Policy coordination to support a transition to sustainable production systems

- Lessons to be learned from the case of biorefineries in Austria[1]

Paper to be presented at the 2004 IHDP Berlin Conference:
"Greening of Policies – Interlinkages and Policy Integration"
Berlin, 3./4.12.2004

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First draft, November 2004

[1] The paper draws on a project supported by the Austrian research programme 'Factory of Tomorrow' (an initiative of the Austrian Federal Ministry of Transport, Innovation and Technology – BMVIT), which is gratefully acknowledged.

A more extensive version with a focus on Reflexive Governance will be published in: Voss, J.-P., Kemp, R. & Bauknecht, D.: Sustainability and Reflexive Governance, Edward Elgar Publishing, (forthcoming). We are grateful to the editors for their helpful comments on an earlier version of this paper.

1 Abstract

Transition processes towards sustainability can be conceptualised at the level of production-consumption systems, ranging from resource extraction to final or intermediate product and service delivery. Policy initiatives play a pivotal role in fostering such transitions, but require an integrated and coordinated policy approach to be effective. However, the coordination of policy initiatives, both vertically and horizontally, cannot be all-encompassing, but needs to be focused on what we call transition fields, i.e. critical segments of a production-consumption system where a transition process can be initiated.

In the case of manufacturing, we are confronted with a high degree of diversity of production-consumption systems. As a consequence, the level of aggregation at which transition fields can be delimited is much lower than, for instance, in energy supply or transport which represent far more homogeneous systems. The case of biorefineries in Austria is an interesting example for studying policy coordination and its impact on the evolution of such a transition field and the corresponding production-consumption system, as well as about the pitfalls and difficulties it involves.

At the beginning of the millennium, the perspective for biorefineries seemed to be quite promising in Austria, because an RTD-programme was set up that aimed to integrate sustainability aspects into manufacturing research, thus building an explicit bridge between sustainability and RTD policy. However, policy coordination involves a wider range of key issues, and we will show by means of the Austrian experience some of the barriers to policy coordination and to an effective management of a transition field. The reasons why this Austrian initiative did so far not show the expected benefits can be traced back to a range of factors, several of which relate to problems of policy coordination: the neglect of European policy developments (**vertical coordination**), both in RTD and other policy areas; a lack of coordination with other relevant national policy domains (**horizontal coordination**); but also a lack of coordination within sustainability-oriented RTD-policy where the limited amount of research funding was spread too thinly across a wide spectrum of transition fields (**internal coordination**).

Along these three dimensions, the different coordination links will be described and analysed in terms of the underlying reasons why they worked well or not. In many cases, the success of the different coordination efforts can be traced back to organisational and institutional factors. Therefore, the paper will conclude with some general lessons that can be learned from the Austrian biorefineries case for the design of coordinated and integrated policies and corresponding institutional settings, with the emphasis being put on the role of RTD-policy.

2 Introduction

Austria is usually regarded as one of the more advanced countries in terms of implementing sustainability policy or introducing environmental technologies. Is the actual process of policy making in the field of R&D policy coming up to this reputation?

In this contribution, we describe an experiment with a new instrument for integrated R&D-policy. This instrument – socio-technical scenarios and pathways of transition developed in a specific participatory process by a wide range of actors – has been developed in the framework of an Austrian R&D programme which aims to establish sustainable production systems. The methodology has been tested with regard to one specific innovation: The concept of biorefineries.

Technology development for sustainable production systems: A complex policy issue

The Austrian R&D policy aims to support a transition towards sustainable production-consumption systems. This specific area of R&D policy is a peculiarly multi-facetted and heterogeneous field with many technological, economic and social interdependencies. In contrast to large-scale infrastructure systems like energy supply, transport or water management which until now have been the focus of attention for systemic transition processes, the field of 'production' is much more heterogeneous and more difficult to address by an overarching transition process for *the* production system as a whole. Therefore, it was decided to focus on the more disaggregate level of 'transition fields' which represent clusters of closely related production technologies (Weber et al. 2003) and will be discussed in more detail later.

Production-consumption systems are very complex results of long-standing development processes, since they are embedded in and closely interlinked with structures and processes in their societal and ecological environments stretching from the extraction of resources and land-use practices, via long production chains right through to private consumption. They just interfere with every single aspect of live. This high degree of interlacement implies that the area is difficult to influence in a targeted way and that only a long-term transition strategy integrating different levels of policy-making can lead to a shift towards sustainability. As production-consumption systems depend on a wide range of actors within and outside the research community, a participatory and integrative approach to strategy development is needed to induce change.

A programme for sustainable production systems and accompanying research

The Austrian Federal Ministry of Transport, Innovation and Technology – BMVIT has accepted the challenge and developed a research programme that explicitly pursues the objective to contribute to the establishment of sustainable production-consumption systems. However, the mere existence of such a programme, entitled 'Factory of Tomorrow', is not a guarantee for success. It provides a context in which the impact of policy and governance on longer-term transition processes can be studied.

With that purpose in mind, an accompanying strategic research project was set up within the programme 'Factory of Tomorrow' in order to establish a platform to *reflect upon strategies to shape a transition towards sustainable production-consumption systems*. The project lays particular emphasis on the contribution of R&D policy to such a transition process, but also takes the role of other policy areas into account.

A case study: The quest for biorefineries

More specifically, it was decided to study the case of biorefineries – plants which process biomass into several useful substances. This case is particularly interesting because right from the beginning, i.e. in the early 1990s, the interest of some researchers in the subject met with the emerging agendas of sustainability oriented R&D-policy in Austria[2].

From a technical point of view biorefineries can be a source of chemical products, such as lactic acid, amino acids, furfural, ethanol and others – depending on the feedstock – some of

[2] The development of biorefineries is furthermore predestined for exemplary accompanying research (with regard to Austrian R&D-policy) because of its following features: 1) high potential for fundamental, systemic change in wide segments of the production system, 2) a relatively young phase of transition (still experimental, with potential for soon pilot implementations), 3) high economic relevance (for Austria), 4) sufficient linking up of actors, 5) relevant research capacities (in Austria), 6) actors with sufficient contact to partners around Europe, 7) the existence of potential lead actors.

which are conventionally synthesized from petroleum. Beside its potential to substitute fossil resources, biorefineries are supposed to be beneficial to rural development and the preservation of Austrian landscapes.[3] However, it is still far from clear which broader scenarios would be compatible with and conducive for an uptake of biorefineries, what the specific conditions for a successful diffusion would be, and whether they would indeed contribute to the transformation of the production system towards sustainability. R&D policy is thus in a situation of ambivalence and uncertainty with respect to the support of biorefineries, which would make a reflexive and adaptive design of the policy process advisable as well as an embedding of this issue within broader socio-technical contexts.

The key questions

By looking at a case study on the participatory building and assessment of socio-technical scenarios, this contribution sets out to address the following questions:

- How can Austrian R&D-policy effectively support the diffusion of innovations presumably contributing to socio-technical transitions towards sustainable production systems?

- What mode and instruments of governance would be suitable for this task?

- To what degree do measures, strategies, and policies need to be transcending policy fields and spheres of power?

- To What extent is policy integration supported by the current Austrian policy context?

Hence the article is structured as follows: First we provide a rough overview of the Austrian governance context with regard to sustainability and R&D policy, pointing in particular to the difficulties of integrating sustainability principles in other sectoral or thematic policies. The process of the emergence of biorefineries in Austria will be briefly reconstructed. The following section will then describe a reflexive exercise that was conducted in the context of the national R&D policy programme in support of sustainable production. The experiences gained in this experiment will be assessed with regard to the needs, prerequisites and impediments of policy integration in Austria.

3 The context: Actors and programmes of R&D policy in Austria

To gain a better understanding of the context of current R&D policies to support the transition towards sustainable production systems, let us start out with some short remarks on the general framework of R&D policy in Austria.

In the 1970s Austrian policy makers became aware of the deficits of a linear 'science and technology push' approach towards technology policy (Meyer 2002). It was increasingly recognised that innovation is an interactive process of knowledge accumulation that interlinks the different phases of innovation and requires cooperation between different actors. As a consequence, new bridging institutions were established in the 1980s, for instance the so-called Christian-Doppler Research Association in 1989 and a first wave of technology transfer centres aiming to reinforce the diffusion of research results. At this time, first efforts were also made to develop targeted research programmes. They were in some cases focusing on the functional characteristics of what will later on be called the national innovation system (e.g. science-industry relations) and in other cases had a thematic orientation (e.g. programmes on

[3] This is especially true in the case of 'green biorefineries', which use green biomass such as grass, clover etc. as feedstock.

transport technology). Both lines of programmes continue to exist in Austria and have been further refined over the past years.

However, all programmes tend to suffer from a major problem in the structure of the Austrian R&D-policy landscape, namely the dispersion of responsibilities. In essence, four ministries are in charge of different segments of research, technology and innovation policy, three of which actively support sustainability objectives. To this adds the growing importance of regional policy initiatives. For instance, in some provinces very active initiatives have been implemented to foster the creation and expansion of industrial clusters. Until the end of the last century, efforts to improve coordination between different political actors in charge of R&D-policy agendas, as well as with sectoral ministries have remained patchy.[4] In the last few years, however, the landscape has changed again. First of all, with the establishment of the Austrian Council for Science and Technology Development in the year 2000, a new actor has entered the scene whose main role it is to improve coordination between different research and technology policy initiatives by formulating an overarching national research and innovation strategy (Rat für Forschung und Technologieentwicklung (RFT) 2002) as well as by formulating recommendations to the Ministry of Finance on research funding programmes suggested by the different ministries.

Sustainability as an issue of Austrian R&D-policy

In general, Austrian government supports objectives of sustainable development as outlined in its sustainability strategy. These objectives also hold for R&D policy.

With the establishment of targeted research programmes sustainability became one of several core topics of Austrian R&D. Under the headline of 'Austrian Landscape Research', a first research programme has been established by the Ministry of Science, thereby more than 200 representatives from research and public administration have been involved in the development of the programme. At about the same time, the National Environmental Plan 'NUP' (BMU Bundesministerium für Umwelt (Detter 1995) was formulated, obviously focusing mainly on the environmental dimension of sustainability. It was followed by the Federal Sustainability Strategy in 2002 which was a reaction to changing requirements at European and international level.

3.1 The programme 'Factory of Tomorrow' and its relation to other programmes

In the late 1990s, a major research and technology initiative was started at the Federal Ministry for Transport, Innovation and Technology (BMVIT) aiming at the development of technologies for sustainable development ('Nachhaltig Wirtschaften'). Of major interest for the purpose of this paper is one of its sub-programmes entitled 'Factory of Tomorrow'[5]. It focuses on the advancement of research and technologies that are supposed to deliver a 'double dividend', i.e. they are supposed to enhance the competitiveness of Austrian industry while at the same time contributing to the establishment of a more sustainable production system.

In general, a lack of horizontal cooperation and the division of labour between ministries in matters of research, technology and innovation policy implies that policies can only to a limited extend be developed in integrated processes. With BMVIT focusing on

[4] See for instance Whitelegg 2004 where the difficulties of policy coordination between transport, transport technology and innovation policy are analysed.

[5] For more details see www.nachhaltigwirtschaften.at and www.fabrikderzukunft.at.

technologically oriented R&D and technology policy initiatives, the changes to the wider policy framework and further preconditions for a structured transition towards sustainability (stakeholder inclusion, social and economic dimension of sustainability) can hardly be achieved. Consequently, the programme 'Nachhaltig Wirtschaften' mainly focuses on environmental technologies and demonstration projects that should serve as a visible orientation and model for adopters ('beacons' as they are called in the programme). There is not much connection to general sustainability research of the Ministry of Science and Education (e.g. focusing on ecosystems, sustainable lifestyles, transdisciplinary research or 'social dialogues' on sustainability), nor is the programme closely integrated in initiatives of the responsible departments for environment or energy[6].

Nevertheless, the programme 'Factory of Tomorrow' aims to support the structural shift towards eco-efficient management and a sustainable production system through research, technological development, demonstration and dissemination measures. Concepts and technologies shall be developed for the production and provision of goods and services in an economy geared towards sustainability. While beside technological also economic, social and structural issues have been addressed in the calls, the thematic priorities mainly focus on three fields:

- Sustainable technologies and innovations in production processes
- Use of renewable raw materials
- Sustainable products and services.

The overall funding volume is comparatively small (about € 10,54 million for the first three calls 2001-2003), while 'production' represents a very broad research domain. As a result the 88 projects funded so far are rather diverse and only loosely integrated into joint research agendas.

4 The Case Study

These pitfalls are part of the reasons, why the programme funded an accompanying strategic research project, which tried to embed these technological projects in broader strategies of a transition towards sustainable development and to foster interaction and coherence. This accompanying project is seen as an experiment for further initiatives to integrate and implement research carried out in the programme. The establishment of a special advisory group with representatives from different funding bodies, ministries and the Austrian Research Council expresses the interest of these research funding organizations to find new ways to link research with implementation strategies and longer term planning. The strategic accompanying project set out to demonstrate the applicability of transition management approaches for R&D programmes by focusing on two exemplary fields of technology development: biorefineries and wood-plastic composites/ biopolymers. In this contribution we will reflect on the results and experiences gained in the case study on biorefineries.

4.1 BIOREFINERIES: what it is and how it became an issue

In the late 1990s, R&D-actors in Austria became interested in the concept of biorefineries and made first assessments of the contribution that biorefineries could make to more sustainable production-systems. Their quest for support of R&D towards an Austrian type of 'green biorefinery' using biomass from meadows fitted within the framework and the goals of a new research funding programme called 'Factory of Tomorrow' which aims to support research

[6] There is one exception, see www.forne.at.

towards sustainable production systems. Several projects within this programme explored the technical and economic potential of green biorefineries.

Expectations in the concept of biorefineries

It is the hope of the advocates of the concept of biorefineries that these technologies and the production concepts brought together under this notion – once adopted by industry – would fundamentally transform the production process of many industrial goods.

Biorefineries are defined as integrated systems combining physical, chemical and/or biotechnological processes and plants in which biogenic raw material of different origins is processed into a whole range of industrial intermediates and/or final products.

In close analogy to other types of refineries such as fossil oil or sugar refineries, the concept of biorefineries aims to convert the complete biomass of whole plants into a whole portfolio of products or precursors for further product lines in integrated processes and free of residues. Besides biobased materials, energy (via biogas generation) may be supplied by this technology. The concept is thus putting broader and longstanding concepts such as bio-based production in concrete terms. Whole crop utilisation and sustainable land use serve as guiding principles (in the sense of Gleich et al. 2004) – and help to create a regional community of supporters of such an innovation.

With the concept of biorefineries, it seems possible to substitute an increasing share of fossil sources with material of biogenic (and potentially regional) origin and thus increase independency from scarce sources of raw material and volatile prices, and reduce CO_2-emissions and other negative effects on the environment. In Austria, especially decentralised and small-scale 'green biorefineries' are considered to be a promising and sustainable concept.[7]

However, despite these high hopes, it is still far from clear whether the concept is economically feasible (in which technical configuration and with which specific products and outputs of the plant), and how it will be integrated in the wider systemic contexts of energy generation, agriculture, landscape preservation and the production system. Consequently there are still major uncertainties about the potential carrier of this development in industry and the agricultural system and which framework conditions (regulations, subsidies etc.) would be necessary for successful implementation of this concept.

While some success in ‚biorefinery systems research' has been achieved in Europe as early as in the 1980s (most notably in Germany and Denmark (see Kamm and Kamm 2004), it took some more years for the first government to commit itself to concrete substitution goals. It was the US president and congress to firstly declare in the year 2000, that by the year 2020 at least 25% of organic industrial feedstock chemicals shall be provided on a renewable basis (US National Research Council 2003). Since then, big industrial plants have been built in the US to produce e.g. lactid acid from maize.

However, biorefineries are not only seen as instrumental for substitution strategies away from increasingly rare and expensive petrol[8]. Some scholars argue that beyond their energy and resource efficiency (due to the synergetic production and use of side-products) they will gain importance because they will provide opportunities to produce completely new products and

[7] 'Green biorefineries' are one of three main types of biorefineries, the other ones being Lignocellulose feedstock biorefineries (using e.g. wood) and crop / wheat refineries (using e.g. maize and wheat), the latter of which are closest to economic viability.

[8] Biorefineries in this sense are expected to benefit from advancements in biotechnological production, which become economically competitive in more and more production processes.

qualities – even beyond the important quality of bio-degradability – that cannot be produced on the basis of petrol. This of course needed specific processes and organizational structures in place that comply with the characteristics of biogenic raw materials (Wimmer et al. 2003, Katter et al. 1999, Kromus 1999).

By their advocates biorefineries are expected to be beneficial especially for industries and agriculture (Danner et al. 1999, Industriewissenschaftliches Institut 2001). Since the integrated processes involve demanding chemical and biotechnical engineering, it is expected that biorefinery technology will be developed first in technologically advanced regions. Therefore establishment of biorefineries is seen as one factor possibly countervailing the shift of industrial production to countries with cheap labour.

Biorefineries in Austria

While some research efforts have been made in the late 1980s with regard to the use of green biomass for ethanol production and use of grass fibres for paper production, research with respect to the concept of green biorefinery has been intensified only in the late 1990s (Narodoslawsky 1999).

Biorefineries were promoted in Austria firstly because of their assumed positive impact on regional development by a) stabilizing the current use of green land, thus 'keeping the landscapes open and attractive' and b) 'direct impact on the economic structure of rural regions'. Therefore 'interest is focused on the type of green biorefineries, using grass from meadows as feedstock. In contrast to the centralized Biorefinery concepts in Europe, the Austrian Green Biorefinery focuses on a decentralized system based on grass-silage…with lactic acid and amino acids (proteins) as key products from silage' (Kromus et al. 2004).

The last years have indeed seen extensive research activities and attempts to set up pilot studies demonstrating the potential of green biorefineries in the region of southern Styria. As by now, industry has not been intensively involved in the funding of these research activities though. Research has thus been limited to a number of projects within the programme 'Factory of Tomorrow', complemented with equity funded activities by several research institutions. Yet a national network of researchers and institutions interested in biorefinery related R&D has been set up and is coordinating research on an informal level.

With their requirements for fundamental changes in production systems (complex logistics, due to seasonal and distributed harvesting, respective requirements for infrastructure, integrated production, completely new and regionally varying product portfolios) the innovation of biorefineries require a systemic multi-dimensional and integrative approach.

The aforementioned hopes in biorefineries, brought forward mainly by a small group of researchers, are to a large extent based on assumptions which have not been spelled out yet. With respect to R&D policies the government agencies find themselves in a (common) ambiguity: The technologies and concepts of biorefineries might yield a high potential to solve several problems in one go (sustainable production, income generation, landscape preservation). At the same time, it has not been assessed at this early stage of technology development, how the innovation would impact on the wider socio-technical context, and under which conditions this impact would be positive. In order to decide on priorities for government funded R&D, how can such promising technologies and concepts be evaluated ex ante, taking into account that their future effects are depending on the broader systemic settings that they will be embedded in?

4.2 Socio-technical scenarios as a tool for integrative policy development

In recognition of the complexity of this question, Austrian R&D efforts to develop green biorefineries have been accompanied by a strategic project trying to introduce a new level of reflection (e.g. on long-term systemic effects) to policy making. However, as we will see, the 'delegation' of reflexivity to accompanying research projects is not without problems and does not necessarily result in a practice of integrated policy development. In the following section we first discuss requirements for effective measures to support technological developments such as biorefineries and subsequently focus on a case study of managing the transition to biorefineries by an accompanying 'transition management' project.

The quest for a multi-level, multi-actor learning process

Since biorefineries are supposed to contribute positively to a change towards more sustainable production systems, and since they seem to foster regional development in Austria, there are a number of arguments why governmental actors could be interested in stimulating this technological development, both by extensively funding R&D and by initiatives in other policy areas. However, recent developments in innovation research and the analysis of technology policy have emphasised, that such measures fail more often than succeed. The reason is seen in the fact, that they underestimate the complex nature of technological innovations and resulting changes at a systemic level. The success of such change processes is highly dependent on the capacity and appropriate strategies to manage the co-evolution of technological change along with new use practices, the reconfiguration of actor networks and institutional changes. Changes towards more sustainable production technologies such as 'green biorefineries' thus can best be understood as gradual transformations of socio-technical systems. Such 'socio-cultural transitions', are often defined as long-term processes that can stretch over several decades and finally result in changes in the socio-technical landscape in the wider sense[9].

From a policy perspective, the understanding of transitions raises 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?

As the case of biorefineries illustrates, uncertainty, ambiguity and complexity of future developments prevent any attempt to plan the future in a linear fashion. Consequently, policy cannot aim at central planning and realisation of future development paths. However, policy may focus on the conscious implementation of structures and on the facilitation of collective processes for the support of long-term transitions. In order to integrate the distributed intelligence[10] required for the development of biorefineries (in research, industry, agriculture etc.) a multi-level and multi-actor learning process in society needs to be initiated. Involving a broad range of actors helps to improve the co-ordination and coherence of their behaviour. An adequate approach to policy and any methodology for such processes therefore should provide for the development of shared problem perceptions, common guiding visions and overarching strategies. These elements should increase the possibilities of a convergence in the decisions and actions of the different actors and thus of a successful 'transition' in terms of certain policy goals such as the development of sustainable production systems.

[9] See for further details Rip and Kemp 1998 and for an extensive case-study Geels 2002.

[10] See Kuhlmann 2001 for an introduction to the concept of distributed intelligence.

All these notions and prerequisites are condensed in a policy approach called 'transition management' (TM) (see e.g. Rotmans et al. 2001). On its basis, a methodology has been developed, mainly in the Netherlands, which aims to provide the necessary framework conditions for such collective learning and co-ordination, and to stimulate processes of anticipating and formulating long-term perspectives that can serve as an orientation and focusing device for the range of actors involved (Elzen et al. 2002). Both, the policy approach and the derived methodology, have served as conceptual starting points and inspirations of the accompanying project on R&D-policy for biorefineries described in the following section.

4.3 Anticipating system change: An attempt to integrate R&D efforts

The project 'Transition towards sustainable production systems' has been set up as a 'strategic accompanying project' to gain a better orientation on how to manage such transition processes and improve the strategic orientation of the programme 'Factory of Tomorrow'. It uses scenario methodologies as a tool for supporting technological change towards sustainable production systems.

The joint development of scenarios by a multitude of actors in the form of visions and the development of transition paths aims to create a common orientation for the participants and thus to increase the coherence of the R&D-efforts within and beyond the programme 'Factory of Tomorrow'. The scenarios shall furthermore support the development of concrete policy options both for technology policy and other policy areas.

In terms of methodology, the objectives of the accompanying research project have been defined as follows:

- To experiment with new methodology of scenario based R&D strategy development, that are adequate to the notion of socio-technical transitions
- and to assess the potential of these methods to improve steering capacities of R&D policy and sustainability governance in general.

In terms of policy support, central tasks were:

- to support strategy development regarding R&D policy and its coordination with other relevant policy areas,
- and respective community building

Such accompanying and applied research is inevitably of a very hybrid character: the borderlines between scientific research, research strategy development, innovation support/ capacity building and policy development are certainly blurred[11]. In other words, they tend to be transdisciplinary in nature.

It is even more important to note, that the project is perceived as an experiment by the Federal Ministry for Transport, Innovation and Technology (BMVIT). Though the project formally has the same status as other research projects of the programme, the following aspects signal a high attention paid to the project by the ministry. As mentioned earlier, a board of advisers has been installed to supervise and support the project advance. This board is staffed by the ministry, members of the (outsourced) programme management, members of the Austrian

[11] Such heterogenous objectives on a multitude of levels hold the danger of conflicting role models for those carrying out such projects, having to be researchers, facilitators, somehow evaluators and policy advisors at the same time.

Research Council and an external expert serving as an advisor to the programme and as a the head of the project selection committee.

The results of the project are expected to primarily provide a *methodological* orientation and – focusing on case studies such as biorefineries – explore *transition paths for selected thematic fields* that are of potential relevance for the future development of R&D policy with regard to sustainable production.

'Transition fields': Delineations at the optimal level of policy coordination

The complexity, diversity and interconnectedness of production-consumption systems raises the question what objects to address with R&D policy.

RTD programmes such as "Factory of Tomorrow" tend to address very specific projects and technologies. One of the crucial challenges of applying transition management approaches to such R&D programmes appears to be the identification of appropriate intermediate levels of analysis (and policy!), which link broadly defined functional transition fields with specific technologies and technological research issues. For such intermediate levels useful conceptual building blocks are still lacking in the transition management discussion.

It is important though, that 'transition fields' are identified at an intermediate level of concreteness, between broad needs areas (such as 'transport' or 'shelter'), normative goals (such as sustainability) and concrete technical experiments and solutions. Our case study on green biorefineries is situated at such an intermediate level which already exhibits systemic interactions to be addressed in the transition process while at the same time linking specific technologies with specific 'needs areas' in a field which is small enough to be effectively addressed by a RTD programme like "Factory of Tomorrow".

In principle, transition fields can be categorised in several different ways. They can be described in terms of different functionalities they address, in terms of policy arenas or in terms of networks or industrial branches. Especially in the case of manufacturing a sectoral differentiation can be useful (at least in some cases) 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. Thus it should be noticed that usefully delimited transition fields can also be constructed around branches (the paper industry) or resource bases (biomass use).

Some fields like 'pharmaceutical production' are readily constituted as 'policy fields' on the different levels of governance. A bit more subtle, some fields are organized semi formally as technological fields or fields of interest. Thirdly, transitions can evolve from the interaction of actors on different levels of socio-technical systems that relate to certain visionary models and concepts or guiding principles (see {Gleich, Haum, et al. 2004 #6461}). This is the case with the concept 'biorefinery'.

4.4 The scenario methodology

One of the main aims of the accompanying project is to develop a level of reflection beyond the individual projects within the programme by involving programme participants (programme managers and project partners) and other stakeholders (firms and interest groups) in a scenario building exercise. 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 anticipating systemic effects of individual strategies the process thus shall lead to increased coherence of individual actions and lay the ground for cooperative strategies and policy support.

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 served to identify two transition fields to be subject to the scenario development process (see above). The status quo and current developments within these fields have then been explored by literature- and internet research and 15 to 20 in-depth interviews per transition field. It is essential to have a clear understanding of the transition fields and how they can be systematically represented in terms of the three levels of analysis (a. broad normative goal or need area, b. transition field and c. individual technological experiment).
2. **Scenario development:** The following scenario development process aimed 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 were collecting important factors of impact on the future of e.g. biorefineries. These impact factors were than combined in plausible impact constellations and effects called 'storylines'[12]. These storylines were then clustered in consistent families thus building the foundation of three different scenarios of 2-3 pages each [13], which were further elaborated and completed by the project team after the first workshop[14]. It was important to ensure that each of the scenarios could 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 results were sent to the participants, who discussed and further specified them at the beginning of the second workshop.
3. **Sustainability assessment of scenarios:** The scenarios differed of course in terms of their overall sustainability orientation. This was intended and is useful with regard to the deduction of policy perspectives, because it allows to discuss further on how to move towards sustainability even under detrimental conditions. The 'normative phase[15]' started with the selection of the most important criteria for an assessment of the sustainability potentials of the scenarios[16]. These criteria were negotiated among the participants[17] on the basis of a pre-selection provided by the 'Technology assessment study on green biorefineries' (Schidler 2003), which itself related to the categorisation of sustainability

[12] One such storyline for example read: 'The industrialisation of milk production in Austria is likely to further reduce the use of green land for grazing, resulting in the succession of woodlands.' Another read: 'High political support of biogas production and respective financial incentives are likely to narrow the biomass feedstock left for biorefineries'.

[13] This methodology could be named 'inductive' or 'bottom-up' scenario development as opposed to the top down deduction of scenarios from a variation of two or three main factors. , the way in which the well known Shell scenarios on the future of energy consumption and others were developed (Van der Heijden 2000)

[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.

[15] Naturally, the explorative and normative elements of these phases cannot be completely separated, for example, SOME normative bias can not completely be ruled out during the 'explorative phase'.

[16] Which was necessary, because the programme does not provide an operational definition of what is 'sustainable production' that could be applied on the scenarios.

[17] Some participants had difficulties to accept this distinctive normative approach of the project, arguing from a fundamental position in favour of 'hard forms of sustainability' (will something allow mankind to survive or not) instead of comparing scenarios against relative sustainability criteria. This might have been eased by clarification beforehand. However the difficulties of such participatory exercises relating to the term 'sustainability' should not be underestimated.

principles suggested by the Helmholtz Society (Coenen 2002, Grunwald Armin et al. 2001). Six criteria were prioritised: 1) economic feasibility, 2) creation of value within regions 3) intensification/ extensification of agriculture, 4) overall energy consumption, 5) preservation of landscape, and 6) participation of rural population. On the basis of these groups of criteria the participants compared the three scenarios and identified positive or problematic aspects with regard to sustainability.

4. **Identification of critical developments and actions:** Also within each of the scenarios, key terms and conditions could be identified which are critical for the future sustainability of the production system. In addition to these key issues, further needs for actions have been pointed out which seem decisive for the realisation of the scenarios and for sustainability potentials. A special focus has been put on a research agenda and adequate support and network structures.
5. **Policy analysis** draws on these considerations in order to identify potential intervention points with respect to which 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.

On average 50-60 people from relevant research institutions (most of which are involved in projects of 'Factory of the Future'), industry and other stakeholders such as relevant financial institutions and government bodies have been invited to the workshops. In the case of biorefineries only 8-15 people participated, which was a first indication of the lack of dedication of both research and industry to this issue. The group was rather dominated by researchers who represent the core community relating to biorefineries in Austria, thus reflecting that the technology is still in a comparatively early stage of development. Consequently, a major interest of the participants was the linking up with representatives of complementary fields, especially policy making and financing. The workshops however, could fulfil the function of bridge building between different communities only to a limited extent. There are indications though, that the scenario process could have served much more as a catalyst if the mandate and the project budget had been larger.[18]

[18] By anonymously filling out a questionnaire after the third workshop, seven participants stated uniformly that they considered the format, methodology and organisation of the workshops as being adequate, but that three days are too big an effort especially for commercial parties. A refund of expenses would probably have eased this barrier at least partially. Also time and money for intensive networking beyond the R&D community was not available within the projects budget. Sporadic participants in the workshops mentioned as one reason for giving them low priority that they did not perceive nor expect a strong commitment of the ministry to change governance in accordance to the projects results.

4.5 Outcomes of the scenario process

A) The main product: Three Scenarios

As a product of this process, images of possible futures regarding biorefineries and crucial bifurcation points in such developments especially with regard to sustainability have been described and may be useful to several actors in the future.

The first scenario called **'Made in Styria'** features conditions for the close cooperation of regional actors (local industry, farmers etc.) realizing a decentralised form of biorefinery adapted to regional conditions, strongly supported by active and integrated policies in favour of sustainable agriculture and substitution of fossil resources.

The second scenario named **'Big players push for biorefineries'** suggests that trans-national companies could adopt the concept at a large scale: They could invest in own R&D efforts, realize big scale centralized plants and would probably buy standardized biomass at low prices from agriculture in the wider region as well as from the international market.

In the third scenario, **'In the succession of bioenergy'**, the production concept of biorefineries is realized as a consequence of developments in the energy system: Due to the widespread operation of bioenergy plants (biogas and biomass combustion) and respective infrastructures, the separation of specific biomass fractions to be processed in biorefineries for the use as chemical feedstock and use of the remaining biomaterial for energy generation could be achieved at very low additional costs.

Although uncertainty about future developments remains very high, the scenarios at least document possible starting points for harnessing the sustainability potentials identified by the actors. In the future, they may serve as a joint reference system for the diverse actors involved in this issue. Furthermore, such scenarios might provide a background for research strategies towards sustainability, ranging from a broad range of exploratory and more ground-laying research projects to applied research pilot actions.

Finally, the scenarios will help the programme management of 'Factory of Tomorrow' and the project selection jury to prioritise research fields and activities by building a conceptual bridge between highly general guiding visions and very concrete projects within the research programme, and by providing a background of plausible developments and crucial bifurcation points, which have been jointly identified by a range of actors.

B) Effects of the interactive scenario process

The actors involved in the scenario workshops modified their views on the subject during the exercise e.g. with regard to the probabilities of certain framework conditions, research priorities and strategies for the promotion of biorefineries. The scenario process stimulated new debates about long-term perspectives for the transition field of biorefineries. By giving them an opportunity to reflect upon the contribution and conditions required for success of their projects, the process facilitated second-order learning effects. A rising awareness for critical framework conditions and necessities for a successful development of biorefineries in Austria could be observed. The participants stated that it was the first opportunity for them to develop such detailed images of the future and assess strategic action with regard to these scenarios. Although it was a rather homogenous group of people, the scenario process was a novel opportunity to exchange views that had not been exchanged before.

As discussed above, the scenario building process was only partly successful in enabling interaction between researchers and other actors external to the R&D-programme, as only few corporate actors and actors from other policy fields participated in the workshops.

C) Policy recommendations

Working out policy recommendations on the basis of the scenario process has not been completed yet. Furthermore, it has to be kept in mind that the responsible ministry (BMVIT) funded the scenario development process as an experiment to assess the usefulness of such exercises for a better priority setting in R&D programmes. It still remains to be seen, whether outcomes of the scenarios will actually be taken up by the research administration.

However, it can already be noticed, that the broader picture provided by the transition scenarios has opened up new perspectives for the further development and the research priorities of the 'Factory of Tomorrow' programme, which aimed to initiate transition processes towards sustainable development from its beginning.

5 Conclusions: Austrian experiences with integrative (R&D-) governance in favour of sustainable production

As the described accompanying project goes beyond the established practices, approaches and institutions in Austrian technology and innovation policy, it is useful to look at the specific barriers these experiments were confronted with, taking into consideration the specific governance context in which 'Factory of the Future' was designed and implemented. Although the specific process described here has to be seen as a rather isolated experiment within the Austrian context – rather happening in the shade of the governmental R&D policy than driving it – some conclusions about the applicability and pitfalls of the concept of reflexive governance can yet be drawn.

We thus come back to the questions of our introduction:

- To what degree do measures, strategies, and policies need to be transcending policy fields and spheres of power?

- To what extend is policy integration supported by the current Austrian policy context?

The need to embed Austrian sustainability and R&D policies in the EU context (vertical coordination)

During the scenario development process, actors realized some interdependencies that sound obvious but have not been spelled out before. The innovation of biorefineries and any local and national strategies aiming at their support rely heavily on

a) adequate EU policies in the fields of agriculture and the use of resources (which currently are both under fundamental revision),

b) the need to embed national RTD policy initiatives in European agendas in order to enhance their effectiveness, and

c) a supportive framework in several fields of national and international economic policy (namely policies on industrial-, structural-, and regional development).

Especially when thinking ahead in terms of scenarios, it became evident that several of the assumptions regarding the feasibility of biorefineries relied on a continuation of specific elements of the current Common Agricultural Policy (CAP), with its specific subsidy framework. Targeted initiatives in Austria, for instance regarding specific subsidies for biofuel crops, can not be regarded in isolation. At a ten years time horizon, however, it is quite likely that the rules of the game of the CAP will change, not the least as a necessity of the enlargement process. However, biorefineries could profit from a shift towards subsidies of energy crops, landscape preservation or sustainable production methods in agriculture, compared to the present subsidies of prices of agricultural products. In any case, policies for

the promotion of biorefineries have to be closely integrated with such developments of European agricultural policy.

European RTD policy has acquired an important lead role for orienting national RTD policy initiatives. This is particularly true for small countries like Austria that seek to complement national funding by European funding. Without a concerted effort by several Member States to move biorefineries as an issue on the European policy agendas, isolated national initiatives have to remain limited in terms of their impact.

Similar arguments hold also for wider economic policy issues, ranging from tax policy (e.g. regarding internalisation of external costs) to structural funds and their role for defining appropriate framework conditions for biorefineries. Also European industrial policy, be it under different titles, matters because biorefineries are not carried by an established industrial constituency like the chemical or the energy industries and thus often escape the attention at European level.

The transition management approach provided means to define overarching transition strategies for the field of biorefineries that take these aspects of vertical policy coordination into account, e.g. by identifying complementary policy measures or requirements needed to enable and strengthen R&D strategies to support biorefineries.

The scenarios thus made clear once again, how important it is to anticipate policy developments and research activities on the EU level when designing Austrian policy and research agendas - and how contingent any local development may be due to these manifold interdependencies.

The need of coordination within Austrian science, environmental and economic policies (horizontal integration)

These experiences strongly support current attempts to re-integrate the rather fragmented Austrian science and R&D policy. It is increasingly accepted that research for sustainable development is a cross cutting issue that needs to be addressed in inter-institutional cooperation. Stimulated by the Austrian Council for Science and Technology Development, an attempt has been made recently to better coordinate the research initiatives on sustainability in different ministries under an umbrella programme called 'Research for Sustainable Development" (FORNE- Forschung für Nachhaltige Entwicklung) (Paula et al. 2004).

Also the recent integration of funding bodies for applied research into the so-called "Forschungsförderungsgesellschaft FFG" improves the perspectives for better coordinated R&D programmes covering the full range of initiatives from applied research to diffusion-oriented measures. It seems unlikely still, that this institutional initiative at the level of funding bodies will be sufficient to erode the "Chinese walls" between departments and ministries, and thus lead to a better coordination of the guiding policy strategies in different policy fields (e.g. industrial & environmental policy). However, such a coordination could induce systemic transitions towards sustainable production systems either in a top-down manner or be more responsive to bottom-up initiatives transgressing interdepartmental boundaries. A better coordination of research funding initiatives can thus be a first step, and one that matters a lot for research performers like firms, universities and research organisations. A better coordinated research and technology policy strategy could then be a next step. If it is pursued on the basis of a long-term strategy of making technologies like biorefineries competitive, it might help create sustainable technology niches that could finally drive transition processes.

Experiences with tapping different domains of knowledge for policy making

Most of the funded research projects within the programme 'Factory of Tomorrow' do not specifically support integrated knowledge production. They tend to be very specific and of a predominantly technical, problem-solving nature. However, a strong emphasis has been put in the programme design on the cooperation of research institutions with commercial partners, based on the expectation that they will jointly develop marketable 'sustainability solutions'. These two realms however are not sufficient from the perspective of socio-technical transitions, comprising also end-users and policy makers to name just two.

The scenario building process actually showed two things at the same time: first, it clearly demonstrated how widely distributed the capacities are that are needed to realize concepts like biorefineries; and second, it became clear how difficult it is to mobilize these actors for joint efforts of strategy development and implementation (i.e. how demanding in terms of time, money and legitimacy).

With the call for accompanying projects, an explicit attempt has been made to add a more process-oriented meta-level of reflection to the programme and to draw on insights from the social sciences. A further important step on this road would be to make a broader strategic perspective and higher standards of inter- and trans-disciplinary co-operation a precondition for the funding of projects, thus pushing R&D actors stronger than now towards integrating important stakeholders in their R&D-activities.

The accompanying project itself was going a long way to achieve trans-disciplinarity in the process of knowledge production. The scenario exercise was intended to integrate the views of all relevant actors along the product chain of biobased production as well as the expectations of members of government with influence on support schemes and framework conditions – by constructing a shared image of the system, its elements and interdependencies.

As discussed above, the participation in the process was limited for several reasons. The lack of commitment on the side of government has been identified as a crucial stumbling block in this regard. However, this is also due to the set-up of the project, which - as a research project - has not been jointly developed or agreed upon by different government departments and has not been adopted (or even been recognised) at a sufficiently high policy level. The possibilities of departments or individuals within government to get actively involved in trans-disciplinary knowledge production are limited and have to be seen in the wider context of the concepts of governance which are hegemonial within a certain government, department or political party.

However, the described scenario process had an important function as an experiment with integrated knowledge production. If the results (despite the limited participation) were meaningful to members of government, the latter could use them as a case of reference for internal lobbying in favour of more such exercises with increased government support.

The need for coherence in prioritisation and resource allocation (internal policy coordination)

Many participants were strongly putting forward that 'Factory of the Future' was perceived as too broad and unfocused for its limited size (the budget of the years 2001 to 2004 was 11 Mio Euro). And indeed, the perspective of Transition Management particularly raises the question of a minimum size and duration of R&D funding measures in order to be effective for inducing a sufficient impulse for system changes. The analysis of 'transition fields' (such as the concept of biorefineries) to find an appropriate level to focus resources at might become a useful framework for designing R&D policy strategies in the future.

What also became very obvious in the scenario process is the fact that the establishment of networks of heterogeneous actors for mutual learning exercises can be very time consuming. In order to get all crucial actors involved, such processes need to be designed in a mid to long term perspective and require sufficiently stable framework conditions for at least five to ten years.

The experiences made in the scenario process with regard to participation lead us to conclude that R&D-policy can only exert a major impact on long-term socio-technical transitions towards sustainable production in the context of a broad participatory process. Compared to these requirements, the resources for the experimental project on biorefineries definitely were not sufficient to trigger anything like a transition process. Further and more substantive steps would be needed to initiate joint and coherent efforts of the different parties involved.

Conclusions on process and methodology: A first step towards policy coordination?

Although the described experiment was conducted in a challenging context with regard to policy integration, it has shown promising results and perspectives for further refinements of the programme 'Factory of Tomorrow' and the development of more integrated programmes and R&D policies. After all, the notions of 'socio-technical transitions' and 'transition management' have proven to be very productive for creating greater coherence among the actors representing singular research projects, industrial investment and public policy, especially in the process of participatory scenario development.

Furthermore, we believe that the participative development and assessment of socio-technical scenarios on such promising and yet ambiguous issues such as biorefineries could help overcome a too technical orientation in many other research programmes aiming at sustainable development too. In general, the consideration of integrated transition strategies seems to be a very promising element of R&D programmes enabling them to create closer links between technical development, social and organisational changes, and policy making for sustainability.

With respect to policy coordination it has to be emphasised that the project in the first place was designed as an experiment trying to involve different types of actors – from policy, industry, research and stakeholder organisations – in a process of joint scenario development. This brought up several issues and mechanisms that determine the possible future pathways biorefineries may take. Policy coordination in its different forms turned out to be a crucial factor and the lack of it can be regarded as an actual barrier to stimulating the development and uptake of biorefineries. Pointing out the need and identifying areas for better policy coordination thus certainly was on of the main strengths of the approach taken.

However, even though insight into such mechanisms is fine, it does not change a lot as long as these issues are not taken up by policy. Although a process like the one described in this paper is helpful for shaping the mindsets of people and identifying issues, barriers and possible individual and collective strategies, it is obvious that policy coordination cannot be achieved by such comparatively "low key" initiatives. In order to make them effective it would be necessary to give them a clear mandate and political backing. This in turn would first of all require the political will to actively improve policy coordination, a development that seems to be slowly emerging in Austrian RTD policy.

Therefore, in spite of its supposedly limited impact on actual policy and policy coordination, the project conducted may well serve as a first "showcase" giving evidence of some of the benefits that can be achieved by transition management-inspired participatory processes.

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