and thus to more realistic expectations as regards the potential of and the barriers to a transition process. From a policy perspective, this raises novel elements for consideration, such as the identification of requirements and barriers imposed by other policy areas, the early consideration of demand-side factors for moving from new promising technology projects to successful products, or the need for a Europeand and international perspective of what is happening in the transition field, both in terms of research and market developments.

— These issues are also reflected at the level of funding programme such as "Factory of Tomorrow". In addition, the more fine-grained perspective of transition fields opens up the possibility of identifying promising key areas for future research, but also of testing them in an anticipatory way using Transition Field Analysis. In other words, Transition Field Analysis can be used to check potential priority research areas for their potential and perspectives with respect to inducing a regime shift, based on a comprehensive transition framework. An important implication of this approach is that continuity and reliability in funding and framework setting are needed to realize a transition. This is clearly an advancement over the "lighthouse" model that was used in several thematic funding programmes in Austria and that led to over-optimistic expectations.

6.2. **The concept and approach of Transition Field Analysis**

The starting point of this contribution was the observation that Transition

Management as conceived in the literature and in practice was geared mainly towards transitions in infrastructure systems and thus not suitable for analysing and exploring scenarios and the potential for regime shifts in more heterogeneous areas like manufacturing of products. Moreover, by focusing on macro-level regimes, the relevance of Transition Management to the design and implementation of specific policies was limited. The notion of transition fields offers a more fine-grained perspective on transitions that is nevertheless compatible with several of the basic principles of Transition Management. It thus also allows dealing with specific policies to foster the emergence and diffusion of new technologies in such a transition field. One of the consequences of this more fine-grained approach is that a transition becomes more dependent on contextual developments and requires the embedding in a multiple scenarios perspective.

These conceptual differences to conventional Transition Management are reflected in the methodology suggested under the headline of Transition Field Analysis. It could be demonstrated that this methodology can serve to support research, technology and innovation policy at different levels. For the example studied, RTI-policy and funding programmes have been at the focus of attention, but several novel implications were raised with respect to other, adjacent policy areas, as well as for cooperative strategies of the actors in the transition field. In view of the experiences with this approach, the methodology of Transition Field Analysis should be further tested and applied in other thematic RTI-area in need of a regime shift (e.g. in the context of the 'Grand Challenges' that are currently being discussed at European and national policy levels), but also for revisiting national strategies of RTI-policy where a great need for a regime shift is perceived in the context of the current crisis.

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