Sustainability **2015**, *7*, 8801-8822; doi:10.3390/su7078801

OPEN ACCESS

sustainability

ISSN 2071-1050

www.mdpi.com/journal/sustainability

Article

How to Succeed in Low-Energy Housing—Path Creation Analysis of Low-Energy Innovation Projects

Pia Pässilä *, Lauri Pulkka and Seppo Junnila

Department of Real Estate, Planning and Geoinformatics, Aalto University, PL 15800, 00076 Aalto, Finland; E-Mails: lauri.pulkka@aalto.fi (L.P.); seppo.junnila@aalto.fi (S.J.)

* Author to whom correspondence should be addressed; E-Mail: pia.passila@aalto.fi; Tel.: +358-40-743-0624.

Academic Editor: Marc A. Rosen

Received: 22 April 2015 / Accepted: 29 June 2015 / Published: 7 July 2015

Abstract: The low-energy and the nearly zero-energy buildings trend is calling for radical new innovations from the construction industry. This study uses path creation theory to examine two innovation concepts for low-energy housing in Northern Europe with contrasting outcomes—with one being an apparent market success and the other a disappointment. The results highlight two issues behind the success, one of a systemic nature and the other concerning innovation management. First, the development of energy efficiency regulations and the dominant technological trajectory regarding low-energy houses are interdependent. However, it seems that while supporting the trajectory of the innovation developed in the first case, regulators created virtually insurmountable cognitive and normative obstacles to finding alternative technological pathways. Second, the significance of proof of concepts for new innovations cannot be underestimated. The importance of a pilot project rests not only on showcasing and testing the technology, but also on its ability to increase political support, investments, and public awareness. The study implies that low-energy construction seems to be the next great challenge, one where genuine co-operation between the industry, public authorities and academia is a prerequisite for success.

Keywords: policy; regulation; innovation; path creation; technology; energy efficient buildings; energy efficiency

1. Introduction

The formulation of the EU's climate and energy targets [1,2] has increased pressures to improve the energy efficiency of buildings. The Energy Performance of Buildings Directive of 2010 [3] and Energy Efficiency Directive of 2012 [4] both gave a clear message to the construction sector on which direction the innovation efforts should take. However, construction industry firms are in general less engaged in R&D and innovation and also receive less financial support to do so [5]. Achieving the needed energy efficiency innovations is thus a great challenge for the field.

In the Finnish context, this challenge is further underlined by the velocity with which the introduction of energy efficiency measures for new buildings has been made. A bill on energy certificates for buildings was first introduced in 2008 [6] and was followed by demands for energy efficiency improvement. In 2010 a requirement for 30% reduction in the energy needs of new buildings came into force [7]. From 2012 onwards, further 20% restrictions on energy use were applied, when a net-energy consumption model taking into account the form of energy used for heating was also introduced [8]. In preceding years, energy efficiency of buildings had been an issue of marginal interest in the Finnish construction sector. Due to the mistakes made after the 70s oil crises when insulation had been increased without the proper management of ventilation issues, which caused moisture damages, energy efficiency measures were also prone to suspicion. This sparked newspaper headlines from both sides, the optimistic [9] and the pessimistic [10].

Since then, the technological functionality of energy savings in buildings has been widely studied (e.g., [11–13]) and earlier studies on the general barriers and drivers in energy-efficient construction and green building have found that other elements than the technology itself affect the innovation processes. Regulation, the conservative nature of building industry and rising energy prices have been identified as common factors affecting these innovation processes [14,15]. The main barriers to highly energy-efficient building have been found to be investment costs, the nonexistence of energy efficiency as a variable in mortgage loans and in the calculations of real estate actors, the fear of moisture damage, credibility problems caused by the inexperience of actors and public tenders focusing only on price issues; important drivers have been found to be building codes, existence of frontrunner companies and construction of leading examples by public entities or companies [16–19]. Important success factors for highly-efficient housing innovations have also been multi-player enterprise collaboration and the existence of a Passive House concept [20].

The focus of this research is to holistically examine two ambitious innovation projects on energy-efficient housing in the Finnish context. The first project aimed to create an energy-efficient apartment building concept. It was led by a construction company and supported by a professional research institute. The second project was led by a private foundation and supported by professionals and house manufacturing companies and had the goal of producing sustainable detached houses. The apartment building concept has already entered the market with great success; in fact, it has become the general benchmark for the construction of energy-efficient houses in Finland. Detached houses, on the other hand, have not yet achieved commercial success. Although both delivered an energy efficient house as a product innovation, only the former became a market success. To explain this outcome, we concentrate on the effects of institutional context and firm/organization-level co-operation in these projects. This analysis provides added knowledge on how the same barriers and drivers for innovation can simultaneously hinder or advance the development of similar kinds of innovations. We also discuss the implications of these findings.

The paper is structured as follows. In the next section, the research question and approach are explained and are followed by introduction of the theoretical background. The cases are described in the section that follows. The fourth section analyzes the path creation processes of both innovation projects and compares the two cases. Then the results of the study are summarized. In the discussion section, the implications of the study and future research needs are presented.

2. Research Question and Approach

This study is based on two case studies of innovation projects on energy-efficient housing which evolved in the same institutional context. They were both initiated before the energy efficiency legislation of 2010 came into force and were faced with the same construction-industry-specific barriers. Both projects produced technically feasible, albeit different, concepts of energy-efficient houses with proven demand. However, one still lacks an important element for an innovation: market success. This raises the research question: why has only one of the projects achieved commercial success?

To answer this question, we build on a case study approach which is appropriate for exploring the questions of "how" and "why" and focusing on a contemporary phenomenon within a real-life context [21]. In the analysis of the cases, first, a narrative analysis [22] was used. A storyline of the projects was written to help to identify main events and causalities leading to the stated outcomes. The case studies were then analyzed using the hybrid socio-economic theory of new path creation developed by Simmie [23] and Simmie *et al.* [24] which is based on the theories of path dependency and path creation. The framework was originally used to describe the path creation process of the wind power industry in Denmark. In this study, it is used to identify how similar industry environments and societal conditions affected the two different innovation paths, both of which aim to transform sustainable housing in Finland. The use of the framework is particularly appropriate given the fact that the innovation projects operated within the same context, thus sharing the initial conditions and landscape change outcome. It proved to be helpful in analyzing the innovation process paths and describing the circumstances that resulted in one path becoming a market success and the dominant practice in the industry while the other one has not yet commercialized. This study thus helps to understand the techno-economic and political factors that led to one project having a much greater impact on how the energy-efficient housing path has evolved in Finland. The framework is discussed in more detail in the next section.

The results are presented in two phases. First, both cases are analyzed independently of one another using the hybrid socio-economic theory of new path creation as a theoretical framework. Based on these analyses, case-specific conclusions are drawn and emerging patterns recorded. Second, a cross-case analysis is conducted by comparing the prevailing patterns. Finally, the implications of the overall study are presented.

3. Theoretical Framework

This article is profoundly interested in successful innovations in the construction sector. It builds on the literature on construction innovation while borrowing concepts of path dependency and path creation from the sociology of technology.

Winch [25] has argued that the innovation implementation models developed elsewhere do not necessarily apply for the construction sector and that comparing its innovation rate directly to other manufacturing industries is unfair [26]. The construction industry has been described as a "complex system industry" [25], "product system" [27,28] or "loosely coupled system" [29]. These descriptions emphasize the interactions between different actors in the innovation processes. It is thus related to the actor-system-network approach [30]. The actors can be outside the original industry, and can include the regulatory framework, supply network, project-based firms, users and technical support infrastructure [31].

The complex system model of construction innovation described by Winch [25] further recognizes the sector-specific actors and divides them into innovation superstructure and innovation infrastructure. The former includes the clients, regulators and professional institutions and the latter trade contractors, specialist consultants and component suppliers. These are tied together by a system integrator, which can be for example the principal contractor. This approach draws attention to both the institutional context as well as the firm level. Winch [25] notes that since construction is a project-based industry, there are two important elements concerning innovation: the adoption/implementation dynamics and problem solving/learning dynamics. By this he means that firms are either adopting new ideas from the surrounding environment and implementing them in projects or that problems caused by pressures from the environment and solved in projects result in new ideas that are then learnt by the firms. Innovations are thus born through this interaction between the environment, projects and firms.

To understand better the trajectories of construction innovation, and to bind these environment-project-firm interactions to a timescale, we draw on the sociology of technology and especially on the concepts of path dependency and path creation. Path dependence basically means that previous choices matter: investments and decisions made in the past define what is feasible today [32]. It has been used to explain how the pre-existing conditions that restrict the available choices for action challenge the creation and establishment of new innovations [32]. In path dependency literature, the creation of new technological pathways is thought to happen through random events or actions [24]. These discontinuous innovations originate outside existing industries and challenge the industry incumbents [33,34]. The concept of path dependency has been challenged by the concept of path creation [35]. An alternative theory to path dependence, path creation focuses more on actors and their interactions [24]. It is described as a process by which actors are able to deviate from existing paths and disconnect themselves from prescribed social rules and taken-for-granted technological artifacts [36,37]. Since creating something new usually requires experimentation and thus being inefficient at first, it presumes the ability to seek future gains. The key to successful path creation lies in the ability (1) to perceive and create opportunities outside the box, (2) to mobilize other people and (3) to encounter apathy and resistance with persistency and flexibility. In addition, it usually takes time [36]. Nevertheless, path dependency and path creation can also be viewed as competing forces when trying to understand the evolution of technologies or industries [32]. Thus, an analysis of how new technological pathways are created needs to take into account both perspectives [24].

A practical analysis model for these two forces is the hybrid socio-economic theory of path creation by Simmie [23] and Simmie *et al.* [24] (see Table 1). It divides the path creation process into five segments: the initial conditions, the path creation process, the path establishment process, the main barriers to the path creation, and the landscape outcome of the process. The initial conditions are the existing path-dependent technological trajectories from which the new paths need to deviate. The path creation process consists of creating the actual invention or novelty. In the path establishment phase, this invention is turned into an innovation. The barriers to path creation can consist of economic, cognitive, institutional, and socio-political factors. Depending on the path creation forces and barriers, the landscape change outcome can either be a change or continuation along an existing path.

Hybrid socio-economic theory is used in this article as an analytical tool to identify the elements affecting the innovation process of the two cases studied. The hybrid socio-economic theory of path creation was chosen because it is compatible with many other theories of innovation, but it also has some distinct advantages compared to relevant alternatives. The cases could be analyzed through the lens of Roger's diffusion theory, which seeks to explain how, why, and at what rate new ideas and technology spread and is best known from its s-curve model of innovation adoption [38]. This approach would, however, emphasize the adoption of innovation by users too much. Path creation can also be viewed as a part of transition theories [39,40]. However, many popular transition theories, such as strategic niche management [41,42], highlight the purposefulness of landscape change through individual innovation processes. Hybrid socio-economic theory is good for the purpose of examining two innovation processes that illustrate the ongoing transition in low-energy housing, but without assuming that the projects had any intention to be part of said transition.

Table 1. The five segments of hybrid socio-economic theory of new path creation, adapted from Simmie *et al.* [24].

Initial Conditions	Path Creation Processes	New Path Establishment Processes	Barriers to New Path Creation	Landscape Change Outcome
Previously formed, existing path-dependent technological development trajectories.	The creation of a new invention	The innovation phase where the invention is taken into practice by the niche agents	Economic, cognitive, institutional, and/or socio-political factors that hinder the success of the innovation	Process outcome of either creation of a new industrial pathway, de-locking of the existing one or failure of the new innovation path

4. Case Studies

Both cases represent ambitious innovation projects by the Finnish housing industry. They took place during the same time period and both steered the housing industry in a more sustainable direction. Despite these similarities, important differences exists. These are described in greater detail below along with the data.

4.1. Case MeraReponen

The first case is a project with the aim of constructing an energy-efficient apartment building. It is named after the leading actor in the project, the Reponen Construction Company. Our study of the MeraReponen case is based on data collected for a thesis project on the development of energy-efficient housing in Finland, which was conducted during 2009–2010. Further update information on the project has been received from the meeting with a representative of the leading firm in three meetings in 2012 and 2013. The main data are based on interviews and written materials, such as project presentation documents and newspaper articles. A detailed data description is provided in Table A1 in the appendix. The interviews were semi-structured and the question themes included how the company/organization of the interviewee got involved in the project and why, the role of the firm/organization, the main challenges and drivers in the project, and how the co-operation between the project partners went.

The background for the project was conducted by the VTT Technical Research Centre. This professional research institute developed energy efficiency techniques in different projects during the 1980s and 90s. Over the years, the models developed became less complicated and more efficient and economical. The VTT enlisted construction companies as partners throughout this phase, but most products were one-time test houses.

The actual project was initiated after the Reponen Company became interested in the work done by the VTT. In 2001, the goal of developing energy-efficient housing was made a part of the Reponen Company's business plan. In its vision, the company aimed to gain a competitive edge as a forerunner in energy-efficient housing. The initial vision was met with skeptical comments from other construction industry actors, who did not see energy efficiency as a great opportunity. Some were also doubtful of the technical functionality of the houses. The project partners were found with the help of the VTT. The partners and their roles are described in Table A2 in the Appendix. The project received financial help from the Housing Finance and Development Centre of Finland (ARA) and Tekes, the Finnish Funding Agency for Innovation (a publicly funded expert organization for financing research, development, and innovation in Finland).

The concept was first tested on in a single apartment built in 2005 in Leppävaara, Finland. The single apartment test was carefully reported and analyzed by the VTT and the results were made known in 2006. The heating costs were cut by 70% compared to a standard apartment, but the building costs were only 1.7% higher than average [43]. The first house was built for the Finnish Youth Housing Association (NAL) and located in Heinola; it was completed in 2009. Since then, as much as 80% of homes constructed by the Reponen Company have been energy-efficient houses with different modifications. The project partners were also able to create production lines for the needed energy-efficient elements and products. The concept is still working well and further development has been carried out to employ it in apartment buildings made from wooden material.

4.2. Case K3 Houses

The K3 Houses initiative attempted to produce detached houses that were environmentally, socially, and economically sustainable. In fact, the three K's are the Finnish words for "beautiful", "sustainable", and "affordable". The case study of K3 Houses initiative was first presented at the CIB International Conference on Construction in a Changing World 2014 [44]. The case study data consists of interviews and written documents, which are described in more detail in the Appendix (Table A3). The interviews were semi-structured. The question themes included how the company/organization of the interviewee got involved in the project and why, the role of the firm/organization, the main challenges and drivers in the project, and how the co-operation between the project partners went.

The initial idea for the project came about as the result of a discussion between a consultant living in the Billnäs area (a district in the Finnish municipality of Raasepori), the real estate manager of the

Billnäs-based Fiskars Corporation, and the Secretary General of the Finnish Cultural Foundation in 2007. The project was driven by the values of sustainability and aesthetics and of combining the two without compromising the affordability of the houses. It arose especially as a result of a lack of innovativeness in the housing industry and an observed lack of co-operation between architects and house manufacturers.

The project was led by the Finnish Cultural Foundation. It was also the main financer for the project (providing approx. 400,000 Euros). An atypical innovator in the construction industry, the Finnish Cultural Foundation is a non-governmental organization and its primary task is to award grants. The project was coordinated by a steering group consisting of the employees and board members of the Foundation, the real estate manager of Fiskars, the project manager consultant, an architect, and the former communications manager of a construction industry association. The steering group was important in the first stages of the project. Later, the project management duties were taken over by an employee of the Foundation.

The project consisted of two phases. First, proposals were requested from eight different architectural companies. The companies completed their designs by the end of 2009. Five of these designs were selected for further development. During this midpoint of the project, when the first designs were handed over to the Finnish Cultural Foundation, the government was preparing new energy efficiency legislation for buildings. Since the Finnish Cultural Foundation had a clear objective to create unique houses rather than just responding to the upcoming norm, they felt the need to modify the aims of the project. The upcoming regulations supported the use of a mechanical design with a vapor barrier structure as a way to achieve the energy efficiency measures. So the Finnish Cultural Foundation decided that the houses planned as part of the K3 initiative should function with an organic design (meaning natural ventilation and a structure without vapor barriers). A report was ordered from Kimmo Lylykangas (an architect specialized in energy-efficient construction) that would attest to the feasibility of the organic house design.

Based on these premises, the architects were paired with the house manufacturers and asked to start designing the final versions of the houses. The final designs were published in 2011 and made available on the project website for free. The project officially ended with the publication of the designs. The designs did arouse interest in house buyers, but the house manufacturers were unable to deliver clear packages with affordable pricing. For this reason, the Finnish Cultural Foundation has continued to keep the discussion alive and sought new ways to get the first houses built.

5. Analysis of the Cases

In this section, we analyze the cases using the hybrid socio-economic theory of new path creation [24]. Because the projects operated within the same context, the initial conditions and landscape change outcomes were virtually identical. Therefore, the main focus of the analysis is on the path creation processes, the path establishment processes, and the main barriers to path creation in the two cases.

5.1. New Path Creation in the MeraReponen Case

The project's initial conditions were marked by the lack of innovativeness in the construction industry and speculation about rising energy prices. Although European energy efficiency legislation was already under preparation, it was not clearly affecting the agenda in Finland during the initiation of the project. Although some delays did occur and a few structural barriers hindered the commercialization of the energy-efficient building, the path creation process for the MeraReponen case was successful one. The process is summarized in Table 2.

Table 2. Path creation process for the MeraReponen case. Initial conditions and landscape change outcome are the same for both cases.

Initial Conditions	Industry's internal environment: - low innovation activity in the construction sector		External pressures: - oil crisis & potentially rising energy prices - global warming - construction sectors' climate change mitigation potential - EU regulation			
Path creation process	VTT—continued experiments with a small number of houses throughout the years and identification of a niche market		Reponen Company—interested in commercializing the energy efficiency innovation		Interested partners group together for the MeraReponen project to seek competitive advantage in the marketplace through new innovation and business logic emerges	
New path establishment process	Demo house - proving the economics and technical soundness of low-energy buildings - gaining market interest	Production lines established for energy-efficient elements - Construction becomes more simple and economic	Environmental policies emphasize urban density - favor apartment houses	Building code requirements for good energy and indoor performance are easier to demonstrate with mechanical design - increased predictability of building permit process	Timing: increasing attention to climate change makes energy efficiency a priority in construction - success in framing the "high-tech" pathway as the solution - followers enter the market	Similar processes abroad, such as the development done by the Passive House Institute in Germany.
Barriers to new path creation	Construction industry traditionally reluctant to invest in actual construction in fear of adding costs during the construction phase that could only save money during the operation phase since not seen as profitable for the builder		Low energy prices	Finding funding	Well- known mistakes made in late 70's oil crises when trying to save energy in buildings	
Landscape change outcome	Energy-efficient construction dominated by mechanical design		Bubbling under: - dissatisfaction with lack of alternatives		Bubbling under: - fear of potential negative implications of homogenous building stock	

The *initial conditions* for the project featured an operative environment dominated by a "business-as-usual" mentality and a lack of innovativeness. Both typical features of the construction industry, where investments in research and development had been low [5]. The industry seemed to rely on the notion that a permanent shortage of housing and a constant demand for new buildings will secure revenues. A lack of investment in research and development and the poor collaboration between academia and industry had also been noted internationally [45]. Despite the fact that the VTT Technical

Research Center of Finland had conducted many studies on the advantages of energy-efficient housing, the industry as a whole remained rather skeptical about it. Until the commencement of the MeraReponen project, energy-efficient building remained more of an invention than innovation.

The *path creation process* for the MeraReponen case was clearly successful. This was in part because the project participants shared the same visionary business plans. The pilot versions helped to prove the economic feasibility of the innovation, which encouraged the project partners to create separate production lines for energy-efficient elements. This helped them to gain economic value by eliminating the need to make the elements and windows for the houses separately or to build them on-site.

The *path establishment process* for the MeraReponen case confirmed the economic feasibility of energy-efficient housing; the construction costs of energy-efficient houses even in this pilot phase were only 5% greater than for regular houses. The economics worked especially well for those developers who remained owners of the houses for a longer period of time. The first buildings were constructed for companies that specialize in housing rental services. As soon as the first building was finished, it was promptly followed by several others. This rising market interest confirmed the impression of those involved in the project that energy-efficient housing is definitely a business asset. This helped to secure continuation along the chosen path.

The discourse on climate change provided background support for the project and helped raise awareness about the issue of energy efficiency in the real estate and construction sector. Also, environmental policies started focusing more on the compactness of communities, which favored apartment buildings over detached houses. The new niche was significantly helped by regulations, which pushed the industry to invest in energy-efficient housing technology. The attention and praise received from politicians benefitted the project. President Tarja Halonen picked the concept to be awarded by the Finnish Association of Civil Engineers in 2007. Minister of Employment and the Economy Jan Vapaavuori attended the laying of the foundation stone for the first such building in Heinola in 2008.

The first building was supposed to be finished by the time of the building fair in Heinola in 2004. This goal was later abandoned because of complaints about the building plan for the area. Another delay occurred in 2007 when the Housing Finance and Development Centre of Finland (ARA) ran out of money. This slowed the construction project by one year. Though these delays were unfortunate and slowed down the process, they did not constitute drastic challenges to the idea of energy-efficient housing. T*he main barriers for the path creation process* included a lack of support for energy efficiency measures in the construction industry and cognitive barriers due to past mistakes made in the construction industry when insulating homes.

The first barrier resulted from the fact that the contractor and the owners and inhabitants of the new houses did not share the same interest when it came to energy costs. The profitability of energy efficiency measures only materialize during the use phase, whereas the costs of these measures materialize during the construction phase. In the real estate market, the pricing is heavily influenced by many factors other than just the energy consumption of the building. As Kyrö *et al.* have stated [46], these include external factors (e.g., location, availability of nearby services, commuting opportunities) and value-determinant factors (e.g., gross rent, yield, vacancy rate, residual value). The influence of energy efficiency on the overall value by way of such value-determinant factors is minor, approximately 2% of the real estate value [47] which results in a decrease in the motivation of the contractor to invest more in energy efficiency. Energy prices have not been rising steeply enough to create considerable demand for energy efficiency measures. This barrier was partly overcome in the project by marketing this solution to housing companies, which benefitted from the savings during the use phase of the building. The new regulations demanding a higher level of energy efficiency for all buildings helped to remove this barrier altogether.

The cognitive barrier to energy-efficient housing was the fear of so-called “bottle houses,” which were constructed after the oil crisis in the 1970s. This type of house had thick insulation, but no additional ventilation, which led to moisture damage and bad air quality. For this reason, attempts to improve energy efficiency were prone to suspicion about possible moisture damage. The matter was discussed in detail when the building code was about to be renewed. Both VTT and Tampere University of Technology prepared a report on the feasibility of energy-efficient housing. The VTT report supported the new energy-efficient housing technology while Tampere University of Technology’s report was more critical. The latter report called for more research on the topic on the basis of the unknown effects of climate change on the Finnish climate, which, combined with possible mistakes made in the planning and construction phases for energy-efficient houses (due to the lack of knowledge of both the designers and building contractors), might result in failures. The results from the VTT report were valued more in the formulation of the energy legislation. This helped eliminate fears about moisture damage in low-energy houses. As more residents moved into the houses, their positive experiences all helped break down this cognitive barrier.

By the time the regulations were enforced, the MeraReponen concept was already clearly below the new limits for energy use. Despite the general decrease in building activity through economic stagnation, their order book was full. The project won many prizes and international opportunities arose in Russia. Reponen soon also broadened the scope of its concept to include low-energy apartment buildings made of wood (the first one was completed in 2011). As the functionality of the technology was proven and pushed forward by legislation, other entrants soon emerged on the market. The concept became a brand name and served as a benchmark for the industry as well as policy makers on how to build low-energy housing. *As a landscape outcome*, the mechanical design is now established as the way to build low-energy houses.

5.2. New Path Creation in the K3 Case

Similarly to the MeraReponen case, the K3 project was affected by the internal environment of the construction industry. However, energy efficiency legislation and discussions about climate change also affected the K3 project. However, the path creation process for the K3 case has not achieved a commercially viable product. The main factors affecting the path creation process are summarized in Table 3.

In particular, the lack of co-operation between architects and house manufacturers was seen as a leading cause for the building of monotonic detached houses. During the conception phase of the K3 initiative, discussions about climate change had already affected the construction industry and the need to promote sustainability in housing through energy efficiency had emerged. The first EU directive on energy efficiency in buildings was accepted in 2002 and the member states were obliged to implement the directive in national legislation by 2006 [48]. In Finland, the implementation process was led by the Ministry of the Environment, and the necessary legislation was set up in 2008 and entered into force in 2010. A further update was made in 2010, which entered into force in 2012.

Table 3. Path creation process for the K3 case. Initial conditions and landscape change outcome are the same for both cases.

Initial conditions	Industry's internal environment: - low innovation activity in the construction sector		External pressures: - oil crisis & potentially rising energy prices - global warming - construction sectors' climate change mitigation potential - EU regulation			
Path creation process	Finnish Cultural Foundation and Fiskars Corporation agree on the need to support values of sustainability and aesthetics in detached house manufacturing		The K3 project created and centered around the Foundation		Organic design proposed as an alternative to mechanical design	
New path establishment process	Attempts to facilitate collaboration between house manufacturers and architects		Gaining strong support from experts	Attempts to influence new building regulation	All house designs made available for free for private and commercial use	
Barriers to new path creation	Environmental policies emphasize urban density - disfavor detached houses	Building code requirements for good energy and indoor performance are easier to demonstrate via mechanical design - autonomy and responsibility of municipal building officials combined with their tendency for risk avoidance was seen to decrease the predictability of building permit process	No production lines established - house manufacturers hesitate to invest in development activities - component suppliers not included in the development phase	No demo house - untested technical solutions - market interest not raised	Timing: increasing attention to climate change makes energy efficiency a priority in construction - failure in framing the "low-tech" pathway as a solution	The focal organization had no direct business interest in the project
Landscape change outcome	Energy-efficient construction dominated by mechanical design		Bubbling under: - dissatisfaction with lack of alternatives		Bubbling under: - fear of potential negative implications of homogenous building stock	

For the *path creation process*, the Finnish Cultural Foundation had a clear vision of deviating from the existing ways of working in the construction sector. The problem the Foundation wanted to tackle had to do with the fact that while house manufacturers typically produce most of the detached houses, only a few of them are actually designed by architects. The Foundation wanted to create a new manner of co-operation between architects and house manufacturers. In addition, it did not want to restrict the sustainability of housing to just energy efficiency; housing should also take into account, for example, materials, building methods, lifespan, and support for sustainable lifestyles. This idea grew more prominent during the project. As it became clear that the new legislation was going to force all new houses to be energy-efficient, the design requirements for the houses were modified. A new direction was found in organic houses. Organic design principles were seen as a means to approach sustainability more holistically rather than treating it simply as a question of energy efficiency. In Finland, many authorities, including the leading legislators, assumed that only mechanical design could achieve low-energy consumption and good indoor air quality simultaneously.

The Finnish Cultural Foundation intended to *establish the path* for its project by engaging the house manufacturers to work with architects. The purpose was to cleverly introduce architectural values into industrial house manufacturing in a manner that would be acceptable and realistic enough to become a part of existing business models. Co-operation between architects and house manufacturers, however, did not work as well as planned. Only one team had a reasonable amount of mutual correspondence. Neither were the house manufacturers able to use the models in their production line. The other interesting factor was the decision to make the models free and available for both private and commercial use. The idea was to distribute the results of the project as widely as possible, thereby enabling the spread of knowledge. The project received strong support in the form of expert analysis on the feasibility of organic low-energy houses, which was used to help with attempts to influence regulators concerning energy efficiency legislation.

The main barriers to path creation came from regulations and from the suspicions that the municipal building officials had about the organic design. Also, the unwillingness or inability of house manufacturers to innovate, the lack of industrial pre-manufactured elements, untested technical solutions, and timing hindered the establishment of a viable path creation process.

The energy efficiency regulations attested to the implicit assumption that mechanical design should be the industry standard, hence the first regulations did not approve of organic low-energy housing. This was changed in the updated regulation. In general, experts in the field still viewed mechanical design as the correct way to construct a low-energy building. This view was made clear by the municipal building officials. In the publication event for the project, an official from Helsinki asked the project leaders whether they were aware that the organic design would not be compatible with the building code and, consequently, such houses would not receive building permits in Helsinki. Although this issue was resolved with officials in other municipalities, and organic houses are in fact now allowed, the incident shows the general suspicion towards organic low-energy houses in Finland.

The reluctance of house manufacturers to take a more proactive approach in the process weakened the results. While the project initially piqued interest among house manufacturers, several possible participants soon backed off. The co-operation between architects and house manufacturers did not work as well as planned; only one architect-house manufacturer team co-operated enough to actually say the design was a result of teamwork, and yet even this design did not make it onto the market as such.

The need to create new low-energy housing technology without having accredited testing methods damaged the credibility of the project. Also, the primary client withdrew from its planned role as developer and neither the Foundation nor the house manufacturers were willing to take responsibility should the houses need a renovation later on. This risk was left to the potential home owners, which hurt the demand for the houses; although potential home buyers were found, they withdrew when faced with this requirement.

Timing influenced the project. At the same time that the designs were being finished, mechanical design was getting more attention from other construction companies and gaining acceptance. Previously, the technical feasibility of the mechanical design had been under suspicion. However, now the question was whether it could even be possible to build low-energy houses without mechanical design.

The *landscape change outcome* of the path creation attempt was that by the end of 2014, not a single industrially manufactured K3 house had yet been built. The Finnish Cultural Foundation's aspirations for house manufacturers to take the initiative in building such homes after the launch of the designs was not realized. New means for building the first homes are still being sought, but it is obvious that as it stands, mechanical design is clearly the dominant pathway in low-energy housing in Finland.

5.3. Comparison of the Cases

Why did the two path creation attempts have such different market outcomes despite their proven technological functionality and demand? In this section, we outline and discuss the differences between the two cases in order to answer that question.

Although the initial conditions were the same, some distinctions about the importance of different factors can be made. Major differences in the beginning stages had to do with the fact that MeraReponen project was motivated more by the trend of rising fuel prices. The K3 project was motivated more by the aspiration to produce beautiful, sustainable, and reasonably priced houses. Also, the low-energy technology used in the MeraReponen project case had been researched for a long time by the personnel at the VTT Technical Research Centre before there was any market interest in commercializing the technology. In contrast, the K3 project relied more on good professional design practices.

The path creation process in both projects originated from an idea by key agents. A niche then formed around these agents. The differences between the projects lies more in the fact that the MeraReponen niche formed around pure business actors, whereas in the K3 case, the niche formed around a private trust dedicated to promoting art and science, (Finnish Cultural Foundation). Also, although it was the intention of the Finnish Cultural Foundation that detached houses would become a profitable business for the companies involved, pushing forward its vision of sustainability could have been emphasized more.

Interestingly, despite some mutual challenges like getting the industry actors interested, most of the factors that supported the MeraReponen project had the opposite effect on the K3 project. The K3 project also lacked some critical elements, such as a tangible demo building. The contradictions between the path establishment processes and obstacles to path establishment in the MeraReponen and K3 projects are illustrated in Table 4.

The landscape outcome for low-energy housing is that the mechanical design used in the MeraReponen project has become dominant in the field and is currently the main model for how to build low-energy houses. There are still some supporters for the organic design proposed in the K3 project who fear that the dominance of just one solution will lead to a lack of alternatives in building stock. Total homogeneity is considered a poor result since, if technical problems were to arise in the long run, it would then affect all new buildings.

Table 4. A comparison of the path establishment process in the MeraReponen case and corresponding path creation barriers in the K3 case.

MeraReponen Case Path Establishment	K3 Case Barriers to Path Establishment
Demo house - proving the economic and technical soundness of low-energy buildings - creating market interest	No demo house - untested technical solutions - market interest not raised
Production lines established for low-energy elements - Construction becomes more simple and economic	No production lines established - house manufacturers hesitate to invest in development activities - component suppliers not included in development phase
Environmental policies emphasize urban density - favors apartment houses	Environmental policies emphasize urban density - disfavors detached houses
Building code requirements for good energy and indoor performance are easier to demonstrate with mechanical design - increased predictability of building permit process	Building code requirements for good energy and indoor performance are easier to demonstrate with mechanical design - autonomy and responsibility of municipal building officials combined with their tendency for risk avoidance reduced the predictability of the building permit process
Timing: increasing attention to climate change makes energy efficiency a priority in construction - success in framing the "high-tech" pathway as the solution - followers enter the market	Timing: increasing attention to climate change makes energy efficiency a priority in construction - failure in framing the "low-tech" pathway as a solution

6. Results

In this paper, we have explored two innovation projects in energy-efficient housing. Despite both being developed in the same context, their outcomes were strikingly different. The comparison of these two innovation projects as path creation processes give some valuable insights on construction innovation. The results highlight two issues that were crucial to the market success of these innovations: one of a systemic nature and the other concerning innovation management.

First, the institutional context and its changes during the innovation projects affected the outcome: path creation was either helped or hindered by the regulatory environment. The development of energy efficiency regulations and the dominant technological trajectory of low-energy houses are interdependent. It seems that while supporting the trajectory of the innovation developed in the first case, regulators created virtually insurmountable cognitive and normative obstacles to finding alternative technological pathways. This was clearly shown by how the building regulations that came into force during the projects did not support the organic design pathway that was developed in the K3 project. Although the current legislation explicitly mentions the possibility for organic design in housing, the use of natural ventilation and structures without vapor barriers is inhibited due to the vagueness of the methods in demonstrating the feasibility of such an option. The issue is left to the individual judgment of municipal building officials, thus decreasing the predictability of building permit decisions. Furthermore, the previous version of the legislation, which was in force between 2008 and 2010, was even less receptive to organic design, rendering the technology impossible to use in low-energy houses. It helped the mechanical design pathway become more established in the MeraReponen project and provided a clear sign to the industry regarding what kind of innovations policy-makers value.

Second, this study confirms the results of previous research in that significance of proof of concepts for new housing innovations cannot be underestimated [49,50]. The importance of a pilot project lies not only in showcasing and testing the technology, but also in its ability to increase political support, investments, and public awareness. While the difference in the outcomes of the two projects was largely influenced by the operating environment, differences in how the projects were managed also played an important role. The lack of a pilot organic house clearly affected the outcome and hindered the commercialization of the K3 project. It created a marketing problem since there was no showcase example and no one was eager to take on the role of the pioneer. Although the models made created interest in potential buyers, this did not materialize into something more since neither the house manufacturers nor the customers wanted to assume full responsibility for possible future renovation work had the technology not worked. In the MeraReponen project, the whole process was designed with the aim of creating actual buildings. This aim was guaranteed by applying for financial help from both Tekes and Ara.

Interestingly, leadership, resources and capabilities of the organizations did not seem to be crucial in undermining the success of the K3 project. The interviewees thanked the Finnish Cultural Foundation for its vision and efforts to push the project forward and for bringing the project participants together. The financial support that the Finnish Cultural Foundation gave to the project was substantial and made the project feasible. Despite some problems the architects and house manufacturers had in their co-operation, all models were finalized on paper. It was only in the latest phases of the project when the biggest obstacles—building regulations and the lacking of a demo house—started undermining its potency.

7. Discussion

This paper broadens the scope of research on energy-efficient buildings beyond the technical sphere through an in-depth comparative analysis of two innovation projects from the development phase to market introduction. The hybrid socio-economic theory of new path creation [24] was used to structure the comparison. The critical techno-economic and political success factors were analyzed to explain why two simultaneous innovation projects that had similar aims, operated in the same context, and produced technically sound, energy-efficient houses had completely different market outcomes.

Although it is an empirical study in the Finnish context and the results are not transferable elsewhere as such, the study brings up some interesting practical as well as theoretical implications and questions. Firstly, it is clear that in both projects, active path creation was done and barriers raised by path dependency existed. Both of these projects clearly started as a result of the main actors adopting ideas for implementation, following the elements of innovation by Winch [25]. The leading actors thus played an important role in the processes. Based on our data, problems of management did not seem to be an issue in either of the projects. In both projects, the leading actors took responsibility for the projects and ensured that the process went forward. That said, the project network in the K3 project was more top-down led than the MeraReponen. Thus, further research on to what extent the difference in the organization of project networks influences innovation processes could be supported.

Also, the negative impact that the regulations had on the innovation process in the case K3 raises the question: how should project participants and especially those in leading positions react to these kinds of path creation barriers, and what possibilities are there for action? In the K3 case, attempts to influence the regulations existed, and later regulations made their model feasible, though it was still more complicated to put into practice than the mechanical version. Perhaps they would have been more successful had they not insisted on having the natural ventilation without vapor barriers. Alternatively, they could have been more active in influencing the regulations earlier on in the process. It is also possible that lobbying or partnering with influential opinion leaders more actively would have helped.

While these are issues that cannot be answered based on this study, it is clear that the analysis of which barriers can be overcome and how is important. It has been reported that collective action [51,52] can be used to gain support for certain technologies. Further studies on how these types of regulative barriers could be overcome, especially in highly regulated fields, could be supported. Also, a further analysis on the debates on the energy efficiency regulations, political interests and power relations between the industrial and political actors could shed more light on which actors influence the innovation environment and how. It is also interesting that neither of the leading organizations in the two ambitious innovation projects is a big player in the construction industry. The leader in the MeraReponen project was a medium-sized company while the leading actor of the K3 project was not even a usual actor in the field. On the one hand, the role of the Finnish Cultural Foundation as a construction industry innovator can be questioned: Would the project have been more successful had the leader been more business oriented? On the other hand, it is likely that the organic design pathway for low-energy houses would never have been created without the Foundation. Also, as a non-profit organization and an outsider to the industry, the Foundation was a more patient innovator without the need for an instant economic win. Further research on the actions of the bigger players in the construction industry might shed more light on the reasons why the bigger players were not active in this role and give further insights on the barriers of energy-efficient housing innovations. That said, it can be noted that the barriers identified in this study do reflect similar issues than previous research in other countries [18,19]. Usually though the barriers are created by missing regulations, not because of regulations which impede the development of alternative modes of reaching the energy efficiency.

In this study, we chose to focus our analysis on the path creation processes and its barriers, which highlighted the institutional context. However, this approach leaves the perspective of the users and their innovation adoption uncovered. Further research could seek to answer whether differences in the energy efficiency techniques influence how energy-efficient houses are welcomed by home buyers. The innovation diffusion model of Rogers could also be used to track the pace of adoption of energy-efficient construction in Finland.

Policy makers have been noted to play a crucial role for the introduction of highly-efficient housing, and there have been demands from the research field for more policy-push in this field [19]. In the cases studied in this article, policy acted as an enabler for one case but restricted action in the other case. This leads to the conclusion that while policies can promote construction innovations, policy makers should be more aware of how their specific actions affect industry innovations. Also, even if they improve the energy efficiency of housing, energy performance regulations can sometimes merely result in the development of incremental innovations [53]. Before implementing policies, evaluation of possible effects on innovations should be conducted. Approaches from transition studies and strategic niche management could be employed to create coherent strategies for purposeful and planned transition to sustainable housing.

The implications of these findings for low-energy housing in the future are interesting. Sustainability within the construction industry now primarily has to do with energy efficiency. However, the ways in which technologies are valued from an environmental standpoint are time bound and can change [54]. Mechanical design has proven to be effective in efforts to increase energy efficiency. However, should the meaning of sustainability change and become more concerned with the carbon footprint during the entire lifecycle of buildings, organic design might become a much more appealing alternative. Legislation that creates pressure to use a specific technology for a general end has a negative effect on the development and availability of options. For example, Williamson *et al.* [55] have noted that in Australia the regulations encouraged a generic model for low-energy housing. This generic model did not, however, meet the occupants' expectations nor did it suit their behavior. Also, the projected energy consumption of the dwellings was not successfully predicted. Thus, the diversification of low-energy housing technologies may be beneficial.

Whether the designs produced in the K3 project will promote diversification in the long run remains to be seen. The analysis of the path creation process would benefit from a follow-up study. Other scholars have argued that alternative paths can exist within an industry even when a dominant path has already been established [35]. A further examination of the Finnish housing industry in the future could show whether one of these two paths to low-energy housing will remain dominant, whether they will shape the construction industry together, or whether some other solutions will replace them both.

The study implies that the success of low-energy construction seems to depend heavily on the innovation capability of the industry and policymakers. The industry has to learn how to create successful partner networks around its new low-energy solutions that contain, e.g., ecosystems. Similarly, public authorities have to learn to understand the interlinked ecosystem-level consequences of their actions aimed at promoting a low-energy future. Finally, low-energy construction seems to be the next great challenge, one where genuine co-operation between the industry, public authorities, and academia is a prerequisite for the success of the cause.

Acknowledgments

The authors thank Tekes—the Finnish Funding Agency for Technology and Innovation—for research funding. The views expressed by the authors do not necessarily reflect those of the funders.

Author Contributions

Pia Pässilä is the primary author. She was primarily responsible for initiating the work; for the acquisition, analysis and interpretation of the data; and for writing the paper. Lauri Pulkka made a substantial contribution to the acquisition, analysis, and interpretation of the data and to drafting and reviewing the manuscript. Seppo Junnila contributed substantially to the interpretation of the data and to reviewing the content of the work. All authors have read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

Appendix

Table A1. Data used for the MeraReponen case.

Source	Details
5 interviews - the CEO of the Reponen Company: He had an active role heading up the project, as he started as CEO the same year the company decided to start developing the low-energy business idea - the development manager at Skaala Company (provided the windows for the low-energy building) - CEO of SPU (firm providing the insulation material for the low-energy building) - an expert at VTT who had a long career at VTT and participated in many low-energy housing projects - a technology expert from Tekes	Interviews were conducted during 2009–2010. They vary from 100 to 130 min in duration. The interviews were recorded and transcribed
Written documents - Saari, Mikko: Builder's low energy choices in a building block. Presentation at the builder's climate and energy seminar in 2008 - Presentation of Jyri Jaskari, Skaala windows and doors at the Hospital Technic Days on the 4th and 5th of February, 2009 - Saari, Mikko. (2008): Passive House. What is it and how can it be done? Presentation at the Housing and Climate Change Seminar. Helsinki - Building Block 2000. Live better—research project. House that saves energy is also healthy. "Article in journal Talotekniikka, May 1997, pp. 32–34 - Building low-energy houses is simple. Article by Tiina Tähtinen in journal Electricity and Heat. 1994 - Martinkauppi, Kirsi (edit.): ERA17 Final report. Ministry of Environment, Sitra Tekes. 2001.	

Table A2. MeraReponen project partners.

MeraReponen Partners	
Name of the partner	Role
Reponen Company	Leader of the projects, a fairly small actor in the Finnish construction industry which employs circa 60 people
VTT Technical Research Centre	A large professional research institute
Skaala	Manufacturer of windows
SPU	Manufacturer of insulators
Meptek Oy (Swegon ILTO Oy)	Manufacturer of air-conditioning units
LS Laatuseinä	Wall elements. Has partnered with Reponen company already in previous projects
The School of Applied Sciences in Mikkeli	Role in both adding to the knowledge base as well as learning more it. Educational cooperation
Finnish Youth Housing Association (NAL)	Owner of the first building block

Table A3. Description of the data for the K3 case.

Source	Details
7 interviews - the Secretary General of the Finnish Cultural Foundation - both project managers - two external members of the initiative's steering group - one architecture firm - one house manufacturing firm	Interviews were conducted mainly in late 2013. They vary from 25 to 110 min in duration. The interviews were recorded and transcribed
Confidential documents - Preliminary report on the relevance, implementation, and challenges of the initiative by a consultant in 2008 (17 pp.) - Project assessment report by the Foundation in 2013 (7 pp.)	The confidential reports were made available by two different interviewees. The preliminary report offers a detailed account of the original idea and the plan for how to implement it. The assessment report consists of two parts, a chronological record of events and a subjective evaluation of the initiative from the Foundation's perspective.
Publicly available documents - Technical report on organic design (65 pp.) - Design guidelines for architects (2 pp.) - Assessment report of the first-round designs (21 pp.) - Comment on proposed building regulation by the Foundation (4 pp.) - Article about K3 houses in popular media (6 pp.) - Initiative website	The Foundation has published the publicly available documents on its website with the exception of an article published in a popular journal. Technical reports and the assessment of the first-round designs were produced by building and HPAC experts. The article about K3 houses was written by the former communications manager of the Confederation of Finnish Construction Industries

References

1. Council of the European Union. *Energy/Climate Change—Elements of the Final Compromise*; Council of the European Union: Brussels, Belgium, 2008.
2. The European Commission. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A Policy Framework for Climate and Energy in the Period from 2020 to 2030. Available online: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014DC0015&from=EN (accessed on 29 June 2015).
3. The European Parliament and the Council. Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the Energy Performance of Buildings. Available online: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32010L0031 (accessed on 29 June 2015).
4. The European Parliament and the Council. Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on Energy Efficiency, Amending Directives 2009/125/EC and 2010/30/EU and Repealing Directives 2004/8/EC and 2006/32/EC. Available online: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:315:0001:0056:en:PDF (accessed on 29 June 2015).

5. Loikkanen, T.; Hyvönen, J. *Sectoral Innovation Watch-Construction Sector*; Innova European Commission: Espoo, Finland, 2011.
6. Finlex. Finlex. Laki Rakennuksen Energiatodistuksesta. Available online: http://www.finlex.fi/fi/laki/alkup/2007/20070487 (accessed on 30 June 2015). (In Finnish)
7. Ministry of the Environment. D3 Suomen rakentamismääräyskokoelma. Rakennusten Energiatehokkuus. Available online: http://www.finlex.fi/data/normit/34165-D3-2010_suomi_22-12-2008.pdf (accessed on 29 June 2015). (In Finnish)
8. Ministry of the Environment. Rakennusten Energiatehokkuus. Määräykset Ja Ohjeet 2012. Available online: http://www.finlex.fi/data/normit/37188-D3-2012_Suomi.pdf (accessed on 29 June 2015). (In Finnish)
9. Jussila, V. *VTT: Järkevästi Tehty Matalaenergiatalo ei Ole Homeriski (Soundly Made Low-Energy House Not Prone to Moisture Damages)*; Tekniikka ja Talous Magazine: Helsinki, Finland, 2008. (In Finnish)
10. Törmänen, E. *Matalaenergiatalot Ovat Homepommeja? (Are Low-Energy Houses Prone to Moisture Damages?)*; Tekniikka ja Talous Magazine: Helsinki, Finland, 2008. (In Finnish)
11. Gunner, A.; Hultmark, G.; Vorre, A.; Afshari, A.; Bergsøe, N.C. Energy-Saving Potential of a Novel Ventilation System with Decentralised Fans in an Office Building. *Energy Build.* **2014**, *84*, 360–366.
12. El Fouih, Y.; Stabat, P.; Rivière, P.; Hoang, P.; Archambault, V. Adequacy of Air-to-Air Heat Recovery Ventilation Syste Applied in Low Energy Buildings. *Energy Build.* **2012**, *54*, 29–39.
13. Guerra-Santin, O.; Tweed, C.; Jenkins, H.; Jiang, S. Monitoring the Performance of Low Energy Dwellings: Two UK Case Studies. *Energy Build.* **2013**, *64*, 32–40.
14. Persson, J.; Grönkvist, S. Drivers for and Barriers to Low-Energy Buildings in Sweden. *J. Clean. Prod.* **2014**, doi:10.1016/j.jclepro.2014.09.094.
15. Ryghaug, M.; Sørensen, K.H. How Energy Efficiency Fails in the Building Industry. *Energy Policy* **2009**, *37*, 984–991.
16. Halme, M.; Nieminen, J.; Nykänen, E.; Sarvaranta, L.; Savonen, A. *Business from Sustainability: Drivers for Energy Efficient Housing*; VTT Otamedia: Espoo, Finland, 2005.
17. Windapo, A.O. Examination of Green Building Drivers in the South African Construction Industry: Economics *versus* Ecology. *Sustainability* **2014**, *6*, 6088–6106.
18. Haavik, T.; Mlecnik, E.; Rødsjø, A. From Demonstration Projects to Volume Market of Sustainable Construction. *Energy Procedia* **2012**, *30*, 1411–1421.
19. Mlecnik, E. Innovation Development for Highly Energy-Efficient Housing. In Proceedings of the CIB International Conference on Construction in a Changing World, Sri Lanka, India, 4–7 May 2014.
20. Mlecnik, E. *Innovation Development for Highly Energy-Efficient Housing: Opportunities and Challenges Related to the Adoption of Passive Houses*; IOS Press: Amsterdam, The Netherlands, 2013.
21. Yin, R.K. *Case Study Research: Design and Methods*; Sage Publications: Thousand Oaks, CA, USA, 2013.
22. Polkinghorne, D.E. Narrative Configuration in Qualitative Analysis. *Int. J. Qual. Stud. Educ.* **1995**, *8*, 5–23.
23. Simmie, J. Path Dependence and New Technological Path Creation in the Danish Wind Power Industry. *Eur. Plan. Stud.* **2012**, *20*, 753–772.

24. Simmie, J.; Sternberg, R.; Carpenter, J. New Technological Path Creation: Evidence from the British and German Wind Energy Industries. *J. Evolut. Econ.* **2014**, *24*, 875–904.
25. Winch, G. Zephyrs of Creative Destruction: Understanding the Management of Innovation in Construction. *Build. Res. Inf.* **1998**, *26*, 268–279.
26. Winch, G.M. How Innovative is Construction? Comparing Aggregated Data on Construction Innovation and Other Sectors—A Case of Apples and Pears. *Constr. Manage. Econ.* **2003**, *21*, 651–654.
27. Marceau, J.; Houghton, J.; Toner, P.; Manley, K.; Gerasimou, E.; Cook, N. *Mapping the Building and Construction Product System in Australia*; University of Western Sydney Macarthur: Sydney, NSW, Australia, 1999.
28. Blayse, A.M.; Manley, K. Key Influences on Construction Innovation. *Constr. Innov.* **2004**, *4*, 143–154.
29. Dubois, A.; Gadde, L. The Construction Industry as a Loosely Coupled System: Implications for Productivity and Innovation. *Constr. Manag. Econ.* **2002**, *20*, 621–631.
30. Law, J.; Gallon, M. The life and death of an aircraft: A network analysis of technical change. In *Shaping Technology/Building Society: Studies in Sociotechnical Change*; Bijker, W.E., Law, J., Eds.; MIT Press: Cambridge, MA, USA, 1992; p. 21.
31. Gann, D.M.; Salter, A. Learning and Innovation Management in Project-Based, Service-Enhanced Firms. *Int. J. Innov. Manag.* **1998**, *2*, 431–454.
32. Lovio, R.; Mickwitz, P.; Heiskanen, E. 15 Path Dependence, Path Creation and Creative Destruction in the Evolution of Energy Systems. In *The Handbook of Research on Energy Entrepreneurship*; Edward Elgar Publishing: Cheltenham, UK, 2011; p. 274.
33. Henderson, R.M.; Clark, K.B. Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms. *Adm. Sci. Q.* **1990**, *35*, 9–30.
34. Christensen, C.M.; Rosenbloom, R.S. Explaining the Attacker's Advantage: Technological Paradigms, Organizational Dynamics, and the Value Network. *Res. Policy* **1995**, *24*, 233–257.
35. Bergek, A.; Onufrey, K. Is One Path enough? Multiple Paths and Path Interaction as an Extension of Path Dependency Theory. *Ind. Corp. Chang.* **2013**, doi: 10.1093/icc/dtt040.
36. Garud, R.; Karnøe, P. Path Creation as a Process of Mindful Deviation. *Path Depend. Creat.* **2001**, *138*, 1–38.
37. Garud, R.; Kumaraswamy, A.; Karnøe, P. Path Dependence or Path Creation? *J. Manag. Stud.* **2010**, *47*, 760–774.
38. Rogers, E.M. *Diffusion of Innovations*; Simon and Schuster: New York, NY, USA, 2010.
39. Geels, F.W.; Schot, J. Typology of sociotechnical transition pathways. *Res. Policy* **2007**, *36*, 399–417.
40. Smith, A.; Stirling, A.; Berkhout, F. The governance of sustainable socio-technical transitions. *Res. Policy* **2005**, *34*, 1491–1510.
41. Kemp, R.; Schot, J.; Hoogma, R. Regime Shifts to Sustainability through Processes of Niche Formation: The Approach of Strategic Niche Management. *Technol. Anal. Strateg. Manag.* **1998**, *10*, 175–195.
42. Schot, J.; Geels, F.W. Strategic niche management and sustainable innovation journeys: Theory, findings, research agenda, and policy. *Technol. Anal. Strateg. Manag.* **2008**, *20*, 537–554.

43. Törmänen, E.; Repo, H. Asuntojen Energiankulutus Vähenee. Available online: http://www.tekniikkatalous.fi/tekniikka/rakennus/2007-11-21/Asuntojen-energiankulutus-v%C3%A4henee-3296522.html (accessed on 21 June 2015) (In Finnish).
44. Pulkka, L.; Junnila, S. Old-Technology Twist to Sustainability Innovation in the Construction Industry: Case-Study of an NGO's Low-Tech Alternative for Energy Efficient Housing in Finland. In Proceedings of the CIB International Conference on Construction in a Changing World, Heritance Kandalama, Sri Lanka, 4–7 May 2014.
45. Dulaimi, M.F.; Ling, Y.Y.F.; Ofori, G.; Silva, N.D. Enhancing Integration and Innovation in Construction. *Build. Res. Inf.* **2002**, *30*, 237–247.
46. Kyrö, R.; Heinonen, J.; Säynäjoki, A.; Junnila, S. Occupants have Little Influence on the overall Energy Consumption in District Heated Apartment Buildings. *Energy Build.* **2011**, *43*, 3484–3490.
47. Christersson, M.; Säynäjoki, A.; Vimpari, J.; Junnila, S. Assessment of Financial and Environmental Potential of a Real Estate Energy Efficiency Investment. In Proceedings of the 2014 CIB International Council for Research and Innovation in Building and Construction, Heritance Kandalama, Sri Lanka, 4–7 May 2014.
48. The European Parliament and the Council. Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the Energy Performance of Buildings. Available online: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32002L0091 (accessed on 30 June 2015).
49. Femenias, P. *Demonstration Projects for Sustainable Building: Towards a Strategy for Sustainable Development in the Building Sector Based on Swedish and Dutch Experience*; Chalmers University of Technology: Gothenburg, Sweden, 2004.
50. Van Hal, A. Beyond the Demonstration Project: The Diffusion of Environmental Innovations in Housing. Ph.D. Thesis, Technische Universiteit Delft, Delft, The Netherland, October 2000.
51. Dowell, G.; Swaminathan, A.; Wade, J. Pretty Pictures and Ugly Scenes: Political and Technological Maneuvers in High Definition Television. *Adv. Strategic Manag.* **2002**, *19*, 97–134.
52. Hargrave, T.J.; van de Ven A.H. A Collective Action Model of Institutional Innovation. *Acad. Manag. Rev.* **2006**, *31*, 864–888.
53. Beerepoot, M.; Beerepoot, N. Government Regulation as an Impetus for Innovation: Evidence from Energy Performance Regulation in the Dutch Residential Building Sector. *Energy Policy* **2007**, *35*, 4812–4825.
54. Kivimaa, P. *The Innovation Effects of Environmental Policies: Linking Policies, Companies and Innovations in the Nordic Pulp and Paper Industry*; Helsinki School of Economics: Helsinki, Finland, 2008.
55. Williamson, T.; Soebarto, V.; Radford, A. Comfort and Energy use in Five Australian Award-Winning Houses: Regulated, Measured and Perceived. *Build. Res. Inf.* **2010**, *38*, 509–529.