Chapter 2
Literature Review

Contents

Abstract The literature offers at least four threads from which theory and insights might be woven. These are (1) research on technological innovation systems, (2) innovation diffusion studies, (3) studies on dominant design, and (4) studies about energy efficiency in the residential building sector. For each, this chapter reviews only the most relevant studies to understand what each thread can contribute to analyzing the phenomenon of diffusion and co-evolution of building standards. The review has shown that each stream of research is related to the topic addressed here, but also that the streams do not address the phenomenon as I intend to do. Research in technological innovation systems (TIS) focuses on the development of technologies and not on development in standards. Research on innovation diffusion concentrates too narrowly on the level of products, technologies, or services. Studies of dominant design are most often about standards directly competing for market dominance, not about norms that evolve in the mode of symbiotic competition at the edges of their markets. Energy studies about the (Swiss) residential building sector use models which seem to be rich in detail complexity but not in dynamic feedback

S.N. Grösser, *Co-Evolution of Standards in Innovation Systems*,
Contributions to Management Science, DOI 10.1007/978-3-7908-2858-0_2,

complexity, leaving out relevant ripple effects when it comes to policy analysis. To conclude, the review of the literature revealed that it could not sufficiently explain the co-evolution of building codes in a socio-technical system. That is the gap which the book addresses.

Keywords Co-evolution • Dominant design • Innovation diffusion • Innovation systems approach • Technological innovation system

Past is experience, present is experiment and future is expectation.
Unknown

Mind the Gap!
London Underground, originally used at the Embankment Station, Northern Line, 1969

Each of following four chapter-sections reviews a distinct thread of literature which might offer some insights about the phenomenon under study. Each chapter-section briefly introduces the subject of the research stream and then reviews the literature most relevant to the subject of standard evolution. It is by design that this entire chapter concentrates only on a few selected publications in each stream, since the vast majority of publications, especially in the field of innovation diffusion and residential building studies, share similarities with respect to the overall topic, but do not offer helpful explanations for the aspect studied here. Using the information from Sects. 2.1, 2.2, 2.3 and 2.4, I then elaborate the research gap in Sect. 2.5.

2.1 Research About Technological Innovation Systems

Technical innovation systems (TIS) research perceives innovations from a system perspective, and therefore is well suited for analyzing the development of standards.

2.1.1 Subject

The central idea behind the innovation systems approach is that determinants of technological change are to be found not only in individual firms or in research institutes, but also in a broader societal structure in which firms, as well as knowledge institutes, are embedded (Freeman, 1987; Lundvall, 1992). The approach made by technological innovation systems (TIS) focuses on technologies as the reference point for the analysis of an innovation system (Carlsson, Jacobsson, Holmen, & Rickne, 2002). In this respect, the approach is different from others which concentrate on the innovation system of a nation (Godin, 2009; Lundvall, 1992; Lundvall, Johnson, Andersen, & Dalum, 2002; Sharif, 2006) or a sector (Asheim & Coenen, 2005; Leydesdorff & Fritsch, 2006; Malerba, 2002). Carlsson et al. have defined technological innovation systems as "networks of agents interacting in a specific technology area under a particular institutional infrastructure for the purpose of generating, diffusing, and utilizing technology" (1991: 96). In its analytical perspective, the TIS approach differentiates between the concepts of actors[1] and their competences, networks, institutions, and functions (Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007b; Jacobsson & Bergek, 2004). In the following, I review literature which pertains closely to the evolution of energy efficiency in standards and also to the diffusion of such standards.

2.1.2 Review

Over the last decade, a growing number of conceptual and case-based empirical studies on innovation systems have applied the TIS-focus. One topic relevant here is that TIS-research has recently focused on the *functions* of an innovation system as a basic unit of analysis. Functions are processes in an innovation system which are important for the performance of that system (Hekkert et al., 2007b). A set of such processes have been proposed, including entrepreneurial activities, knowledge development, knowledge diffusion through networks, guidance for research, market formation, resource mobilization, and creation toward legitimacy. These functions have been corroborated as helpful for explaining the success of emerging technologies (Hekkert, Harmsen, & de Jong, 2007a; Negro & Hekkert, 2008; Negro, Hekkert, & Smits, 2007). For uncovering the relevant functions of a system, researchers have suggested either an event-history analysis or a process mapping by which the interactions between system functions and their development over time can be analyzed (Hekkert et al., 2007b). First empirical studies have been published that use these techniques (Safarzynska & van den Bergh, 2010a; Surrs & Hekkert, 2009; Suurs, Hekkert, Kieboom, & Smits, 2010).

Besides the element of system functions and their mapping, the TIS-approach has also developed several frameworks for analyzing innovation systems. The initial frameworks concentrated on networks, institutions and firms' perceptions, and competencies and strategies (Carlsson et al., 2002; Carlsson & Stankiewicz, 1991; Jacobsson & Johnson, 2000). More recent work has contributed either a multi-level perspective (Markard & Truffer, 2008b), a frame for the co-evolution of demand and supply (Safarzynska & van den Bergh, 2010b), or a biological evolution perspective of recombination and mutation (Safarzynska & van den Bergh, 2011).

---

[1] In the book, I use the term "*agents*" to represent an abstract conceptualization of real-life "*actors*" in a system. A more detailed discussion about this terminology is available in Müller et al. (2012).

TIS-research has almost always applied the single case-study approach. In the last few years, research has addressed such topics as the development of stationary fuel cells (Markard & Truffer, 2008a), natural gas as an automotive fuel (Suurs et al., 2010), the development of hydrogen and fuel cells (Suurs, Hekkert, & Smits, 2009), biofuels (Surrs & Hekkert, 2009), the diffusion of cogeneration (Hekkert et al., 2007a), and biomass (Negro & Hekkert, 2008; Negro et al., 2007). The case-study approach is required, since a resource-intensive in-depth analysis of the case needs to be undertaken in order to gain the system knowledge necessary to understand the drivers of innovation and change.

Also in recent years, the topic of co-evolution has received more attention from TIS-researchers. Co-evolution is a broad concept that indicates a simultaneous development of two entities in a system, e.g., complementary products (Bucklin & Sengupta, 1993), clinical knowledge and technological capabilities (Merito & Bonaccorsi, 2007), scientific and technological networks (Murray, 2002), or capabilities and preferences (Consoli, 2008). What appeared to be closest to my interest is the research by Hung (2002) about institutions. It turned out, however, that he has addressed institutions as national industries, not as voluntary and legal standards as I do. Another relevant factor from this stream of research comes from Dijk and Yarime (2010) who provide a co-evolutionary analysis of the emergence of hybrid-electric cars. Their analysis is novel, since it integrates actor perspectives, feedback effects, and competition between products. They use a graphic approach to visualize the feedback interactions in the system. The approach I use here can be considered as a more formal version or an extension of their approach.

A second study from the TIS-stream relevant for the book is the work of Beerepoot & Beerepoot (2007), who concentrate on stricter government regulation as an incentive to innovation in the residential building sector. They conclude that in the Netherlands, government regulations currently seem not to contribute to the diffusion of radical innovation in energy techniques for residential buildings. Their analysis lacks an explicit longitudinal perspective and a clear conceptualization of the process of standard development. Geels (2004) considers especially the second aspect as a *game* among, e.g., producers, authorities, and customers in a system; understanding the evolution of regulations would provide a more concrete understanding of this *game*.

2.2 Research About Innovation Diffusion Models on the Micro Level

The evolution of standards can be influenced from the diffusion of individual products, technologies, services, or processes. One example is the creation of de-facto technical standards, e.g., in the video industry (Besen & Farrell, 1994) or in the smart card market (Wonglimpiyarat, 2005).

2.2.1 Subject

Innovation diffusion is a classical field of research which belongs to the marketing sciences. It tries to forecast the sales of novel products, technologies, processes, or services to support decision making in organizations. According to Schumpeter, an innovation is a "creation of a new product or a new quality of product that is not yet known by the customers"(1926: 23). Rogers understands an innovation as "ideas, practice, or object that is perceived as new by an individual or other unit of adoption"(Rogers, 2003: 12). Diffusion is a "process in which an innovation is communicated through certain channels over time among members of a social system"(Rogers, 2003: 5).

2.2.2 Review

Innovation diffusion has been studied extensively over the last four decades. The field originated with research about the diffusion of hybrid corn for planting (Griliches, 1957). The product-diffusion model of Bass (1969) is, possibly even today, the most used diffusion model. Scholars in the field have regularly assessed the overall development of the field and reported their insights in reviews (Baptista, 1999; Hauser, Tellis, & Griffin, 2006; Islam & Meade, 1997; Mahajan & Muller, 1979, 1996; Mahajan, Muller, & Bass, 1990, 1995; Mahajan, Muller, & Wind, 2000; Meade & Islam, 2006; Peres, Muller, & Mahajan, 2010; Wejnert, 2002). Besides marketing research, the field of sociology also addresses innovation diffusion and provides numerous studies, of which the most-widely known is Rogers (2003). Rogers's publication is at the same time a rich source for sociological research about innovation diffusion. Since a review of such an extensive field as innovation diffusion can never be comprehensive, I chose to be selective.

The early diffusion models addressed the dissemination of a single product of technology (Bass, 1969; Fisher & Pry, 1971; Mansfield, 1961). Subsequent model generations have attempted to relax the assumptions of these initial models. The approach of system dynamics (Sterman, 2000) was helpful in enriching the discussions about innovation diffusion. In particular, the work of Milling and Maier (Maier, 1996, 1998; Milling, 1986, 1987, 1990, 1991; Milling & Maier, 1993) has helped develop models with more realistic assumptions, such as experience effects, flexible prices, or the effect of advertisements. Most diffusion models until about 1995 concentrated on the technical and economic aspects of diffusion.

Thereafter, a growing number of studies on innovation diffusion have accounted for the social aspects and social dynamics of diffusion (Abrahamson & Rosenkopf, 1997; Lanzolla & Suarez, 2010; Thun, Größler, & Milling, 2000). A recent example of this is provided by Dattée and Weil (2007). They have analyzed the dissemination of DRAM-chips, and demonstrate that social factors have significant effects on the resulting substitution patterns.

Diffusion research has also addressed the dissemination of innovative energy-efficient products or services in the building sector (e.g., Brown, 1984; Darley & Beniger, 1981; Ganguly, Koebel, & Cantrell, 2010; Svenfelt, Engström, & Svane, 2011). For the purpose of the book, I address in particular the study by Higgins et al. (2011), who have analyzed policies for GHG-reductions in housing stocks. At the outset, this research appeared to be the closest relevant diffusion research to our objectives here, especially because the authors include in their model the voluntary and mandatory adoption of reduction technologies for evaluating the effectiveness of different intervention schemes to reduce GHG emissions from residential housing. While their research comes close to mine, their model assumes, however, the evolution of reduction technologies as exogenous. Moreover, it appears that voluntary and mandatory technologies are independent from each other. These two aspects are the central interests of my research. After highlighting the relevant studies from innovation diffusion, I turn to the research about dominant designs.

2.3 Research About Dominant Design

Research about dominant design might provide theories or models about how designs, i.e., standards, are formed. As will be shown, the major assumption about direct competition between standards is one which does not hold for the research object I address.

2.3.1 Subject

Research about developments of dominant designs addresses formation processes of industry standards (Nemet, 2009; Suarez & Utterback, 1995; Utterback, 1994). In the event that a product, process, or service design becomes dominant, it assumes a prevailing position in an industry, and often displaces competing designs; this has happened, for instance, in the computer disk industry (Clayton, 2003) and the automobile industry (Utterback, 1994).

2.3.2 Review

The work on dominant design can be traced back to Abernathy's and Utterback's dynamic model on product and process innovation (1975, 1978). There Utterback has detailed the concept of dominant designs and applied it to several industry (Utterback, 1994). What is common in this understanding of dominant design is that designs compete in limited markets for dominance at the expense of other designs. This mode of interaction could be described as direct competition, zero-sum competition, or pure competition.

Recent publications have contributed to enlarging the perspective on dominant design, in that other modes of interaction between designs are also possible. Pistorius and Utterback (1997) have suggested that, besides direct competition, which they term "pure competition", symbiosis, and predator–prey like interactions also occur. Most interestingly for my work here is the recent notion of *multiple designs*. These designs exist in parallel when specific conditions are fulfilled, e.g., distinct features of the individual designs or fast technological-development processes for design advancement (de Vries, de Ruijter, & Argam, 2011). After briefly outlining the only most relevant work from research about dominant design, I review the literature on energy studies in the residential built environment.

2.4 Research About the Residential Built Environment

The final stream of literature relevant to this book concerns studies of the residential built environment. Chapter 4 introduces the residential building sector of Switzerland, which is used as case for this book. The interested reader might refer to that chapter for a comprehensive introduction.

2.4.1 Subject

The residential built environment consists of interrelated agents (Fig. 4.7) that collectively develop a country's physical stock of residential buildings. Its inert characteristics result from long lifetimes of relevant assets, such as building envelopes or heating systems. This property indicates that decisions with respect to residential housing, once incorporated into the physical asset stock, require a significant time until the consequences of those decisions have propagated through the system. Hence, building codes about required energy efficiency are an important lever for reducing the energy demand of the residential building stock.

2.4.2 Review

An extensive body of research about the residential built environment has developed mostly during the last two decades. A number of studies estimate the future energy demand of the residential building sector. For example, Urge-Vorsatz and Novikova (2008) employ a wide-scope analysis, and estimate the worldwide potential for reducing energy demand and GHG emissions in the residential building sectors based on the assessment of 80 country- or regional-level specific mitigation studies. In addition, they have calculated the costs for society in achieving the given demand objectives. Kannan and Strachan (2009) have focused their research on demand mitigation in the UK residential sector. Their energy-sector and housing-stock models suggest that the de-carbonization of the power sector, combined with an increased use of energy-efficient appliances, would be the most feasible option for sustainably reducing energy demand.

More specifically, for Swiss residential building stock, Siller et al. (2007) demonstrate the effect of different construction and refurbishment scenarios on the stock's energy-relevant properties. They conclude that the political objective of a 2000-Watt Society[2] could be achieved with ambitious efforts. Additional research corrobates these results (Koschenz & Pfeiffer, 2005; Schulz, Kypreos, Barreto, & Wokaun, 2008).

The studies cited up to now estimate the energy demand for some future point in time; however, most of them underutilize the explanatory potential of qualitative historical data for obtaining a more detailed understanding of the technological, social, legal, and economic mechanisms in the residential built environment. This is what Nassen and Holmberg (2005) have strived for. Their model explains the development of the level of energy efficiency of newly constructed multi-dwelling buildings in Sweden. They address the question of why new construction in 2005 was at the same level of energy efficiency as the average existing building. Their study points out that the evolution of the installed-energy demand of the building stock depends strongly on the diffusion of energy-efficient technologies, but less on building standards. Sartori et al. (2009) come to a similar conclusion for the case of Norway.

Other studies about residential buildings also investigate the diffusion of energy-efficient technologies that are directly related to residential housing; for instance, heating technologies (Johansson, Nylander, & Johnsson, 2006; Madlener, 2007; Purohit, 2008), solar panels and solar energy (Jager, 2006; McEachern & Hanson, 2008), biomass (Qiu, Gu, Catania, & Huang, 1996), and gas boilers (Weiss, Dittmar, Junginger, Patel, & Blok, 2009). These studies ask questions about the factors fostering or hindering the diffusion of energy technologies. One relevant factor is users' expectations about future energy prices (Amstalden, Kost, Nathani, & Imboden, 2007; Atkinson, Jackson, & Mullings-Smith, 2009). Other factors include the relative price of the technology, the knowledge of the involved agents about the innovation, the innovation's availability, the uncertainty associated with the innovation, the innovation's complexity and trialability, and the external pressure to employ innovations (Acker & Kammen, 1996; Amstalden et al., 2007; Ansar & Sparks, 2009; Chan, Qian, & Lam, 2009; Fisk, 2008; Howarth, Haddad, & Paton, 2000; Joelsson & Gustavsson, 2008; Rogers, 2003).

Besides these behavioral factors, certain market characteristics significantly limit the diffusion of energy-efficient technologies. Poor market signals, and high costs of technologies, long payback periods, insufficient incentive systems, and high risks stand against a higher rate of diffusion of energy-efficient technology (Biermayr et al., 2001; Meier & Ott, 2005; Sunikka, 2006). As a result, the uptake

[2] The 2000 Watt Society is a political vision to achieve an energy demand of 2,000 W per capita; Chap. 4 provides more details.

of energy-efficient innovations is slow, even though they are proven to be technical and economically feasible (Atkinson et al., 2009; Audenaert, De Cleyn, & Vankerckhove, 2008; Cuddihy, Kennedy, & Byer, 2005; Mathews, Richards, & Vanwyk, 1995; Morrissey & Horne, 2011).

While the diffusion of energy-efficient technologies is important, they cannot be used directly, however, for the development of building standards, since standards command a broader perspective. They are not limited to the applications of only a certain technology, but combine a wide range of them, e.g., for insulation, heating, and warm water generation, to fulfill the required levels of energy efficiency for the respective standard. In such cases, the evolution and diffusion of building standards is a subject not directly related to the diffusion of energy-efficient technologies.

Some studies also address the topic of regulation in the building environment. For instance, Burby et al. (2006) have compared the residential refurbishment activity in a sample of New Jersey jurisdictions regarding the influence of the presence of an energy-efficiency building code. They conclude that the presence of such a code results in energetic relevant renovations, while the overall renovation activities remain stable. Van der Heijden and de Jong (2009) review a large body of regulatory literature in the field of building regulation, and conclude that this field has attracted little attention from regulatory scholars when compared to other fields of regulation. They argue that more theoretical work is required for a better understanding of building regulations and control. A most stimulating paper with respect to regulation is Imrie (2007), who argues that building regulations are strongly entwined with, and are even constitutive of, architects' practices. The paper develops the hypothesis that building regulations influence both practice and process in architectural design.

2.5 Research Gap for the Book

After having reviewed the relevant literature, I develop the gap the book has addressed by referring to the shortcomings of the four streams of research.

Viewed from a conceptual level, TIS studies offer several possible relations. Recent studies have addressed elements of dynamics and feedback mechanisms. However, even though the studies are conceptually stimulating, they cannot offer more advanced means for analyzing the innovation system "*residential building sector*" than the ones I use in this study (see in particular Chap. 3). On a substantive level, the insights about development of technologies cannot be used on the level of concrete causal insights, because the evolution of building codes is significantly different from a technology. As a matter of fact, I perceive the evolution of standards as taking place on a higher level of complexity in a system. While certain contributions to the field come close to the topic of my research (e.g., Beerepoot & Beerepoot, 2007; Hung, 2002), they still differ from it significantly.

Studies about innovation diffusion most often address the diffusion of specific products, technologies, services, or processes. Most often, too, these studies address only diffusion of such products or technologies, and not the development of these factors. When studies address the diffusion of multiple technologies (e.g., Dattée & Weil, 2007), they still do not trace the formation of a standard in an industry related to these products or technologies. Moreover, studies on innovation diffusion for the most part fail to account for the influences from regulatory regimes or industry standards. To summarize, most of the models used for innovation diffusion are limited with respect to their narrow boundaries, their concentration on short time horizons, and their neglect of the effects which diffusion has on the wider system. Virtually no mathematical model has gone beyond these limits.

Research on dominant design, especially recent studies about multiple designs, resonates well with my research, since the voluntary and legal building codes interact in a mode which can be characterized as symbiotic competition at the edge of their markets. Thus, this research can draw conceptually on de Vries et al. (2011). However, what is missing is their failure to provide a longitudinal analysis of the co-existence of these designs. Others have already stated that the emergence of dominant designs is treated as a black-box process—involving a sophisticated interaction among technological and non-technological factors (Lee, Oneal, Pruett, & Thomas, 1995). This is true even today. My research intends to provide causal inferences about the content of that black box.

The last stream reviewed here concerns energy studies of the residential building environment. Most of these studies focus on green energy technologies and their diffusion, e.g., the technological and economic feasibility of existing reduction technologies, and factors that hinder or facilitate adoption technologies. This focus is related to, but nevertheless different from, the research object of the book. Some studies address the Swiss residential built environment by trying to estimate the potential for reducing energy demand and/or GHG emissions (Koschenz & Pfeiffer, 2005; Schulz, 2007; Schulz et al., 2008; Siller et al., 2007). These studies, however, use models which, though apparently rich in detail complexity, lack feedback complexity. Moreover, the models used in these studies do not explicitly represent the development of energy efficiency in building codes; rather, they assume it.

To summarize the contributions from these four streams of literature, I have developed a framework in which they can be positioned (Fig. 2.1). The framework has the dimensions of *Model Boundary* and *Degree of Formalization*. As can be seen from the figure, TIS research (1) assumes a position with a broad model boundary, but uses less mathematically formalized means. Innovation diffusion, on the other hand, (2) which is mathematically highly formalized, assumes a position almost opposite to TIS research, because these models have, on average, tight model boundaries.

Research on dominant design (3) is, again on average, somewhat less formalized than innovation-diffusion studies, but also a degree broader with respect to their boundaries. Energy-related studies (4) cannot be placed at any one position in this framework, since this stream uses multiple methods which strive for the extremes

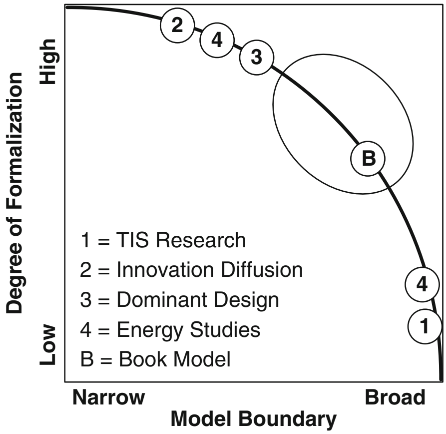

Fig. 2.1 Framework for positioning the considered streams of research

of both dimensions. Consequently the resulting model of the book (B) I position on the curve in the middle of the approaches that have just been introduced. (B) is high on scope of model boundary, and also has a relatively high degree of mathematical formalization. The oval around (B) indicates the area in which the methodological combination that I use in this book can be applied most beneficially. What Fig. 2.1 shows, both literally and directly, is the gap which this book addresses.

To conclude, the phenomenon of standard development is under-represented and under-researched in the streams of literature reviewed here. The available (mathematical) models are mostly narrow in scope, and do not account for the higher-level concept of a standard. While the system-level models address other topics pertinent to innovation systems, they do not specifically address standards.

References

Abernathy, W. J., & Utterback, J. M. (1975). A dynamic model of product and process innovation. *Omega, 3*(8), 639–656.

Abernathy, W. J., & Utterback, J. M. (1978). Patterns of industrial innovation. *Technology Review, 80*(7), 40–47.

Abrahamson, E., & Rosenkopf, L. (1997). Social network effects on the extent of innovation diffusion: A computer simulation. *Organization Science, 8*(3), 289–309.

Acker, R. H., & Kammen, D. M. (1996). The quiet (Energy) revolution—Analysing the dissemination of photovoltaic power systems in Kenya. *Energy Policy, 24*(1), 81–111.

Amstalden, R. W., Kost, M., Nathani, C., & Imboden, D. M. (2007). Economic potential of energy-efficient retrofitting in the Swiss residential building sector: The effects of policy instruments and energy price expectations. *Energy Policy, 35*(3), 1819–1829.

Ansar, J., & Sparks, R. (2009). The experience curve, option value, and the energy paradox. *Energy Policy, 37*(3), 1012–1020.

Asheim, B. T., & Coenen, L. (2005). Knowledge bases and regional innovation systems: Comparing Nordic clusters. *Research Policy, 34*(8), 1173–1190.

Atkinson, J. G. B., Jackson, T., & Mullings-Smith, E. (2009). Market influence on the low carbon energy refurbishment of existing multi-residential buildings. *Energy Policy, 37*(7), 2582–2593.
Audenaert, A., De Cleyn, S. H., & Vankerckhove, B. (2008). Economic analysis of passive houses and low-energy houses compared with standard houses. *Energy Policy, 36*(1), 47–55.
Baptista, R. (1999). The diffusion of process innovations: A selective review. *Journal of Economics and Business, 6*(1), 107–129.
Bass, F. M. (1969). New product growth for model consumer durables. *Management Science, 15*(5), 215–227.
Beerepoot, M., & Beerepoot, N. (2007). Government regulation as an impetus for innovation: Evidence from energy performance regulation in the Dutch residential building sector. *Energy Policy, 35*(10), 4812–4825.
Besen, S. M., & Farrell, J. (1994). Choosing how to compete—Strategies and tactics in standardization. *Journal of Economic Perspectives, 8*(2), 117–131.
Biermayr, P., Baumann, B., Schriefl, E., Skopetz, H., Stieldorf, K., Zelenka, H., Berger, M., & Ornetzeder, M. (2001). *Analyse férdernder und hemmender Faktoren bei der Markteinführung von innovativen Wohnbauten: Endbericht*. Wien: Institut für Energiewirtschaft.
Brown, M. A. (1984). Change mechanisms in the diffusion of residential energy-conservation practices: An empirical-study. *Technological Forecasting and Social Change, 25*(2), 123–138.
Bucklin, L. P., & Sengupta, S. (1993). The co-diffusion of complementary innovations—Supermarket scanners and Upc symbols. *Journal of Product Innovation Management, 10*(2), 148–160.
Burby, R. J., Salvesen, D., & Creed, M. (2006). Encouraging residential rehabilitation with building codes: New Jersey's experience. *Journal of the American Planning Association, 72*(2), 183–196.
Carlsson, B., & Stankiewicz, R. (1991). On the nature, function and composition of technological systems. *Journal of Evolutionary Economics Letters, 1*(1), 93–118.
Carlsson, B., Jacobsson, S., Holmen, M., & Rickne, A. (2002). Innovation systems: Analytical and methodological issues. *Research Policy, 31*(2), 233–245.
Chan, E. H. W., Qian, Q. K., & Lam, P. T. I. (2009). The market for green building in developed Asian cities: The perspectives of building designers. *Energy Policy, 37*(8), 3061–3070.
Clayton, M. C. (2003). *The innovator's dilemma: The revolutionary book that will change the way you do business*. Cambridge, MA: Harper Paperbacks.
Consoli, D. (2008). Co-evolution of capabilities and preferences in the adoption of new technologies. *Technology Analysis & Strategic Management, 20*(4), 409–425.
Cuddihy, J., Kennedy, C., & Byer, P. (2005). Energy use in Canada: Environmental impacts and opportunities in relationship to infrastructure systems. *Canadian Journal of Civil Engineering, 32*(1), 1–15.
Darley, J. M., & Beniger, J. R. (1981). Diffusion of energy-conserving innovations. *Journal of Social Issues, 37*(2), 150–171.
Dattée, B., & Weil, H. B. (2007). Dynamics of social factors in technological substitutions. *Technological Forecasting and Social Change, 74*(5), 579–607.
de Vries, H. J., de Ruijter, J. P. M., & Argam, N. (2011). Dominant design or multiple designs: The flash memory card case. *Technology Analysis & Strategic Management, 23*(3), 249–262.
Dijk, M., & Yarime, M. (2010). The emergence of hybrid-electric cars: Innovation path creation through co-evolution of supply and demand. *Technological Forecasting and Social Change, 77*(8), 1371–1390.
Fisher, J. C., & Pry, R. H. (1971). A simple substitution model of technological change. *Technological Forecasting and Social Change, 3*(1), 75–88.
Fisk, D. (2008). What are the risk-related barriers to, and opportunities for, innovation from a business perspective in the UK, in the context of energy management in the built environment? *Energy Policy, 36*(12), 4615–4617.
Freeman, C. (1987). *Technology policy and economic performance: Lessons from Japan*. London: Pinter Publishing.

Ganguly, I., Koebel, C. T., & Cantrell, R. A. (2010). A categorical modeling approach to analyzing new product adoption and usage in the context of the building-materials industry. *Technological Forecasting and Social Change, 77*(4), 662–677.

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy, 33*(6–7), 897–920.

Godin, B. (2009). National innovation system the system approach in historical perspective. *Science Technology & Human Values, 34*(4), 476–501.

Griliches, Z. (1957). Hybrid corn: An exploration in the economics of technological-change. *Econometrica, 25*(4), 501–522.

Hauser, J., Tellis, G. J., & Griffin, A. (2006). Research on innovation: A review and agenda for marketing science. *Marketing Science, 25*(6), 687–717.

Hekkert, M. P., Harmsen, R., & de Jong, A. (2007). Explaining the rapid diffusion of Dutch cogeneration by innovation system functioning. *Energy Policy, 35*(9), 4677–4687.

Hekkert, M. P., Suurs, R. A. A., Negro, S. O., Kuhlmann, S., & Smits, R. E. H. M. (2007). Functions of innovation systems: A new approach for analysing technological change. *Technological Forecasting and Social Change, 74*(4), 413–432.

Higgins, A., Foliente, G., & McNamara, C. (2011). Modelling intervention options to reduce GHG emissions in housing stock—A diffusion approach. *Technological Forecasting and Social Change, 78*(4), 621–634.

Howarth, R. B., Haddad, B. M., & Paton, B. (2000). The economics of energy efficiency: Insights from voluntary participation programs. *Energy Policy, 28*(6–7), 477–486.

Hung, S. C. (2002). The co-evolution of technologies and institutions: A comparison of Taiwanese hard disk drive and liquid crystal display industries. *R & D Management, 32*(3), 179–190.

Imrie, R. (2007). The interrelationships between building regulations and architects' practices. *Environment and Planning B: Planning and Design, 34*(5), 925–943.

Islam, T., & Meade, N. (1997). The diffusion of successive generations of a technology: A more general model. *Technological Forecasting and Social Change, 56*(1), 49–60.

Jacobsson, S., & Johnson, A. (2000). The diffusion of renewable energy technology: An analytical framework and key issues for research. *Energy Policy, 28*(9), 625–640.

Jacobsson, S., & Bergek, A. (2004). Transforming the energy sector: The evolution of technological systems in renewable energy technology. *Industrial and Corporate Change, 13*(5), 815–849.

Jager, W. (2006). Stimulating the diffusion of photovoltaic systems: A behavioural perspective. *Energy Policy, 34*(14), 1935–1943.

Joelsson, A., & Gustavsson, L. (2008). Perspectives on implementing energy efficiency in existing Swedish detached houses. *Energy Policy, 36*(1), 84–96.

Johansson, P., Nylander, A., & Johnsson, F. (2006). Electricity dependency and CO_2-emissions from heating in the Swedish building sector—Current trends in conflict with governmental policy? *Energy Policy, 34*(17), 3049–3064.

Kannan, R., & Strachan, N. (2009). Modelling the UK residential energy sector under long-term decarbonisation scenarios: Comparison between energy systems and sectoral modelling approaches. *Applied Energy, 86*(4), 416–428.

Koschenz, M., & Pfeiffer, A. (2005). *Potenzial Wohngebäude: Energie- und Gebäudetechnik für die 2000-Watt-Gesellschaft*. Zürich: Faktor-Verlag.

Lanzolla, G., & Suarez, F. F. (2010). Closing the technology adoption–use divide: The role of contiguous user bandwagon. *Journal of Management, 36*(5), 345–358.

Lee, J. R., Oneal, D. E., Pruett, M. W., & Thomas, H. (1995). Planning for dominance: A strategic perspective on the emergence of a dominant design. *R & D Management, 25*(1), 3–15.

Leydesdorff, L., & Fritsch, M. (2006). Measuring the knowledge base of regional innovation systems in Germany in terms of a triple helix dynamics. *Research Policy, 35*(10), 1538–1553.

Lundvall, B. A. (1992). *National systems of innovations: Toward a theory of innovation and interactive learning*. London: Pinters Publishing.

Lundvall, B. A., Johnson, B., Andersen, E. S., & Dalum, B. (2002). National systems of production, innovation and competence building. *Research Policy, 31*(2), 213–231.

Madlener, R. (2007). Innovation diffusion, public policy, and local initiative: The case of wood-fuelled district heating systems in Austria. *Energy Policy, 35*(3), 1992–2008.
Mahajan, V., & Muller, E. (1979). Innovation diffusion and new product growth-models in marketing. *Journal of Marketing, 43*(4), 55–68.
Mahajan, V., Muller, E., & Bass, F. M. (1990). New product diffusion-models in marketing: A review and directions for research. *Journal of Marketing, 54*(1), 1–26.
Mahajan, V., Muller, E., & Bass, F. M. (1995). Diffusion of new products—Empirical generalizations and managerial uses. *Marketing Science, 14*(3), G79–G88.
Mahajan, V., & Muller, E. (1996). Timing, diffusion, and substitution of successive generations of technological innovations: The IBM mainframe case. *Technological Forecasting and Social Change, 51*(2), 109–132.
Mahajan, V., Muller, E., & Wind, Y. (Eds.). (2000). *New-product diffusion models*. Boston: Kluwer.
Maier, F. H. (1996). *Substitution among successive product generations-an almost neglected problem in innovation diffusion models*. Paper presented at the 1996 International System Dynamics Conference, Cambridge, MA.
Maier, F. H. (1998). New product diffusion models in innovation management—A system dynamics perspective. *System Dynamics Review, 14*(4), 285–308.
Malerba, F. (2002). Sectoral systems of innovation and production. *Research Policy, 31*(2), 247–264.
Mansfield, E. (1961). Technical change and the rate of imitation. *Econometrica, 29*(4), 741–766.
Markard, J., & Truffer, B. (2008a). Actor-oriented analysis of innovation systems: Exploring micro-meso level linkages in the case of stationary fuel cells. *Technology Analysis & Strategic Management, 20*(4), 443–464.
Markard, J., & Truffer, B. (2008b). Technological innovation systems and the multi-level perspective: Towards an integrated framework. *Research Policy, 37*(4), 596–615.
Mathews, E. H., Richards, P. G., & Vanwyk, S. L. (1995). Energy efficiency of ultra-low-cost housing. *Building and Environment, 30*(3), 427–432.
McEachern, M., & Hanson, S. (2008). Socio-geographic perception in the diffusion of innovation: Solar energy technology in Sri Lanka. *Energy Policy, 36*(7), 2578–2590.
Meade, N., & Islam, T. (2006). Modelling and forecasting the diffusion of innovation—A 25-year review. *International Journal of Forecasting, 22*(3), 519–545.
Meier, R., & Ott, W. (2005). *Grundlagen für eine Strategie Gebäudepark Schweiz*. Bern: Bundesamt für Energie.
Merito, M., & Bonaccorsi, A. (2007). Co-evolution of physical and social technologies in clinical practice: The case of HIV treatments. *Research Policy, 36*(7), 1070–1087.
Milling, P. M. (1986). *Decision support for marketing new products*. Paper presented at the International Conference of the System Dynamics Society, Seville.
Milling, P. M. (1987). *Manufacturing's role in innovation diffusion and technological substitution*. Paper presented at the Proceedings of the 1987 International Conference of the System Dynamics Society, Shanghai.
Milling, P. M. (1990). *Systems research and corporate policy making*. Paper presented at the Advances in Systems Research and Cybernetics, Windsor, ON.
Milling, P. M. (1991). *An integrative view of R&D and innovation processes*. Paper presented at the Modelling and Simulation 1991, San Diego, CA.
Milling, P. M., & Maier, F. H. (1993). *Dynamic consequences of pricing strategies for research & development and the diffusion of innovations*. Paper presented at the International System Dynamics Conference, Cancun.
Morrissey, J., & Horne, R. E. (2011). Life cycle cost implications of energy efficiency measures in new residential buildings. *Energy and Buildings, 43*(4), 915–924.
Müller, M. O., Groesser, S. N., & Ulli-Beer, S. (2012). How do we know who to include in transdisciplinary research? Toward a method for the identification of experts. *European Journal of Operational Research, 216*(2), 495–502.
Murray, F. (2002). Innovation as co-evolution of scientific and technological networks: Exploring tissue engineering. *Research Policy, 31*(8–9), 1389–1403.

Nassen, J., & Holmberg, J. (2005). Energy efficiency—A forgotten goal in the Swedish building sector? *Energy Policy, 33*(8), 1037–1051.

Negro, S. O., Hekkert, M. P., & Smits, R. E. (2007). Explaining the failure of the Dutch innovation system for biomass digestion: A functional analysis. *Energy Policy, 35*(2), 925–938.

Negro, S. O., & Hekkert, M. P. (2008). Explaining the success of emerging technologies by innovation system functioning: The case of biomass digestion in Germany. *Technology Analysis & Strategic Management, 20*(4), 465–482.

Nemet, G. F. (2009). Demand-pull, technology-push, and government-led incentives for non-incremental technical change. *Research Policy, 38*(5), 700–709.

Peres, R., Muller, E., & Mahajan, V. (2010). Innovation diffusion and new product growth models: A critical review and research direction. *International Journal of Research in Marketing, 27*(2), 91–106.

Pistorius, C. W. I., & Utterback, J. M. (1997). Multi-mode interaction among technologies. *Research Policy, 26*(1), 67–84.

Purohit, P. (2008). Small hydro power projects under clean development mechanism in India: A preliminary assessment. *Energy Policy, 36*(6), 2000–2015.

Qiu, D. X., Gu, S. H., Catania, P., & Huang, K. (1996). Diffusion of improved biomass stoves in China. *Energy Policy, 24*(5), 463–469.

Rogers, E. M. (2003). *The diffusion of innovations*. New York: Free Press.

Safarzynska, K., & van den Bergh, J. C. J. M. (2010a). Evolutionary models in economics: A survey of methods and building blocks. *Journal of Evolutionary Economics, 20*(3), 329–373.

Safarzynska, K., & van den Bergh, J. C. J. M. (2010b). Demand-supply coevolution with multiple increasing returns: Policy analysis for unlocking and system transitions. *Technological Forecasting and Social Change, 77*(2), 297–317.

Safarzynska, K., & van den Bergh, J. C. J. M. (2011). Beyond replicator dynamics: Innovation-selection dynamics and optimal diversity. *Journal of Economic Behavior & Organization, 78*(3), 229–245.

Sartori, I., Wachenfeldt, B. J., & Hestnes, A. G. (2009). Energy demand in the Norwegian building stock: Scenarios on potential reduction. *Energy Policy, 37*(5), 1614–1627.

Schulz, T. F. (2007). *Intermediate steps towards the 2000-Watt society in Switzerland: An energy-economic scenario analysis*. Swiss Federal Institute of Technology Zurich: Dissertation.

Schulz, T. F., Kypreos, S., Barreto, L., & Wokaun, A. (2008). Intermediate steps towards the 2000 W society in Switzerland: An energy-economic scenario analysis. *Energy Policy, 36*(4), 1303–1317.

Schumpeter, J. A. (1926). *Theorie der wirtschaftlichen Entwicklung*. Berlin: Duncker und Humblot.

Sharif, N. (2006). Emergence and development of the national innovation systems concept. *Research Policy, 35*(5), 745–766.

Siller, T., Kost, M., & Imboden, D. (2007). Long-term energy savings and greenhouse gas emission reductions in the Swiss residential sector. *Energy Policy, 35*(1), 529–539.

Sterman, J. D. (2000). *Business dynamics: Systems thinking and modeling for a complex world*. Boston, MA: McGraw-Hill.

Suarez, F. F., & Utterback, J. M. (1995). Dominant designs and the survival of firms. *Strategic Management Journal, 16*(6), 415–430.

Sunikka, M. (2006). Energy efficiency and low-carbon technologies in urban renewal. *Building Research and Information, 34*(6), 521–533.

Surrs, R. A. A., & Hekkert, M. P. (2009). Cumulative causation in the formation of a technological innovation system: The case of biofuels in The Netherlands. *Technological Forecasting and Social Change, 76*(8), 1003–1020.

Suurs, R. A. A., Hekkert, M. P., & Smits, R. E. H. M. (2009). Understanding the build-up of a technological innovation system around hydrogen and fuel cell technologies. *International Journal of Hydrogen Energy, 34*(24), 9639–9654.

Suurs, R. A. A., Hekkert, M. P., Kieboom, S., & Smits, R. E. H. M. (2010). Understanding the formative stage of technological innovation system development: The case of natural gas as an automotive fuel. *Energy Policy, 38*(1), 419–431.

Svenfelt, Å., Engström, R., & Svane, Ö. (2011). Decreasing energy use in buildings by 50% by 2050—A backcasting study using stakeholder groups. *Technological Forecasting and Social Change*.

Thun, J.-H., Größler, A., & Milling, P. M. (2000). *The diffusion of goods considering network externalities: A system dynamics-based approach*. Paper presented at the 18th International Conference of the System Dynamics Society, Bergen.

Urge-Vorsatz, D., & Novikova, A. (2008). Potentials and costs of carbon dioxide mitigation in the world's buildings. *Energy Policy, 36*(2), 642–661.

Utterback, J. M. (1994). *Mastering the dynamics of innovation: How companies can seize opportunities in the face of technological change*. Boston, MA: Harvard Business School Press.

van der Heijden, J., & de Jong, J. (2009). Towards a better understanding of building regulation. *Environment and Planning B: Planning and Design, 36*(6), 1038–1052.

Weiss, M., Dittmar, L., Junginger, M., Patel, M. K., & Blok, K. (2009). Market diffusion, technological learning, and cost-benefit dynamics of condensing gas boilers in the Netherlands. *Energy Policy, 37*(8), 2962–2976.

Wejnert, B. (2002). Integrating models of diffusion of innovations: A conceptual framework. *Annual Review of Sociology, 28*(3), 297–326.

Wonglimpiyarat, J. (2005). Standard competition: Is collaborative strategy necessary in shaping the smart card market? *Technological Forecasting and Social Change, 72*(8), 1001–1010.

http://www.springer.com/978-3-7908-2857-3

Co-Evolution of Standards in Innovation Systems
The Dynamics of Voluntary and Legal Building Codes
Grösser, S.N.
2013, XXVIII, 268 p., Hardcover
ISBN: 978-3-7908-2857-3
A product of Physica-Verlag Heidelberg