The life and death of a sustainable housing concept? The trajectory of passive houses in Denmark as part of the zero carbon transition

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Abstract

This paper makes an exploratory analysis of the diffusion of passive houses in Denmark using transition theory. Strategic niche management and technological innovation system approaches are combined to provide a framework that allows for multiple dynamics i.e. social forces enabling or constraining changes, especially niche developments and the role of legitimacy. The passive house niche analysis shows a slow process, barriers of cost and technology and limited adoption in Denmark; roughly 18 projects over the last six years, and a slow descent over 2011-2012. The concept has early moral legitimacy, but the further development of legitimacy fails as costs and indoor climate makes the cognitive legitimacy contested. The passive house concept competes with other sustainable building niches, they are all small and they appear to have been introduced successively over time. Finally there are a tendency of segmentation of villas, small buildings and office buildings respectively. Sustainable building exhibits a particularly active role for government policymaking, or in transition theory terms "regime internal" dynamics. These combined dynamics between sustainable housing niches, the regime internal dynamic and globalisation as well as EU-regulation are counter to transition theory assumptions dominated by the EU- initiatives. The analysis moreover leads to the view that sustainable housing concepts are only viable in time windows, and that the contribution of the passive house trajectory was a stepping stone towards low carbon housing.

Keywords: passive houses, transition theory, Denmark, sustainable building

1. Introduction

Many change initiatives and conceptualisations in construction management research and practice tend to build on relatively insular initiatives (Green, 2011). The understanding of sector change within construction remains under conceptualised. Especially there is a need to address the intersection between innovative and conservative forces as well as the type of drivers around these change processes. The reputation of the construction sector as conventional and lacking of innovative forces is often alluded to but efforts are seldom put into trying to explain or analyse the barriers to change. With this as our point of departure this paper investigates the introduction of Passive houses onto the Danish market. Passive houses have been established as a sustainable housing concept in central Europe for quite some time and a number of houses and building projects have been constructed following the given criteria. However in a Danish context the diffusion has been slow

By adopting a theoretical framework combining strategic niche management research (SNM) and Technological Innovation Systems (TIS) this paper presents an analysis of the emerging innovation system of sustainable buildings in the Danish Construction industry. It places passive houses as one among several competing concepts and niches. In this perspective sustainable buildings are part of a multifaceted landscape of innovation around an existing regime, built on the current ways of working and developed over generations. The housing/building regime is challenged from various niches and from the socio-technical landscape through trends such as globalization and EU- initiatives. The passive house niche is here subjected to an analysis showing the processes, experienced barriers and limited adoption. This is juxtaposed with other sustainable building niches and their competition is mapped and discussed. The paper further discusses the role of government policymaking as a 'regime internal' dynamic. Combining these dynamics, i.e. social forces enabling or constraining changes between sustainable housing niches, the regime internal dynamic and globalisation as well as EU-regulation leads to the view that sustainable housing concepts are only viable in relatively short windows of time; and that the contribution of passive house trajectory is more of a stepping stone towards low carbon housing, than a final solution.

2. Method

The paper adopts an interpretive sociology framework. The theoretical position combines two transition theory contributions, that of Science Technology and Society studies and Evolutionary Economics in accordance with Coenen and Lopez (2010) and Markard and Truffer (2008).

Given the explorative nature of our research the empirical design is a case study of the development of passive house in Denmark. The study uses a mixed method approach combining quantitative and qualitative data collected through several sources. This includes mapping of sustainable housing concepts and their emergence through desk research using Google and Infomedia (Danish Newspaper database) and other press articles. Further secondary data have been retrieved from students work such as master theses supervised by the authors. First hand data collection includes participation in architects and engineers' workshops on the topic. The trustworthiness of results is achieved through

triangulation, by the comparison of information collected through different channels (Bryman and Bell, 2007).

It is recognised as a limitation of the paper that the full implication of combing of strategic niche management and technological innovation systems is not discussed here.

3. Theoretical framework: Transition theory

The transition theory literature is currently being developed as a response to the societal challenges of climate change. It encompasses looking at the drivers, emerging actor constellations, technologies and barriers in play. The two transition theories selected here, Strategic Niche Management (SNM) and the Technological Innovation System (TIS), both offer conceptualisations of sectorial change affected by multiple dynamics. Here the combination of the two is chosen to complement and strengthen their respective conceptualisation of sectorial dynamics. In brief the multilevel framework and strategic niche management of Geels and others (e.g. Geels, 2005, 2011; Schot and Geels, 2008) focuses on the analysis of dynamics of upcoming niches challenging the existing regime, whereas the technological innovation system (e.g. Bergek and Jacobsson, 2007) offers a broader set of potential dynamics including the role of the public audience, i.e. legitimization. Bergek and Jacobsson (2007:576) define legitimation as "acquiring a social acceptance of new technologies".

3.1 Multilevel framework and strategic niche management

The SNM view approaches innovation in a sector as a socio-technical phenomenon. Three levels of socio-technical interaction are identified: Niches form the micro-level where innovations emerge; The socio-technical regime forms the meso-level, which accounts for the dominating stabilized socio-technical pattern of interaction that are reproduced by institutionalised learning processes; and Finally the macro-level which is shaped by the socio-technical landscape, an exogenous environment beyond the direct influence of niche and regime actors (Geels, 2005).

Schot and Geels (2008:545) note:

"The core notion of the multi-level perspective (MLP) is that transitions come about through interactions between processes at different levels: (a) niche innovations build up internal momentum; (b) changes at the landscape level create pressure on the regime; (c) destabilisation of the regime creates windows of opportunity for niche innovations".

This suggestion that regime shifts would (predominantly) come about through bottom–up processes of niche expansion is addressed in this contribution. Within sustainable buildings, regime push is an important dynamic. This means that Schot and Geels' (2008) argument regarding that alignments of processes at multiple levels are explanatory for construction Niche innovations are still important, but these innovations would probably diffuse more widely if they link up with ongoing processes at regime and landscape levels. The strategic niche management perspective allows for a range of actors

to be included in the conceptualisation. At the niche level entrepreneurs as single persons would occur, whilst at the regime and landscape level aggregate actors like the EU and nation states would occur. It should be noted that the strategic niche management perspective does not encompass processes of legitimation. As such it does not give a central role to the public audience, processes of public communication and other elements of legitimation processes. Even if such social processes are not counter or alien to the dynamics outlined.

3.2 Technological Innovation systems

The technological innovation system (TIS) approach focuses on the dynamics of the systems both in terms of structural growth and key innovation-related processes. Carlsson and Stankiewicz (1991:93) define a technological system as:

"a dynamic network of agents interacting in a specific economic/industrial area under a specific institutional infrastructure and involved in the generation, diffusion, and utilization of technology."

According to Bergek et al. (2008) a TIS is made up of: (i) firms and other organisations; (ii) networks; and (iii) institutions. Firms refer to firms within the entire value chain and organisations include universities, research institutions, industry- and other professional organisations. TIS as championed by amongst others (Bergek et al., 2008; Carlsson and Stankiewicz, 1991; Jacobsson and Bergek, 2011) views the 'functions' of the innovation system as central. The eight key functions are:

- Development of formal knowledge
- Entrepreneurial experimentation
- Materialisation
- Influence on the direction of search
- Market formation
- Resource mobilisation
- Legitimation
- Development of positive externalities

The interplay between these functions is multiple, complex and cannot be reduced to a linear progression. *Formal knowledge* according to the TIS approach (Bergek et al., 2008) is an explicit research-based knowledge. The TIS develops if it manages to expand the breadth and depth of its knowledge base and diffuse and combine it into the system. *Entrepreneurial experimentation* on the other hand is development of tacit, explorative, and applied knowledge. Experimentation is viewed as important for the innovation system, through the innovators conducting technical experiments, struggling with uncertain applications and markets and discovering and creating business opportunities (Bergek et al., 2008). *Materialisation* involves the development of (and investment in) artefacts such as products, production plants and physical infrastructure within the technological innovation system. The *influence on the direction of* search is one of the more agency oriented elements in the TIS model. In the early interaction some actors are able to orchestrate the assembled effort and direct it in a particular direction and thereby strengthening the TIS development. Such a dynamic of directed search would also attract new external actors, for example supply-side actors that

direct their search and investments towards the TIS. It could also attract customer oriented actors who find the direction attractive and representing future feasible products. *Market formation* relates to articulation of demand and market development in terms of demonstration projects, nursing or niche markets (Schot and Geels, 2008), bridging markets and, eventually, larger markets and large-scale diffusion. *Resource mobilisation* is about the TIS having to mobilize human capital, financial capital and complementary assets. When the mobilisation goes further than suppliers and users to other sources it is a sign of a high mobilisation. The socio-political process of *legitimacy* forms through actions by various organisations and individuals. Central features are the formation of expectations and visions as well as regulative alignment, including issues such as market regulations, tax policies or the direction of science and technology policy. *Development of positive externalities* reflects the strength of the collective dimension of the innovation and diffusion process. It also indicates the dynamics of the system since externalities magnify the strength of the other functions. It should be noted that other contributors have argued that functions can be substituted with activities in appreciating a more agency oriented conceptualisation of an innovation system (e.g. Markard and Truffer, 2008).

3.3 Synthesis of MLP/SNM and TIS

Both models implicitly and explicitly operate with different levels of aggregation. Geels (2011) claims that these levels can be derived to concrete contexts. Markard and Truffer (2008) suggest that a technological innovation system and the niche/regime level are at the same aggregation. At the niche/ regime level at least five of the so called functions in TIS, innovation processes overlap heavily with the niche dynamics described in Schot and Geels (2008):

- Entrepreneurial experimentation
- Materialisation
- Influence on the direction of search
- Market formation
- Resource mobilisation

The *entrepreneurial experiment* and influence on the direction of search are very close to the ‘competition of design’ and ‘search for a dominant design’, conceptualised by Geels. These concepts highlight how an early development of a concept/technology, in this case a sustainable building concept, would develop under protective conditions amongst designers and users with market mechanisms relaxed. The *market formation* is a gradual process from a tight network of producers and users into slightly more decoupled network relations with commencing demand and supply mechanisms. The two aspects of ‘legitimisation’ and ‘creation of positive externalities’ are on the other hand not an immediate commonality between the concepts. *Legitimacy* is related to obtaining social acceptance and compliance with relevant institutions. Legitimacy is not given but has to be formed through conscious actions by various organisations and individuals in a socio-political process. Gaining legitimacy would involve cognitive, normative as well as regulative aspects. The most commonly described strategy for industry legitimation is to conform to established institutions. However, deinstitutionalisation and reinstutionalisation, as described by Greenwood et al. (2002), is

another means of attaining it. If legitimacy is attained for a technological innovation this would support obtaining resources for its further development, and it would generate demand and give actors in the new TIS political strength. For example, Bergek and Jacobsson (2008) argue that attaining legitimacy is a prerequisite if new industries are to be formed around renewable technologies, as the incumbent energy production regimes might otherwise actively counter them. Greenwood et al. (2002) point at several steps in gaining legitimacy. They assign early legitimacy as being value oriented 'moral' legitimacy. If the emerging products and practices cannot be referred to existing institutions, functional superiority has to be established, labelled 'pragmatic' legitimacy. At a later stage the legitimation might solidify and become cognitive (Greenwood et al., 2002)

4. Case: Passive Houses in Denmark

A passive house according to the Darmstadt criteria (Passivhaus Institute, 2012) encompasses four central properties: (i) The specific space heating demand should be lower or equal to 15 kWh per m2 per year; (ii) the heating load should be ≤ 10 W/m; (iii) the tightness of the building envelope should be ttested with a pressure test showing air changes of ≤ 0.6/h; (iv) the specific cooling demand should be ≤ 15 kWh per m2 per year and the total specific primary energy demand ≤ 120 kWh per m² per year.

4.1 The central European development

The early development towards passive houses can be traced back to work on experimental low energy houses that was undertaken simultaneously in a number of countries, e.g. Austria, US, Sweden, Denmark, Germany, during the period 1975-1990. From the early 1990's the development around Institut Wohnen und Umwelt, Darmstadt, took precedence. The first batch of houses built according to Darmstadt standards, such as those in Dörpe and Kranichstein (Hinz, 1994), were used to develop and institutionalize a standard for passive houses, incorporating specific design parameters, energy consumption calculation software (PHPP) and tests. By the year 2000 around 100 passive houses had been built according with the Darmstadt standards (passivhausinstitute.de, 2012), with a well-established design. The Darmstadt institute database portfolio of passive houses as of early 2012 encompasses 1753 projects. 1586 of these are in Germany, 33 in Austria, 12 in Denmark, 10 in Switzerland and 3 in Sweden. The vast majority of these projects are single family houses.

4.2 The context of Danish building

Following the oil crises in 1974 the Danish building sector began to pursue a coordinated path of improving insulation and reducing the energy consumption (Marsh et al., 2010). According to these authors the Danish population grew with 7% reaching 5.4 million in the period 1975- 2005 while in the same period the total floor area of housing grew with 53%. Average housing space per capita grew from 34 m2 to 48 m2. The housing stock in 2005 was at 2.6 million units, encompassing 1.5 million singular units (houses). In the period 1975- 2000 (after the oil crises) a 19 percent reduction of heat consumption was realized, an improvement that was mitigated by a 69 percent growth in energy consumption due to more intensive use of household appliances and IT (Marsh et al., 2010). Marsh

describes this period as a long-term political and social consensus that developed in response to the 1970s oil crisis. A range of planning, fiscal, and regulatory policy initiatives were taken. As a result energy planning in Denmark underwent a radical change from oil to natural gas and district heating, produced by centralized combined heat and power plants (Marsh et al., 2010). It can be added that it is only by around 2002 that EU initiatives began to have importance since Danish regulation and other initiatives up to that point were ahead of those stipulated by the EU. The building volume in 2007 to 2011 is shown below. By including 2007 the impact of the financial crisis in 2008 becomes clearer.

	2007	2008	2009	2010	2011
Commenced new build in mio m2	10,6	9,15	6,30	5,15	4,75
Commenced Housing Buildings	26000	17000	10000	10500	11500

Figure 1: Building activity 2007-2011 (source: Denmark Statistics)

New building regulations have been implemented in Denmark over the last ten years. These have largely followed EU directives and have substantially tightened the demands on energy consumption. In 2006 building regulations were implemented following the EU directive EUBP 2002. Introducing two energy classes 1 and 2 (also called 2015 and 2010) referring to the years they would become obligatory. The building regulation BR10, from august 2011 installs a third class '2020' with even stricter demands. These reforms have been accompanied by a range of initiatives such as Directive No 2010/31/EU on the energy performance of buildings, the EU (2009) directive leading to national renewable energy plans, initiatives of developing sustainable skills amongst construction workforce, financial and fiscal arrangements.

In summary, the development can be divided into two phases. In the first phase between1974-2002, Denmark as a national state had a broad alliance of actors pushing for energy savings and accompanying technologies; whereas from 2002 and onwards the initiative shifted to the EU. The reform tempo has been quicker over the past ten years than previously. The Danish housing sector, like in many other countries, had a serious bubble that burst in 2008.

4.1 The story of passive houses in Denmark

The interest for passive houses occurs in the above sketched context of sustainable housing and more traditional housing development. As described by Marsh et al. (2010) there has been a strong tendency in Danish building to gather around one common solution, which is then supported by law with occasional subsidies. This tendency has continued even after the EU taking over the initiative, but now with implementation of EU legislation as the key driver. The passive house community is therefore a niche environment that distinguishes itself from other parts of the industry. Especially the architectural environment in Denmark second largest city, Aarhus, has been important in constituting

this niche. The architect school in Aarhus, local architects and alliances of architects, consulting engineers and contractors have followed the German development over a long period of time. This community shares features with other grassroot developments of renewable energy, such as wind turbines (Steen et al. in Foxon et al. (2008)). In 2005 the consultancy Ellehauge and Kildemoes obtained funding for the EU-project "Promotion of European Passive Houses" together with a range of European partners. The clear understanding of the project is that passive houses are a well-documented sustainable solution. Ellehauge and Kildemoes created a website, commenced educational activities, and arranged study visits to Germany and Austria, together with other knowledge dissemination activities. The project was finalized in 2007, but the website was continued and later transferred to another social carrier, a new association for passive houses in Denmark. One active person in this niche community, the architect Olav Langenkamp, designed and built his own villa according to passive house criteria and got it certified. The house was completed in March 2008 and is the first passive house in Denmark. When building the house Langenkamp had to use German suppliers to get components that would be certifiable. The contractor was therefore a German company, Ökologischer Holzbau Sellstedt (Langenkamp.dk, Passivhus.dk).

ISOVER, the insulation manufacturer initiated a project of 10 passive houses “komforthusene”, where the idea was to let building sector actors tender for the various houses to obtain as much experience with passive houses as possible (cf. the breath of formal and informal knowledge (Bergek et. al. (2008)). Also, part of the project was that the experiences with indoor climate and more should be documented, involving Aalborg University in a three year long measurement program. By September 2008 eight out of the ten planned passive houses, Komforthusene were inaugurated by the Minister of climate. Two of the “Komforthusene” houses were later changed into non-passive houses. Through these early projects the passive houses got the reputation of being expensive. In a later evaluation report (Isover, 2010) it is shown that the Komfort houses are indeed more expensive to build. Isover (2010) claim 6-12 %, but also claim that compared to longer term energy savings these extra expenses are compensated for within fifteen years. Apart from being expensive the early passive houses all share the dependence on German suppliers of components. This also goes for the 2009 dormitory project “H2 College” (Bertelsen and Koch, 2011). The dormitory encompasses 66 apartments, in two blocks built as passive houses, with hydrogen and earth warming. A building association Fruehöjgaard is the client and Aarhus Arkitekterne, NIRAS, and Ökologischer Holzbau Sellstedt were the architects, consulting engineers and contractor respectively. Gradually over 2009-2010 various component suppliers start engaging in passive house projects. In 2010 for example the Danish window manufacturer Rational was part of a vocational training school, built as a passive house, using Rationel Aldus Super Lavenergi windows.

In summary, the development of passive houses mobilized both small grassroot players as well as larger players in the industry. The single house projects become “mature” and its concepts market like where the clients enter a more classical relation when demanding a project. But most of the Danish passive house projects occur as part of publically financed demonstration and/or innovation projects with the intention of first communicating the values and qualities of passive houses to a wider audience of possible future clients (what Greenwood et al. (2002) would call moral legitimacy); second to underpin this by supporting the legitimization process in the form of providing formalized knowledge about the design, the costs, the building process etc. A less controllable part of the

communication is that the passive houses appear expensive and difficult to live in as the indoor climate is controlled with complex equipment.

4.2 The concepts competing with passive houses

From 2005 and onwards an increasing number of sustainable housing concepts have emerged. In particular, the preparation activities before the United Nations Climate Summit, COP 15 in 2009 seems to have initiated a number of projects attempting to exploit the marketing options related to the summit. Figure 2 provides a list of concepts found in Denmark.

Concept/Year of introduction in DK	**Found/Estimated number of projects**	**Actors (examples)**	**Examples**
Passive house, Darmstadt criteria/ 2008	18		H2 College (dormitory) Komforthusene
Active House (Velux group)/2009	3	Velux	Lystrup, Cph.
DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen)/2012	2	Green Building Council Danmark Ramboll Ålborg University	
Svanemærket (Nordic Ecolabel)/ 2011	2	Odense Kommune, pluskontoret, Køge kommune, Det grønne hus (Agenda 21)	2 kindergartens Fremtidens Parcelhuse Køge
BREEAM (Building Research Establishment Environmental Assessment Method)/2010	>6 large Projects	Grontmij DK	Vestas HQ, Sillebroen shopping center, Grontmij HQ
LEED (Leadership in Energy and Environmental Design)/2010	>7 larger projects	COWI,KPC, Sjælsø	FN-byen, UL Intern. Demko HQ
EU Green House/2008	7	NCC	Skejby Company House I-III (also BREEAM)
Energy Class II (EUBD 2002)/ 2010	>4 large projects		KPMG, Flintholm City Court Kolding Christian Union HQ Industriens Hus,
Energy Class I (EUBD 2002)/2006	>9 large and small projects and7 under construction	Arkitema, KAB, Ramboll, Pihl, Lind og Risør, a.m.o	Stenløse Syd Multimediehus Navitas
Other concepts made once Sabro, ZERO+, lavenergi,	5		Sabroe Sønderborg Zero plus Vordingborg

Figure 2: Sustainable Building concepts 2005-2012 (source: desk research)

The year of introduction, as provided the left hand column, is given as when the first realised building occurs. The list is not exhaustive but gives an impression of a veritable cacophony of concepts and indicates a limited breakthrough of sustainable building concepts compared to the overall building activity in the same period.

5. Discussion

The passive house niche analysis shows slow and hesitant processes, involving public support as the lever for development. It took 16 years from the first realised passive house outside Darmstadt in 1994, to realise the 18 Danish projects in our sample. Indeed, all were built after 2006. As the niche commenced to produce material results a key experienced barrier turned out to be the initial price of the houses. As a direct result the passive house concept has experienced limited adoption, keeping it on the niche level. This is despite of its German origin and backup, which provides well established knowledge, legitimate institutions, design procedures and more. Over 2011 and 2012 we found three finalised passive house buildings, compared to six in each of the years 2009 and 2010. When the passive house development is juxtaposed with other sustainable building niches and their competition is mapped it becomes clear how voluntary concepts that go beyond what is specified in the legislation have been introduced in succession over time, e.g. passive, active, DGNB. But it is also clear that the early compliance with future legislation, especially energy class 1, has tended to dominate these voluntary steps. There are tendencies of segmentation, where LEED, BREEAM, DGNB a.o. are used for office buildings, whereas passive house, active house, Svanemærket and ZERO+ mostly are used for single family houses and smaller buildings such as kindergartens.

Both TIS and SNM highlight the importance of a dominant design. This study of sustainable building shows that none of the concepts has obtained this. Instead they continue to exist in parallel. Passive houses represent a well stabilised design with an institutional set up in Germany. Nevertheless this does not render the concept sufficiently strong as concept in what is a growing and active part of the construction market. We have seen how the EU processes create regime dynamics that are more prevalent for the development of sustainable buildings than the niches. Usually it is expected that regime driven innovation would conserve existing ways of working (Geels, 2005; Markard and Truffer, 2008). This is evidenced by the far bigger number of projects built according to the required levels set out in the official regulations during the investigated period. In the Danish setting the restructuring of government responsibilities into a ministry of climate, energy and building can even be viewed as the more important dynamics in 2011 in the sustainable building context apart from the central EU initiatives discussed above. Seen from a grass root perspective the commodification of a type of house, using a certificate is less interesting than promoting sustainable buildings in a broader sense. There will therefore be a tendency for grassroot engagement to move from one innovative approach to the next, especially if the approaches get too commercial. In terms of legitimation it appears that passive houses had a certain degree of moral legitimacy in the 1990's and that this contributed to the creation of the first houses. However as the passive house concept was well developed it could also be argued that it also possessed a certain degree of cognitive legitimacy in these early stages. At a later stage the cognitive legitimation was more difficult to retain as active house were perceived as a stronger concept (it gained pragmatic legitimacy, i.e. it was not yet

underpinned by formal knowledge) and the passive houses suffer from contested reputation because of higher cost and indoor climate issues.

6. Conclusion

The passive house niche analysis showed a slow process, barriers of cost and technology, limited adoption and over 2011 and 2012 an apparent descent. Roughly 18 projects over the last six years have been realised. The niche has not been able to exploit its basis in formalised knowledge and cognitive legitimisation to become a dominant design. When juxtaposed with other sustainable building niches, it appears that all these are small and they appear to substitute each other over time. Also there are a segmentation of villas, small buildings and office buildings respectively. Rather than just being about niche technologies it is the voluntary early adoption of future law that is prevalent. Therefore government policymaking as the "regime internal" dynamic contributes as well. Compliant with the theoretical framework there are multiple dynamics in play. These combined dynamics between sustainable housing niches, the regime internal dynamic and globalisation as well as EU-regulation leads to the conclusion that sustainable housing concepts are only viable in fairly confined windows of time, and that the contribution of passive house trajectory probably is more of a stepping stone towards low carbon housing, than a final solution.

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