Passive houses in Austria: the role of intermediary organisations for the successful transformation of a socio-technical system

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Abstract
In Austria, the first passive house was built in 1996. Since then the market for passive houses has rapidly increased. Statistics show that there were more than 4000 residential units with about 10,000 passive house residents at the end of 2006 – more per capita than in any other country of the world. Sustainability requirements, however, have led to profound shifts in the need for collaboration between the actors involved in planning, constructing and using buildings.

This paper draws on a qualitative case study to analyse the development and dissemination of passive houses in Austria by focussing on the role of intermediate organisations. Empirically, the paper is based on qualitative interviews with representatives of relevant organisations as well as the analysis of various documentary sources.

The case study shows that new types of buildings, such as 'passive houses', have given rise to new actors and organisations to organise integrative planning processes, to set standards and market the passive house concept, to certify components, to transfer knowledge to professionals, to assist consumers in choosing architects, installers and technologies or to organise participation processes. New interest organisations mediate between producers and the policy level, energy agencies act as system builders to transfer these new technologies and practices into the mainstream building sectors, etc. Intermediation processes fulfilled by a broad range of organisations turned out to be of crucial importance for the coordination and shaping of the socio-technical system.

Introduction
A significant proportion – up to 40% – of the energy consumption of industrialised societies is caused by the operation of buildings, i.e. heating, cooling, lighting, use of various electric appliances. This energy is used in an extremely inefficient way by the existing building stock, which leaves us with enormous and often cost-efficient potentials to reduce our overall energy use and as a consequence significantly reduce greenhouse gas emissions. Even without the use of sophisticated and advanced technologies an efficiency improvement by a factor of 10 compared to the total building stock and at least a factor 5 compared to current building codes and design practices for new buildings can be achieved without considerable rises in building costs.

While the innovation behaviour of the construction sector (especially residential buildings) has long been regarded as conservative and rather slow in the uptake of new technologies and processes (see e.g. Nam & Tatum 1988, Pries & Janszen 1995, Toole 1998) the sector is increasingly coming under pressure. On the one hand new technologies are changing design practices (e.g. design and simulation software) and the organisation of the construction process (e.g. increasing prefabrication of components while at the same time maintaining a high flexibility to adapt products to customer and site demands), on the other hand the pressure on environmental and energy efficiency standards as well as the implementation of the EU directive on the energy performance of buildings increases and requires a re-organisation of current building practices. Higher environmental standards require a higher systemic integration of the building: efficient ventilation systems with heat recovery e.g. require an air-tight building envelope; 'intelligent' handling of solar radiation and heat loads within the building requires specific design features; characteristics of building services, design of building structure, properties of building envelope have to positively interact if energy efficiency potentials are to be harnessed. The focus of such types of innovation is not so much on new technologies but rather on so-called architectural innovations (Henderson & Clark 1990), i.e. new combinations and interrelations of components. However, such integration cannot merely be achieved at the technical level, but requires socio-technical integration such as a closer collaboration of companies and professionals involved, new competencies, regulations, communication structures etc. What is needed thus is a process of profound socio-technical change in the building sector, change that encompasses technologies and social practices alike.

For environmental (energy/climate) policy the crucial question is, how it is possible to facilitate such sectoral transformation processes and direct them towards desirable outcomes, in our case towards construction practices resulting in energy-efficiency, low material consumption and economic affordability of buildings. Obviously, the governance of sectoral transformation processes involves complex coordination tasks, a situation which is aggravated by the fact that the construction sector (just like other sectors) is not centrally and hierarchically organised but depends on the interests, power and strategies of a multiplicity of actors.

As we will point out in more detail below, socio-technical transformation processes usually start in limited market or technological niches or generally in emergent new socio-technical constellations, which eventually may radically transform existing practices at a broader scale. In the case of buildings, the evolving niche of highly energy efficient passive houses seems to have the potential to profoundly transform existing construction practices – at least in countries like Austria. However, in other countries similar concepts, such as carbon-neutral buildings in the UK, exist. Passive houses in Austria are a well-suited example to study transformation processes in the building sector and factors, which contribute to a successful growth of this emergent socio-technical system.

In this paper we will analyse the development of passive houses in Austria over its first decades. In our analysis we will draw on different concepts from innovation studies and social studies of technology to be able to better assess the performance of this new socio-technical niche and identify potentials and challenges in the way this niche is organised as well as in its institutional contexts. The development and diffusion of passive houses by no means is merely a process of technological improvement and optimisation of construction processes, but profoundly is embedded in social and cultural contexts. Moreover, we will focus on a type of actors which is crucial to organise this change process, as new actors and organisations are needed e.g. to organise integrative planning processes, to set standards and market the passive house concept, to certify components, to transfer knowledge to professionals, to assist consumers in choosing architects, installers and technologies or to organise participation processes. New interest organisations mediate between producers and the policy level, energy agencies act as system builders to transfer these new technologies and practices into the mainstream building sectors, etc. Such intermediation processes fulfilled by a broad range of organisations turn out to be of crucial importance for the co-ordination and shaping of the socio-technical system.

Before engaging in more depth with our case study analysis we want to set out some hypotheses and conceptual background regarding the development of new socio-technical niches, the role of intermediary organisations and generally the establishment of new socio-technical practices.

Niches, innovation systems and intermediation processes as basic concepts to understand the socio-technical development of passive houses

SOCIO-TECHNICAL NICHES AND INNOVATION SYSTEMS

Transforming the construction sector towards sustainability certainly is not a straightforward process of developing new technologies or designs. In order to establish new and sustainable construction practices a growing number of actors has to be aligned to this new concept, new institutions have to be established and institutional contexts modified etc. In the context of science and technology studies there are three related concepts which try to better conceptualise the establishment and growth of new socio-technical constellations such as passive houses: the concept of niches and their strategic management, the concept of bounded socio-technical experiments and the concept of technological innovation systems.

Especially the niche concept has to be seen in the context of a multi-level model of innovation. The multi-level perspective of socio-technical transitions distinguishes socio-technical transformation dynamics at different levels of aggregation: a micro-level of niches (technological projects, emerging technologies, e.g. early passive houses) as a source of variety and an 'engine for change', a meso-level of regimes understood as "semi-coherent set of rules" (Geels 2004, 904) (such as the construction regime) providing stable structures and a selection environment for innovations and a macro-level of socio-technical landscapes as slowly changing socio-technical contexts at the level of societies (Rip & Kemp 1998). A strength of the multi-level perspective lies in explaining the resistance to radical innovations due to the stability of regimes as a rule set or grammar that structures and coordinates both actors and technologies within functional subsystems of society on the one hand and on the other hand in providing a concept for the success and dynamics of radical innovations as regime transitions following pressures on these regimes by evolving niches (Weber & Hoogma 1998) or changes at the landscape level (Geels & Schot 2007). In a 'normal' case, niches do not gain enough strength to transform regimes. However, there are certain patterns which can be observed, when niches contribute to radical change (Geels 2002, 1271-72): several niches can cumulate and gradually transform a regime, niches can link up with established technology as technological add-on or hybridisation, or niches can break out of their confinement by 'riding along' with the growth of a particular market. In our case study on passive houses we will focus on such processes through which niches can substantially impact on existing regimes.

Strategic niche management (see e.g. Hoogma et al. 2002) refers to the creation and nurturing of protected spaces (e.g. market niches, controlled field experiments) to broaden the design process by involving a broader range of actors and facilitate interactive learning of the actors participating. A central aim of the development of niches is to learn about needs, problems and possibilities connected with the environmental innovation experimented with, and to help articulate design specifications, user-requirements or side-effects of the innovation. Managing the development of environmental technologies in niches (and finding the right timing to open these niches to the wider market and competition) certainly is one of the more advanced and reflexive forms of managing environmental innovations and technologies by organising social learning process involving producers, technology designers and users in a joint process. This focus on conscious experimentation and learning is shared by the concept of bounded sociotechnical experiments (see Szejnwald Brown et al. 2003; Szejnwald Brown & Vergragt 2008). Socio-technical experiments are "driven by a long-term and large-scale vision of advancing the society's sustainability agenda, though the vision needs not be equally shared by its participants. Its goal is to try out innovative approaches for solving larger societal problems of unsustainable technologies and services" (Szejnwald Brown & Vergragt 2008, 112).

The internal structure of niches remains rather vague and the focus rather is on the interactions between niches and regimes. In contrast, the concept of technological innovation systems (TIS) (Carlsson & Stankiewicz 1991) is putting more emphasis on the structure of TIS, i.e. the actor networks, institutions, knowledge base and its external blocking and inducement mechanisms (Johnson & Jacobsson 2001). As it is related to a specific technology base, a TIS can consist of market niches, projects and experiments and can be local or global in scale (see e.g. Hekkert et al. 2006). Technological innovation systems are internally defined by technologies, actors, institutions and their relationships and dynamics. Research on TIS mainly concentrates on specific functions (or activities), which are important for the growth and performance of TIS, as well as on blocking and inducement mechanisms – often of an institutional type – as the influence of the TIS-environment. Typical functions of "emerging" innovation systems are (Bergek et al. 2008):

- Knowledge development and diffusion
- Influence on the direction of search (visions, expectations; regulation and policy; articulation of demand)
- Entrepreneurial experimentation (experiments in new applications and technologies)
- Market formation (development of niches and, learning spaces'; user involvement; etc.)
- Legitimation (social acceptance and compliance with relevant institutions)
- Resource mobilisation
- Development of external economies, free utilities', variety, etc.

Our aim in the empirical part of the paper will be to analyse the growth of the socio-technical system of 'passive houses' before the backdrop of these concepts: as a series of small-scale socio-technical experiments, as a managed niche challenging the existing construction regime, and as an emerging and growing technological innovation system gradually establishing actor networks and institutional relationships to fulfil the functions identified in the TIS-literature as a prerequisite of successful expansion.

INTERMEDIATION AND COORDINATION

Now let us turn to our second focus of analysis. The management of niches, the set-up of socio-technical experiments and facilitation of social learning processes, the provision of innovation-system-functions such as search orientation, legitimation, resource mobilisation etc. all require organised efforts of coordination, facilitation or governance. Such type of change processes are usually characterised by an absence of a central steering power (though there are certainly often significant differences in power between actors involved), by long-term orientation and a context of uncertainty.

They thus require actors, which mediate between the different groups involved: between users and producers, producers and policy, research and production or within the group of technology and product developers and suppliers constituting the niche or innovation system. As Moss (2005, 24) summarizes, intermediary functions include activities such as adapting technologies to contexts of application, translating knowledge into new products and services, connecting people, building networks, lobbying and advocating reform, or raising awareness and broadening perceptions. These functions are provided within four basic organisational forms: bridge builders (facilitating dialogues etc.), 'info-mediaries' (disseminating information etc.), advocates, and entrepreneurs (innovators and 'eco-preneurs').

The management and transition of socio-technical systems towards sustainability can be improved by a systematic support of mediation processes and different types of intermediary actors. A better understanding of new types of intermediation in socio-technical change, of the roles intermediary actors play in these processes and of the supportive conditions for intermediation, will help us to develop more appropriate strategies to support socio-technical transitions towards sustainability. The socio-technical niche of passive houses is an example of such a socio-technical change process towards sustainability, which has the potential to ultimately transform the whole sector of house building.

In the following sections we will analyse the development of passive houses before the background sketched out above: passive houses as an emerging socio-technical niche or innovation system and the role intermediary actors play in facilitating the growth of this niche. With this type of analysis we hope to better understand the socio-technical processes involved in the development of passive houses and to identify requirements and opportunities to turn this niche into a mainstream practice of constructing buildings.

Table 1. Passive house standard requirements (Source: Passivhausinstitut 2009)

Area	Requirements
Space heating requirement	The building must not use more than 15 kWh/m² per year in heating energy
Air tightness	With the building de-pressurised to 50 Pa (N/m²) below atmospheric pressure by a blower door, the building must not leak more air than 0.6 times the house volume per hour
Total primary energy consumption	Total primary energy consumption (primary energy for heating, hot water and electricity) must not be more than 120 kWh/m² per year
Specific heat load	The specific heat load for the heating source at design temperature is recommended (not required) to be less than 10 W/m²

Case study on Passive Houses

PASSIVE HOUSE AS ENERGY STANDARD FOR BUILDINGS

A "passive house" is a building that meets a specific energy standard (see Table 1). The original concept for this standard was developed by Bo Adamson from the University of Lund (Sweden) and German physicist Wolfgang Feist from the Institut für Wohnen und Umwelt (Institute for Housing and Environment) in the year 1988. In the 1990s the concept was developed through a number of German research projects. The first building according to the passive house standard was built in Darmstadt in 1990 (Passive House Kranichstein). This building, a four-unit row house, was both regularly used by homeowners as well as a research and demonstration project (Feist 2006).

Passive houses need about 80% less heating energy than new buildings designed to the standards of the 1995 German Thermal Insulation Ordinance. The standard has been named "passive house" because the passive heat inputs – delivered externally by solar irradiation through the windows and provided internally by the heat emissions of appliances and occupants – essentially suffice to keep the building at comfortable indoor temperatures throughout the heating period. But it is also a part of the passive house philosophy that efficient technologies are used to minimize the other sources of energy consumption in the building, notably electricity for household appliances. The overall energy demand in a passive house is lower by at least a factor of 4 than the specific consumption levels of new buildings designed to the standards presently applicable across Europe (Passivhausinstitut 2009). As the standard focuses on energy consumption only, several initiatives to discuss and extend the passive house standard in the wider context of sustainability – covering aspects like ecologically rated constructions, resource consumption, indoor environmental quality or quality of service – have been launched over the past years (Schuster and Lipp 2001; Waltjen, Pokorny et al. 2008).

The "passive house" standard can be met using a variety of technologies, designs and materials. However, designing a passive house means to consider the following construction principles (Passivhausinstitut 2009):

- Maximizing passive solar gain: using windows with low-emissive triple glazing and super-insulated frames, main glazing areas are oriented to the south and are not shaded;
- Using super-insulation: exceptionally good thermal envelope, preventing thermal bridging and air leakage;
- Combining efficient heat recovery with supplementary supply air heating (ventilation system);
- Using high-efficiency appliances only;
- Meeting the remaining energy demand with renewable energy sources.

Built passive houses show a variety of architectural stiles. While most of the realised projects feature characteristically eco-building attributes, like large southwards-oriented windows and reduced stylistic elements, in recent years also Passive houses that are hardly to distinguish from normal buildings have been built.

DISSEMINATION OF PASSIVE HOUSES IN AUSTRIA

Although in the beginning most of the passive house activities took place in Germany, the concept soon was adopted in Austria too. The first passive house was built in the province of Vorarlberg in 1996 by a private owner. In the year before, a first refurbishment-project aiming at passive house standard was completed in the same province (Lang 2004). More buildings in other provinces followed shortly after. Figure 1 shows the diffusion of passive houses in Austria since 1995. While in the second part of the 1990s the total number of buildings rose continuously on a low level it has significantly increased in the last years. Since 2004 the yearly growth ratios add up to more than 40%. At the end of 2007 there are more than 4000 residential units completed with about 10,000 passive house residents throughout Austria. Most of these buildings are newly constructed private single-family houses. Although the passive house standard has mainly been adopted in this sector, other types of buildings such as several larger residential buildings, office buildings, schools and kindergartens, and even a supermarket have been constructed according to the standard.

In comparison to the existing building stock and the absolute number of new buildings finished per year these figures are still small. Statistics show that around 4% of all new residential buildings in Austria have been constructed according to the passive house standard in 2006. However, according to estimates the share of passive houses could reach 30% or even more within the next few years. In some regions the share of passive houses is already clearly over the national average. The leading province in this respect is Vorarlberg with almost 14% share of passive houses of all new buildings in 2007 (IG Passivhaus 2009). Experts think that it is most likely that the passive house standard will leave its market niche and will become one of the leading energy standards at least for newly constructed buildings. The fact that the standard is specified in the subsidy schemes for residential buildings in six out of nine Austrian provinces serves as a strong argument for this prediction. In these provinces new buildings that meet the passive house

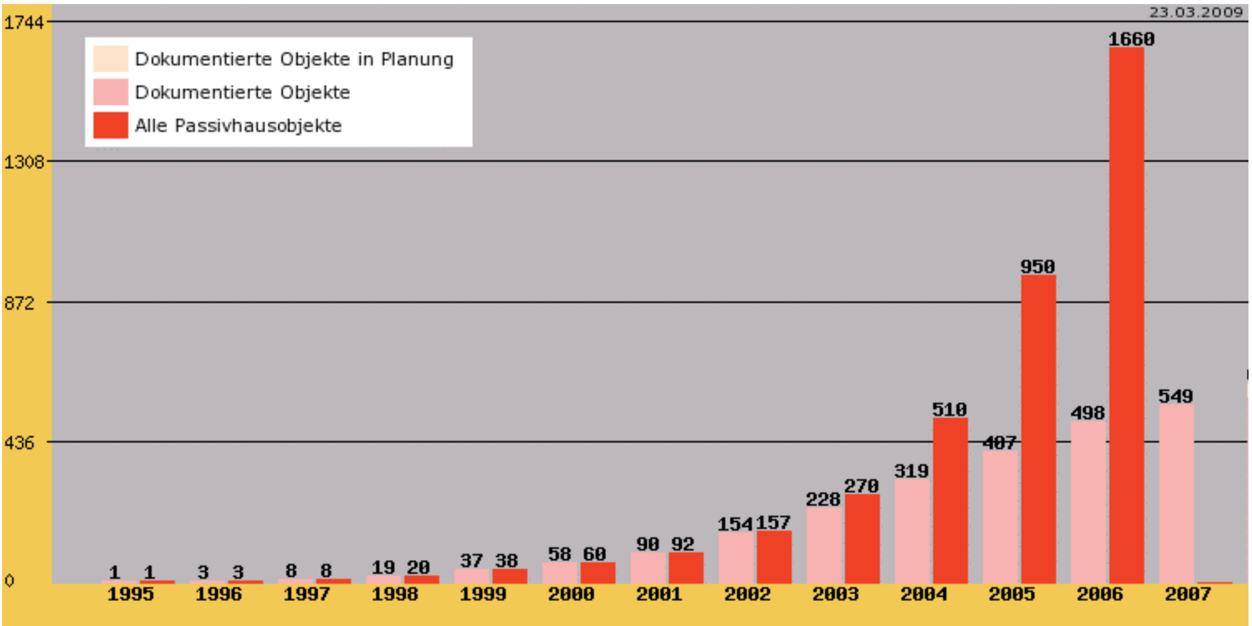

Figure 1. Dissemination of Passive Houses in Austria. (Dark red bars are number of completed passive houses) (Source: IG Passivhaus)

criteria already may expect to get up to 30% higher subsidies compared to low-energy houses. Moreover since 2007 in one of the provinces (again Vorarlberg) the passive house standard is obligatory for social housing projects. In the meantime the term "Passivhaus" is widely known by the informed public and in most cases perceived positively.

At the moment Austria is the worldwide leading country regarding the diffusion of passive houses. Compared to Germany, which is leading in absolute numbers, there are 2,5 times more passive houses per capita in Austria (IG Passivhaus 2009).

A BRIEF HISTORY OF THE PASSIVE HOUSE IN AUSTRIA

In this section we will describe the development of the passive house activities as a sequence of typical phases. Each of these phases is characterised by typical socio-technical arrangements – actors entering the market or coordinating activities, regulations and institutions being changed and set-up etc. – and each poses specific challenges for the further development and diffusion process. Based on interviews with passive house practitioners and available written documents the development of the passive house four such phases – each with typical activities – could be identified. The development of the passive house concept originally started as a scientific challenge. This early set-up phase was followed by a regional niche growth in the Austrian province of Vorarlberg. Based on instructive regional experiences the niche could grow to the national level. In recent years the socio-technical niche of the passive house increasingly becomes institutionalised and stable.

1. Early set-up phase (1988 – 1996)

In this first phase the main focus of all passive house activities was to establish an advanced energy standard by defining a set of criteria to be met and to demonstrate that the concept could work in practice. In the 1980s the passive house standard was only one idea to change the energy needs in buildings among others. The basic vision was to minimise the energy losses as far as possible. Most other concepts did focus on maximising active solar gains. Pilot projects of that time – like the "Jenni-Haus", Switzerland, or the Energy Self-sufficient Solar House in Freiburg, Germany – give evidence that it was a time of socio-technical variation with different competitive concepts.

In these first years Wolfgang Feist together with some colleagues from the Institute for Housing and Environment developed the socio-technical core (Weyer 1997) of the passive house concept. This socio-technical core consisted of the basic vision (minimize energy losses), threshold values and requirements for the Passive House energy standard and preliminary technological specifications and construction principles.

Early experiments with the first demonstration building in Darmstadt (Passive House Kranichstein) showed that the concept would work – at least under specific conditions (use of best available or yet to be developed technology, perfect integration of used technologies, consideration of some architectural rules). Based on extensive data collection at the demonstration building in Kranichstein and simulation models a software-tool for the design of Passive Houses was developed (Passive House Planning Package, PHPP). The development of the passive house concept and early experimentation took place in the context of the German 'Institut für Wohnen und Umwelt (IWU)' (institute for housing and environment), a publicly owned, interdisciplinary research institute which is also devoted to turn research results into practice in cooperation with various non-research partners. Like similar institutes the IWU took over the role of a research intermediary, coordinating the transfer of research ideas into practice, establishing pioneering actor constituencies, promoting certain concepts in public and at the policy level etc.

At the end and as a result of the set-up phase the Passivhausinstitut was established in Darmstadt (Germany) in 1996 as an independent research institution and as an intermediary specifically devoted to organising the further development and diffusion of passive houses. The institute offered consulting for architects and engineers, a certification scheme for passive houses and started to organize an annual international conference on passive houses. Although many technical and other problems were unsolved at that time the available research findings and practical experiences helped to stabilize the socio-technical core of the concept. Around this proved socio-technical core the institute could be established and dissemination activities could be started.

2. Regional niche growth (1993 – 1999)

While the passive house concept was just in development it was already adopted in Austria. This regional dissemination of the passive house was characterised by early projects almost exclusively situated in the province of Vorarlberg. And what is more important, those early-realised buildings had not been built for demonstration purposes but to meet regular habitation needs. Within only a few years a reasonable number of passive houses were constructed and regularly used[1]. This was possible by and resulted in a local passive house community, consisting of architects, energy consultancies, planners, producers of passive house technology (e.g. ventilation systems) and building companies.

In this phase the Energy Institute Vorarlberg (EIV)[2] served as the central change agent. The institute was responsible for the initial knowledge transfer from Germany, the dissemination of the concept in the region and it served as a platform for communication, cooperation and learning. Every new passive house project was documented and discussed at an annual summer school and similar meetings. Positive as well as negative experiences were not only disseminated within the local community but from the beginning this knowledge has also been connected to the developments in Germany. As a consequence, research on passive houses very early could build on a broader range of practical experiences and the other way round practitioners could profit from newest research findings. The EIV soon became a 'crystallisation point' for the emerging 'community of practice'.

As the EIV served also as a think tank for the regional government it was able to influence regional building policies. In Vorarlberg, building legislation and subsidies strongly supported low-energy houses and therefore the construction of passive houses.

The dynamic growth within this geographically small regional niche soon attracted attention. Architects from other Austrian provinces became familiar with the passive house concept and realised first buildings. This resulted in several private passive house projects in other provinces, which provided an important basis for the following phase.

3. Outgrowing the niche at national level (1998 – 2005)

Surprisingly the broadening of the passive house niche to the national level was mainly driven by research activities. Firstly, the EU-project CEPHEUS[3] stimulated the set-up of additional demonstration projects in several provinces. Secondly, one year later the national research programme 'Building of Tomorrow'[4] was launched. Both initiatives helped to improve and spread knowledge on passive houses on a national level and supported the dissemination of realised buildings significantly. Moreover the increased research dynamic stimulated new cooperation and the establishment of a national passive house research community. Important national actors from the building sector (solar energy architects, research institutes, companies, technology providers, etc.) and new intermediaries (consultancies such as Environmental Advice Centres) became involved in emerging research networks.

The national programme 'Building of Tomorrow' could also be seen as a national effort to integrate and homogenise different concepts of sustainable buildings. Contrary to the CEPHEUS project the longer and much larger research programme 'Building of Tomorrow' enabled and forced the integration of divers concepts like active solar, green buildings or passive houses. Through research the passive house energy standard also became a topic in the field of refurbishment and modernisation of the existing building stock[5].

At the end of this phase the knowledge about passive houses as well as the available technology has changed considerably. Today it is no problem to choose between several national sup-

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1. The local builder Richard Caldonazzi designed and constructed the first passive house in 1996. It became the first residential house without conventional heating system in Austria. The building was extremely well insulated (35 cm cork), equipped with special triple-pane glazing, a custom-built ventilation system and a solar water heater. As it turned out that the building concept worked very well in practice, the later called "Caldohaus" soon became an attraction for ecologically interested architects, energy experts, commercial builders as well as prospective building-owners. Till this day more than 3000 people had the opportunity to visit the Caldohaus in organised field trips – most of them organised by the EIV. In 1997 a five-unit row house project was completed. It was equipped with specially designed windows and a new type of ventilation unit combining a heat exchanger and a heat pump. This concept – although deficient in this first version – became the prototype for the so-called "compact device", the now best-selling ventilation system for passive houses in Austria. The first apartment house project aiming at passive house standard was constructed only shortly after. Just as the two smaller buildings before, this project offered extremely important learning opportunities too. In this project most tenants were extremely dissatisfied in the beginning. An evaluation showed among other things serious technical problems with the ventilation system. It also became clear that the quality of the windows would be extremely important in Passive Houses and that the main glazing areas have to be oriented entirely to the south to receive enough passive solar gains. This project showed that the average tenant would be much more critical and sensitive to problems than a highly motivated homeowner.

2. The Energieinstitut Vorarlberg (EIV) is an independent non-profit organisation based in the province of Vorarlberg. Founded in 1985 by the local government and major regional stakeholders, the EIV concentrates on the rational use of energy, renewable energies and ecological buildings. The institute offers training and consulting for private households, companies and communities, but it is also involved in some research activities and serves as an influential think tank for the local government.

3. CEPHEUS was the first trans-national research project on passives houses funded by the European Union. CEPHEUS – which is short for "Cost Efficient Passive Houses as European Standards" – was to learn more about ultra-low energy houses under different climatic conditions and to improve and promote the passive house standard in Europe. The project consortium consisted of Austrian, Swedish, Swiss, French and German partner organisations. Austria was able to contribute the largest number of projects (9 out of 14) as well as residential units (84). The Austrian examples covered a broad range of possible passive house designs, construction materials and building forms: Freestanding single-family houses, terraced houses and multi-floor apartment buildings built with solid, light or mixed building techniques (Krapmeier and Drössler 2001).

4. In 1999 the Austrian Federal Ministry of Science launched the first mission-oriented research programme on Technologies for Sustainable Development. The thematically focus of the first sub-programme was on sustainable buildings (called "Building of Tomorrow"). The aim of this programme was to develop and to promote the market introduction of components, construction elements and methods for residential and office buildings which conform to the guidelines for sustainable development. In the concept of the programme it was also stated that two contrasting building concepts would be regarded as starting points for further developments: the (active) solar building concept and the passive house concept (BMWF 1999).

5. During the last years a number of research projects have been carried out within the framework of the research programme 'Building of Tomorrow'. Among studies dealing with more general technical questions a number of reports document different types of refurbishments aiming at passive house standard: Single-family house (Lang et al. 2007), multi-floor building (Domenig-Meisinger et al. 2007), school building (Obermayr 2004). According to IG Passivhaus 30 passive house refurbishment projects had been completed in Austria by the end of 2006 (IG Passivhaus 2009).

pliers of special passive house windows and other passive house specific technology. All over the country it is easy to find architects with passive house experience. The term passive house is widely known as a quality label for ultra-low energy buildings. Again, this was to a great extent caused by the 'Building of Tomorrow' programme, which not only funded a huge number of research projects but also made much effort to disseminate information and popularise the topic of sustainable buildings.

4. Institutionalisation and stabilisation (since 2001)

The so far last phase is characterised by growing importance of interest organisations, a broad acceptance of the passive house concept in the general public and the increasing influence of the passive house standard on subsidy guidelines and legislative norms. In the last years we could also observe that the passive house concept has been linked up with important policy aims, especially with climate mitigation policy.

The establishment of the IG Passivhaus is very important in this respect. The IG Passivhaus is an interest group focussing on the dissemination of the passive house concept. It was founded in 2001 – not surprisingly – in the province of Vorarlberg. Drexel & Weiss, the leading Austrian producer of ventilation systems, was mainly responsible for this organisational step. This company was involved in most of the early passive house projects and designed – based on these experiences – the first compact ventilation system for passive houses. Later, the marketing manager of this company realised that the success of this new compact system would be closely linked to the market success of the passive house in general. Hence he consulted all the other companies in Vorarlberg, which had already experiences with the construction of passive houses. As a result the IG Passivhaus Vorarlberg was founded. The eleven founding organisations represented a wide spectrum of competences and areas. As the mission of the IG was strictly oriented at the dissemination of the passive house concept the Energy Institut Vorarlberg decided to become a founding member too. In the following years Drexel & Weiss tried to build up both a market for ventilation systems as well local interest groups in other Austrian provinces; and both worked out quite well. Since 2006 the IG Passivhaus operates on the national level with regional branches in most of the provinces. Although financed by private companies the IG Passivhaus aims at company and product neutral passive house lobbying. Major aims are public relations activities, political lobbying (e.g. for higher subsidies) and the dissemination of information for the general public.

Discussion

With a focus on intermediation activities we can learn a number of lessons from the passive house case study.

One conclusion, which we can certainly draw from our analysis, is that the socio-technical system of passive houses has not been a development centrally planned, coordinated and steered by public policy or any other single actor. Passive houses have been very much developed in a bottom-up fashion without central steering but requiring a high degree of coordination and intermediation processes. Various processes had to be facilitated and coordinated:

- the development of technical and design standards;
- the creation of a vision and orientation for the further development of the passive house niche (general standard of the future; costs only slightly exceeding the costs of conventional houses; increasing focus on solar energy use and renewable building materials, etc.);
- certification procedures for building components meeting the passive house standard to make it easier for users and supply side actors (such as builders, architects, construction companies, component producers, etc.) to find appropriate components on the market;
- the dissemination of information about passive houses;
- the creation and extension of a competent actor constituency (training courses, PR for passive house architecture, etc.);
- support for the development of qualified demand structures (i.e. home owners or building developers who know what to ask for, whom to ask and how to assess the quality of offers when they intend to build an energy efficient building), etc.

These processes were facilitated by a number of organisations of different type: public and private research organisations engaged in energy-efficient building design; private non-profit (e.g. the passive house institute) or commercial (e.g. consultancies) organisations, regional or national energy agencies offering energy advice, information dissemination and supporting the growth of actor constituencies; semi-public institutions such as management organisations for research programmes (such as 'building of tomorrow') or interest organisations (IG Passivhaus) coordinating the already stabilised passive house community and lobbying for better regulations and support structures. In sum, intermediation activities have been a crucial ingredient for the growth of the passive house niche and have been distributed over a large number of organisations. Some of these organisations have been especially set up as passive house intermediaries (Passivhaus-Institut, IG Passivhaus), but the larger part was made up from already existing organisations with a wide range of tasks, which were often only temporarily engaged in facilitating the development of passive houses.

Our case study also sheds light on the changing role of intermediation processes over time. Intermediation requirements undergo significant changes along the career path of a new socio-technical system. While the formulation of a coherent concept and vision was a central prerequisite in the early development phase to get researchers and interested pioneering companies and users interested in this concept, in subsequent phases the establishment of demonstration projects and the availability of technical components had to be coordinated; the growth of the actor constituency had to be facilitated (information, training, PR etc.). In more mature stages the extension of the niche to a national level, the accumulation of niches (integration of passive houses, solar architecture and ecological product initiatives into one broader and coherent concept), and finally institution building and institutional alignments became of predominant interest (support schemes, building codes, policy targets, etc.). If such a process is coordinated by one or a few organisations, a high degree of organisational flexibility is required to adapt to the changing intermediation tasks. In our case study the picture was somewhat different, as subsequent phases usually were characterised by different predominant intermediary organisations – the Passivhausinstitut in the set-up phase, the Energy Institute Vorarlberg in the creation of a regional niche, the programme management of 'Building of Tomorrow' in the establishing of a national niche and integration with other niches, and possibly the IG Passivhaus or similar organisations in creating supportive institutional contexts for the mainstreaming of passive houses. Summing up, the evolution and growth of the socio-technical system around the passive house concept is characterised by a succession of changing intermediation needs, which could be met by a succession of different intermediary organisations with a changing focus of activity.

Intermediation activities turned out to be closely related to the so-called 'functions of technological innovation systems' that we have discussed in the theoretical chapter at the beginning. A successful development performance of technical innovation systems such as passive houses is expressed by the fulfilment of a number of functions. Among these are

- 'orientation', i.e. vision building in the early development phase, the creation of an integrated vision (passive principles & active solar technology & ecological materials) in the more mature phase as well as an appropriate structure and orientation for further research activities;
- 'knowledge generation', i.e. research, the evaluation and dissemination of experiences, training courses etc.;
- 'entrepreneurial experimentation', i.e. experimentation with different design concepts and technologies;
- 'market creation', i.e. the articulation of qualified demand, the creation of a sufficiently large community of architects, planners, builders etc.; and finally the
- 'creation of positive externalities', i.e. knowledge spill-overs to conventional building practices which was overtly visible during the development of the passive house concept.

Intermediation processes thus are intrinsically linked up with the challenges faced by growing socio-technical systems (or technological innovation systems to use a related term) and thus also the strategic management of niches. Supporting the growth of niches and subsequently transforming socio-technical regimes such as the construction regime towards more sustainability needs intermediation activities of various types (systemic coordination, facilitation, brokering, advocacy, demand articulation, information transfer, etc.).

The strategic management of niches and the governance of system transformation towards sustainability are moreover characterised by a complex and often symbiotic relationship between commercial, civil society and public sector organisations. While it is true that the mode of governing socio-technical change has changed and in certain respects has moved farther away from the nation state and public policy, the state level and policy support are still of crucial importance for the success of change processes towards sustainability. Especially in the early phase of developing the core ideas and setting up early experiments, recruiting pioneers, etc. public policy only played a minor role – though most of the research involved was publicly subsidised. The more complex relation to the policy level is subsequently expressed by the fact that many of the intermediary organisations involved were formally independent organisations but often established, funded or even owned by various public administrative units. This is certainly the case for the various energy agencies involved in system building and the dissemination of passive houses (the Energy Institute in Vorarlberg is a quasi-public organisation) and this is also true for the management of the 'Building of tomorrow' programme where a private organisation managed a public programme in close cooperation with the responsible ministry. Intermediary organisations thus can be seen as an important vehicle for public policy to support change processes towards sustainability within new governance contexts. Our case study shows that such 'public governance through intermediaries' already takes place, but that there is still an enormous potential to improve information flow and cooperation between policymaking and intermediaries. A closer cooperation and use of intermediaries by public policy could improve the interrelations of supportive legislative, regulative and financial support structures on the one hand, and constituency building and market formation in a bottom-up perspective on the other. More research should be done to improve our understanding of integrated governance strategies comprising the public sector and civil society initiatives alike.

Conclusions

In our case study we have focused on the development of passive houses in Austria as an example of an emerging socio-technical practice for the design of highly energy-efficient buildings, which has the potential and currently seems to set out to profoundly transform dominant construction practices of buildings. The example is of high public interest because it could serve as a model for other sectoral transformation processes towards sustainability.

A main focus of our analysis was on the role of intermediary organisations in their role as facilitators and coordinator of system building and change processes, as information brokers and generally as links and mediators between different societal subsystems such as economy, policy, research or civil society. Our investigation of the development of passive houses could provide interesting insights in the roles and challenges for intermediary organisations involved in socio-technical change. Though it is difficult to generalise from case studies, the development of passive houses is certainly not an untypical example for the development of new socio-technical niches. Intermediation processes fulfilled by a broad range of organisations indeed turned out to be of crucial importance for the coordination and shaping of system growth. An interesting insight was the changing type of intermediation requirements along the different development stages of the passive house niche and the succession of different organisations carrying out these intermediation activities at different stages. The relation between the governance of socio-technical change and public policy certainly was more complex than guessed at the start of the project. While there was indeed little hierarchic and direct steering of system change by the state, public policy and administration still did play a crucial role for the success of passive houses. On the one hand, many of the most important intermediary organisations were publicly funded and were closely related with public organisations, on the other hand the interplay between public policy (and its responsibility for legislative and regulatory processes and financial support) and intermediary organisations as links to the heterogeneous constituency of actors and users needed for the growth of the passive house niche was of crucial importance. However, this complex relationship underlines the importance of a working constellation of intermediary organisations for public policy. There still is significant potential to improve the interaction between intermediaries and public policy and to more consciously involve intermediaries in system change towards sustainability as a strategy of public policy.

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