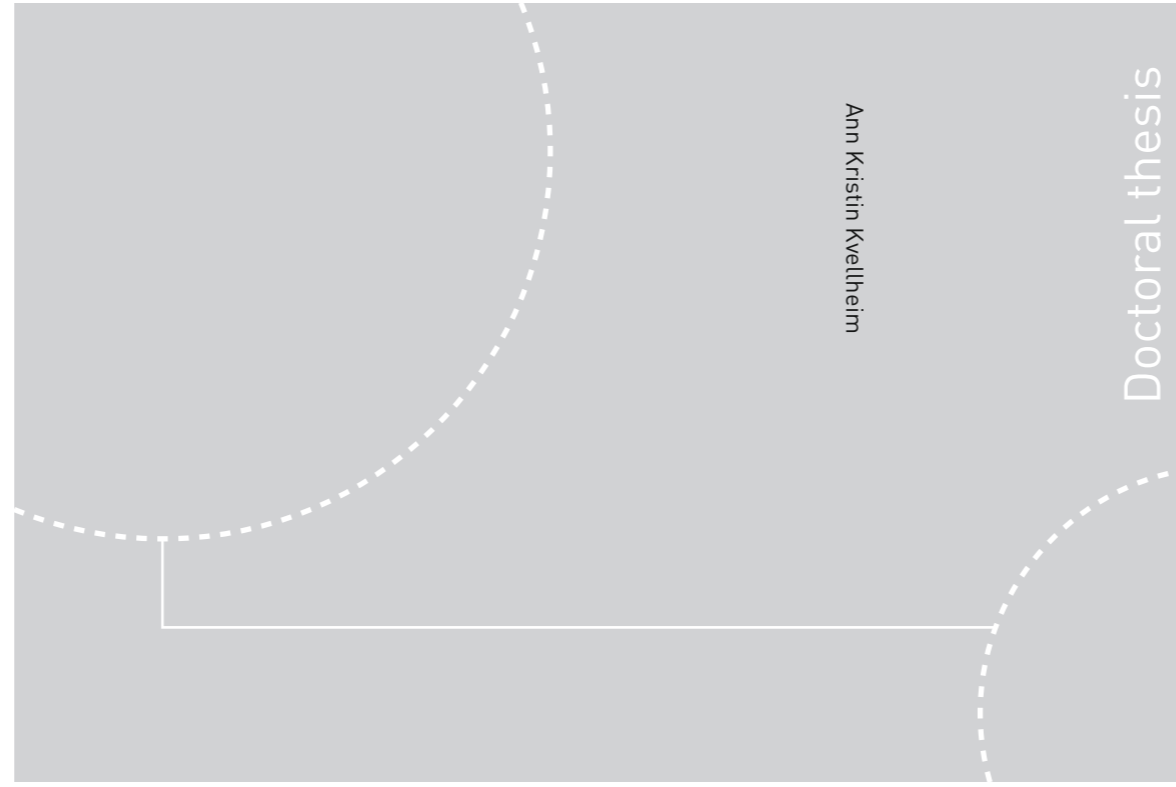


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Innovations in the intersection between the building and the power sectors and the transition to sustainability

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Preface

During several years working on designing, implementing and evaluating public incentives directed towards the building sector, I learned a lot about energy-efficient buildings. This experience made me curious about ambiguities at the policy level regarding energy-efficiency measures and how to exploit the potential in the building sector when it comes to climate change mitigation. On the one hand, visions are either lacking or vague, while on the other hand, frontrunners have appeared and projects are applauded. So, what is expected from the building sector, really? As I started to explore the prospects of power-producing buildings, the diverging interests between (parts of) the building and the power sectors became evident. European policies aim for a closer connection between the sectors, but how does this apply in the Norwegian context?

In this thesis, research has been made into innovations at the interface between the building and the power sectors, looking, in particular, at how these innovations affect the sustainable transition to a low-carbon society. The research topics are positioned in the interface between the building sector and the power sector. The first is the largest onshore sector in Norway, both in terms of revenues and employees. The second is part of the national character, which means it is of huge significance historically, culturally and not least economically. Hydropower production provides low-cost renewable energy, affecting energy security, the environment and industrial and commercial development. The cross-sectoral innovations between the two sectors face additional challenges beyond those of innovations confined to only one sector.

I am grateful that I got the opportunity to study these issues as a PhD Candidate within the Research Centre on Zero Emission Buildings (ZEB). It has been a privilege to me to be part of ZEB, to attend some of the ZEB meetings and to participate in ZEB activities. I am also grateful to the research group at my Department of Interdisciplinary Studies of Culture, which has provided me with fresh insight and a new perspective on the world. Many thanks also to Linköping University and in particular Harald Rohrer and Anna Bergek for taking the time to discuss my research at an early stage in the process.

I am much obliged to my supervisors Thomas Berker, Margrethe Aune and Birgit Risholt, who have guided me through these years as an aspiring researcher. Particularly, I am grateful to Thomas Berker who provided the necessary patience and wisdom that was needed to see this thesis through. I am also grateful to my colleague and friend, Anne Gunnarshaug Lien, who made me believe that I could complete such a project. You were right.

Finally, I am grateful to the most important people in my life: Bjørnar, Vilde and Vetle who offered distraction, love and support throughout this project. Without you, I would be a lesser person.

Ann Kristin Kvellheim

January 2018

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List of Abbreviations

AGR: Aggregator Role
ANT: Actor-Network Theory
BIPV: Building-Integrated Photovoltaics
BM: Business Model
CCS: Carbon Capture and Storage
CHP: Cogeneration of Combined Heat and Power
EEA: European Economic Area
EPBD: Energy Performance in Buildings Directive
EPC: Energy Performance Contracting
EU ETS: European Union Emissions Trading System
LSP: Leasing of Solar Panels
MLP: Multilevel Perspective
NBI: Norwegian Building Institute
PV: Photovoltaics
RED: Renewable Energy Directive
R&D: Research and Development
SCOT: Social Construction of Technology
SNM: Strategic Niche Management

STS: Science and Technology Studies

TIS: Technological Innovation System

TM: Transition Management

ZEB: The Research Centre on Zero Emission Buildings

ZEN: The Research Centre on Zero Emission Neighbourhoods in Smart Cities

1. Introduction

The Paris treaty, signed in 2015, is an historic agreement that obliges the member parties to curb greenhouse gas emissions so that global temperature rise is kept within 2 °C. To achieve this ambitious goal, a range of measures are needed – including significantly reduced greenhouse gas emissions from the building sector.

Buildings in Europe are responsible for about 40 percent of total final energy requirements and 36 percent of its CO₂ emissions (European Commission, 2016). Particular challenges include increasing energy-efficiency and decarbonizing the power system (The European Climate Foundation, 2010). Europe is greening its power system, which is to be carbon-free by 2050 (ibid.). These developments are part of an even-larger transition towards a low-carbon society. As a consequence, in Norway as well as in many other countries, buildings are becoming progressively energy-efficient and power-producing. However, building politics in Norway is ambiguous as frontrunners are present and ambitious projects applauded, but there is a lack of overarching vision. This thesis researches energy-efficient buildings that are also power producers. The research issues are therefore located in the interface between the two sectors; the building sector and the power sector. The purpose of this thesis is to provide insight about cross-sectoral innovations such as power-producing buildings and thereby contribute to further development and dissemination of knowledge. Therefore, the general research question of this thesis is how the development and implementation of innovations in the interface between the building and the power sectors contributes to a sustainable transition.

1.1 Context

The oil crisis of 1973–74 caused oil prices to soar. This was followed by increased interest in energy saving in Norway as well as internationally. In the 1980s, the Norwegian state began to grant loans for energy-efficiency measures both in residential and non-residential buildings. This arrangement ended in 1993, causing a decline in energy-efficiency measures, particularly in the municipal building stock. To encourage more energy savings, a tax on the grid tariff was introduced and, from 2001, was redistributed on the basis of applications.¹ In addition, the building code began to incorporate stricter rules on how to reduce heat loss from the building envelope and gradually included a demand for energy flexibility. In addition to concern over climate change and new EU standards, the development of a voluntary passive house standard contributed to stricter building codes and a subsequent focus on reduced heat loss, energy use and increased energy flexibility (Müller and Berker, 2013). This development has contributed to a change – supported by research – in how buildings are designed, constructed and used. However, issues such as the challenge of interdisciplinary collaboration in the development of advanced building concepts and how to manage cross-sectoral innovations have received little attention so far. This thesis fills in some of the less-advanced research areas related to the factors affecting the implementation of highly energy-efficient and power-producing buildings and the role of buildings in the sustainable transition ahead.

The European objective to decarbonize the power sector has less-obvious implications to Norway than to most other countries, since nearly all electricity generated in Norway is already renewable. Still, Norway is obliged to implement EU regulation through the European Economic Area (EEA) agreement.

¹ <https://snl.no/energi%C3%B8konomisering> Accessed 1st June 2017

Several directives are relevant in this context, in particular the Renewable Energy Directive (RED) (The European Parliament and the Council, 2009) and the Energy Performance in Buildings Directive (EPBD) (The European Parliament and the Council, 2010). The EPBD is still not fully adopted into Norwegian legislation; it is essential how the concept of “nearly zero energy” and how the “renewable sources produced on-site or nearby” objective in the EPBD are defined in the Norwegian context. The RED requires an increased *share* of renewable energy. This means that either the renewable energy production must increase, or the energy consumption must be reduced. Or preferably both which is the ambition of the type of buildings studied in this PhD thesis.

The awareness of the potential of buildings for climate change mitigation has risen in recent years, both in the EU and in Norway. In Norway as in many other countries, the minimum building standards are regulated through a building code. In line with the development and spread of new building standards in central Europe, this building code has become increasingly strict in terms of regulating energy use, particularly over the last decade. By 2017, the Norwegian building code, TEK 17, is said to be at a “Passive house level”, which is generally accepted as a very ambitious energy standard. The spread of the passive house standard is studied by Müller and Berker (2013), who describe it as a success story of technological innovation. In Norway, the passive house concept was particularly influential, which is partly related to the generous investment support provided by the state-owned enterprise Enova.²

The passive house standard is, however, an energy standard and does not directly address greenhouse gas emissions. The passive house standard has been taken as a starting point when working to develop zero-emission buildings. Eight years of research has been carried out on building design, construction and use by the Research Centre on Zero Emission Buildings, ZEB.³ Some of its main contributions are the definition of a zero-emission building as well as several demonstration projects (Marszal et al., 2011). However, no system or transition analyses – requested in the mid-term evaluation by the Research Council of Norway (2013) – have been carried out. This thesis is financed through ZEB and aims to fill in this gap by taking a system focus on innovations in the intersection between the building and the power sectors; innovations such as power-producing buildings.

1.2 Content of the thesis

This thesis is researching building power – how the development and implementation of innovations in the interface between the building and the power sectors contribute to a sustainable transition. Innovations are uncertain and complex to begin with. However, when linked to sustainability and situated in a cross-sectoral environment, this complexity increases. In this overview chapter, the complexity of sustainable innovations is further explored. Research questions emerging from reviewing the papers as a whole encompass cross-boundary collaboration, the issues of regime dynamics, resistance and how sustainability is interpreted in the research papers that are included.

2 “Enova SF is owned by the Norwegian Ministry of Petroleum and Energy and contributes to reduced greenhouse gas emissions, development of energy and climate technology and a strengthened security of supply.” www.enova.no/about-enova Accessed June 25 2017.

3 ZEB was initiated in 2009 by The Research Council of Norway as one of originally eight so-called FME-centres (Centres for Environment-friendly Energy Research). ZEB has aimed to develop buildings that emit no greenhouse gases, by studying the entire life-cycle of the building from its components and materials to its operation.

Additionally, the governance of transitions in such a complex and uncertain context is also elaborated upon.

To answer the general research question of this thesis, I have explored different objects in an innovation process: the research, the policy and the entrepreneur. Instead of limiting my focus to only one of these issues, I believe that the complexity of the research question would be better examined by a diverse approach. As such, the research process can be described as an approach that zoomed in on three separate but interconnected aspects of the development and implementation of innovations in the interface between the building and the power sectors:

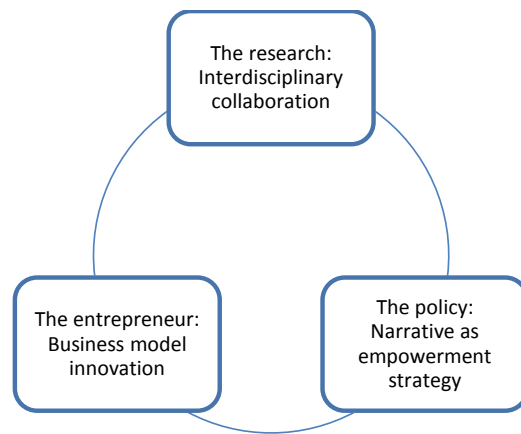


Figure 1: Cornerstones of the thesis

The first area of research was the research process itself. In an interdisciplinary environment such as ZEB, how do researchers and non-academic partners manage to collaborate? Second, the attention was shifted to the empowerment of a specific cross-sectoral innovation. How can narratives be framed and used as an empowerment strategy to affect public opinion? And finally, focus was laid on the entrepreneur and their potential to affect the transition pathway through business model innovation. An overview of the central themes, research methodologies and outcomes follows in Figure 2:

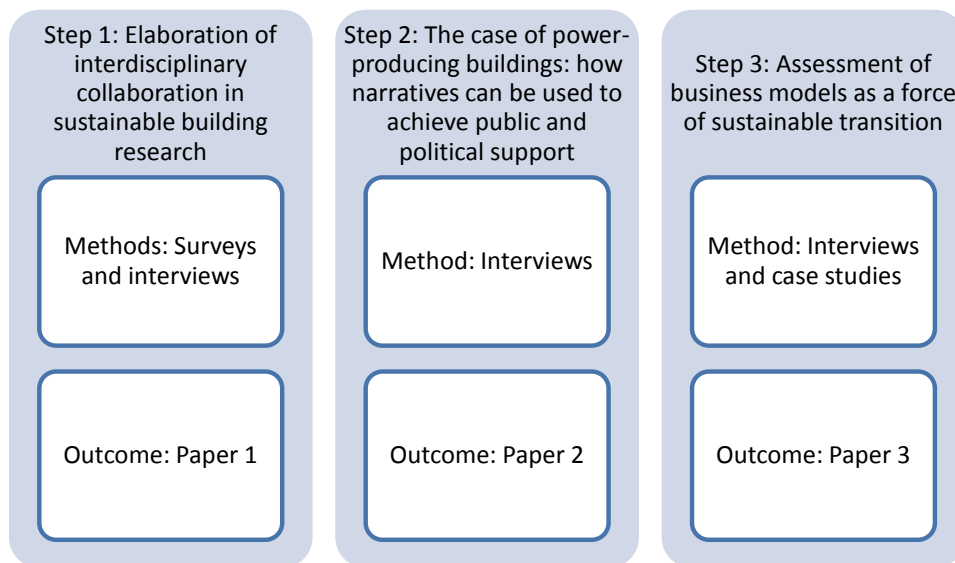


Figure 2: Overview of the research approach

Despite the simplified depiction of Figure 2, this is not to be understood as a linear process. The research has zoomed in on different aspects of importance, applying different theoretical frameworks. A common theme of all three papers is cross-boundary collaboration to achieve sustainable innovation. The first paper focusses on research into sustainable buildings and the complexity of collaboration across “social worlds”. The second paper highlights policies and the interpretation and implementation of sustainable solutions. The final paper focusses on the transition potential of sustainable business models. Papers I and II are accepted for publication by the journals “Science and Public Policy” and “Energy Policy” respectively. The third paper has been sent to the journal “Environmental Innovation and Societal Transitions”.

This thesis extends the debate on how cross-boundary collaboration affects the development and implementation of innovations in the interface between the building and the power sectors. Development and implementation of such innovation is even more uncertain than “regular” innovations and is marked by ambiguity, uncertainty and antagonism, which will be elaborated on in Section 5. Situated in a setting which requires collaboration between distinctively different groups or systems adds complexity, but also potential. The findings are of significance to the challenge of climate change mitigation because they suggest different strategies to overcome the difficulties associated with the achievement of long-term objectives. Furthermore, they give clues about how to manage and steer the implementation process. This thesis does not, however, discuss under what conditions and to what extent the particular innovations are unequivocal contributions to a sustainable transition. This is rather taken for granted. This and other suggestions for future research are brought forward towards the end of the conclusion.

This thesis is divided into two parts: Part A is an overview of the research involved as well as an analysis of the primary research question of the thesis. Part B contains the papers that the thesis centres around. The overview, in the following section, provides a summary of the papers included. In Section 3 and Section 4, the most-relevant theories are elaborated upon and previous research is

presented and discussed. Section 5 provides an analysis of insights gained by collating the papers into the same volume and relates these insights to the findings of the research questions across the papers. This is followed by a conclusion in Section 6 that seeks to answer the overall research question of the thesis. The methodologies that have been applied are examined in Section 7 before the references in Section 8. The semi-structured interview guides are given in the appendix.

2. A summary of the papers

2.1 Boundary objects as facilitators of sustainable building research

Introduction

Buildings with high environmental ambitions play an increasingly important role in national and international green growth and climate change mitigation initiatives. This paper aims to provide insight into the knowledge of the complex collaboration across different disciplines and across academics and non-academics within the Research Centre on Zero Emission Buildings (ZEB) in Norway. The paper also contributes to the literature on transdisciplinary collaboration by discussing the notion of boundary objects to better understand – and ultimately also improve – transdisciplinary collaboration.

Buildings are complex constructions. This complexity increases when performance ambition increases, as is the case in the construction of zero-emission buildings. How does this complexity affect transdisciplinary collaborations including cases that involve both academics and business partners?

Transdisciplinary collaboration can be defined as crossing boundaries; both of the divisions between academic disciplines and between non-academic and academic collaborators. The collective enactment of practices creates deeper divisions affecting, among others, the language that is used and the skills that are necessary to participate.

Star and Griesmer (1989) (Star, 2010) observed that certain boundary objects allow for collaboration across “social worlds”. Boundary objects involve a constant back-and-forth between limited uses and meanings related to the involved social worlds and more vague uses and meanings shared across these social worlds. If this back-and-forth stops, the object loses its boundary-spanning function.

ZEB is an example of an arena in which members of different social worlds “meet around issues of mutual concern and with a commitment to action”, a commitment that is summarized more specifically as the creation of “buildings that have zero emissions of greenhouse gases related to their production, operation and demolition”.⁴

Method

As part of the five-year mid-term evaluation of ZEB, a short questionnaire, containing questions about preferences and experiences with the centre was circulated among the partners. Around the same time, the centre’s five academic work package leaders were asked to describe their goals and ambitions for the centre. In 2014 and 2015, as a third and final step, 18 interviews of senior officials primarily within or related to ZEB, was conducted. The interviews were based on a semi-structured interview guide and were transcribed and analysed. Open coding was the method of analysis for the surveys. Open coding implies comparing the answers to the same questions among all the respondents and identifying clusters of codes (Corbin and Strauss, 2014). After categorizing the data in this way, similarities and differences were identified, both between the academic disciplines involved and between academic and non-academic partners.

⁴ From the ZEB homepage, <http://zeb.no/index.php/about-zeb/about-the-zeb-centre>, visited 17 March 2016

Findings

This paper was based on three evaluations of sustained collaboration between different disciplines that crossed the science–society boundary. Its focus was on boundary objects that have facilitated collaboration and it was shown that neither of the two identified candidates for boundary objects – the pilot buildings and the concept of robustness – were able to span all boundaries involved in the centre’s work. The pilot buildings appeared more central for the non-academic partners. Their expressed intention to use these buildings to showcase their greenness and innovative capacity is potentially in conflict with the academics’ interest in research on new, and, by implication, not-quite market-ready solutions. Furthermore, the corporate imperative is to implement one’s own products in the pilot building, which, in the eyes of academic or other non-academic partners may not necessarily be the best or most appropriate solution.

Despite these limitations, pilot buildings were a useful realization of the “issues of mutual concern and the commitment to action” that characterize the ZEB centre. As illustrated in the paper, the second boundary object, which was the concept of robust solutions, was more applicable to collaboration across disciplinary boundaries than across the science–non-science divide. The researchers from different fields agreed on the goal of creating something that would be durable, flexible, forgiving and strong. Compared to this, for the non-academic partners, there was no particular significance attributed to the fact that the solutions were supposed to be robust; this they took for granted, in one case even calling it a cliché.

Discussion and conclusion

The case of zero-emission buildings, presented here as part of a larger shift towards green construction, represents a stable and productive collaboration between members inhabiting a large number of different social worlds. The more diverse the boundaries that are to be spanned, the more important the work done by, and with the help of, boundary objects becomes. In the case studied in this paper, even a working combination of boundary objects was necessary, namely “a well-functioning building” combined with a commitment to “robust solutions”. In other cases, some other object or commitment can be seen, depending on which “mutual issues and commitments to action” are at the centre of each specific transdisciplinary collaboration. Nevertheless, both specific and visible material objects crafted during the collaboration, as well as the commitment to these objects’ qualities represent an important combination of boundary objects that should be considered in all kinds of transdisciplinary collaboration.

This paper illustrates that even before the power sector becomes involved, diverging interests and perspectives have to be taken into account. The next paper introduces the power sector into the picture.

2.2 The power of buildings in climate change mitigation: The case of Norway

Introduction

Power-producing buildings, mainly exploiting solar power, are part of a trend towards more renewable production and also more decentralized, small-scale production. Since buildings are major energy consumers, there is a significant energy potential in the building stock if less energy is used, or if energy is produced locally. This study explores the introduction of power-producing buildings in Norway. The absence of an explicit inclusion of renewable local power production in energy policy is a

contrast to the existence of state-supported projects. There is ambivalence at the policy level towards power-producing buildings and the distributed energy production they represent. This situation is common when new technologies are introduced (Kemp et al., 1998).

This paper extends the literature with its focus on empowerment strategies in the late stages of the development of a niche (Raven et al., 2016). Linking the niche of power-producing buildings to a regime environment also illustrates that niche empowerment is a highly political process, involving power and antagonism. The decarbonization of the power system is about to take place all over Europe, and therefore issues of decentralized power production are also relevant in other settings/contexts.

Based on this background, the following research questions have been formulated: What niche empowerment strategies – and counterstrategies – are implemented in the case of power-producing buildings? How can the policy ambivalence regarding such buildings be understood, given the narratives that are established? And in what way could narratives function as bridging devices in this context?

Method

The empirical material was collected through 32 qualitative interviews with expert representatives. Interviewees were chosen because of their knowledge of, experience with or their position regarding power-producing buildings. The qualitative method is preferred when there is insignificant research-based knowledge on the area in focus (Kvale and Brinkmann, 2009a). It allows the researcher to adapt to new knowledge and encourage thick descriptions. Experts are chosen as interviewees because the research focus is not part of general knowledge and few people have any experience with the problem to be addressed (Littig, 2009).

Findings

The most prominent arguments when exploring the narrative in favour of power-producing buildings, are the *alternative use* argument and arguments that portray the building sector as clever and solution-oriented. Opponents are seen as primarily protecting their own business interests.

The supporting narrative is countered by an anti-narrative which aims to neutralize the niche development. The anti-narrative argues that electricity supply is already clean and abundant, and that small-scale power production is not an answer to the challenges that the power system is facing. Opponents argue that the existing electricity supply is above all cost-efficient, whereas distributed power production is the opposite. The current power system simply possesses superior qualities compared to the alternative technologies.

On the whole, representatives from the building regime advocate the supporting narrative, whereas interviewees within the power regime advocate the anti-narrative. The extent of expected success for the niche will be affected by the ability to form a narrative that corresponds to the issues that are regarded as important by the public authorities. According to Raven et al. (2016), being able to link the niche to a broader sociopolitical agenda seems imperative for the niche to succeed.

Discussion and conclusion

The diffusion of a potentially path-breaking innovation is not merely a question of users and markets; the elements in a wider selection environment must be taken into account. Support for and resistance against power-producing buildings materialize in different ways, and narratives and anti-narratives are

formed as part of the discourse. Raven et al. (ibid.) suggest that if a narrative succeeds in framing the developing technologies as solutions to specific regime challenges, then it has a greater chance of succeeding. Following this logic, niche proponents should look into how the role of buildings in alleviating the risk of blackouts, which is a primary concern for the authorities, can be framed. If power-producing buildings could represent a solution to problems as defined by incumbents, this would result in regime actors embracing the niche instead of fighting it. This illustrates a way in which the narrative could function as a bridging device.

This paper describes how a discursive strategy can be used to affect public opinion and thereby also policymakers. The next subsection explores how the entrepreneur can be a force for sustainable transition by implementing sustainable business models.

2.3 Challenging the status quo: Business models as a force of sustainable transition

Introduction

Unsustainable business practices do not change by accident; rather, they rely on conscious leadership that places sustainable innovation at the core of the organizations' business models (Schaltegger et al., 2016). To achieve such inclusion, it is useful to understand what drives business model (BM) innovation and what the most promising models look like. The motivation behind orienting towards sustainable market transition is frequently to increase competitive advantage as a frontrunner (Loorbach and Wijsman, 2013). Societal transitions can offer opportunities to business, but businesses can also bring about sustainable change by including sustainability in their innovation targets. In this paper, the force of BMs is explored through the analysis of three green BMs that represent solutions to a broad range of challenges in the interface between the building sector and the power sector. The challenges identified were:

- 1) how to increase energy-efficiency in buildings;
- 2) how to increase the amount of renewable energy by utilizing buildings; and
- 3) how buildings can contribute to levelling out the peak load curve.

The BMs or case studies selected to debate each of the challenges were energy performance contracting (EPC), leasing of Solar Panels (LSP) and the aggregator role (AGR).

The evaluation of how business models work and their prospects for playing a significant role in the green transition ahead is crucial not only for the businesses but even more so for the society as a whole. It is of particular importance to policymakers that can influence the external conditions, including the institutional framework, that allow a business model to prosper. This paper investigates whether business models are a potential transformative force in the low-carbon transition ahead and goes on to look at how the transition management framework could complement business model theory when assessing business models.

Method

This paper builds on the 32 interviews undertaken in connection to the second paper. In this material, three particular challenges were identified in the interface between the building and the power sectors. Furthermore, three BMs were identified that correspond to each of the three challenges, and seven additional interviews were undertaken to map the cases represented by the BMs.

All interviews were expert interviews, and the first 32 interviewees were chosen on the basis of their knowledge of, experience with, or position regarding highly energy-efficient buildings. The next seven interviewees were chosen as representatives of the selected cases. When performing case studies, the selection of cases is important. According to George and Bennett (2005), when there are few cases, the risk of a skewed selection is higher when the selection is random. In this paper, the cases were selected to correspond to the challenges and a table of interview objects are presented towards the end of Section 7.

Findings

The EPC targets the energy-efficiency challenge and is a well-documented and market-based model. Even if energy-efficiency is largely uncontroversial, it is not forcefully advocated. Since improved energy-efficiency is a matter of national interest, suppliers lean on the public actors to promote the model. It is a niche that is very close to the regime; it is affected by subtle landscape pressure, but, since Norwegian hydropower is such a clean and cheap resource, Norwegian authorities are reserved in their promotion of the model. It does not represent any radical change and is therefore unlikely to contribute to any structural, long-term alterations.

The need to increase the share of renewable energy is targeted by LSP. LSP is a minor, but still rapidly growing, mechanism for the production of solar power in Norway. There are few suppliers of LSP, but an increasing number of energy utility companies have entered the market. The largest supplier is an independent start-up company that is by itself challenging the conventional structure of the power sector. This BM is spurred by international development towards more decentralized power production (The European Parliament and the Council, 2010, Sims and Schock, 2007).

The challenge of peak load is perceived as an increasing threat to energy security. More sectors are becoming electrified and hence demand for electricity is increasing. It is expensive and harmful to the environment to expand the grid infrastructure in line with the increase in peak demand. For this reason, more sustainable strategies are being developed and AGR is an example of this. The BM was explained by an interviewee as being more-or-less inevitable, with reference to a supertanker that is difficult to stop. The supertanker is a representative of the landscape level, with this BM right in the core of national preferences – to secure a stable energy supply.

The paper has undertaken a risk assessment of all case studies and the result can be depicted like this:

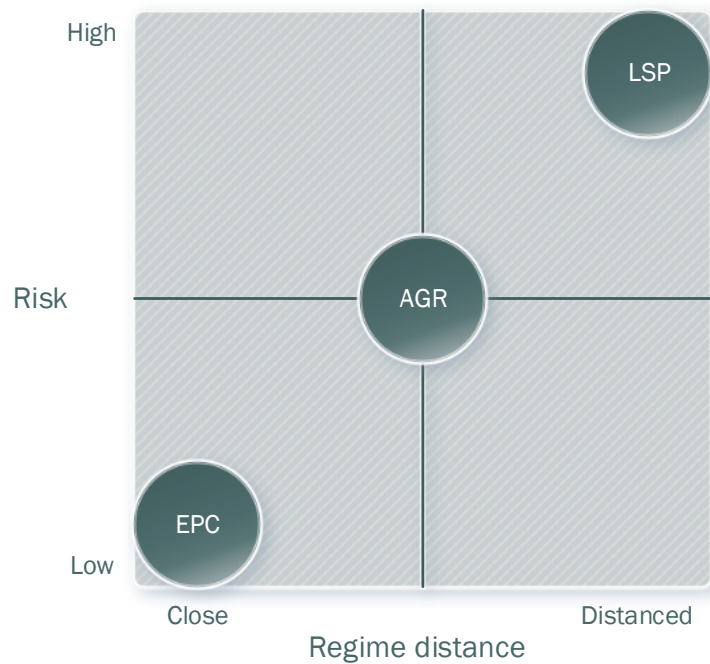


Figure 3: Business models related to regime distance and risk assessment

There is a lower risk associated with those BMs that are closer to the regime. However, BMs representing incremental change are unlikely to be a driving force of a sustainable transition. Also, the pressure from the landscape level related in particular to LSP and AGR seems obvious. This indicates that niches can be affected directly by landscape pressure without intermediation of the regime.

Discussion and conclusion

The interplay between transition levels indicates how the BMs will evolve further. At the regime level, one could suggest an instability caused by a major landscape pressure from anthropogenic climate change. This pressure is particularly relevant to the power sector, which is to become carbon-free by 2050, according to EU strategy. Other landscape pressures stem from EU directives, for example the Energy Performance in Buildings Directive (EPBD) as well as market development of renewable energy commodity prices and improvement of products.

This paper explores the power of business models to create a sustainable societal transformation. It does so through case studies of three business models in the interface between the building sector and the power sector in Norway. In the analysis, business model theory and transition management theory are combined. In Norway, as in many other countries, buildings are increasingly important to the power system in terms of distributed energy production, energy-efficiency projects and as a potential source of demand-side flexibility to keep load curves even. Unsustainable business practices need conscious leadership in order to change. If the mechanisms and the role of businesses and their business models could be better understood, then this would also contribute to more accurate transition management processes.

In the rest of Part A, I refer to each paper by number: Paper 1, 2 and 3; or the first, second and third paper, as they are represented in this section.

3. Theory on sustainable innovation

In this section, theories that are relevant for the dissertation as a whole are elaborated. A common thread in this thesis is cross-boundary collaboration to achieve sustainable innovation, and the analyses have been conducted by applying diverse transition theories, in particular strategic niche management and transition management. Hence, I will start by explaining the development from innovation theory to more recent transition theory before I examine cross-boundary collaboration in general and boundary objects in particular. I then move on to elaborate the most central frameworks of transition theory: the multilevel perspective, transition management, strategic niche management and technological innovation system analysis. In addition, a relationship is established between business model theory and transition theory. When dealing with transitions, there are highly relevant issues related to power and governance and this is discussed in Section 3.10. Finally, I end this section by highlighting some of the most prominent criticisms of the theories in question.

3.1 From innovation theory to transition theory

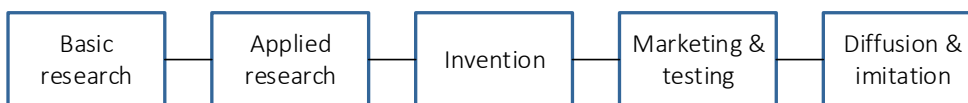
Early conceptualizations of innovation

The first detailed efforts to analyse the innovation process can be traced back to the early 20th century and the work of the economist Joseph Schumpeter. Innovation has been largely associated with technology development and deemed necessary to economic growth (Sørensen, 2015). However, as defined by Schumpeter (1934), innovation (or “development” as he initially phrases it) is the realization of “new combinations” of existing resources, equipment and so on (ibid. p. 65). Furthermore, he sees innovation as a social activity, which he referred to as the “entrepreneurial function”. Schumpeter places innovation in the midst of a three-stage process between invention and diffusion (or “swarming” as referred to by Schumpeter), eventually leading to the deployment of innovation in the market (ibid.). The innovative power, reflected in the objective of ZEB, echoes Schumpeter’s definition of innovation as the commercial or industrial application of something new. Schumpeter identified innovation as the critical dimension of economic change. He was the first to point out the role of the entrepreneur as being crucial to innovation and economic change, as the entrepreneur introduces new combinations that may replace the old ones. In doing so, the entrepreneur introduces product and process innovation mechanisms, through which new production units replace outdated ones. This replacement process is referred to as “creative destruction” (Metcalfe, 1998). Another categorization of innovations based on Schumpeter’s work is made according to how radical they are compared to the existing situation. There are *incremental innovations*, which are continuous improvements, mainly resulting from “learning by doing” and “learning by using” processes. *Radical innovations* are discontinuous events that are usually the result of deliberate research and development activities. “*Constellations*” of radical and incremental innovations may cause changes in the technology system that affect several branches of the economy and may create entirely new sectors. *Technological revolutions* or changes in the “techno-economic paradigm” are very far-reaching changes that have pervasive impacts on the behaviour of entire economies (Fagerberg, 2003a). In addition to being honoured for his ideas in innovation, Schumpeter is also recognized as the most influential evolutionary economist of all time (Fagerberg, 2003b). In evolutionary economics, the basic argument is that innovation is the main factor behind long-term economic development. The more innovation, the higher the degree of variety and the more dynamic the economy will be (ibid.). Imitation, learning and user-induced improvements characterize evolutionary processes, along with actors and knowledge. Economic knowledge is fundamentally seen

as a set of routines that are reproduced through practice (ibid.) The role of the entrepreneurial function of the firm is particularly important, as outlined by Schumpeter, whereas Nelson and Winter (1977) explicitly focussed on innovation as an organizational phenomenon, unequally distributed among the population of firms. The notion of “entrepreneurial function” points to a system perspective (Fagerberg, 2003b). How does evolutionary economics relate to the other strands of research? The boundaries between evolutionary economics and business studies are increasingly blurred according to Fagerberg (ibid.). Geels (2010) discusses ontologies and their relevance to sociotechnical transitions in which he identifies evolutionary economics – which focuses on firms, innovation and market competition – as particularly relevant to sociotechnical transitions.

An early conception of innovation was the linear model, whose origin is unclear but generally known to be developed in the period around the second world war (Asner, 2004) (Freeman, 1996). “Science invents, industry adapts and society conforms”, which was the motto of the 1933 World Exhibition in Chicago, is likely to have been inspired by the same thoughts and ideas. According to the model, technological innovations are stimulated either by scientific advancements (technology push) or by economic development on the demand side (market pull) (Rosenberg, 1969). Advantages of the linear model are that it has a clear division of labour and there are fewer interfaces where cross-boundary collaboration becomes necessary.

The linear model:



Firm-specific linear model:

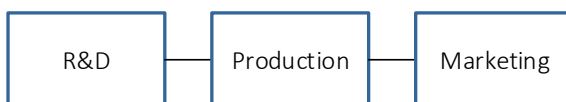


Figure 4: The linear innovation model (Freeman, 1996) p. 28

The main criticisms against the model are, according to Kline and Rosenberg (1986), first that it portrays research as a driver of innovation while in most cases the driver is unfulfilled market needs. Second, it underestimates the many feedback loops and reverse processes involved in technological change. Finally, it is mainly focussed on radical change and thereby underestimates the many processes of incremental change (Abernathy and Clark, 1985). Rosenberg declared the linear model dead in 1994. However, Godin (2006) argues that the model is still in use due to statistics: the statistics on research and development have been accepted as a proxy for innovation and hence the link between research and innovation has survived, despite much criticism.

Diffusion of innovations

Ultimately, innovations are meant to be taken up and spread in a wider market. However, most innovations never find their way to a larger market. The approach to find and explain patterns in the process of adoption of a new technology is referred to as the theory of diffusion of innovations. This theory was developed by Everett Rogers and illustrated in the well-known S-curve shown in Figure 5 (Rogers, 2003).

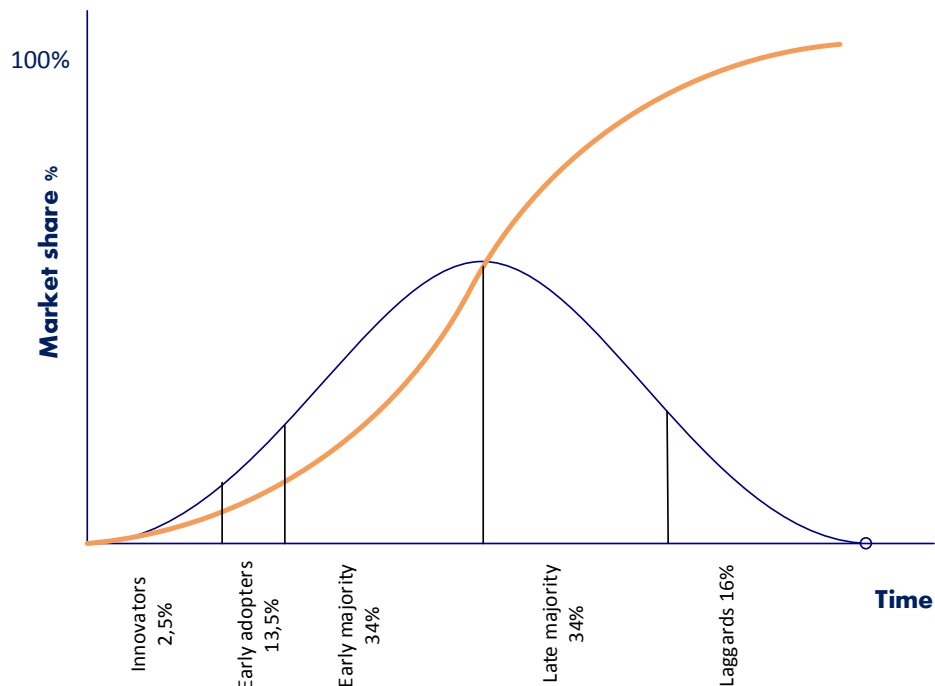


Figure 5: Diffusion of innovation, based on Rogers (2003)

The adoption of innovations normally follows a bell-shaped curve when plotted over time on a frequency basis. If the cumulative number is plotted, then the S-shaped curve is found (Rogers, 2003). A normal adopter distribution is expected for an innovation because of the cumulatively increasing influences on the decreasing numbers of individuals that have still not adopted the innovation. The S-shaped curve “takes off” when interpersonal networks becomes activated and spread the individual evaluations of an innovation from peer to peer in a system (ibid.). The work by Rogers was important not least in establishing a common terminology with which to discuss diffusion of innovation.

Towards a systems-based conceptualization of innovation

Contrary to the earliest rather over-simplified conceptualizations of innovation, at the end of the last century, models of innovation were presented as affected by and dependent on contextual factors (Fagerberg, 2003a). A well-known approach is the chain-linked model developed by Kline and described by Kline and Rosenberg (1986). This model aims to depict the complexity of innovation by illustrating the continuous feedback loops between all stages of the innovation process. Instead of research, it is the unfilled market need that is the primary driver for innovation in this model.

The complexity of the innovation process was also addressed by evolutionary economists in the late 1980s, most notably Freeman (1989), Lundvall (1992) and Nelson (1993). They put emphasis on the interactive, systemic and endogenous view on innovation and its role in economic development. There is no common definition of an innovation system, but one definition by Edquist (1997) is that an

innovation system is all important economic, social, political, organizational, institutional and other factors that influence the development, diffusion and use of innovations. Numerous attempts to visualize these complex connections have been made. One that illustrates the main elements and their connections in a perspicuous way is depicted below:

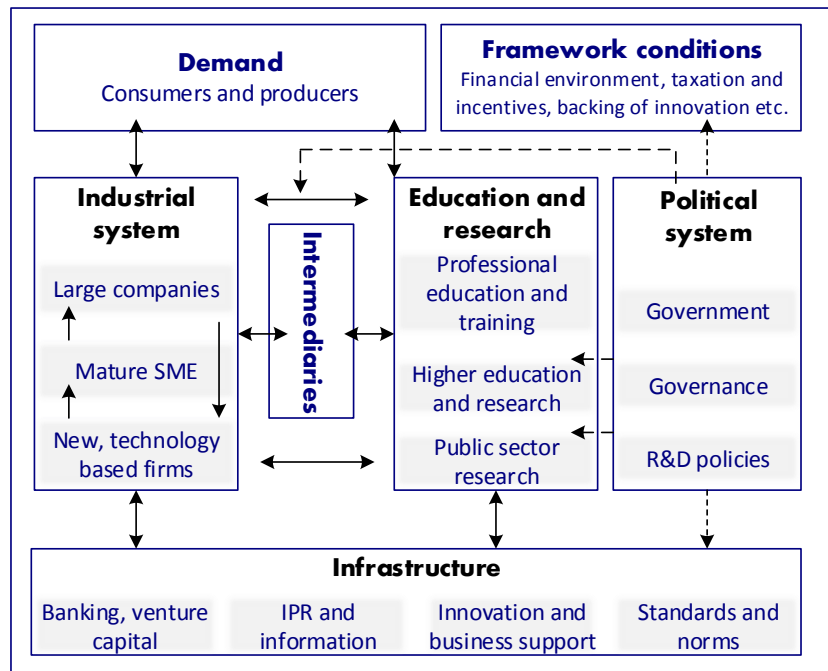


Figure 6: An innovation system model, adapted from (Kuhlmann and Arnold, 2001) p. 2

The depiction of an innovation system in Figure 6 illustrates some of the complexity of such a model. In an innovation system, the role of institutions is important as it explains why actors behave as they do within the system. In Figure 6, institutions are embedded in the framework conditions as well as the political system and the consumer and producer response to an innovation. Actors and networks are located in the industrial system, education and research as well as being in intermediaries (bodies that facilitate interaction among actors and networks) such as knowledge brokers, environmental organizations or research institutes. The system is resting on a platform of tangible and intangible infrastructure, where interactive learning as well as feedback loops and virtuous cycles all form part of this picture (Soete et al., 2010). Innovation system approaches like this contribute to a broadening debate on sources of innovation which goes far beyond R&D.

The innovation system approach has provided insight into the important role of institutions and has gained popularity among policy actors even on a supranational level. The units of analysis in innovation system theory are national, regional, sectoral or technological systems. Lundvall is known to emphasize the national institutional framework. This framework focusses on understanding the innovative economic performance of nations (Lundvall, 1992), with particular attention to sources of innovation (learning, search and exploration), the nature of innovation (where the incremental and cumulative nature is stressed), as well as non-market institutions such as user–producer interactions and “regularities of behaviour” (ibid.). Other innovation system approaches focus on regional clusters

of innovative activity and claims that innovation is region specific, with reference to specific areas such as Silicon Valley. Sectoral innovation systems approaches assume that processes and components of innovation are sector specific so that sectors, even across nations, have comparable innovation systems. These systems have a specific knowledge base, technologies, input and demand (Malerba, 2002). Finally, the technological innovation system approach is centred around a specific technology, where “networks of agents [are] interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion and utilization of technology” (Carlsson and Stankiewicz, 1991) p. 93.

A system innovation is a transition from one sociotechnical system to another. Innovation system analysis is part of the wider transition research umbrella, which is a newer approach to sustainable development. The difference between an innovation and a transition is described by Alkemade et al. (2011) as partly due to the time aspect – as transitions consist of several innovations and are typically much longer processes than are innovations – but also that innovations are not necessarily sustainable, whereas transitions are mainly associated with a sustainable end goal.

3.2 Collaboration across boundaries

Collaboration and knowledge sharing is proven to foster innovation (Kimble et al., 2010). Furthermore, the idea that innovation requires collaboration across boundaries is well established (Fagerberg et al., 2005). However, effective cross-boundary collaboration is challenging since knowledge within a group reflects this group’s particular norms, trainings and preoccupations. This is the main reason why a homogenous group is less likely to produce new ideas than a heterogeneous group. Clearly, it can be challenging to collaborate across boundaries. For the collaboration to be successful, the different groups or communities that are collaborating must reach a shared understanding of their mutual task and how to achieve it (Kimble et al., 2010).

To facilitate collaboration across boundaries, people, artefacts and organizations can all have a role. Several roles are described in the literature, such as the role of brokering, intermediaries and boundary objects. The concepts can briefly be described like this:

- 1) A broker translates the knowledge inherent in one group to the language of another. It is described by Wenger (1998) as a complex job, which involves processes of translation, coordination and alignment between perspectives. The broker requires legitimacy in order to fulfil this role.
- 2) Boundary objects are “- artefacts, documents, terms, concepts, and other forms of reification around which communities of practice can organize their interconnections.” Ibid. p. 105.
- 3) Intermediation seems to be used interchangeably sometimes with “broker” and with “boundary objects”. However, it appears, from a literature review (Howells, 2006), to be mainly associated with the role of an organization in facilitating or intervening in a process that is sometimes referred to as a boundary organization, and other times as a (knowledge) broker.

Like brokers (and intermediaries), boundary objects are also addressing communication between communities, although their role is more indirect (Kimble et al., 2010). In the remainder of this subsection, the focus is on boundary objects as this is the concept that has been the main focus of Paper 1.

The term “boundary object” originates from Star and Griesmer’s study of the Berkeley Museum of Vertebrate Zoology. According to Star and Griesmer (1989), boundary objects are artefacts that articulate meaning and address multiple perspectives. Boundary objects are flexible, in the sense that they have different meanings in different social contexts. At the same time, boundary objects have a fixed structure, which makes them recognizable across social worlds. Being organic arrangements, boundary objects allow different groups to work together through a more-or-less well-structured back-and-forth negotiation (Star, 2010).

According to a review on the subject of boundaries performed by Akkermann and Bakker (2011), boundary crossing and boundary objects has received growing interest over the past few decades. This interest is boundary crossing in itself; it spans several disciplines such as education and learning (Kimble et al., 2010), project management (Sapsed and Salter, 2004) and science and technology studies (Star and Griesemer, 1989).

In this thesis, boundary objects have been described as facilitators for collaboration. Given the interpretive flexibility, is there something that could not work as a boundary object? According to Star (2010), it is hard to exclude anything that inhibits interpretive flexibility as a potential boundary object. It could work under certain circumstances. However, it is a question of scale and scope. Star argues that boundary objects are most useful at the organizational level and that the most meaningful scope is a specific one. Cross-boundary collaboration is identified as a common theme of the thesis, and is further elaborated in sections 4.3 and 5.1.

3.3 Sustainable transitions and the most prominent theoretical frameworks

Incremental change to a system is likely to be insufficient to tackle the challenges of climate change. More radical, systemic changes are needed along with an understanding of how such changes come about. This is facilitated through theoretical frameworks like the technological innovation system approach (Hekkert et al., 2011, Bergek et al., 2008), the multilevel perspective on sociotechnical transitions (Geels, 2002, Smith et al., 2010), transition management (Kern and Smith, 2008, Rotmans et al., 2001, Loorbach, 2010) and strategic niche management (Kemp et al., 1998, Raven et al., 2010, Smith, 2007).

Sustainable development

Since its definition by the so-called Brundtland Commission (The World Commission on Environment and Development, 1987) sustainable development has been extensively discussed and hundreds of definitions have been added (Dale and Hill, 2001). It has been accused of being an oxymoron but Newman (2005) rather finds it likely that the long-lasting debate over the meaning of the term is due to the expression of an equilibrium. According to Newman (ibid.) society is a complex dynamic system. This mismatch, between the stable equilibrium and a dynamic society, has contributed to the long-lasting debate. Moreover, perhaps the debate itself is useful, highlighting the process rather than the goal.

Innovation itself is a complex phenomenon with an uncertain outcome (Berker, 2010, Rip, 2012). Sustainable development is even more complex, since long-term change is deemed by some to be impossible to steer, while simultaneously deemed by others to be too important not to try. How to cope with uncertainty, ambivalence and distributed power is discussed by Newig et al. (2007), who make three fundamental observations: sustainable development is a normative, yet extremely vague concept, which raises issues of governance and political steering; most contributions approaching

sustainability governance from multiple angles have in common that they assume sustainability goals as given; and that sustainability poses a different set of governance challenges than other policy fields. The interpretation of what is sustainable and the goals of sustainable development are rarely simply and clearly defined. More often, they are ambivalent, difficult to agree upon and hard to specify. (Walker and Shove, 2007).

Sustainable transitions

A transition can be conceptualized as the process of moving from one stable sociotechnical regime to another in such a way that the structure of the regime has fundamentally changed (Smith et al., 2010, Verbong and Geels, 2010, Rotmans et al., 2001). The changes needed for a transition to take place involve several interrelated actors, networks and institutions. Transitions are systemic by nature and therefore also hard to initiate and manage. A transition is a development from one stable situation to another. Ultimately, transition goals are decided by society, but government can play a significant role by inducing change in a stepwise manner (ibid.). The transition process can be illustrated as a four-step progression (Figure 7), with each step evoking different changing processes in the society.

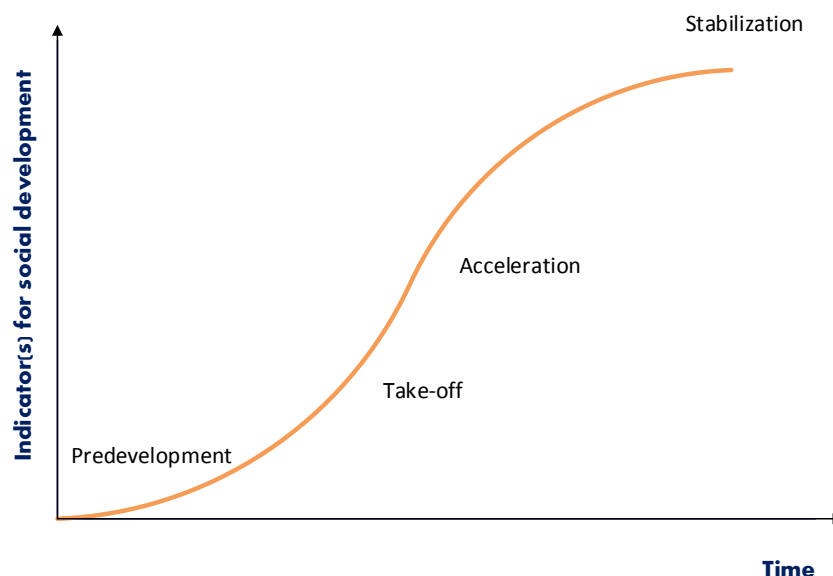


Figure 7: The four phases of transitions (Rotmans et al., 2001) p. 17

The concepts of speed and acceleration are relative as the transition process will develop at different pace throughout different periods. For some time, nothing will happen, whereas in other time periods, a number of developments will take place simultaneously. Four different transition phases can be distinguished:

- 1) predevelopment phase, where no significant change to the status quo occurs;
- 2) take-off phase, where incumbents are challenged and the system is starting to change;
- 3) acceleration phase, where visible structural changes take place and changes in several systems are accumulating and reinforcing each other. In this phase, collective learning, diffusion and embedding processes are happening; and

4) stabilization, where “a new dynamic equilibrium is reached” (Rotmans et al., 2001) p. 17.

This S-shaped curve is similar to the diffusion curve depicted in Figure 5. However, the Y-axis has different denomination. The phases of transition sum up all innovations and structural changes at a certain point in time, whereas diffusion of innovations merely illustrates the cumulative spread of an innovation.

Large-scale transformations, such as the greening of the power sector, are referred to as sociotechnical since the changes that are needed will not only imply changes of a technological character but also changes in policy, markets, user practices and cultural meanings (Geels, 2004b, Unruh, 2000). Transition theory draws upon inputs from several disciplines, but also develops its own theories. The four main frameworks, the multilevel perspective, strategic niche management, transition management and technological system analysis, are elaborated below.

3.4 The multilevel perspective (MLP)

The most prominent of the frameworks developed under the transition theory umbrella is the multilevel perspective (MLP). This is a central framework used, in particular, to explain large-scale transformations in retrospect (Geels, 2002) (Fuenfschilling and Truffer, 2014, Geels and Schot, 2007, Smith et al., 2005, Smith et al., 2010). In terms of ontological foundation, MLP is based on crossovers from evolutionary economics and science and technology studies (STS) (often associated with constructivism), which means that there is a focus on variety, selection and retention but also an emphasis on the selection environment being wider than users and markets (Geels, 2002, Geels, 2010, Rip and Kemp, 1998). A selection environment comprises several features of the regime, such as industry structures, markets and dominant practices, the established knowledge base, dominant technologies and infrastructures, cultural significance, and public policies and political power (Smith and Raven, 2012). Changes in the selection environment can destabilize a regime and make the introduction of a niche innovation more likely to succeed.

The MLP framework consists of three levels: landscape, regimes and niches. The framework was introduced by Rip and Kemp (1998), albeit referring to the analytical levels as macro, meso and micro. MLP is a middle-range theory⁵(Merton, 1968) that has become widespread in a short period of time. Although MLP has been adopted as a useful framework, like other prominent theories, it has been criticized and suggestions for improvements have been brought forward (Smith et al., 2005, Genus and Coles, 2008, Markard and Truffer, 2008). The criticism is outlined and discussed in subsection 3.11. Next, I elaborate further on some of the most central concepts in MLP that are also shared by all transition frameworks.

The regime and its incumbents

A regime is understood to be a dynamically stable structure consisting of actors, networks and institutions. In the context of this thesis regimes can be described as well-defined and -integrated set of collaborative relations internal to the regime. The regime concept has been cultivated in particular by Geels and Scot (Geels and Schot, 2007, Geels, 2011, Geels, 2002, Schot and Geels, 2008). The notion “technological regime” was used by Nelson and Winter as early as 1977 (1977) and developed

⁵ Described by Merton as “theories that lie between the minor but necessary working hypotheses that evolve in abundance during day-to-day research and the all-inclusive systematic efforts to develop a unified theory that will explain all the observed uniformities of social behavior, social organization, and social change” p. 448.

further by Kemp and fellow researchers (Kemp, 1994, Kemp et al., 1998). Regime incumbents have vested interests in regime preservation and can resist and block pressures to change. Hence, the introduction of a radical and potentially path-breaking innovation is typically resisted, according to Geels (2014) and Hess (2014). A path-breaking innovation has the potential to change the present regime through altering the selection environment (Raven et al., 2016, Schot and Geels, 2008).

Niche innovation

Innovations like power-producing buildings that might challenge the regime and its incumbents are typically developed in niches, which are outsiders or sites where innovations can be nurtured and mature (Kemp et al., 1998, Smith and Raven, 2012). According to Kemp et al. (ibid. 1998 p. 186), “niches are platforms of interaction; they emerge out of a process of interaction shaped by many actors”. To be successful, the niche innovation is dependent upon a balance between protection and exposure to the selection environment (Smith and Raven, 2012).

The landscape

The macro level – the *landscape* – represents an external environment of factors and processes that impact both regimes and niches. It consists of a set of heterogeneous factors such as wars, earthquakes, climate crises, oil prices, broad political coalitions, cultural and normative values (Geels, 2002). Geels and Scot (2007) explain the landscape level as “deep-structural ‘gradients of force’ that make some actions easier than others”. Furthermore, Kemp and Rotmans (2005) conceptualize the landscape as background variables channelling transition processes while being largely independent and autonomous.

MLP is often depicted like this:

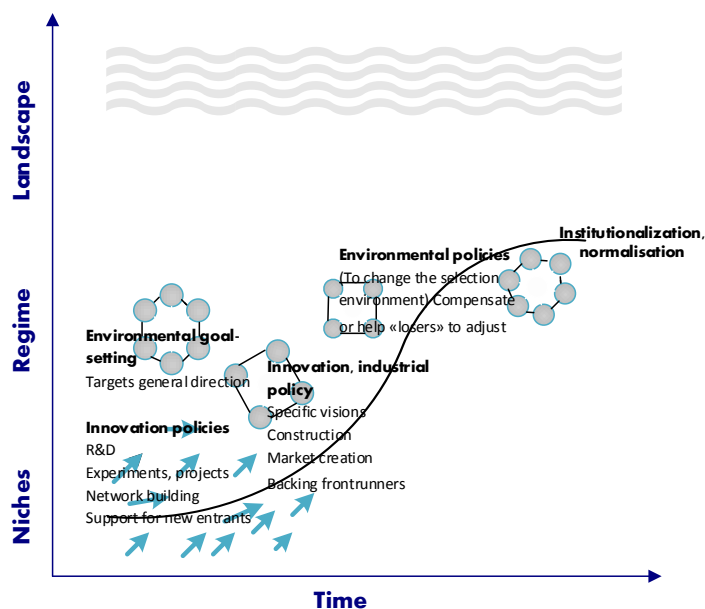


Figure 8: The MLP framework, based on (Geels, 2002)

The arrows at the niche level illustrate how niches are developing to become parts of the regime. Within the regime there are many sub-regimes consisting of networks, actors and institutions that can overlap. An actor may be part of the regime and part of a niche at the same time. This dynamic situation has been problematized as it is empirically challenging to analyse (see more in Section 3.11). Landscape features generally provide pressure on the regime so that it becomes unstable, which makes it easier for niches to enter and eventually replace regime actors and potentially induce a regime shift. When a new regime eventually stabilizes, a sustainable transition has taken place.

3.5 Strategic niche management (SNM)

The SNM approach suggests that sustainable transitions can be induced by creating technological niches: protected spaces where experimentation with the co-evolution of technology, user practices and regulatory structures takes place (Schot and Geels, 2008). These technological niches have a hard time, however, bridging the “valley of death” between R&D and market introduction (ibid. p. 537). Building on Kemp, Schot and Hoogma (1998), strategic niche management provides a framework of analysis to comprehend what it takes for an innovation to become part of a larger market. This framework illustrates how an innovation can be shielded, nursed and empowered to stand a better chance when faced with a harsh selection environment.

Niche protection

Niche protection is separated into three components: shielding, nurturing and empowerment. Shielding is defined as “processes that hold at bay certain selection pressures from mainstream selection environments” ((Smith and Raven, 2012). p. 1027). Nurturing refers to processes that support technology development within the niche (Boon et al., 2014). It involves interacting processes that focus on learning, networking and the articulation of technological expectations (Raven et al., 2016). The least-developed of the protection strategies, according to researchers such as Smith and Raven (e.g. (2012) and (2016)), is how niche empowerment works and how it complements the other strategies. Empowerment strategies work at altering the selection environment to make it easier for the niche to enter the regime.

Niche protection strategies are either inward- or outward-looking (Smith et al., 2014). By looking inwards, the strategy is oriented towards knowledge creation and networking. The alignment of experiments in a research centre is an example of inwards-oriented niche protection strategy. In the latter stage of niche protection, the niche is facing the broader selection environment. Here, outward-looking processes involve actors in, for example, lobbying and narrative work. According to Smith et al. (ibid.), outward-oriented narratives are used to expand the space for niche development and the sociotechnical configurations that follow. The narrative work of niche advocates is frequently countered by anti-narratives.

Niche management

Protected spaces can be empowered in two ways, according to Smith and Raven (2012): Firstly, the niche can be developed so that it fits into and conforms to a partially changed selection environment. This is referred to as “fit and conform empowerment”. Empowerment can alternatively be achieved if the niche itself is able to change its selection environment, rather than be subordinated by it. Such empowerment is referred to as “stretch and transform”. The process of empowerment will imply structural change that is likely to be met by power and antagonism. This resistance materializes in many forms of power exercise, and is described by Geels, among others (2014).

3.6 Transition management (TM)

SNM and TM have some similarities as they are a policy tool and a policy model respectively, developed around the same time by some of the same scholars (Kemp, 1994, Hoogma et al., 2002, Kemp et al., 1998, Rotmans et al., 2001). The differences are primarily the subject of study, the level of aggregation, the research approach and the prescriptive implications and models (Rotmans, 2005).

Transition management is a governance approach and a strategy that ensures that long-term visions are embedded in short-term policy:

Transition management should be seen as complementing rather than conflicting with current policy, bringing added value by placing it in a more long-term perspective. It is a proactive, anticipatory strategy that is particularly sensitive to grassroots innovation. (Rotmans et al., 2001) p. 24.

Often, transition management is explained along the lines of multiple levels to help picture the different processes happening. Experiments are undertaken at the micro-level, in outlying niches or sites where innovations can be nurtured and mature (Smith and Raven, 2012). Transition management is taken up by, for example, the Dutch government, which aims to manage, facilitate and accelerate sustainable transitions through visioning, learning and experimenting (Rotmans et al., 2001, Meadowcroft, 2009). The idea is that visioning is guiding the selection and development of experiments and that these experiments should be learned from and improvements made. Built on Rotmans et al. (ibid.), visioning aims to create an alternative future state that represents what the final transition would look like. It is room for several alternative but not mutually exclusive visions. A collective transition objective is agreed upon and interim objectives formulated before finally, social support is engaged. This implies a shift from one equilibrium to another, which means that the status quo represented by the regime is challenged. There are many ways in which society might be trapped in suboptimal outcomes (Meadowcroft, 2009). Transition management employs means to break out of these system lock-ins.

Awareness of the potential force of coherent action by entrepreneurs through sustainable business models is increasing. An unstable regime can be viewed as consisting of a number of unsustainable business models. Section 3.8 provides further detail on business model theory.

3.7 Technological innovation system (TIS)

The focus on the technological aspect of the innovation system was developed by (Carlsson and Stankiewicz, 1991). The Technological Innovation System (TIS) places the focus on emerging systems and highlights the role of entrepreneurs in system building. TIS can cross sectors, regions and nations and has, during the last decade, been progressed into a functional approach, providing the opportunity to address more concrete issues, as has been requested by researchers such as Soete et al (2010). In an overview of systems of innovation (ibid.), Soete concludes that previous innovation systems have mainly been analysed qualitatively. In order to become more policy relevant, more concrete conclusions must be reached and in that way, one is able to give concrete policy advice (ibid.). TIS analysis consists of a structural and a functional part: the structural analysis involves mapping actors, networks and institutions that are particularly relevant to the technology in focus; the functional analysis is comprises empirically validated indicators especially adapted to the respective TIS. The functional approach has been cultivated by Bergek and Hekkert with their research fellows

(Bergek et al., 2008, Hekkert et al., 2007, Bergek et al., 2005). An overview and comparison of system function indicators has been made by Markard and Truffer (2008).

Hekkert et al. (2007)	Bergek et al. (2005)	Chaminade and Edquist (2005)
Entrepreneurial activities	Entrepreneurial experimentation	Creating and changing organizations
Knowledge development	Knowledge development and diffusion	Provision of R&D
Knowledge diffusion		Provision of education and training
Guidance of the search	Influence on the direction of search	Articulation of quality requirements from the demand side
Market formation	Market formation	Formation of new product markets
Resources mobilization	Resource mobilization	Incubating activities
		Financing of innovation processes
		Provision of consultancy services
Creation of legitimacy	Legitimation	Creation/change of institutions
	Development of positive externalities	Networking and interactive learning

Table 1: System function indicators in three pioneer publications on functional analysis (Markard and Truffer, 2008) p. 602

Comparison of different studies makes it possible to arrive at a set of indicators that are commonly defined and understood (Markard and Truffer, 2008). While Chaminade and Edquist use “activities” as the analytical term, Bergek and Hekkert have chosen “functions”, which seems to be better fitted to the systems concept. While functions can be ascribed to all types of system elements (actors, networks and institutions), activities, however, at least in a narrow interpretation, can only be performed by actors, and not by institutions or networks (Markard and Truffer, 2008).

3.8 Business model (BM) theory

The concept of business models is old, but has only recently been broadly researched by academia (Gronum et al., 2016). There are a number of definitions of a BM, and there is a need to distinguish it from other business-related concepts such as strategy. According to Casadesus-Masanell and Ricart (2010). p. 205, “An organization’s business model is the reflection of its realized strategy”. A *green* BM is adding value by including products or services that are “green”, or less harmful to the environment than the alternative.

Failing to develop new BMs is assumed to be one reason why established firms are suddenly facing serious challenges. This can be exemplified by the challenges faced by the large energy companies due to the German “sun energy revolution”, or what Germans call “die Energiewende” (see, for example,

(Wainstein and Bumpus, 2016) and (Richter, 2013)). BMs have increasingly been recognized as a source of market disruption, irrespective of the underlying product (Chesbrough, 2010, Teece, 2010). The principal aim of a BM is to create and capture value. Boons and Lüdeke-Freund (2013) point at business models as a source of competitive advantage by means of BM innovation. According to Osterwalder and Pigneur (2010) a BM can be depicted as a “canvas” consisting of nine building blocks:

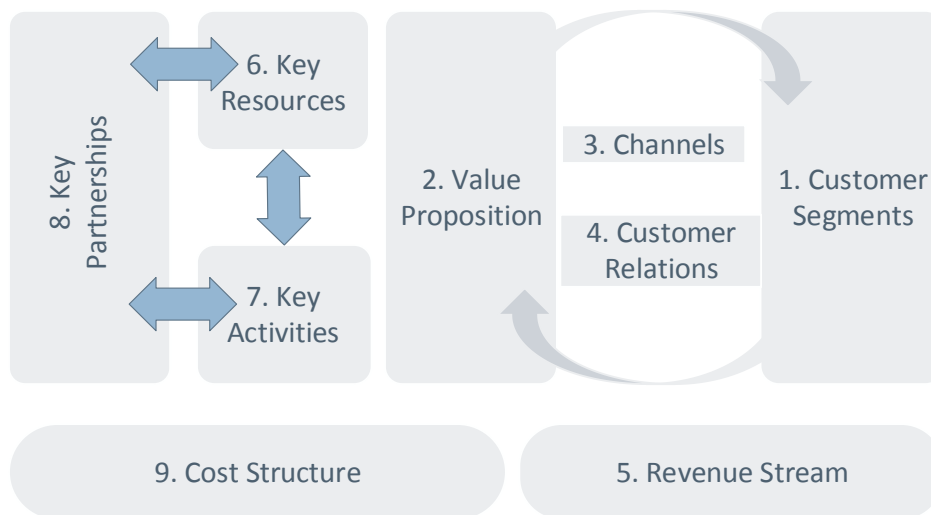


Figure 9: Building blocks of a business, adapted from (Osterwalder and Pigneur, 2010)

Initially, it has to be decided who the value is created *for*; who are the most important customers? The next step is to decide upon what needs are satisfied through the BM? It has to be considered how to reach the customers; which channels are working best and with acceptable costs? Also, customer relations are important to consider; should it be a distanced impersonal relationship or a closer, perhaps co-creating relationship? Furthermore, issues regarding willingness to pay, pricing, as well as a system to handle payment logistics are central to decide upon and establish. Additionally, key resources, activities and partners are required, all of which are guided by the chosen value proposition. Finally, the cost structure is of vital importance with two classes of cost structure commonly distinguished: value driven and cost driven. The focus in a cost-driven cost structure is mainly on minimizing costs in every possible way. In a value-driven cost structure some kind of added value is demanded to distinguish the product or solution from potential competitors.

Dominating technologies and prevalent infrastructure have potential lock-in effects that reinforce established BMs and potentially hinder or block the introduction of innovative BMs that challenge the present order (Unruh, 2000).

3.9 Transition management and business model theory

The way in which experiments are set up, with the aim of influencing their speed and direction, is increasingly influenced by the understanding of the dynamics of transitions (Loorbach and Rotmans, 2010). Experiments in the early phase are usually undertaken by governments, according to Loorbach and Wijsman (2013). However, this is about to change as businesses are starting to explore the transformative force of their markets (ibid.).

A BM may have a more-or-less regime-friendly end-result. New BMs can take the role of experiments at the niche level. Bidmon and Knab (2014) suggest that it is easier to commercialize a new product or solution if it lies close to the current regime. However, such a product or solution would likely not induce any structural changes. Unsustainability and instability at the regime level could be taken as business opportunities with a transforming potential (Loorbach and Wijsman, 2013). As the systemic BM gains increased focus, this indicates a belief in systemic approaches as a way to anticipate and possibly guide transition (ibid.).

Taking on the role of a niche actor, businesses and their BMs could be termed “key loci of focus” to characterize the interactions within and between the levels in a transition (Wainstein and Bumpus, 2016). Landscape pressure and regime tensions have been found to translate down to the business model niche (Bidmon and Knab, 2014). Furthermore, according to Smith (2007), niches have been found to have direct interaction with the landscape pressures, also without meddling at the regime level.

As illustrated by Loorbach and Rotmans (2010), there is an unexpected diversity of transition management practices. These include regional, sector specific, international and industry- and business-specific practices. Business can contribute to the establishment of a shared vision by demonstrating the feasibility of certain solutions (ibid.).

[The carbon lock-in literature] exposes the central role that the private sector has in sustaining the current energy regime. In fact, its resilient trajectory can be interpreted as a lock-in at the BM level. (Wainstein and Bumpus (2016) p. 574.)

By failing to develop innovative BMs, the current equilibrium will be continued and the status quo prevails. The co-evolutionary relationship between the wider sociotechnical system and the business model could be pictured as in Figure 10.

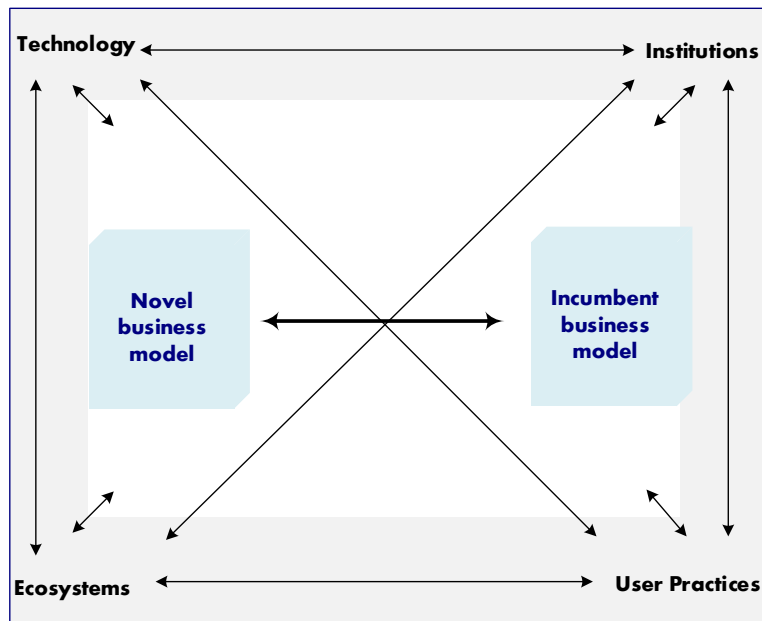


Figure 10: Co-evolutionary relationship between business models and the wider sociotechnical system (Hannon et al., 2013) p. 1034

Hannon et al. (2013) have centralized the business dimension and split this into novel and incumbent BMs. The situation on the middle of a sociotechnical system enables us to understand how and why BMs are co-evolving with their wider environment.

3.10 What about power and governance?

An important and often-recurring discussion is how power and politics materialize in innovation development and implementation. In this thesis, power and politics are a pervasive, though underlying, theme. It lies in the funding of research, in the uptake and spread of research results and in particular, it lies in the choice of energy sources and in how far and in what ways the building sector should play a role in climate change mitigation.

Power

Sustainable transition is associated with a transformation of the regime and a particular power struggle between the current regime, upcoming niches and landscape pressures (Avelino and Rotmans, 2009). There are many forms of power, but according to Avelino (ibid.), a general definition is that power is the ability to mobilize resources.

Power is a relational concept that is as important as it is vague. By articulating relations between policymakers and incumbents at the regime level, power and politics are introduced (Geels, 2014). Power is vital for the analyses and is key to gaining an understanding of the actions that are taken. The regime possesses power over the challengers that are developed in niches. As the regime destabilizes, the power relations change. Niches need to be empowered to stand a better chance when facing the regime. Empowering involves processes that make a niche competitive, either within the current regime or as a challenger to the regime (Smith and Raven, 2012, Raven et al., 2016).

Agency lies at the heart of policy ambitions and agency and power are intimately related (Smith et al., 2005). According to Dahl (1957) in Smiths et al. (2005), “power is the ability to get others (through force or persuasion) to do something they might not otherwise have done” p.1503. Power facilitates agency.

Regime resistance is typical when faced with the prospect of comprehensive change. In a normal situation (stability), the regime is strong and hard to change. Change or transformation can be induced in different ways, for example by increased pressure from the landscape, which destabilizes the regime and thereby creates a window of opportunity for niches. Another example is that change can be brought by countervailing power.

The incumbent organizations will mobilize political resources to block an effort to change the regulatory and industrial policy environment to scale up the challenger. Blocking strategies may be quite successful at keeping niches from scaling up, [...] Often when the support of a countervailing power is mobilized, the incumbent industry will shift strategy from marginalization and blockage to incorporation and transformation. (Hess, 2013) p. 849.

For a sustainable transition to take place, the transformation of the regime is necessary. In a stable situation, the regime is the constellation with the most power and hence antagonism and resistance towards challenge is expected (Hess, 2016, Geels, 2014). This power inequality changes as the regime destabilizes. According to Avelino and Rotmans: “During the phase of instability, the societal system is ‘losing systemic power’ because actors fail to apply the appropriate mix of power to mobilize the necessary resources for the survival of a system.” (Avelino and Rotmans, 2009) p. 560. The most important “power presumption” of transition theory concerns the relationship between the niche and the regime (ibid.). Here it is assumed that the stable regime destabilizes either due to landscape pressures and/or the challenge of innovations developed in niches and approaching the regime. The regime could react by absorbing the niche, and seek a synergetic relationship. If the regime succeeds in absorbing the niche, a “lock-in” occurs (Avelino and Rotmans, 2009). A lock-in is a reverse transition path (Rotmans, 2005) meaning the situation is locked at the present regime. According to Rotmans the only way to clear a lock-in situation is by applying force from outside the system.

Governance

Governance towards a sustainable transition is a massive political challenge. This is for instance illustrated by Meadowcroft (2009) who points at the funding of the carbon capture and storage (CCS) technology in the Netherlands. While there is public support and funding for R&D, the position has been that real-world deployment should be undertaken by commercial actors. However, since the technology remains uncertain and the EU emissions trading system (EU ETS) is not giving sufficient investment incentives, commercial application does not happen. The technology is likely to be delayed without government support, which would leave less funding for other energy pathways (ibid.). This case is expected to be applicable to many technologies and countries. Rotmans et al. (2001) agree with this conception of political challenges: (2001) p. 30 “....no single actor can steer the transition to an innovative, low-emission energy supply. All social actors look to the government to take the lead.” Moreover, Meadowcroft reminds us that a selection environment is made and remade by the interventions of many actors, including government (Meadowcroft, 2009). Furthermore, it should not be surprising, according to Meadowcroft (ibid.) that reflexivity has been in short supply. He asks rhetorically: “When have policy directions [...] entirely escaped the orbit of economic and political power?” p. 336.

The cross-sectoral approach of issues in the interface between the building and the power sector gives way to even more issues of power and politics. An example is a conflict described by Späth and Rohrer (2015) that emerged because of the commissioning of a policy to reduce the environmental impact of space heating, involving two strategies rooted in different sectors: A) efficient cogeneration of combined heat and power (CHP) and district heating; as well as B) applying a low-energy design to reduce space heating in the city of Freiburg. This can be taken as an example of the increased difficulty of management when more than one sector is involved. Often, as also in this case, the power distribution between the sectors is skewed and sunk costs and vested interests are guiding the decisions. The typical focus on a single sub-regime gives a rather one-dimensional picture, since context and interaction with other sub-regimes are downplayed (Raven and Verbong, 2009) (Smith et al., 2010). Whether incumbents actively oppose fundamental change is discussed by researchers such as Geels and Hess (e.g. (Geels, 2014, Hess, 2014, Hess, 2013)) and will be further elaborated upon in Section 5.

3.11 Strengths and weaknesses of the main theories

Transition theory has developed and become popular over the last few decades. With popularity, comes criticism. This criticism is negotiated in an open process and improvements are made along the way.

Sustainable transition is associated with a transformation of the regime and a particular power struggle between the current regime, upcoming niches and landscape pressures (Avelino and Rotmans, 2009). However, these assumptions are not made explicit in theories; in particular, the multilevel perspective and transition management have been criticized for ignoring the aspect of power. This, and other criticisms towards transition theory, are elaborated in this section which concludes with a reflection on the relevance of this critique to this thesis.

The multilevel perspective

MLP provides a relatively straightforward way of organizing and simplifying the analysis of complex, large-scale structural transformation demanded by sustainable development (Smith et al., 2010). As the main transition framework, MLP also attracts the main criticisms. The abstract parsimony of MLP carries some potential pitfalls which are examined in this section. I elaborate on lack of agency, operationalization deficiencies as well as some other prominent critiques and also provide the defence brought forward by the proponents.

Lack of agency

Criticism of MLP has been brought forward by researchers such as (Smith et al., 2005, Genus and Coles, 2008) who argue that MLP should pay more attention to agency and should be integrated more with constructivist theories such as SCOT and ANT. Smith et al. (2005) argue that the MLP tends to be too descriptive and structural, leaving room for greater analysis of agency as a means to more informed, deliberate and effective processes of regime transformation.

The proponents of MLP on the other side argue that the MLP framework is “shot through with agency” (Geels, 2011) p. 29, and furthermore that MLP “accommodates agency in the form of bounded rationality (routines, search activities, trial-and-error learning) and interpretive learning.” Ibid. p. 30. Geels argues that there are different types of agency, and admits that some types of agency are less developed in the MLP framework, such as rational choice and power struggles. Therefore, one way to bring agency into the framework is to introduce power and conflict by

discussing the incumbents and their relation to the political level and adjacent regimes (Geels, 2014). Power and agency are related because, like agency, power *does something*. By articulating relations between policymakers and incumbents at the regime level, power and politics are introduced (Geels, 2014). Agency, is typically seen as confined to the niche level. Therefore, a crossover between MLP and TIS is argued to bring more analytical power to the analysis since MLP has its strength mainly at the meso-level whereas TIS is more engaged with the micro-level, albeit focussing on structures and functions (Markard and Truffer, 2008).

Operationalization deficiencies

Another prominent critique is how to operationalize, identify and separate structural elements – in particular at the regime level. This makes it unclear how to apply the framework empirically (Berkhout et al., 2004, Genus and Coles, 2008). Åm takes up this point in her article on solar scientists (Åm, 2015). An alternative framework is suggested, “the arenas of development” which was previously also suggested by Jørgensen (2012), and a common feature among the two theoretical approaches is identified, that of “translation”. Åm concludes that it is difficult to distinguish between the theoretical concepts of landscape and regime with empirical data. Furthermore, actors cannot analytically be attached to levels.

According to Geels (2011), empirical analyses often use “regime” when they should have used “system”. There is an analytical difference between regime and system, which is more precisely distinguished in theoretical papers (Geels, 2004a, Geels and Schot, 2007). Geels (2011) defines system as referring to tangible and measurable elements whereas regime refers to intangible and underlying deep structure (2011). Geels and Schot (2007) argue that the object of analyses can be seen as nested levels but that such empirical levels are not the same as the analytical levels of MLP. This is further complicated as operationalization can be done in different ways.

Other prominent critiques

Shove and Walker (2007) argue in favour of more model diversity and caution against a sole focus on MLP. In Geels’ article on different ontologies and MLP (Geels, 2010), he emphasizes the difficulty of synthesizing several ontologies. Since different theories and frameworks are built on different ontologies, some of the differences are insurmountable. It is useful to understand on which ontologies a theory is built in order to understand and adequately criticize it. Every theoretical choice means leaving other angles out. That is why Shove and Walker call for a diversity of theories. No single theory alone will give the whole picture. However, in terms of *usefulness* in the sense of giving answers or direction to, for example policymakers, it is valuable to enable comparison and this is easier if some sort of cohesion of analysis is sought after.

Many researchers have called for a broader focus on regime dynamics rather than the most common unilateral focus on niches in MLP (Geels, 2014, Smith et al., 2005). Geels, who takes a central position in cultivating the MLP framework, has suggested an extension of the current framework by:

- 1) seriously studying regime dynamics, rather than focussing only on green niche innovations;
- 2) conceptualizing existing regime actors as actively resisting fundamental change, rather than being locked-in or inert; and
- 3) introducing power and politics into MLP, both in a general sense, by articulating relations between incumbent firms and policymakers at the regime level, and in a specific sense, by distinguishing (...) ways in which regime actors can mobilize power to resist fundamental change. (Geels, 2014) p. 35–36.

At the end of this section, as well as in Section 5, I argue that this thesis has included these suggestions by Geels.

Strategic niche management (SNM)

SNM refers to the process of managing niche formation processes through real-life experiments. Processes of co-evolution can be stimulated through experiments with innovations and new sociotechnical arrangements (Hoogma et al., 2002). Hoogma et al. realize that the initial belief in the power of experiments was probably too high. The study concludes that the transformative power of experiments is small unless they are linked to long-term strategies for structural change involving policymakers. SNM should therefore be expanded to include diffusion policies and policies for exploring structural change through system innovation (ibid.). Niche innovations struggle to bring about regime transformations without broader forces and processes (Schot and Geels, 2008). MLP has improved the contextualization of SNM with its typical inward-oriented focus on niche processes. Because of this focus, SNM has primarily been criticized for its bottom-up, niche-driven bias, placing too much weight on the role of niches and niche-driven transitions (Geels and Schot, 2007). Furthermore, there is still work to be done to advance and expand the significance of SNM. Smith and Raven argue that niches, as protective spaces, are insufficiently conceptualized (Smith and Raven, 2012). Also, Schot and Geels (2008) suggest that niche external processes, such as the role of visions in the process of niche formations, links SNM closer to TM.

Transition management (TM)

One article that brought criticism towards TM is “CAUTION! Transitions ahead” by Shove and Walker (2007). In this article, the authors are interrogating the transition management branch of the transition theories and ask questions such as: Who are managing a transition, on what authority and on whose behalf? What are the everyday politics of transition management? Who wins and loses as transitions are managed? (ibid.) Their main point is that simplification and accompanying concepts and tools may obscure political goals by smoothing over conflicts and inequalities, working with tacit assumptions of consensus and expecting far more than participatory processes can ever hope to achieve (Shove and Walker, 2007).

Rotmans and Kemp (2008) suspect that Shove and Walker are interpreting transition management theory as social engineering theory, while it was originally a response to more deterministic, blueprint-based steering methods used in recent decades. They argue that transition management is a governance model for interactions between market, state and society and not a “megalomaniac attempt to remake society” (ibid. p. 1010).

It could be that the SNM and the TM approaches are complementary (Loorbach and van Raak, 2006). Where TM has its strengths in participatory processes, social learning and agenda building, SNM has its strength in development of specific innovation pathways, technological learning and how to organize such a process (ibid.).

Technological innovation system (TIS)

The TIS approach has also been criticized for its shortcomings, in particular for its lack of regard to context (Markard et al., 2015). Markard and Truffer argue that it is “inward oriented and does not pay much attention to the system’s environment.” (2008) p. 610. This critique has been used by some to rule out TIS as a useful framework with which to analyse sociotechnical transitions. Amendments to the framework have been proposed in response to this critique, such as in Bergek et al. (2015). Others

argue that the functional approach is an explicit approach to take context factors into account (Markard et al., 2015). To address some of this criticism, attempts have been made to merge the MLP and the TIS frameworks (Weber and Rohracher, 2012, Markard and Truffer, 2008). This is a crossover that is feasible since the two frameworks share ontology; MLP is developed from evolutionary economics and constructivism, while TIS is built on evolutionary economics and functionalism.

Delineation of TIS has attracted attention. It is important how TIS is delineated in breadth (narrow or broad technological field), what to analyse and also the relations between structure within and outside of TIS. In the process of delineation, contextual elements are likely to be left out (Markard et al., 2015). The boundary-drawing is not a one-time choice but an iterative process going back-and-forth, adjusting as boundaries are moving. The explanatory value has so far been limited to static situations or emerging TIS (ibid.). The TIS framework has, as has the MLP framework, been accused of not paying sufficient attention to the political dimension, while the response to this criticism is that this is included in the structural analysis. In line with Markard et al. (2015) I ask as the last point, what the limits for policy recommendations are? The ability to give policy recommendations is one of the primary motivations behind TIS analyses; however, these recommendations tend to be in favour of the technology in focus (Bening et al., 2015). There is a call for TIS scholars to provide better justification for their policy recommendations in future research; however, Markard et al. (2015) argue that how TIS scholars (ab)use the framework is not to be blamed on the framework itself. Nevertheless, a clear normative statement should be made when there is engagement in favour of a specific technology (ibid.).

Frameworks applied in this thesis and the response to the critiques

All theories and frameworks have strengths and weaknesses, opportunities and limitations. It is important to be aware of these, and to compensate where possible. In this thesis, a range of methods and approaches have been applied rather than relying on a single comprehensive method. This diversification is done in an effort to find the best approach to each research question. The critiques of the frameworks used in this thesis have been handled in the following ways.

- As a response to the critique of an overly unilateral focus of niches, I have been more focussed on the dynamics of sociotechnical transitions and their various boundary-crossing affordances both within niches and between different regimes.
- Existing regime actors have been conceptualized as actively resisting new cross-boundary collaborations, rather than locked-in and inert.
- Power, politics and governance have been elaborated upon both by expressing the relations between the incumbent firms and policymakers, and illustrating how regime actors can mobilize to resist fundamental change.

These measures are in line with Geels' suggestions for improvement and contribution to further the sociotechnical transition (Geels, 2014).

4. Presentation of relevant previous research

The main objects of transition studies have been sociotechnical systems such as the energy system, infrastructure, water supply and sanitation, transportation, food production and waste management (Markard et al., 2012). Buildings are the locus of practices where the outcome of many systems, such as food and energy, meet. Perhaps this can help to explain why even innovations in the interface between the power and the building sector have little extant research in the field of transition studies. As was mentioned in the introduction, changes in building design, construction and use have been supported by research whereas development and implementation of innovations are less researched. There is, however, some work of relevance, a selection of which is presented and discussed in this section. From the Norwegian setting, the known works on transition studies relating to the building sector are included, along with work that analyses building-energy policy and interaction. From other contexts, I have selected literature on how to bring about structural change, in particular when crossing the boundaries of several regimes. Obviously, empirical studies of the building sector and the power sector have been preferred. Since the literature related to energy systems is so abundant, it is unlikely that I have a complete overview. However, the selected studies have revealed gaps and new developments for research, which will be elaborated further in this section.

There is a broad range of theoretical approaches that have been used to study and explain transitions. These include general theories such as evolutionary economics (Nelson and Winter, 1982) and the actor–network theory (Latour, 1996), as well as approaches with a more specific focus on technology, like the social construction of technology (Bijker et al., 2012) and reflexive governance, among others (Markard et al., 2012). Some of the frameworks claim to combine two or more ontologies, and some researchers urge for cross-disciplinary approaches (Geels, 2010, Weber and Rohracher, 2012). The sustainable transitions framework was established as a research area as well being integrated into practical politics during the 1990s. Its academic development started primarily in the Netherlands and the UK and it has also gained ground in Sweden. In Norway, interest has started to grow more recently (Nykamp, 2016). In this section, I present and discuss selected contributions of particular relevance to this thesis.

4.1 The Norwegian building and power sectors

To ease the understanding of the Norwegian context, a description of the structures and conditions of the building and the power sectors is necessary.

The Norwegian building sector is large, fragmented and complex (Ministry of Local Government and Modernisation, 2012). There are nearly four million buildings in Norway and the building area is distributed as depicted in Figure 11:

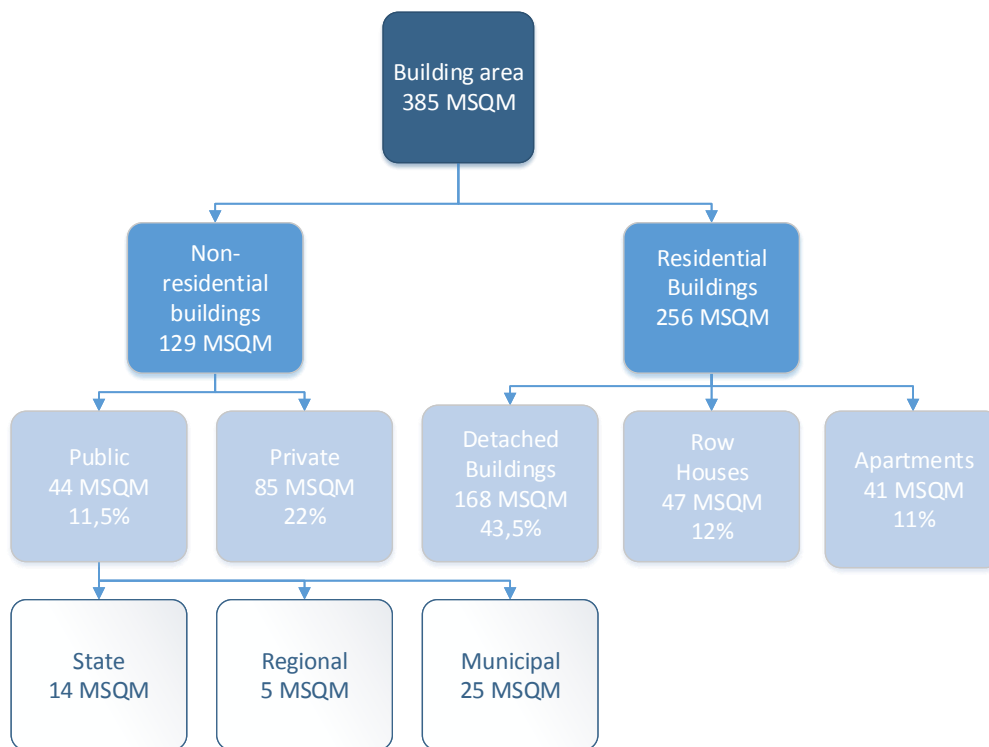


Figure 11: Building area for residential and non-residential buildings (Ministry of Local Government and Modernisation, 2012)

The building and construction sector comprises the construction and maintenance of domestic and non-domestic buildings as well as the development of roads, airports and facilities related to railways, tramlines, defence and energy (The Federation of Norwegian Construction Industries, 2017). Seen together with construction, it is the largest on-shore business in Norway in terms of turnover (preliminary numbers for 2016 are 522 MRD in total, 270 MRD of which relate only to construction and maintenance of buildings). In terms of number of companies, it is the largest business overall⁶ with 57 231 companies in 2016 (24 329 companies in building construction) (Statistics Norway, 2017a).

The Norwegian power sector also consists of a large number of actors, though not nearly as many as the building sector. The sector is organized around the activities of production, transmission and sales. Hence, there are three groups of actors: the power producers, the grid owners and the power suppliers. There are around 180 power producers, of which the largest is Statkraft, who produce about half of the electricity in Norway (Ministry of Petroleum and Energy, 2015). Some of the power producers are also grid owners and licenced suppliers. All producers, grid owners and suppliers of electricity need a licence from the Norwegian Water Resources and Energy Directorate (NVE). The roles are partly overlapping, which could be depicted by Figure 12.

⁶ http://www.bnl.no/globalassets/dokumenter/rapporter/bnlfaktabrosjyre_web_spreads.pdf Accessed January 23 2018

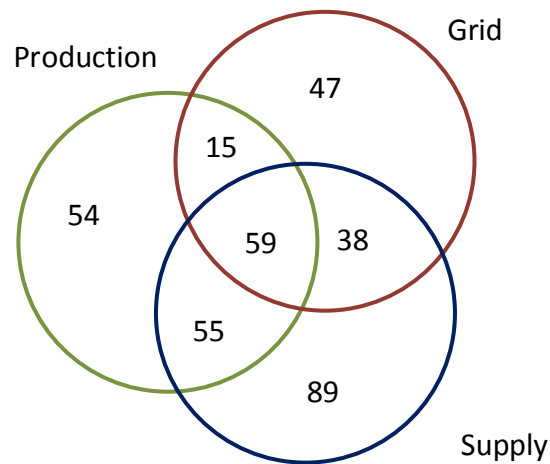


Figure 12: Number of licenced actors in the power sector sorted by (overlapping) activities Source: *ibid.*

Around 90 percent of all hydropower production is publicly owned. The combination of public ownership and a variety of actors is distinctive to the Norwegian power sector (Ministry of Petroleum and Energy, 2015). The production of electric power was 149 TWh in 2016 of which 96.3 percent was hydropower. It was exported 22.1 TWh and imported 5.7 TWh (Statistics Norway, 2017b). These figures vary over the years, mainly due to temperature and precipitation. The annual profit of all enterprises in the power industry was 16 billion NOK in 2016.

The Norwegian electricity market was deregulated in 1991, and subsequently formed an integrated power market together with Sweden, Finland and Denmark – the first integrated, intercountry power market in the world (Bye and Hope, 2005). Even if the electricity market reform has worked well, little has happened since 2002 and it is a common perception that the sector faces structural changes in the years to come. This is also described in a report from the Ministry of Petroleum and Energy (2014). According to the report, the number of actors in the power sector is too large and many are too small in order to achieve a coordinated, efficient and reliable power supply. The introduction of new requirements, for instance the requirement to supply Advanced Measurement Systems (AMS) to all customers in 2019, is particularly challenging for the smaller actors.

Energy and buildings

When it comes to energy demand, the building stock in Norway represents 40 percent of the final energy requirements, which is comparable to several EU countries (Sartori et al., 2009). The industry is dominated by small and medium-sized enterprises that cooperate on the design and construction of buildings. However, Ryghaug and Sørensen (2009) argue that energy-efficient construction is seriously constrained by three interrelated problems:

- 1) Deficiencies in public policy to stimulate energy-efficiency;
- 2) Limited governmental efforts to regulate the building industry; and
- 3) A conservative building industry.

According to Ryghaug and Sørensen, these problems could have been solved if Norwegian policy effectively imposed *translation* of energy-efficiency policy into building industry actions. However, it

has failed to do so, which "... constitute a set of barriers to innovation and implementation of new technologies. However, ..., the challenges are strategic rather than structural." p 989. Even if the industry is dominated by conservative actors with a low R&D rate, the structure is not the core barrier to energy-efficient construction. This observation by Ryghaug and Sørensen is in line with findings presented later in this thesis.

An important step in the development of energy-efficient and power-producing buildings in Norway has been the establishment of the Norwegian Research Centre on Zero Emission Buildings (ZEB) in 2009. The main objective of ZEB has been "... to develop competitive products and solutions for existing and new buildings that will lead to market penetration of buildings that have zero emissions of greenhouse gases related to their production, operation and demolition."⁷ Market penetration must be understood as more than just a few pilot projects. With reference to the diffusion curve by Rogers, this would probably imply a position along the curve from the innovators to the early adopters, which means from 2.5 percent to 13.5 percent market share. As of now, at the end of the project period of ZEB, this objective must be interpreted as a long-term goal. It has been prepared for by developing solid definitions of what a zero-emission building is, as well as demonstrating the practicality of the concept through pilot projects that are thoroughly documented. In many ways, the development of zero-emission building concepts has built upon the success of the passive house concept, and not only by adapting the design principles. The research centre has among its partners an internationally recognized architect company, Snøhetta, to ensure the high architectural quality of the pilot projects. It places importance on standardization and the development of tools as well as establishing a community of like-minded professionals. However, compared to the passive house concept, a number of differences are still evident that can also function as barriers: the zero-emission concept is much more complex than the passive house concept. Even if definitions are established, these are not institutionalized in, for example, a standard and hence trust is put on hold. Even if powerful commercial actors are backing the concept, there are fundamental unsolved issues, such as the local production of renewable energy to "offset" the emissions that are left when all processes have been trimmed towards the goal of zero emissions. To be able to calculate this, ZEB has defined a CO₂ factor of electricity. In Norway, all CO₂ factors on electricity larger than zero are contested and so far, no consensus has been reached at the policy level.

Energy-related building policy in Norway is affected by the perception that electricity represents zero or low emissions since the power system mainly consists of hydropower. It is hard to picture that electrons flow freely across national borders and in addition, in years of draught and low temperatures, the imported electricity is partly based on coal and Norwegian hydropower may be exported to substitute for fossil power. Policymakers are reluctant to increase export capacity due to fear of price increases. This would, for instance, harm energy-intensive industries, who argue that they might be forced to move production elsewhere. Also, the functioning of the EU Emissions Trading System (EU ETS) is further complicating this picture. The power sector is included in the EU ETS, whereas the building sector is not. The system works as such: all power producers have an emissions allowance. If they produce less than is estimated (due to less demand, for example) then they can sell their emissions allowances to another producer who needs to produce more. Hence, emissions are fixed and only measures taken outside the sectors included would have genuine potential to reduce emissions further. This argument is sometimes abused to argue for doing nothing in the sectors

⁷ <http://www.zeb.no/index.php/en/about-zeb/about-the-zeb-centre> Accessed May 9 2017

included in EU ETS. It is not evident why Norway should need a decentralized energy production system and arguments of the need for a greener or more renewable energy system are poorly understood.

Except for the building code, there are no requirements for energy-efficiency and energy production, nor are there strategies to help settle the peak load challenge. There are, so far, no restrictions regarding CO₂ emissions from materials or construction processes. A recent report on emissions from Norwegian construction sites constitutes a step towards increased awareness.⁸

4.2 Sustainable transitions and the building sector

A search for transition analysis of the building sector offers few results. This is even more surprising since the buildings sector is usually seen as having a large potential, not only through the practices which take place in buildings, but also as change actors. Rohracher (2001) makes the point that only a fraction of the challenge of making the building stock more sustainable is technical in nature. The necessary technical changes can only be brought about by introducing the technical potential in its social context. It is about construction of technologies, which is an interactive effort and illustrates the inseparability of the technical and the social. What is needed is to interactively integrate more actors in policy design and implementation (ibid.). Sørensen (2016) stresses the point that an innovation is an equivocal good. It is not necessarily sustainable, and some innovations are even potentially harmful. To become part of society, the innovation needs to be socialized or domesticated. If an innovation is not domesticated, then it cannot be useful (Sørensen, 2015). Rohracher relates sustainability in the building environment not only to products and processes such as construction or energy use, but also to the way we relate to them and the consequences they have on our lives (Rohracher, 2001). The complexity is addressed through assessment procedures for the sustainability of buildings, for example by the BREEAM label, which has been translated to Norwegian conditions by BREEAM NOR. The greening of the building sector adds challenge to an already complex situation and Rohracher argues that much more challenging than the search for enhanced technical solutions is “the social embedding and the social interactive process of designing, constructing and using buildings.” (Rohracher, 2001) p. 139. Rohracher’s article discusses three means by which sociotechnical analysis could contribute to a sustainable transition: by the support of the restructuring of the sociotechnical system on the organizational and institutional level; by increasing transparency and reflexivity in the sustainability discourse; and through the broadening of design processes by the inclusion of more actors who were not previously involved. Also, according to evolutionary economics (Freeman, 1994), the success of an innovation depends on the interaction with users.

O’Neill and Gibbs have produced research on the green building sector and sociotechnical transitions in the UK (O’Neill and Gibbs, 2014). They found that green entrepreneurial activity will be increasingly important to future market success. There is no contradiction between economic development and environmentalism. However, they argue, focussing on the lone entrepreneur as a driver of sociotechnical transition is a flawed approach. Wider recognition of contextual factors, relations and networks should be internalized; this is intrinsic in some transition theories, such as MLP. Focussing on

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https://www.energinorge.no/contentassets/353232a3baee42649fedec71bf9eae28/utslippsfrie_byggeplasser_dnvgl_juni_2017.pdf Accessed June 23 2017

the wider networks, including the social and the political, is likely to illuminate areas of improvement that are crucial to enable a sustainable transition (ibid.).

In an article by Berry et al (2013) a zero-emission home project in Australia is studied. Here, it is found that a (government-induced) niche responding to landscape pressure could contribute to the transition of a whole industry. In Lochiel Park Green Village, environmental goals were set regarding the reduction of energy use, greenhouse gas emissions and potable water use. Barriers were found at many levels, in particular attached to incumbents who resisted change. However, the experience of creating the niche sustainable housing estate caused a number of individuals and organizations to interact with new performance standards, construction techniques and technologies. These interactions set off small changes to industry practices, government policies and housing products available. The article concludes that the single niche event clearly has had an impact, but that to experience structural change, multiple niche events, with associated dissemination of learning, may be necessary.

In a PhD thesis by Gazis (2015), the multisector case of building-integrated photovoltaics (BIPV) is analysed. He found that the two sectors involved (the PV industry and the construction industry) have distinct supply chains and stakeholders with different knowledge bases, metrics, priorities and visions for the future, juxtaposed within the innovative product, BIPV. More importantly though, he observes that "... they are associated with either of the two fundamental functions of the innovation system, which are the development and diffusion of technology, causing a characteristic disjuncture along the innovation process". (Gazis, 2015) p. 290. The BIPV sector is closely related to the PV industry, which has contributed to a focus on incremental innovation, despite BIPV being disruptive applications that challenge both the configuration of the centralized power grid as well as established practices within the construction sector. Furthermore, Gazis adds that the construction sector is more interested in the societal embedding of BIPV innovation than in the technological learning, in which the PV industry is particularly interested.

In a Norwegian setting, building-energy policy originally was about energy-efficiency measures rather than energy production. A report by the Fridtjof Nansen Institute (FNI) (Boasson, 2009) identifies a massive growth in measures directed towards energy use in buildings after the year 2000. However, these measures are both inconsistent and badly coordinated and the report aims to explain why.

First, the report points at lack of political steering: "There is nothing that suggest any political steering behind the development of support schemes from the Housing Bank."⁹ (ibid. p 14). The report claims that the development of policy measures has been handled by the experts rather than by business or the politicians.

Second, the directives from the EU were interpreted by the recipients, who adapted them to a traditional Norwegian approach with the main focus on the building envelope instead of small-scale renewable energy production, which was more the focus in Europe. Formally, the recipient of EU-policy has been the Ministry of Petroleum and Energy, which consistently works to minimize the societal costs of all measures to reduce (or produce) energy. According to Boasson, this ministry has little concern for creating markets for environmental goods or other improvements, for instance in

⁹ The quote is translated from Norwegian by the author.

building processes. However, the building code has been developed by the Ministry of Local Government and Modernization, which is not marked by the same socioeconomic tradition.

Third, structural conditions within the building industry have led to little political influence. The industry is characterized by many small actors and few large, dominating companies. The industry's trade unions have relatively scarce resources. This has led to increased focus on short-term goals instead of addressing long-term conditions. These points have resulted in a powerful civil service with large influence over policy development. Therefore, it becomes crucial which part of the civil service is responsible for which part of the policy development. The division between the responsible ministries and its civil service has not been problematized in the period. Hence, the report concludes that it is evident that the outcome of the policy-measure development process would have been different if the division of responsibility was different, too.

In the same vein as the FNI report, the aforementioned article by Ryghaug and Sørensen (2009) explores the failure of energy-efficiency in the building industry. The article unveils that energy-efficiency issues are framed by economic features rather than features of energy conservation. This emphasis on energy economizing, called ENØK, put "Energy-efficiency in the iron cage of economics" p 985. According to Ryghaug and Sørensen, the ENØK policy was left to translate itself into practice, but failed to do so due to a range of reasons such as contracting arrangements (in particular owner–tenant problems) and low energy prices. Furthermore, the article points at the building code as an ineffective incentive to reduce energy consumption. Even if the code was meant as a minimum requirement, it was often taken as a maximum. The article also points at a low level of investment in R&D and innovation in the building industry, due to the industry not being particularly concerned with innovation. Re-use of solutions, time pressure in design processes and apparently unalterable practices concerning contract regimes are said to have caused this.

Compared and contrasted with today's situation, the FNI report and the article by Ryghaug and Sørensen illustrate a seemingly massive leap that has been undertaken over less than a decade. The reputation as a conservative industry is challenged by forward-leaning actors, some of which take seats as partners in research centres like ZEB. The German passive house standard has affected the development of energy-efficient buildings in Norway with the introduction of a Norwegian passive house standard for both residential (2010) and non-residential buildings (2011). However, the adoption of the standard in the Norwegian context has been characterized by controversies, particularly related to health issues associated with living in passive houses and competencies of the construction workers (Müller, 2014). The controversies can be seen as closed when a version of the standard becomes part of the national building code. Building codes have vastly improved and are now thought to be one of the drivers of energy-efficiency measures in new buildings. Controversies around building practices have also been seen in the UK, where the passive house standard is seen as *one* solution, rather than *the* solution. Other green building practices exists, as noted by O'Neill and Gibbs (2014). EU directives, like the EPBD and the RED, have contributed to a push on policy actors to actually implement energy-efficiency measures in the building sector.

In a more recent report by SINTEF Energy (Knudsen and Dalen, 2014) an emerging societal interest for energy-efficiency is identified. The report specifically elaborates the interaction between buildings and the energy system. Ownership and management of energy infrastructure are identified as important economic barriers. There are developments, like regulation of third-party access to the district heating

grid, as well as the plus customer (or 'prosumers') regulation, that can be seen as a first step towards a more interactive energy system. However, the costs and benefits in a Norwegian context are not clarified. The need for increased cooperation and coordination between different policy sectors, not least between the building and energy sectors, is underlined. Municipalities that are hosting innovative pilot projects and the innovative approach by the building industry are identified as important drivers that could have joint impact on the further development of a Norwegian policy framework. This, the report continues, could be an important addition to the initiative stemming from the EU legislation. According to the report, there are few policy analyses assessing these issues in a Norwegian context.

In a rare example of transition analysis addressing the Norwegian building industry, Ørstavik (2014) applies a crossover approach using MLP and TIS to study building materials for wet rooms. He concludes that the frameworks are complementary tools for analysis of innovation in construction. TIS analysis penetrates into the innovation process on the level of functions in a way that cannot be matched by MLP. On the other hand, only MLP theory integrates an institutional perspective into the theory (ibid.). In this article, Ørstavik shows how the implementation of an innovation is resisted by powerful actors, and how the Norwegian Building Institute (NBI) worked as a broker. Furthermore, he finds that disruptive innovation is a mechanism of institutionalization and that finally the innovation broker contributed to increased trust among actors involved. However, the brokering potential could be expanded if NBI could also contribute to decreasing the perceived risk of the technology shift (ibid.).

Nykamp (2016) undertakes a broad analysis of the transition to sustainability in the Norwegian construction sector. As green buildings have shifted from a niche activity to more mainstream appeal, they are also of increasing strategic importance to firms in the construction sector. She concludes that multilevel interaction processes constitute a transition pathway for the regime that is influenced both by niche developments and landscape pressure.

4.3 Other relevant research

The main focus of transition studies is sociotechnical systems such as the energy system, infrastructure, transportation, food production and waste management. This thesis concerns both the building and energy sectors. Contrary to the relatively few cases concerned with the analysis of the building and construction sector, there are significant number and variety of transition studies regarding energy. Studies were selected below that address issues related to the challenges of structural change when the energy system is involved. It is no coincidence that among these studies, two are based on cases from the Netherlands and two from the UK. As previously explained, transition theory is particularly well established in these countries.

Even if the Norwegian context is unique in several respects, it is not difficult to find research of relevance to Norway.

Energy transition policy in the Netherlands

In an article on the restructuring of energy systems for sustainability, Kern and Smith (2008) analyse an energy transition project carried out by the Dutch Ministry of Economic Affairs. The authors ask to what extent the approach taken by policymakers opens up a possibility for structural change, and does the experience in this case reveal difficulties for TM overall?

Kern and Smith (2008) regard the TM model as promising and politically acceptable, since it does not disrupt existing policies. However, they remind us that structural change of energy systems is politically difficult. This is also demonstrated in other papers such as Smith (2007), who questions whether niches can become powerful enough to overturn an existing regime given the numerous problems facing radical niches. To summarize the reasons why this particular “energy transition” project failed, Kern and Smith present four main points:

- 1) The need to set long-term goals in TM theory may conflict with the need to measure short-term success;
- 2) TM theory stresses keeping options open to prevent lock-in and backlash from premature option selection. However, since stakeholders suspect that the government is selecting preferred technologies, this causes insecurity. Government is readily criticized for a lack of commitment and consistency;
- 3) When regime incumbents are included in the transition process, the risk is that it will prevent structural change in favour of incremental innovation; and
- 4) What works best, sticks or carrots? In practice, control policies (sticks) are politically challenging. Carrots are politically preferred, but do they provide sufficient pressure?

Kern and Smith (2008) conclude that the energy transition project they researched risks failure due to capture by the incumbent energy regime, which is undermining policy ambitions for structural change of the energy system.

The theme of this article relates to this thesis in several ways. In particular by problematizing the political difficulties related to structural change of energy systems, which is also the case in Norway. Even if there are policy ambitions for structural change, incumbents could undermine these ambitions. This has been explored in Paper 2 and Paper 3 of this thesis.

The development of PV in the UK and the construction of protective spaces

Smith, Kern, Raven and Verhees (2014) explore the development of PV in the UK in recent decades. The authors ask how this can contribute to a better understanding of the dynamics of spaces for PV innovation?

PV is seen as promising from a sustainable development perspective, but these expectations are neither widely shared nor institutionalized in the UK. Some implications arise from an understanding of the dynamics as being “protective spaces” in SNM. The construction of protective spaces was required for the development of PV. “Spaces” is a useful concept, with PV networks being engaged in outward-oriented activities such as the societal interpretation of PV. Narratives constitute and characterize protective space and narrative claims translate into conditional forms of support, which again translates into criteria for more technologically oriented assessments of performance (ibid.). Interpretation of performance and requirements offers feedback through assessments in ways that condition and alter narratives. The authors note how demonstration programmes become political exercises as well as methods of technology assessment. Even this limited focus on the UK points to the widespread process in the construction and contestation of protective spaces. The article concludes that spaces for sustainable innovation are socially constructed and hence politically contested.

The potential for spread of PV production in Norway was at first rationalized away due to an allegedly low potential. But also in Norway, protective space is developed that includes narratives where PV development is framed as attractive, as is highlighted in the second paper of this thesis. Counter

narratives are also comparable; questioning solar incidence and the rationality of decentralized systems in a well-functioning central electricity system.

Regime dynamics

Geels (2014) elaborates on regime resistance and how power and politics relate to the MLP. In this article, Geels identifies various distinctions of power that are used by incumbents to resist regime changes. The identified forms of power and resistance are instrumental, discursive, material and institutional. The article draws on political economy and illustrates and underlines the points with the use of various examples; in particular from the UK electricity system, due to its contribution of 32 percent to UK CO₂ emissions. So far, the coal industry has resisted climate change pressure through a “clean coal” discourse, comparable to the “low-carbon oil” approach from Norwegian Statoil.

The power of firms to influence policies and wider political debates has risen over the last few decades due to a pro-business, neo-liberal discourse, according to Geels. The constellation of firms and policymakers are powerful and the voices of groups such as consumers become comparably weaker. The resistance by the regime actors is also observed by Hess (2013) who argues that this is so important it should be at the centre of the analytical framework.

The author concludes that in order to influence sociotechnical transitions more forcefully, the following actions should be taken:

- 1) Regime dynamics should be studied in depth, instead of the narrow focus on green niche innovations;
- 2) Regime actors should be conceptualized as actively resisting structural change; and
- 3) Power and politics should be integrated into the MLP.

This article is relevant in the Norwegian setting as it points out the dynamics to be expected when a niche is approaching the regime. In addition, it offers a framework to discuss these dynamics. The regime incumbents are found to have close ties to the policymakers as they have mutual interest in maintaining the status quo. The use of power to resist structural change is seen in areas such as public discourse, in policy documents, in networks and institutional inertia to adapt.

Boundary-crossing innovations

Raven and Verbong (2009) investigate how innovation can change the relation between multiple sociotechnical systems. This is done by analysing two Dutch cases: the use of biomass in the waste and electricity regime; and CHP in relation to the natural gas and electricity regime to explore boundary-crossing dynamics.

During the journey of an innovation, some encounter “boundary-crossing dynamics”, where an innovation not only crosses systemic boundaries but it also fundamentally changes the nature of the relations between the systems as it develops. By looking at their empirical material, the authors found that innovations initially develop against the backdrop of a single regime. Furthermore, landscape dynamics create an expectation of application against the backdrop of an additional regime, but institutional problems prevent a rapid diffusion towards the second regime. When rules are changing (or institutions are restructured), diffusion to the second regime may be enabled. The diffusion process induces deep changes to the relations between the regimes involved.

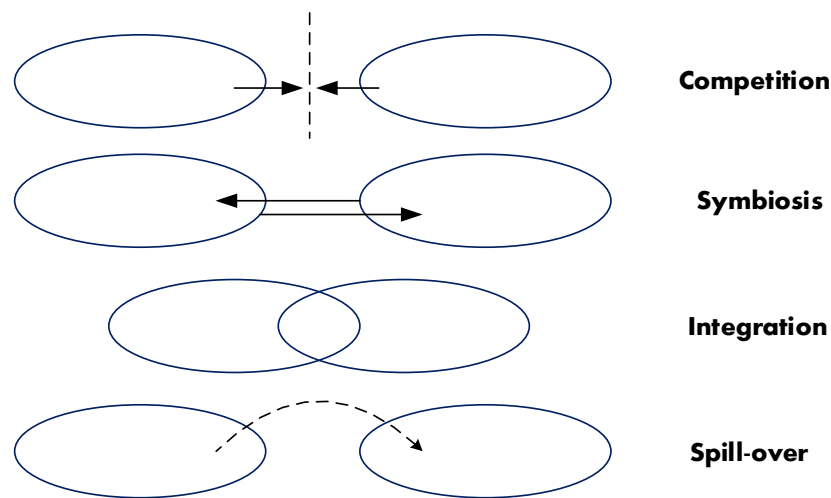


Figure 13: Schematic representation of a typology for multi-regime interactions (Raven and Verbong, 2009) p. 91

The authors conclude that innovation policy should have a focus that is wider than single regimes and which involves different policy arenas: “Indeed, connecting disconnected policy arenas might be the very challenge when it comes to radical innovations that challenge established regime boundaries.” (ibid.) p. 92 and end by calling for further research on border-crossing dynamics.

The article relates to this thesis by pinpointing the challenges – and opportunities – of innovations that relate to more than one regime. At first, multi-regime interaction seems to impose additional barriers to the growth of the innovation. However, if successful in connecting disconnected policy arenas, then this has the potential to lead to even more fundamental innovations. The four types of multi-regime interactions identified by Raven and Verbong are ideal types and the authors acknowledge that more empirical research is needed and that there may be more, and different, types of relations between regimes in transitions. The research reported in this thesis sheds light on phenomena located at the boundaries of multiple regimes, mainly in situations of competition and attempted integration.

4.4 Brief summary

Research on sustainable transitions mainly focuses on sociotechnical systems and the role of niches in bringing about structural change. Since buildings comprise several systems, it has not been the main focus of transitions research. However, buildings are the locus of central processes and are potentially a major contributor to a sustainable transition. If these processes and their systemic contexts are better understood, then they might also be governed and managed.

In the Norwegian context, there has so far been little research on structural change that centres around the building sector. The studies I have reviewed have different perspectives, ranging from elements of the building sector to a broad study concluding that green buildings are becoming of mainstream interest and thereby also strategically important to the industry. From the policy perspective, studies have evaluated the Norwegian building-energy policy and essentially explained why it has not worked. Developments since the early 2010s have led to changes such as a mandatory passive house level of performance in all new buildings and large investments in research on zero-emission buildings. This research is yet to be completed.

In line with the Norwegian studies, the relevant literature from outside Norway has also focussed on barriers. Rohrer (2001), which builds on the case of Austria, argues that the real challenge to the greening of the building sector is the social implications, and not the technical aspects.

Studies of energy and policy-related cases have illustrated that there is a general challenge – incumbents are resisting structural change. In addition, regime interactions that occur when boundary-crossing innovations are developed are shown to offer support as well as challenge to transition processes.

This thesis starts with the observation of a new situation in Norway. After years of energy-efficiency rhetoric without much impact, ambitious energy goals for buildings have entered the mainstream and the next steps towards zero-energy buildings – including renewable energy production on the building – has attracted so much attention and resources that it has begun to challenge the energy regime. By contributing to a better understanding of this new situation, the thesis contributes to the closing of a knowledge gap in the Norwegian research literature. The main gap in the international literature that is addressed in this thesis is related to boundary-crossing collaboration. When collaborating across boundaries, different systems and cultures meet and sometimes collide. There is a huge potential in achieving such collaborative relations, since this could spur structural change. Being able to collaborate between different regimes with different sets of rules, provides a solid basis for change, including the need for and challenge of policy coordination when faced with complex multi-regime governance systems. An analytical approach has been employed to understand how boundaries are bridged, in practice, between the multiple tiers of responsibility and policy areas where different sustainability criteria exist.

5. Cross-cutting analysis

The papers included in this thesis discuss the development and implementation of innovations in the interface between the building and the power sectors, each from a different angle. In this section, research questions that are found in the intersection between the papers are analysed.

A common denominator of this thesis is *collaboration across boundaries* to enable sustainable innovation. These could be the boundaries between different disciplines or between social worlds; it could be challenges of interaction between different regimes, and it could be boundaries between innovative business models and the prevailing business models. Building on the typology developed by Raven and Verbong (2009), interaction across system boundaries can be divided into four (or more) typologies: competition, symbiosis, integration and spill-over. In the following, the typology by Raven and Verbong (2009) is used to complement the suggestions of Geels (2014) in the cross-cutting analysis of the three papers included in this thesis. The three papers are discussed in relation to the developed typology in Section 5.1. Geels (2014) also elaborates on collaboration across boundaries, emphasizing regime dynamics (Geels, 2014, 2009), regime resistance and the incorporation of power and politics when analysing sociotechnical transitions which has been illuminated in Section 5.2. Uncertainty is a natural consequence of different systems colliding, which affects governance as explained in Section 5.3. The analytical categories are cross-boundary collaborations in which regime dynamics and resistance, governance and ambiguity are connected. The papers have revealed that collaboration that crosses boundaries becomes more challenging and often requires something to facilitate this collaboration. This “something” can take different forms but has been termed “bridging device” as elaborated upon in Section 5.4.

5.1 Collaboration across boundaries

According to Fagerberg et al. (2005) there is a larger potential for innovation than usual where (system) boundaries are trespassed. When collaborating across boundaries, friction arises as the different systems or sociotechnical regimes imply a different set of rules, which are embedded in for example technological artefacts and networks. Together, these rules fulfil a societal function including intermediary activities such as market transactions, logistics and policy-making (Akrich, 1992). The stability of the system is due to the alignment of rules, and most innovations are incremental, hence changing the rules gradually, if at all. As explained in Section 3.2, creativity is spurred by heterogeneity. In line with this thinking, the papers included in the thesis illustrate situations where creativity could thrive; they describe environments which are favourable for innovation, making us view the challenges that arise when collaborating across boundaries somewhat differently.

While invention may happen accidentally, innovation does not occur by accident, but rather develops along a set of guiding routines, described by Nelson and Winter as a “technological regime” (Nelson and Winter, 1977, Nelson and Winter, 1982). The selection environment strongly determines what is to be developed, and what is not. According to Raven and Verbong (2009), connecting disconnected policy arenas might be the main challenge when it comes to radical innovations that are approaching the established regime boundaries. If boundary-crossing interaction overcomes the challenges, then new (or significantly changed) rules would be developed. This would change the selection environment and guiding routines and open up the possibility of new and more-radical innovations.

The typology developed by Raven and Verbong is briefly described in Section 4.3. It illustrates four ideal types of cross-boundary interaction. In the following paragraphs, this typology is used to discuss the papers included in this thesis.

The interaction in Paper 1 does not take place on a systemic level; instead, it takes place among actors within the research centre ZEB, which represents a niche seeking to enter the regime. Is the typology applicable also in this case? In the paper, the difficulties of collaboration among different social worlds are elaborated upon. Certainly, different “rules” apply to the different groups set to collaborate, based on different training, occupation and experience. Learning and the transfer of knowledge among the actors involved can be characterized as a *spill-over* interaction. In addition to internal spill-over effects, such as practical insight into business interests and priorities acquired by the academics, external spill-over effects could also be observed. For example, actors from the niche had to acquire new knowledge about energy production (in particular solar power) and CO₂ factors related to different energy sources, in order to be able to achieve the common target of zero emissions. To overcome the differences among the actors involved and to make the interaction work, some facilitator was required, which was described as a set of two interacting boundary objects.

The cross-sectoral innovation represented by power-producing buildings in the second paper has led to a situation that currently bears a resemblance to *competition*. The building regime has taken on tasks that have previously been sorted out by the power regime by producing power on or nearby buildings. The building regime requests access to infrastructure and has gained through changes in the selection environment such as reduced prices on solar panels, with actors being established to serve the growing demand. Competing actors are also being established within the power sector, but such actors seem to hold back, presumably in fear of harming their current business. There is a mutual suspicion that the other sector is taking its decisions primarily based on business interest, instead of contributing to a sustainable development. There also seems to be disagreement about what a sustainable development would imply in terms of power production. To facilitate the expansion of power-producing buildings, it is suggested to develop a narrative that responds to the problem statement of the power sector. When doing this, the type of interaction may evolve in the direction of *symbiosis*, whereby the sectors could become mutually dependent. If the building sector could offer a solution to a primary challenge of the power sector, such as peak load, then this could be the case. Symbiosis would generally result in stronger and more stable ties between regimes (Raven and Verbong, 2007).

The last paper discusses the introduction of three innovative business models that each address challenges in the intersection between the building and the power sectors. By comparing the characteristics of the new business models with the regime, their potential to thrive is assessed. Here, it is the case of new business models challenging more established business models, where the new business models – which have the least-different rules and collaborative relations (compared to the more established ones) – are less likely to be defeated by the use of institutional (political) power. Different typologies can be detected in each of the three cases. In the case of the Energy Performance Contracting (EPC) business model, this business model sits close to the regime, and *integration* is likely. The Leasing of Solar Panels (LSP) business model has features comparable to the discussion in Paper 2; the conclusion is therefore also comparable, as I would argue that the LSP business model could arouse *competition* between the regimes involved. The Aggregator (AGR) business model is aimed at reducing the risk of peak load, which is a critical aspect linked to energy security. By

providing this risk reduction, the Aggregator fulfils a critical function for society. The potential for *symbiosis* is good and perhaps also *integration* on the actor level.

Arguably, the typology is most useful for understanding interaction on the system level. In the case of Paper 1, we follow actors who seek to achieve a common goal. It would be useful to investigate these issues further and expand empirical observation to include both the systemic level and the actor level. Based on the discussion of cross-boundary collaboration in the papers included in this thesis, I would argue that such dynamics do matter when forming an understanding of the transformation of sociotechnical regimes and the emergence of innovations.

The next section explores how regimes react to attempts of transformation.

5.2 Regime dynamics and resistance

In this thesis, it has been illustrated that regime actors resist cross-boundary collaborations, rather focussing on their existing collaborations within the regime. In a stable situation of a sociotechnical regime there are a number of aspects that help to stabilize the structure: interdependencies among actors, vested interests, sunk cost, networks, infrastructure and much more. The existing regime is extremely resilient and will take action to preserve its interests, which are primarily the upholding or strengthening of the current situation. Resistance from incumbents could be understood as a reaction to being exposed to a different set of rules, threatening to transform the present rules in a fundamental way (causing structural change). It illustrates the non-collaborative move of the prevailing regime.

For a sustainable transition to take place, a transformation of the regime is necessary. In a stable situation, the regime is the constellation with the “most power” and hence antagonism and resistance towards change is expected (Hess, 2016, Geels, 2014). This power inequality changes as the regime destabilizes. According to Avelino and Rotmans, “During the phase of instability, the societal system is ‘losing systemic power’ because actors fail to apply the appropriate mix of power to mobilize the necessary resources for the survival of a system” (Avelino and Rotmans, 2009) p. 560. The most important “power presumption” of transition theory concerns the relationship between the niche and the regime (ibid.). The assumption is that the stable regime destabilizes either from landscape pressures and/or the challenge of innovations developed in niches that are now approaching the regime. Regime stability can, according to Geels (2014), be conceptualized as the outcome of active resistance from incumbent actors through material, instrumental, discursive and institutional forms of power and resistance (Geels, 2014). Below, the connection between the niche development phase and the respective protection strategies, types of resistance from the regime and how this materializes, is illustrated.

Development phase	Creation	Maintenance	Phasing out	
Protection strategy	Shielding (active)	Nurturing	Empowerment	
Power and resistance	Material	Instrumental	Discursive	Institutional
Materialization	Regime provided space based on established capabilities and resources.	Forming alliances and networks. Experiments.	Narratives, lobbyism, framing.	Legislation, normative work, practice.

Table 2: Protection strategy in relation to materialization of power and resistance. Developed from (Geels, 2014) and (Raven et al., 2016)

The development of a niche spans from its “creation” and “maintenance” to “phasing out”, referring to the phase in the niche’s development in which it is challenging the regime. The different protection strategies are related to the respective development phases. Power and resistance from regime incumbents can take on many forms and the subcategorization according to the development phase is not stringent. However, it does offer an indication, which is developed further by the examples of how this power and resistance materializes.

The niche–regime dynamics is illustrated in particular in Paper 2, through the forming of narratives that portray power-producing buildings very differently. There is an expressed suspicion from some niche actors that the power industry is protecting its business instead of embracing an innovation that could (potentially or allegedly) contribute to a low-carbon transition. Narratives are a discursive strategy that can work both to resist change, but also to induce change. A strategy that can shape not only what is discussed, but also how issues are discussed, is very forceful. The supporting narrative and the anti-narrative discussed in Paper 2 is an example of a discursive dynamics between a niche and the regime. The anti-narrative is found to legitimize the current system and is put forward by regime actors including actors from the power industry, policymakers and trade associations.

Institutional power and resistance is mainly forceful in the phasing out of the niche, and can be materialized in things such as practices, myths and habits, normative work and more formal institutional work like the forming of laws, guidelines and the like. Institutional power is possessed on all levels in a transition model, although formal institutional power is mainly possessed by the regime. In Paper 3, it was found that arguably the regime could get rid of troublesome business models by the “stroke of a pen”: by introducing restrictions, limiting possibilities by laws or otherwise reducing the prospects of an innovative business model. Laws and regulations are a very forceful and definite form of power that can be used to effectively block the development of a niche into a serious regime contender.

Material power and resistance is linked to infrastructure and sunk cost, which is an underlying issue when discussing both the prospects of power-producing buildings as well as business models such as “Leasing of Solar Panels” and the “Aggregator role”. An argument of the regime is that the existing power supply is very cost-efficient (since the infrastructure of dams and cables are already there) and should therefore be preferred. This is strengthened by planned reinforcements and expansion of the current infrastructure (Ministry of Petroleum and Energy, 2015-2016). Instrumental power lies in the alliances between policymakers and incumbent firms and how these alliances, as well as formal and

informal networks, affect the system. Instrumental power is also exercised through the demonstration projects provided by the niche, which can be learned from by the regime.

By studying the regime dynamics of green BMs that are challenging the dominant BMs in Paper 3, it was also found that the niche can have interaction with (be affected by) the landscape level without the mediation of the regime. This can be exemplified by the description from one interviewee about the need for flexibility mechanisms, for which his BM provided a solution: "It [the development of flexibility mechanisms] comes like a supertanker". This means that the development might be slow, but it is very difficult to stop. Power works both ways, but before the regime is sufficiently destabilized to facilitate structural change, the regime possesses superior power over the green niches that are demanding deep, structural change.

Political economy brings in the idea that policymakers and incumbent firms can be conceptualized as a frequently allied at the regime level, focussing on the maintenance of status quo. In line with Geels, I would argue for the need to comprehend and enact the destabilization and decline of current regimes (Geels, 2014). In this respect, the destructive power referred to by Schumpeter as creative destruction needs to be further reflected upon and understood.

5.3 Governance when there is uncertainty and ambivalence

Uncertainty and ambivalence is a likely result of the cross-boundary collaboration and multi-regime dynamics discussed in Section 5.1 and 5.2, respectively. When different regimes or cultures are compelled to collaborate, it becomes unclear which rules and norms are applicable. In addition, as reflected upon in Section 3.3, sustainable development increases complexity, which makes governance more challenging. In Norway, sustainability goals connected to the building sector/power sector are partly vague, contested or non-existent. There are ambiguities at the policy level regarding, for example, energy-efficiency measures and how to exploit the potential in the building sector when it comes to climate change mitigation. On the one hand, visions are lacking or vague, but on the other hand, frontrunners are present and projects are applauded. What is expected from the building sector, really?

The ambiguity that is typically attached to a vague concept like sustainability is causing challenges to the governance of sustainable transitions. Ambivalent policies are typically regarded as problematic and might be reinforced by the inherent ambivalence of the sustainability concept (Walker and Shove, 2007). However, Walker and Shove argue that a careful and thorough analysis of ambivalence raises interesting and challenging questions about different styles of governance that can be applied to the pursuit of sustainability objectives. The modernist, linear approach to governance is typically working towards clearly defined "end states" or goals by engineering of social and environmental change. By doing so, it attempts to minimize ambivalence. Governance of sociotechnical transitions, on the other hand, represents a contrast that emphasizes the complex and dynamic co-evolution of the technical and the social. Transition management is continuously revising goals and including multiple stakeholder perspectives. It lives with, instead of always working to resolve, conflicts and differences (Kemp et al., 1998, Smith et al., 2005). Working against ambivalence can both produce and sustain it, according to Bauman (1990), and from this perspective, allowing for some ambivalence is probably wise. However, to embrace certain forms of ambivalence can obscure the politics and power involved and can gloss over questions about how systems are specified and managed (Walker and Shove, 2007). Voss et al. (2015) refer to this ambivalence as a metaproblem of governance, where knowing when to nurture and when to diminish ambivalence is part of an "efficacy paradox of complexity." This

is characterized by the simultaneous obligation to maintain openness, flexibility and adaptability while at the same time reducing each of the three to be able to make decisions and retain the ability to act (ibid.). Paper 2 emphasizes that ambiguity leads to options being held open, although it is unclear if this is due to uncertainty about the consequences of taking action or otherwise. In Paper 1, boundary objects are identified as facilitating collaboration across disciplines and social worlds. Star and Griesmer (1989) explain that boundary objects need to be sufficiently plastic to adapt to different needs, and at the same time sufficiently robust to maintain a common identity across the different social worlds. This means that the object is initially elastic (or ambiguous) and when a concept is open to interpretation, it can more easily be agreed upon. If collaboration across social worlds is an important means to an end, then the creation and management of boundary objects is a key process in developing and maintaining coherence.

The policy ambivalence regarding innovations in the intersection between the power and the building sectors was given particular focus in Paper 2 and Paper 3. In light of the discussion above, it is clear that it is not only a negative asset and that ambivalence is produced rather than curbed through fighting it too fiercely. However, a governance strategy that allows for some uncertainty, but that formulated long-term visions, would be a step forward to accelerate climate change abatement. This is set forward by Walker and Shove: (2007):

What is missing is a more distributed, and in a sense a more complete, recognition of the contingency and ambivalence of sustainability as defined and reproduced through the actions, inactions and interactions of multiple, variously powerful agents. p. 223.

Governance is expected in the development of a sustainable transition (Kern and Smith, 2008). The trick is to find a balance between leading the way, and at the same time be open and flexible to new ideas and a changing environment. The governance strategy of transition management has as a central tenet the need for long-term perspective in order to guide short-term development. Other tenets are the acknowledgement of uncertainty, the importance of networks and self-steering, and the necessity to provide room for innovation (Loorbach, 2010). In such an environment, bridging devices should be strengthened to facilitate the demanding process towards sustainability.

Transition management is based on certain assumptions about power relations, empowerment and leadership (Avelino and Rotmans, 2009). Avelino and Rotmans argue that power should be more explicitly incorporated into the transition management framework to strengthen it both theoretically and empirically as a governance theory. Grin in (Avelino and Wittmayer, 2016) discusses transition governance in terms of actors' capacity of acting otherwise. The focus on the empowerment of niche actors by creating space for entrepreneurs and innovators is done by enabling them to attain the necessary conditions for power: resources, strategies, skills and willingness to exercise innovative power. It is possible to link niche actors to each other so they can form broader and stronger networks of "niche-regimes" that can ultimately exercise transformative power (Avelino and Rotmans, 2009). Furthermore, niche actors are linked to regime actors, which can exercise constitutive power to establish a new structural distribution of resources. This regime dynamics has been discussed previously, and the power of governance in transition processes should not be underestimated.

Although Norway has not implemented transition management as a governance strategy, elements of it are seen, such as public support schemes for frontrunners as well as institutional adaption to demand such as the established legal right to sell power produced on buildings back to the grid.

5.4 Bridging across boundaries

A common theme to the three papers is boundary-crossing collaboration in the service of sustainable innovation. As elaborated in Section 3.3, sustainability is a vague concept that is likely to cause some uncertainty if not explained further. In addition to this, sustainability practised at the niche and the regime levels are very different (Smith, 2007). The dynamic interaction between two regimes, the power and the energy regime, is exposed, as well as those between the regime and the niche and also new interactions within the niches. The niche is also especially meant to be in opposition to the incumbent regime. As a result, bridges between the niche and the regime are needed (*ibid.*). In this thesis, the need for a facilitator was found and not only in the niche–regime relation, but also between different actor groups and their different perspectives and interests.

In making collaboration work across “social worlds”, disciplines or sectors, there are many challenges. This is due to differences in terminology, training, experiences, vested interests and much more. The results of these challenges are consequences such as a lack of understanding and a lack of a common reference frame to facilitate collaboration. The differences can often make collaboration fail, or remain demanding. In the ZEB research environment, cooperation between social worlds has been described in Paper 1. As stated by Star and Griesmer (1989), all scientific work is heterogeneous. It is not enough to simply impose one world’s vision on the rest. If done so, it would fail. Instead, boundary objects could serve as “bridging devices”; however, this would be temporary (*ibid.*). To facilitate collaboration in the case of ZEB, two boundary objects were identified, one material and one immaterial. These boundary objects work as bridges between the social worlds involved.

Increased research on niche–regime interaction is demanded by researchers such as Geels (2014) and Smith (2007). In Paper 2, narratives were proposed as a means to bridge gaps between the niche and the regime. The bridging is shown to go both ways: the niche is learning about the regime’s unsustainability and instability, and can use this knowledge to improve the niche; the niche is then addressing issues of importance to the regime, and is thereby in a better position to work as a bridging device and become a transformative force.

The third paper studies business models as a force of sustainable transitions while applying the transition management framework. BMs can be described as a “market device” and a key to characterize the interactions within and between the levels in a transition (Wainstein and Bumpus, 2016). The same need for sociotechnical bridging as between the niche and the regime is presumed to be required between a green BM and the incumbent BM. Doganova and Eyquem-Renault (2009) found that business models are vague concepts that are often ill-defined, and as such they could actually work as a “boundary object made of narratives and calculations” (*ibid.*) p. 1561. Described like this, they are closely related to the bridging devices described in the other two papers. In line with this view, Raven et al. (2016) state that successful narratives bridge positive expectations about the technology. In Paper 3, development on the landscape level makes a bridge to the commercial niche actors, without the mediation of the regime. These actors thereby develop green BMs in response and attempt to further challenge the regime.

A common commitment to the robustness of specific power-producing buildings, narratives that connect diverging interests, and business models that create value by relating resources and actors in new ways – these are the bridging devices that were found and proposed in this thesis. The need for bridging devices mainly emerges out of cross-boundary collaboration – regime interaction between

levels, systems and system actors that are heterogeneous or consist of diverse practices and are driven by different interests.

6. Building power towards a sustainable transition

The general research question of this thesis has been how the development and implementation of innovations in the interface between the building and the power sectors contributes to a sustainable transition. In answering this, I have provided a discussion of previous relevant research as well as an overview of relevant theories and frameworks and some of the major criticisms. The papers, along with their core findings, have been presented together with a cross-cutting analysis. In the empirical work I have found evidence for the importance of cross-boundary collaboration. In order to have such collaboration work, “something” is needed to facilitate the otherwise difficult meeting of different systems and cultures. In this thesis the facilitator has been termed a “bridging device”. Bridging devices can take on different forms and overcome the difficulties of sustainable innovation either among “social worlds”, between niches and regimes and even between the landscape and niches. Regime resistance is a likely reaction to structural changes for which avoidance strategies exist. Government and governance have a key role in sustainable transitions and should find a balance between leading the way and facilitating an open development process where actors are able to participate.

Current literature on sustainable transitions is mainly concerned with the role of niches in bringing about structural change (Geels, 2014). This thesis has extended the literature on sustainable transitions by exploring cross-boundary collaboration in different settings. Often, structural change implies friction between systems as different rules and practices are clashing. However, when collaboration is crossing boundaries, the potential for significant (radical) innovation increases, and thereby also increasing the potential for structural change. Hence, in order for sustainable transition to take place, it is important to facilitate cross-boundary collaboration. (This is not confined to sustainable transitions, but to all structural change.) In this thesis, facilitators for cross-boundary collaboration have been identified and described.

The general approach in this thesis has been to zoom in on research issues of importance to the development and implementation of compound innovations such as power-producing buildings from different theoretical angles. Since the challenge is complex and diverse, so is the approach. First, I focussed my attention on the research into zero-emission buildings, which is an interdisciplinary challenge as it demands collaboration between academics and the non-academic partners of ZEB. This kind of collaboration can be challenging: how does it work? It was found that boundary objects were used to facilitate a successful collaboration. In the second paper, I moved to the system level to research how the niche of power-producing buildings is framed by its proponents and opponents. I found that the building and the power regimes have diverging narratives and that ambiguity and uncertainty prevail about the way forward. A bridging narrative was identified that could help to settle the differences and reduce ambiguity. More sustainable business models are needed for a transition to a low-carbon society to succeed. Could business models be a force in the sustainable transition ahead? If so, how could this be facilitated? It was found that business models can have dual interpretations. As business developments, they can be either incumbent BMs or innovative BMs belonging to a niche. Innovative business developments can receive inputs from the landscape level directly, without meddling from the regime level. However, the BM as a flexible *concept* is open to interpretation and could therefore work as a bridging device. As such, it could become part of a governance strategy towards sustainability. In the end, governance is needed to lead the way, regardless of the uncertainty and ambivalence that prevails concerning sustainable innovations.

6.1 Practical implications

Returning to the general research question of this thesis: how the development and implementation of innovations in the interface between the building and the power sectors could contribute to a sustainable transition, I now expand on some of the implications of practical significance.

Collaboration across boundaries is challenging. Furthermore, sustainability is a vague concept that frequently induces uncertainty. Sustainability practised on the niche and on the regime levels are very different (Smith, 2007). When these levels interact, these differences are exposed. This reinforces the need for a “bridging device”. In this thesis, I have found that different artefacts and concepts can act as bridging devices and that this function is extremely useful in diverse processes, including those not directly linked to sustainability. It can take on multiple forms, such as the boundary objects in Paper 1, working as bridging devices across “social worlds”, facilitating collaboration, or the bridging narrative in Paper 2, bridging differently practised sustainability across the niche and the regime. Finally, in Paper 3, it is found that the need for more sustainable business developments and sustainable BMs can be facilitated by the BM concept itself. This is because a BM is both a business tool as well as a concept, with interpretative flexibility that could, thereby, work to make innovations comprehensible to the regime.

The nature of the interaction between the building and the power sectors concerning power-producing buildings presented in this thesis provides useful learning points for similar cases. The peculiarity of the Norwegian context lies mainly in the power sector, where nearly all electricity production stems from hydropower. This, together with solar power being a technology that is still in development (both technologically and in relation to market developments) has led to a questioning of the rationale: why should solar power production be increased in Norway? The questioning of the rationale is, however, not limited to contexts where renewables are in large supply. In other contexts, such as in the UK, the rationale behind solar power production has been questioned, as described in Section 4.3 (Smith et al., 2014). This takes place despite the fact that sources of electricity in the UK are dominated by gas and nuclear.¹⁰ Independent of electricity mix, a technology on the rise is nevertheless a threat to the long-established incumbents and given the strategic importance of energy to a nation, the actors within the sector have the ears of the authorities.

The practical implications of the bridging devices have been illustrated in the articles: boundary objects were facilitating collaboration between social worlds in the first paper. As interdisciplinary collaboration is widely encouraged, this lesson could make an impact. In the second paper, the building regime should construct a narrative that addresses concerns of importance to the collaborating regime. This finding can be utilized in order to affect opposition in a certain direction. In the third paper, cross-boundary collaboration was facilitated by the flexible concept of BMs. Cross-boundary collaboration implies the matching of originally incompatible sets of rules, which can be anticipated to lead to ambiguity and uncertainty. The regime dynamics that follow could result in diverse approaches to collaboration such as competition, symbiosis, integration, spill-over or alternatives and combinations depending on how the collaborating regimes adapt. By highlighting that both challenges and opportunities exist in the successful collaboration across boundaries between systems and cultures, this thesis provides insight into a less-researched topic with a huge potential in terms of transitions. In addition, it offers tools to handle these challenging interactions. Managing

¹⁰ <https://www.ofgem.gov.uk/data-portal/electricity-generation-mix-quarter-and-fuel-source-gb> Accessed January 23 2018

cross-boundary collaboration to a successful end could be the key to achieving and/or advancing sustainable transitions.

I would argue that a careful management of cross-boundary collaboration improves the otherwise limited chances of success for a sustainable transition. However, even if the tools and strategies discussed are valuable contributions, they might still be insufficient in the end. The bridging devices proposed and described here presuppose that the subject to be bridged is willing to be bridged. If this basic willingness is lacking, there is a need for the involved regimes to change in a more profound sense in order for a sustainable transition to take place.

6.2 Lacks, shortcomings and suggestions for future research

This thesis analyses sustainable innovations in a Norwegian context and has closed a gap in the research literature on newer developments in Norway. In particular, it addresses cross-boundary collaboration and identifies how to facilitate such a challenging collaboration. It would be useful to extend the scope of analysis to other contexts for comparison. There are several country-specific aspects to the analysis, such as the energy system and most institutions that are in place. However, there are many similarities as well and in the context of the EU and the EEA, some important, formal, institutions are the same. A comparison could be made to compare and contrast – exchanging experiences and learning between contexts.

Most studies of sustainable transitions focus around the potential of niches to contribute to structural change. This thesis moves beyond that, and analyses different situations where cross-boundary collaboration is necessary to achieve a (not necessarily common) goal. In this challenging conflict-zone where written and unwritten rules are matched, there is a creative potential that could lead to structural change. To facilitate such processes is therefore vital, and more empirical studies of how to make cross-boundary collaboration work are needed.

Whether or not the particular innovations in this analysis are unequivocal contributions to a sustainable transition has not been considered. This has either been taken for granted, or not decided on at all, such as when looking at innovation in power-producing buildings. However, many of the challenges are of a non-technical character and more research resources should be assigned to the study of these aspects. Furthermore, the sustainability of an innovation depends on system borders that are drawn, and this could be the subject of several studies in the social sciences.

This thesis has studied aspects concerning the supply side as well as policy-related issues important to the development and implementation of highly energy-efficient buildings. Demand-side issues regarding implementation of highly energy-efficient buildings have not been explored here. This also includes participatory processes and grassroots movements to support, or in other ways affect, the development and implementation of innovations such as power-producing buildings. This could, for example, illustrate whether such influence is effective at altering policy for a certain cause, or otherwise highlight concerns that users may have.

More research on sustainable innovations in the interface between the power and the building sectors on a spatial scale could reduce the perceived complexity of the aggregated level in this thesis. National systems seem to be entrenched around dominant vested interests and divides, whereas urban scales may allow for crossing of institutional boundaries and the reconfiguration of systems to a larger extent (Markard et al., 2012).

Furthermore, I refer to the articles, which elaborate on suggestions for further research related to the respective research questions.

7. Presentation and discussion of data and the underlying methodology

The main empirical approach used in this thesis is based on qualitative interviews. Below, I discuss qualitative research in general and interviews in particular and relate my research to the aspects discussed. Towards the end, two paragraphs on surveys and Jaccard diagrams are included.

Reliability and validity

Qualitative research primarily achieves reliability through making the research process transparent and through making the theoretical stance explicit (Silverman, 1993). Typically, regardless of what approach is used, the researcher wishes to produce valid and reliable results that can be extended to more cases or a larger population. However, the aim of a qualitative interview is normally not to say something general about a population, but to increase the understanding of a certain issue. This has been the case in this thesis, and qualitative methodology has been used to get a deeper knowledge of how innovations in the interface between the power and the building sectors could contribute in the (upcoming or) ongoing sustainable transition towards a low-carbon society. Generalization without representative data material causes trouble both in the validity of the results, and by invoking critique of qualitative research methods. Validity and reliability is described this way by Kirk and Miller in (Holstein and Gubrium, 1995):

...the objectivity or truth of interview responses might be assessed in terms of reliability, the extent to which questioning yields the same answers whenever and wherever it is carried out, and validity, the extent to which inquiry yields the “correct” answers.

The quality of the research is dependent upon the choice of respondents/informants, and whether or not they are willing and able to participate. Who is chosen for interviewing is dependent on the research question(s) to be answered and to some extent the resources available. Furthermore, the skills of the interviewer are likely to affect how the interviews are performed and hence the results from them. Before I started on this thesis I was working for many years with a policy actor on designing and implementing incentives to reduce energy use of buildings. This has been a great advantage as I gained an overview of the actors as well as personal knowledge of many individuals particularly in the building regime. This has made it easy for me to identify the appropriate contact to speak to; I have been able to reach all my preferred interviewees with limited efforts. On the potentially negative side, I might have missed actors placed outside my original network. By applying the snowballing principle (Noy, 2008), I extended the number of interviewees but the extension was based on my original network. However, being part of a national research centre (ZEB), which also aspired to include actors from the power regime, I argue that the population of potential interviewees was largely known. In addition, as argued in the respective papers, Norway could be referred to as a close community, which means that interaction across disciplinary and sectoral boundaries is permitted (Guy and Shove, 2000). In particular, concerning actors in the power regime and actors connected to the case studies in Paper 3, I performed quality assurance by asking informants and contacts, as well as searching on the internet to find the right individuals.

Who is being interviewed matters. It is highlighted that choosing your interviewees is crucial, and interviewee relevance to the case is crucial. Deliberate selection of interviewees to give variation is a strategy to increase reliability in qualitative research interviews (Kvale and Brinkmann, 2009b). Depending on the research question at hand, experts are often chosen as interviewees as they are

people with a lot of relevant knowledge. According to Kvale and Brinkmann (2009a), elite interviews are done with people that are either leaders or experts and usually hold powerful positions. Another definition of the elite is from Dexter (Dexter in (Littig, 2009)), saying that the members of the elite are “the influential, the prominent and the well-informed”. Experts are defined by their occupational or professional knowledge and decision-making competences. They can be members of the elite group, but do not necessarily have to. The regular skew power relation where the interviewer is in charge is levelled out by the status of the interviewee. To be up to such an interview situation, the interviewer must be well-informed, be familiar with the terminology and know something about the background of the interviewee (Kvale and Brinkmann, 2009a). Experts are often used to being interviewed and they often have an agenda they want to push in the interview. It is demanding for the interviewer to navigate around these “statements”. Furthermore, experts usually have a secure status, which makes it safe to challenge their opinions and also provoke them (ibid). All interviews I performed were expert interviews in the sense that my interviewees were chosen because of their particular knowledge of a specific topic but also in some cases because of their influential positions. Because of my background, I was up to the interview situation as I knew the topic well and in many cases also my informants. A potential downside of this knowledge would be if it made me unable to see aspects other than what I already “knew”.

How many interviews are enough?

The strive for reliability in research implies for interviews that procedures are replicable, which means they are transparent. But, since each interview situation is different and knowledge is produced in that specific situation, the exact replication of information/interview results is unlikely. Nevertheless, by being transparent this can be evaluated by other researchers. The human variables cannot be fully controlled, but at least the research design and implementation produced by one researcher could be replicated by another when desired. Transparency is also important for others to be able to evaluate the analysis/interpretation of interview results. The ability to do so is dependent on how well the interview results are documented, most commonly by transcription of interviews as was the case in this thesis. In total, I did 57 interviews. All interviews, except for two (of a more supportive character) were taped using the speech recorder on my mobile phone. Afterwards, they were saved as mp3 files on my computer and transcribed. I used a professional transcriber for about half of the interviews and transcribed the rest myself.

Galvin (2015) asked if interviews produce reliable knowledge. He investigated 54 journal articles focussing on building-energy consumption, where semi-structured interviews have been used to produce data on customer skills, beliefs, attitudes and practices. Galvin’s main point is how one could know that the number of interviews conducted are sufficient to say something about a specific target population. The background for this article by Galvin seems to be his experience with qualitative research that has “gone beyond its limits” and generalized on the basis of very few interviews. In particular, he is sceptical towards the saturation principle, saying that interviewing can cease when the next respondent does not come up with any new issues. No-one knows what the next interviewee would have said, and assuming that all themes have been found is therefore a logical problem. He demonstrates, by the use of statistical methods, the probability of finding an issue in small-sample qualitative interviews, given its frequency in the population. This shows that in theory, no finite number is ever enough. However, by implying margins of error, this conclusion can be modified. The saturation principle is often adhered to, but still debated among qualitative researchers. Often, saturation is claimed but not demonstrated or justified (Mason, 2010). This makes it an easy target for

criticism. Furthermore, Galvin is concerned with the reliability of qualitative research interview results and states that if the interviews are not a random sample, then the reliability of the findings becomes weaker. According to Galvin, it is very difficult to obtain a true random sample for interview research. Galvin uses the example that even if a sufficient proportion of the population are known to the researcher, people self-select for reasons that are often unknown for the researcher. However, the problem of self-selection is also present in other methods and is therefore not limited to qualitative research interviews. Other researchers argue that random sampling is inappropriate for qualitative studies. According to Marshall (1996) the answer lies in the aim of the study. If it is not the aim to generalize the findings to the whole population, then random sampling would rather mislead research as it is not the most effective way to develop an understanding of complex issues relating to, for example, human behaviour (ibid.). Marshall provides several reasons for this: first, qualitative sampling tends to be small and this increases the risk of sampling errors; second, the whole population should be known, which is seldom the case; third, a random sample would produce representative findings only if the research characteristics are evenly distributed in the population; and fourth, some interviewees give “richer” data simply because people are not equally good at observing, understanding and interpreting their own or other people’s behaviour (ibid.).

After bringing forward this critique, I discuss sample sizing and selection methods in this thesis as well as how I decided when there were enough interviews.

Sizing and selection methods

In the first paper, the theme was transdisciplinary research within ZEB. Therefore, the total population size was limited and nearly all members were included in either the initial surveys or the consecutive interviews. In the second paper, the population size was much bigger, containing actors both within the power and the building regimes. Here, the selection of interviewees was informed by my previous experience and knowledge of the actors in the field. Furthermore, as a researcher embedded in a research centre working on my research topic, I had access to information on who I should include. Since I was performing a system analysis, I was selecting representatives from the policy level (ministries, directorates and other actors working on how to incentivize change), interest organizations (trade organizations, environmental organizations), industry actors (entrepreneurs, property developers, building owners) as well as representatives from academia and research. The study did not include demand-side issues and therefore, demand-side actors are (largely) not interviewed. The selection process was inspired by grounded theory, in the sense that it was not predetermined and was open for adjustments along the way – thereby encouraging creativity. The central focus of grounded theory is the development of theory through constant comparative analysis of data collected from theoretical sampling (Coyne, 1997). Glaser (1978) defines theoretical sampling as the process of data collection for generating theory whereby the analyst jointly collects codes, and analyses his/her data, deciding which data to collect next and where to find them, in order to further develop the theory or hypothesis as it emerges.

In the third and final paper, I built on the 32 interviews for Paper 2 that also uncovered three overarching challenges in the intersection between the building and the power sectors in Norway. From these challenges, I identified three business models that targeted each of the challenges respectively. The business models are taken as case studies which, according to Gerring (2004), may be defined as “an intensive study of a single unit for the purpose of understanding a larger class of (similar) units”. In addition to the study of readings about the actual cases, I did another seven

interviews to get the necessary in-depth descriptions. Here, choices have been made in two rounds: first the cases were chosen and then the interviewees were chosen. According to George and Bennett (2005), when there are few cases, the sample bears the risk of being skewed if selection is random. Here, I could choose among a few cases, and did choose cases that, in my judgement, seemed to have the most backing in terms of market developments, trends or current issues. When cases were chosen, the actors that held the respective business models were identified and interviewees were chosen. For the energy performance contracting (EPC) business model case, there are around six suppliers in Norway. I chose one of the most prominent and did interviews of one project director as well as one of their customers from a list of customers who had been approved by the EPC supplier. Furthermore, I interviewed the only supplier of the aggregator role (AGR) in Norway, so far, as well as one of their customers, also approved by the AGR supplier. Finally, I chose the only independent supplier on the solar cell roofing market in Norway to interview about their Leasing of Solar Panels (LSP) business model. Here, I chose to review three articles on customer preferences instead of choosing interview objects from the several hundred customers of the LSP. The risk of selection bias was considered too high. The sampling process has been sometimes given, and sometimes purposefully selected. The risk of arriving at a false conclusion or findings is considered small due to the research questions that were investigated.

An appropriate sample size for a qualitative study is one that adequately answers the research question (Marshall, 1996). Often, the saturation principle – as criticized by Galvin – was used. It is difficult to determine when all the important aspects of a question have been identified. In my research, I have aimed to provide as detailed descriptions of the research questions at hand as possible given the constraints faced by all researchers; time and money. I stopped the interviewing only when new aspects ceased to be uncovered; however, I cannot be absolutely sure that new aspects would not be brought up if the interviewee sample was larger.

Choice of method and assessment of data

In this subsection I will explain the choice and implementation of method as well as critically assess the interpretation of the data.

All interviews were guided by a semi-structured, open-ended, interview guide and were recorded. The material was then transcribed and finally analysed. Analysis is the interplay between researchers and data: it is both science and art (Corbin and Strauss, 2014). The material was analysed using open coding. According to Burnard (1991) the aim of open-coding analysis is to produce a detailed and systematic overview of the themes and issues addressed in the interviews. This is to link the themes and interviews together under an exhaustive category system. When interviews are transcribed, they are read through and notes are made. Then, the content is labelled into categories or headlines, which are subsequently reduced through regrouping and identification of broader categories. Each transcript is worked through and coded according to the list of category headings (*ibid.*). The categories across all interviews are copied and put together, which often makes it possible to identify patterns or a lack thereof. However, Burnard claims that researcher bias can destroy the validity of the findings. This could be alleviated by asking other researchers that are not involved in the particular study to perform the same exercise of categorizing and coding. This has not been done in any of my three papers, which could potentially reduce the validity of the data. However, the method of open coding is transparent and could be replicated by other researchers. Therefore, any flaws in validity could be discovered if coding is undertaken in a systematic way. In Paper 1, the coding process was inductive using sampling

and re-coding. In Paper 2 and 3, the coding process was deductive using a pre-existing frame. Rather than reducing the categories progressively, the core variables were identified during the interview processes and subsequently applied to the transcribed material.

My role as an interviewer and the selection of interviewees was discussed in the first subsection of this Section 7. It remains to assess how this might have affected the interpretation of the data. The collection of data and proceeding analysis takes place in a given context and is interpreted in that particular context. As Silverman stated, “No method of research can stand outside the cultural and material world” (Silverman, 1997) p. 249. This statement suggest that researchers must be aware of their role in applying a particular method and in interpreting the subsequent data. As an interviewer, the role is thought to be neutral and simply contributing to the release of what is already there without participating to the construction of answers. Nevertheless, the interaction between interviewer and interviewee will most likely shape the outcome (Holstein and Gubrium, 1995). Being an interviewer with prior knowledge of the topic of research, it is reasonable to question not if, but in what way the interview situation was shaped. Especially when some of the interviewees were former colleagues and collaborating partners. Any possible skewness has been sought levelled out by interviewing primarily *experts* which would presumably not alter their answers due to any knowledge the interviewer brought up. On the positive side, it may have given me access to data not otherwise shared with an interviewer, since I could have been taken for an insider and collaborator and hence trustworthy. The number of interviewees has also been relatively large which could contribute to a larger variety in the interview data.

Table 3 illustrates the main occupation of the interviewees at the time of the interview.

	Paper 1	Paper 2	Paper 3
Building sector – public	1	5	1
Building sector – private	4	5	2
Power sector		3	3
Trade associations		6	
Academia and research	12	4	1
Policymakers	1	8	
Environmental organizations		1	
Total	18	32	7

Table 3: Interviewees sorted by occupation

In the table, the interviewees are sorted by occupation and also by which role they were interviewed for. For example, I have interviewed municipalities, which could have been categorized as “policymakers”, but in this respect they were interviewed as large-building owners and hence categorized as “building sector – public”.

Below, I will offer more-detailed information related to the implementation of the chosen method in each of the papers.

Paper 1

The choice of qualitative interviews as the main methodology in Paper 1 followed from the research questions to be answered. When there is insignificant research-based knowledge on one area the qualitative method is preferred (Kvale and Brinkmann, 2009b). Qualitative method allows the researcher to take new knowledge into account and encourage in-depth analysis. In Paper 1, two email surveys, in the form of a written interview, were conducted followed by 18 qualitative interviews. The written interviews were directed towards the academic work package leaders and the non-academic partners and consisted of open-ended questions. The first written interview was conducted to find out what research areas the work package leaders found important and what was to be achieved through the centre's research. The second written interview was a general evaluation among the non-academic partners. The choice of written interviews as the preferred method was due to requests and some provided questions from both the centre's leadership and from the Research Council of Norway. Both written interviews were subject to an open-coding strategy as well as a co-word analysis, finding relations between words. The two last paragraphs in Section 7 provide further information for written interviews and Jaccard diagrams. The written interviews with the academic work package leaders gave diverse answers, with one exception: research in ZEB should lead to "robust solutions". This spurred the framing of questions in the subsequent interviews. To investigate what was meant by "robust solutions", interviews were a natural choice, as the aim was to increase the understanding of a particular concept (robustness). The population was largely confined to participants in the ZEB centre and all members of the centre management were interviewed. From the non-academic partners, a selection was made. All partners in the centre board were interviewed since they are elected to the board in order to represent the partners at large. To check against a potential bias, an organization that has been negative to the preceding passive house development was interviewed. The rationale behind this choice was that the same criticism could be made towards ZEB, as passive house principles are also important in ZEB projects. No other outspoken critics are present. In total, 18 interviews were conducted and transcribed. Subsequently, a quite extensive open-coding process was initiated, as described at the beginning of this subsection.

Since the object of study was the research centre on zero-emission buildings, a large share of the population has been included in the research. However, this is *one* research centre and more empirical studies should be undertaken among other research centres or similar entities.

Paper 2

In Paper 2, I started with a Technological Innovation System (TIS) analysis of zero-emission buildings as described in subsection 3.7. The level of analysis was multi-product (or competence bloc), as zero-emission buildings fulfil several functions: not only as a building, but as a solution to a climate challenge and as a power producer. After determining the level of analysis, other key issues to the researcher are delimiting the system and finding the actors (Carlsson et al., 2002). Dealing with an analysis like TIS, the qualitative interview is a choice of methodology that is likely to give the researcher the necessary in-depth descriptions and – particularly important in this case – the opportunity to adapt to new knowledge. Interview objects were selected due to their knowledge of, experience with, or position regarding, zero-emission buildings. After finishing the 32 interviews, they were transcribed. The analysis that followed was based on open-ended coding, where the focus was to find patterns within or across the regimes involved. The coding process was deductive, using

predetermined variables, and the task was mainly confined to finding patterns. The pre-existing frame for the coding process was variables linked to the functions in TIS. However, the position towards power-producing buildings became the main variable of the analysis.

A possible weakness in the data material for this paper is the application of a singular method: the qualitative interview. Even if the number of interviewees is extensive, it is difficult to tell if all the relevant aspects have been captured. One group that has been left out of this thesis is the consumer. I have, due to time constraints, chosen to focus the research on the supply side, as well as on policy actors. Consumer preferences towards power-producing buildings should be taken up in future research.

Paper 3

From the interviews related to the TIS analysis, three challenges were identified in the interface between the building and the power sectors regarding how to increase energy-efficiency, generate energy on or nearby buildings, or alleviate the challenge of peak load. This formed the point of departure for Paper 3. These challenges can be viewed as unsustainable business practices and hence innovative business models could be a solution. Consequently, I identified five business models that targeted one of the challenges and I started to explore these by undertaking 11 qualitative interviews, eventually leading to the dismissal of two of the models – green leasing contracts and public-private partnership – to advance sustainable solutions. They were dismissed because of lack of clarity in terms of conditions and/or shifting political preferences, which led to tepid interest among the potential suppliers. The three remaining business models answered each of the three challenges respectively and were identified and mapped through 7 of the 11 interviews. Again, the need for comprehensive descriptions and the possibility to make alterations due to new knowledge was the reasoning behind the choice of qualitative interviews as a method. The interviews were transcribed and analysed using a deductive coding process with a pre-existing frame, namely the conceptual framework of BM theory, in addition to central concepts of transition theory.

The case study as a research strategy can be inflexible as issues brought up during the data collection are not easily included in all cases. However, with only three cases to compare and contrast, this was not a significant problem, as I was able to reach my interviewees to ask additional questions.

The placement of case studies in relation to the regime is non-transparent and based on the personal judgement of the researcher. This could raise questions about the conclusions that are drawn. However, the variables included in the judgement were systematized in a table; this could be developed further, with increased transparency, to create an interesting tool.

In two instances, the qualitative data analysis software QDA Miner (v.2.0, see (Lewis and Maas, 2007) for a review) was used to support the qualitative analysis. In these cases, the textual material was more standardized than in the cases where data was acquired through semi-structured interviews, enabling a more-structured approach to the analysis. More specifically, for the first paper, in 2014, the five work package leaders of the Research Centre on Zero Emission Buildings were asked to answer three open questions about the centre's actual, expected and desirable research outcomes by email, which resulted in condensed but free-form descriptions of the researchers' main concerns at this time. The second group of texts, analysed with the help of the same software, came from the answers given by non-research partners that were part of a questionnaire designed by the main funding agency

(Norwegian Research Council) around the same time, which also comprised standardized questions. Here, only the answers to the open question concerning the overall evaluation of the centre were considered.

The resulting texts comprised no more than 1,000 words each and were internally structured by cases (each case representing a respondent) and paragraphs (inserted by the respondent and preserved for the analysis). The texts were first coded by grouping responses into 10–15 larger categories. In the next step, each text was analysed for co-occurrence of coded segments of text within a paragraph, assuming that paragraphs represent logical units, i.e. co-occurrence of codes was interpreted as a logical connection between the codes. Intersection and union between codes was then measured by calculating the Jaccard similarity index and was visualized through a hierarchical tree diagram, which was used as the basis for further qualitative analysis.

8. References

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9. Appendix: Sample interview guides

9.1 Paper 1

Interview guide paper 1

(Intervjuguiden ble tilpasset ut intervjuobjektets bakgrunn og tilhørighet.)

Fortell om forskningsprosjekt, anonymisering, bruk av opptak, etc.

1. Om deg og ZEB
 - a. Deg
 - i. Hvilken bakgrunn har du?
 - ii. Hvordan begynte du å jobbe med bærekraftige bygg?
 - b. ZEB og [arbeidsgiver]
 - i. Hva tenker du om ZEB sitt formål og resultatene de har oppnådd så langt?
 - ii. Hva tilfører samarbeidet med ZEB til [arbeidsgiver]?

Nå har jo [arbeidsgiver] satset en del på å bygge opp egen kompetanse på området.

 - iii. I hvilken grad kan du tilskrive resultater fra [arbeidsgiver] sine prosjekter til ZEB?
2. Politikk og virkemidler
 - a. Norske politikere har gjennom klimameldingen signalisert at byggeforskriftene i Norge skal være på passivhusnivå i 2015 og på nullenerginivå i 2020. Hva mener du om disse respektive målsettingene?
 - b. Hvilke fremtidsperspektiver har du for norsk byggenæring? Deskriptivt og normativt i et mellomlangt perspektiv (10-30 år).
 - c. Hva synes du om norsk energi og klimapolitikk når det gjelder tiltak rettet mot byggenæringa?
 - d. Hvilken rolle har ZEB i norsk klimapolitikk?
 - e. Hvis målsettingen er å redusere klimagassutslippene, hva er de beste tiltakene for å oppnå dette? Hvordan kan det sikres at tiltakene blir gjennomført?
 - f. Hvis målet er å få til nullutslippsbygg, hvilke tiltak mener du hadde vært de beste? Hva hindrer at slike tiltak evt ikke skulle bli innført?
 - g. Er det andre mål enn nullutslippsbygg som er bedre? På hvilken måte?
3. Begrepet «robusthet»
 - a. Forskerne i ZEB sier at ZEB skal bidra til robuste løsninger. Hva forstår du med begrepet «robust»?
 - b. Finnes det ulike dimensjoner av begrepet? Teknisk, sosialt, økonomisk...?
 - c. Er robust det samme som bærekraftig?
4. Forskning i fremtiden
 - a. Hva skjer når 8-årsperioden til ZEB utløper om 2,5 år? Bør det komme et «nytt ZEB»? Evt et annet forskningscenter med hvilket fokus?
5. Sluttspørsmål: Er det noe som jeg ikke har spurt om, men som du gjerne vil si noe om?

9.2 Paper 2

Interview guide paper 2

(Intervjuguiden ble tilpasset ut intervjuobjektets bakgrunn og tilhørighet.)

Fortell om forskningsprosjekt, anonymisering, bruk av opptak, etc

1. Om deg og byggebransjen
 - a. Deg
 - i. Hvilken bakgrunn har du?
 - ii. Hvilken rolle/ansvarsområde har du i din nåværende stilling?
 - b. Byggebransjen
 - i. Hvordan kan byggsektoren bidra til reduksjon av klimagasser (utenfor Norge)?
 - ii. Hvordan vil du karakterisere norske bygg i et klimaperspektiv?
 - iii. På hvilken måte/med hvilke tiltak kan norsk byggesektor bidra til reduksjon av klimagasser?
 - iv. Mener du at det er et realistisk potensial for å innføre nullutslippsbygg i Norge)? (Definer kort nullutslippsbygg: bygg hvor det tas i bruk verktøy gjennom byggeprosessen for å underbygge at bygget er «klimanøytralt» i et livsløpsperspektiv)
 - v. Hva er de viktigste barrierene/hva skal til for at nullutslippsbygg skal bli en vanlig del av tilbud og etterspørsel i Norge?
 - vi. Hvilke utfordringer er forbundet med at det i fremtiden kan bli mange små produsenter av kraft?
 - vii. Når kan nullutslippsbygg eventuelt bli norsk byggestandard?
 - viii. Hva synes du om norsk energi og klimapolitikk når det gjelder tiltak rettet mot byggenæringa?
 - ix. Innovasjon er viktig for utviklingen av nullutslippsbygg. Er dagens nivå og måte å drive innovasjon på tilstrekkelig? Hva mangler eventuelt?
2. **Strukturell analyse (aktører, nettverk og institusjoner)**
 - a. Hvilke aktører er særlig viktig for utviklingen av nullutslippsbygg?
 - i. Politics and policy
 - ii. Forskning og utdanning
 - iii. Produksjon av bygg (tilbudssida)
 - iv. Etterspørselssida
 - v. Finansiering og støtteordninger
 - b. Hvilke nettverk ser du på som viktige for utviklingen av nullutslippsbygg?
 - c. Er det nettverk/aktører som er viktige, men som ikke er etablert eller delaktig i dag?
 - d. Hvilke (formelle) rammeverk er særlig viktig for formingen av en mer miljøvennlig byggpolitikk? (eksempler: lover, regler, standarder + de rapportene som ligger til grunn)
 - e. Er det uformelle rammeverk som hindrer/bremser utviklingen?
 - i. Byggtradisjoner
 - ii. «Sånn gjør vi det her hos oss»
 - iii. Status i nøkkelyrker

- iv. Kunnskap og kompetanse om hvordan bygge miljøvennlige bygg
- v. Koordinering/samarbeid på ulike nivå blant aktørene (også på policy-nivå)
- vi. Får ikke solgt slike bygg.
- vii. Prisnivå
- viii. Annet?

3. Funksjonell analyse

- a. Kunnskapsutvikling og -spredning
 - i. Incitament: hvem er med/ ikke med og **hvorfor**? Hvordan beskrives potensialet?
 - ii. Type kunnskap og kilder til kunnskap: hvilken kunnskap er det særlig behov for forutsatt at vi skal ha nullutslippsbygg i framtida? Mangler denne kunnskapen? Hvem skal tilby/fasilitere den?
 - iii. Hvordan sørge for at kunnskap utvikles og spres? (imitasjon, refleksjon, erfaring) Hvem har ansvar for læring og kvalitet i byggebransjen?
 - iv. Interne forhold: hvilke alternative løsninger/konsept finnes det? Er det få eller mange alternativer? Er det ulike drivere for ulike alternativer? Hvilke flaskehalsbarrierer blir nevnt? Er det incentiver for aktører i alle deler av verdikjeden? Støtter lovverk/regulering opp under kunnskapsutviklingen?
- b. Entreprenører og eksperimentering
 - i. Hvor mange nyetableringer er skjedd som følge av TIS/nullutslippsbygg? Hvor er disse? (Enkeltstående eller del av større foretak? UNI? Stat?)
 - ii. Hva eksperimenteres det med og hvor bredt skjer dette (nye produkter, løsninger eller nye selskap)?
- c. Ressurs-mobilisering
 - i. Hvilke finansielle ressurser er tilgjengelig? (Se aktør-kart) Hvilke mangler?
 - ii. Hvilken kompetanse er sentral og tilgjengelig? Eventuelt mangler?
- d. Legitimering (nært knyttet til institusjoner)
 - i. Hvilke lover og reguleringer er relevante for utviklingen av TIS/nullutslippsbygg? Gis det rom for vekst i dette rammeverket?
 - ii. Standarder og andre skriftlige forordninger som eksisterer eller bør etableres?
 - iii. Hvilke visjoner og forventninger finnes? Er disse forskjellige for ulike aktører?
 - iv. Er det legitimt å investere i et nullutslippsbygg?
 - v. Hvordan beskrives TIS i media?
 - vi. Formelle møteplasser? Hvilke?
 - vii. Lobbyister som arbeider for å styrke legitimiteten til TISen?
 - viii. Er det nøkkelaktører involvert, som bidrar til å styrke legitimiteten?
 - ix. Konkurrerende innovasjonssystemer og maktforholdene derimellom?
- e. Veiledning i søken etter informasjon/ en retning
 - i. Hvilke barrierer er det mot å bygge nullutslippsbygg/ta disse i bruk? Hvilke potensial?
 - ii. Hvilke valgmuligheter er det mhp tekniske løsninger, ulike applikasjoner, markedssegment, geografiske markeder, strategier etc. Og hva ligger bak valg av strategi?
- f. Markedsformering
 - i. Hvem er kjøperne? Ulike segmenter?

- ii. Hva motiverer kjøpere?
- iii. Hvordan vet du hva kunden vil ha?
- iv. Er det mellomledd (intermediaries)?
- v. Hvordan utvikles markedet over tid og hva er driverne?
- g. Utvikling av positive eksternaliteter
 - i. Konkret; hvilke investeringer er gjort som andre kan dra fordel av?
 - ii. Hvilken usikkerhet oppfatter aktørene? Hvorfor? Hvordan redusere usikkerheten?
 - iii. Er det spesialiserte deltakere (som støtter hele verdikjeden)?

For aktører i kraftbransjen/tilknyttet kraftbransjen

1. Hva er ansvarsområdet i din nåværende stilling?
 - a. Er du/dere involvert i byggprosjekt hvor energiproduksjon er en del av prosjektet?
Hvilke erfaringer har dere i så fall gjort dere?
2. Hvordan kan bygg bidra til reduksjon av klimagasser i Norge?
3. I EU direktivet EPBD står det at bygg skal være nær nullenergibygge i nær fremtid. Hva betyr dette?
4. Hvordan bør overskuddsenergi fra bygg håndteres?
5. Har dere plusskunder? Hvorfor/hvorfor ikke?
6. Hva synes du om opprinnelsesgarantier? Selger dere opprinnelsesgarantier?
7. Hvilken betydning har EU ETS for kraftbransjen?
8. Hvilke fordeler og ulemper er knyttet til bygg som har overskudd av energi. Ser dere noen markedsmuligheter her?
9. Kan bygg bidra til å utgjevne effekttopper? Forklar.
10. Hvilke muligheter ser dere med AMS?
11. Hva tenker dere om det omsøkte forskningscenteret ZEN?
12. Hvordan vil markedet for kraftproduksjon og distribusjon utvikles fremover?

Sluttspørsmål (til alle): Er det noe som jeg ikke har spurt om, men som du gjerne vil si noe om?

9.3 Paper 3

Interview guide paper 3

(Intervjuguiden ble tilpasset case og intervjuobjektets bakgrunn og tilhørighet.)

Fortelle om forskningsprosjektet. Opptak og sitering mv.

- 1) Kan du fortelle litt om din bakgrunn og din rolle i firmaet du arbeider for?
- 2) Når begynte [arbeidsgiver] å arbeide med [forretningsmodellen]? Hvor modent er modellen?
Fortell litt om prosessen bak [case] som du er involvert i.
 - a. Hvem er involvert (internt og eksternt)?
 - b. Hvilke vurderinger ble gjort i forkant av beslutningen om [case]?
 - c. Hvilket tidsperspektiv er det?
 - d. Hva er suksesskriteriene?
 - e. Hvem tar beslutninger knyttet til endringer og evt videreføring av modellen?
 - f. Kjenner du til direkte eller indirekte konkurrenter? (Varianter av denne forretningsmodellen eller andre?)
 - g. Hvordan er praksis i Norge sammenlignet med andre land?
- 3) Om [forretningsmodellen]:
 - a. Retter seg mot hvilke kundesegment?
 - b. Hvilken verdi leveres? Hvilket problem/utfordring løses?
 - c. Hvilke MF kanaler og distribusjonskanaler er falt ned på?
 - d. Hva er betalingsvilligheten? Hvordan betaler kundene?
 - e. Ut fra hvilken verdi som tilføres/problem som løses(value proposition): hva er nøkkelressurser og nøkkelaktiviteter og gode partnere for å nå de overordnede målene?
 - f. Hvordan ser kostnadsstrukturen ut? Hva koster mest?
 - g. Eksempler på vellykkede/mislykkede prosjekter? Hvorfor lyktes/mislyktes disse?
- 4) Risiko:
 - a) Er [forretningsmodellen] etablert eller ny? Veldokumentert eller eksperimentell? Er den unik evt på hvilken måte?
 - b) Hvilken risiko medfører [forretningsmodellen] for din arbeidsgiver? Hvilken risiko er det for andre involverte?
 - c) Hvilket potensiale ser du/hvor ligger potensialet?
- 5) Hvilke barrierer og drivere påvirker suksessen? Hva kan komme til å bli et problem? Er disse analysert/vurdert – evt på hvilken måte?

Sluttspørsmål (til alle): Er det noe som jeg ikke har spurt om, men som du gjerne vil si noe om?

Part B: Papers

Paper 1: Boundary objects as facilitators in sustainable building research

Authors: Thomas Berker and Ann Kristin Kvellheim

Introduction

Emerging from deep green niches advocating sustainable housing in the 1970s, buildings with high environmental ambitions play an increasingly important role in national and international green growth and climate mitigation initiatives (Lovell 2004). Within these efforts to reduce the energy consumption related to construction, operation and demolition of the built environment, the special importance of scientific and technological advances is widely recognized, as are the challenges to implement radical innovations in the construction sector, which is notorious for its risk-aversion and traditionalism.

In line with the growing significance of energy efficient buildings in national and international environmental policy initiatives, in Norway, as in other countries, in recent years, we have witnessed increased public support for research and development related to energy-efficient buildings. Acknowledging that there is an implementation gap in addition to knowledge gaps, new forms of transdisciplinary collaboration, i.e. collaboration across academic disciplines that at the same time crosses the boundaries between academic and non-academic work, have been developed.

In this article, we present our experiences in a large Norwegian research centre that succeeded to both bridge disciplinary boundaries and the divide between academic and non-academic knowledge production. Based on two surveys and 18 in-depth interviews with researchers and non-academic centre members in the Norwegian Research Centre on Zero Emission Buildings (ZEB), this article pursues two goals: First, we want to provide insight into what we have learned about the complex collaboration in this unique test-bed devoted to creating a break-through of zero emission buildings in Norway. Second, we contribute to the literature on transdisciplinary collaboration by discussing the contribution of the notion of boundary objects to better understand – and ultimately also improve – transdisciplinary collaboration.

Our starting point, in line with our “situatedness” (Haraway 1988) as “embedded” researchers in a research centre that features strong integration between science, its context of application and different disciplines, is that we take the existence of new, transdisciplinary research constellations (Thompson Klein 2004) as a given. Thus, we move beyond categorizing and then evaluating instances of this shift towards new, collaborative production of knowledge that has been the topic already of a number of recent publications (e.g., Turnhout et al. 2013; Wilkinson 2014; Cherney 2015; Felt et al. 2016). In this article, we deliberately do not look from the outside at these new constellations, wondering what they do and what they mean. Instead, we look from the inside out and direct attention towards the tools and processes that were used in one specific transdisciplinary research centre. Informed by theoretical understandings and key concepts provided by symbolic interactionism (social world and boundary object) and based on two surveys and qualitative interviews, we describe what has facilitated collaboration in order to enable other, similar projects to skip some detours and

spare them of having to invent the wheel of transdisciplinary work from scratch. However, before this, we describe the case for transdisciplinary work in construction (next section), which is followed by an outline of our theoretical framework.

Transdisciplinary challenges in sustainable construction

In recent years, impressive progress towards sustainable construction has been made. It is now possible to build in such a way that the resulting building can make up not only for the energy used during operation but also for the energy embedded in the building itself during its construction through a reasonable amount of on-site renewable energy production. This is usually achieved through the use of high performance insulation, elimination of thermal bridges, and efficient mechanical ventilation with heat recovery. These advances add to traditional building designs' complexity therefore increasing demands for coordination.

At the same time, construction in general - despite notable national and regional differences - has long been known for its rigid division of labour, leading to inefficiencies and defective outcomes (Egan 1998; Latham 1994). Other related criticisms against the weak innovation capacity of the sector address its inability to create sustained learning (Bresnen and Marshall 2001), as well as its high degree of

“fragmentation both ‘horizontally’ in terms of discipline/trade (i.e., mechanical, electrical, structural) and ‘vertically’ in terms of project life cycle (i.e., project shaping, design, construction, commissioning and operation).” (Sheffer and Levitt 2010, 8)

A perspective on buildings as just another consumer product becomes difficult to maintain if actual construction processes are analysed. Buildings and their context may vary considerably, which makes each construction project different (De Wilde, Augenbroe, and van der Voorden 2002). In this sense, construction resembles more complex systems industries (Miller et al. 1995; see also Winch 1998) than, say, the car industry, particularly when performance ambitions increase as is the case in the construction of highly energy-efficient buildings.

To overcome these multiple sources of fragmentation and discontinuity, Gann (1997) recommends the use of intermediaries, as follows:

“In the context of construction as a project-based process, the role of intermediaries, which form a technical support infrastructure is important in providing the kind of long-term repository of knowledge required to support technical development and implementation. These intermediaries include government agencies, education and R&D institutes as well as professional bodies and industry associations.” (Gann 1997, 259)

During the last decade, particularly in the context of green construction, these calls for the introduction of intermediaries that collect and translate the results of “innovation and learning at the project level, where many novel problems are encountered and solved” (Harty 2005, 514) into a reusable resource, have been answered. Diverse private initiatives, such as the UK Building Research Establishment (BRE) and the German Passive House Institute (PHI), not only rate and certify green buildings but also engage actively in building research, train consultants and present themselves as knowledge brokers. At the same time, academic building research has been strengthened by funding

bodies all over the world and building researchers are increasingly working in interdisciplinary and transdisciplinary constellations (Berker and Bharathi 2012).

Collaboration across social worlds

On the most basic level, transdisciplinary collaboration can be defined as crossing two sets of boundaries, both the divisions between academic disciplines and between non-academic and academic collaborators. How these boundaries are described and, consequently, what their transgression entails, can be conceived differently depending on which theoretical perspective is used. An institutional approach, for instance, will look at two organizations to determine how individuals that are located in between these organizations could create new perspectives (e.g. Tushman 1977). Other approaches look at characteristics of institutions (Barbora and Corredera 2009) or the individuals (D'Este and Perkmann 2011) involved and derive factors that favour or impede the crossing of boundaries. However, different forms of knowledge are not only divided from each other by the institutional membership of their producers. Neither are motivations and attitudes sufficient predictors of boundary-spanning activities. The collective enactment of practices creates deeper divisions affecting, among others, the language that is used and the skills that are necessary to participate. Referring to the tradition of symbolic interactionism (Strauss 1978), Clarke and Star (2003) describe how social groups in their frequent internal interactions skilfully create meanings together that, in turn, divide these groups from each other. Within this framework, constant negotiations, conflicts, and misunderstandings between groups happen to an extent that these groups appear to live in different 'social worlds'.

The various boundary spanning activities that we are discussing here become much less novel and extraordinary if they are understood as part of a social sphere that consists of a patchwork of communities that engage in a broad variety of practices that *routinely* span institutions. For example, in the context of discipline-spanning activities, Thompson-Klein (1996, 138) reminds us that disciplines are not only dynamic entities but also "deeply fissured sites comprised of multiple strata, and they are often influenced by other disciplines".

If segmentation and separation is the rule, how then is successful collaboration possible? The concept of social arenas was introduced to describe instances in which social worlds become coordinated across their divisions. These arenas are "composed of multiple worlds organized ecologically around issues of mutual concern and commitment to action" (Clarke and Star 2003: 113). Taking this as starting point, symbolic interactionists have described different practices that bring social worlds together in social arenas, such as 'staged intersections' (e.g., conferences in which people from different social worlds are brought together, Garrety 1998). In addition, there has been a focus on activities of standardization, (e.g., in standardized packages which tie theories and laboratory test routines together, Fujimura 1988) and systems of categorization (Bowker and Star 1994).

The most prominent of these boundary spanning concepts developed by symbolic interactionists, however, is derived from the observation that certain boundary objects allow for collaboration across social worlds and that they do so in a very specific way (Star and Griesemer 1989; Star 2010).

In her last article on the topic, written partly in reaction to the extraordinary success of the concept, Star (2010) tries to salvage some of its specificity. Boundary objects are objects defined in the widest sense, "something people [...] act toward and with" (Star 2010, 603), and can as such be material or immaterial, and are open to different interpretations. The specificity of boundary objects, thus, lies

not in their flexibility but in that they are used in a way that involves a constant back-and-forth between different limited uses and meanings related to each social world that is involved *and* more vague, ill-structured meanings and uses that are shared across these social worlds. If this back-and-forth stops, the object loses its boundary spanning function, being either owned by just one group or being too general to cater to the involved groups' "information and work requirements" (Star 2010, 602).

The uses of boundary objects

Several authors based on a broad variety of case studies have proposed amendments to the concept of boundary objects. Turnhout (2009), for instance, shows how in the case of Dutch ecological indicators, shared values and preferences were important for the boundary object to work in the way described by Star and Griesemer (1989). Lejano and Ingram (2009) in a study of policy innovations surrounding water management in the California Bay-Delta find that the boundary objects themselves contribute little to explain successes and failures in mediation. Instead they propose to focus on how new Ways of Knowing – i.e. coherent narratives – result from close social interaction of groups with different Ways of Knowing. Similarly, Macpherson and Jones (2008) found that in their case of organizational change in a medical company the boundary objects themselves were important but not sufficient mediators between different communities. According to their analysis, these objects promoted a broad variety of activities and created ambiguity, which then prepared the ground for social practices and political actions that actually produced the changes under study.

A closer look at these amendments reveals that they describe how a situation of heterogeneity – be it characterised by different views of nature (Turnhout 2009), different narratives (Lejano and Ingram 2009) or different organisational teams and their culture (Macpherson and Jones 2008) – has been resolved into a working agreement facilitated by shared values, close and frequent social interaction or power. In this sense, they are descriptions of the role of objects in collaboration and their finding that objects are important but not sufficient to explain the outcome is not surprising.

A more specific use of the concept of boundary objects would seek work arrangements in which certain objects allow productive collaboration without shared values, narratives, close social interaction or the use of power. In this context, it is useful to inscribe boundary objects in a larger field of possible ways how tensions in collaboration across social worlds are resolved - or not. Taking Galison's (1997) concept of trading zones as vantage point, Collins et al. (2007), for instance, distinguish between exchanges that are characterised by different degrees of coercion and heterogeneity. In the four sectors created by these two axes, boundary objects inhabit a 'fractionated' trading zone which shows high degrees of collaboration (i.e. a relative absence of coercion) under the condition of high heterogeneity. Collins et al. (2007) describe their model as dynamic. When degrees of coercion and homogeneity increase then boundary objects cease to exist giving way to other types of working arrangements.

Thus, the concept can be expected to shed light only on certain stable arrangements in which different social worlds meet without being transformed and which are nevertheless experienced as productive by all collaborators. Star and Griesemer's original contribution was not to describe surprising and volatile instances of such collaborations that were enabled by some magic objects, but to analyse the networks around objects that created stable 'zones of indeterminacy' (Lainer-Vos 2013) in which the worlds meet without collapsing or colliding. It is the puzzlement about the sheer

possibility of such 'zones' that has led to the description of objects that seem to contribute to how productive stability under such unlikely circumstances.

Boundary objects in a changing construction sector

Despite isolated calls for a paradigm shift that would unite the whole construction sector under one common understanding of sustainability (e.g. the programmatic statement that 'form follows function' should be replaced by 'form follows energy', see Berker and Larssæther 2016), there is little reason to believe that the various social worlds involved in construction soon will be able to collaborate seamlessly drawing on a shared repertoire of meanings and tools. The ideas and ideals attached to architecture and particularly sustainable architecture are just too different (Guy and Farmer 2001; Farmer and Guy 2010) and so are the various forms of expertise involved.

Explicitly geared towards overcoming fragmentation in the sector since the 1990s we have seen a the proliferation of new standards and standardised processes and tools that were proposed to give building research and construction a common direction towards sustainability. Rephrased in the terms introduced in the previous section, this would amount to a move from a fractionated space to a more homogeneous one in which social worlds at least partly merge. In fact, some of these proposals, most prominently the passive house principles and certification schemes like BREEAM, have been adopted widely.

However, as Müller and Berker (2010) show, the extraordinary success of passive houses far beyond the German origin has at least as much relied on their interpretative flexibility as on their standardising capacity. Analysing the emergence of BREEAM, Goulden et al. (2015) find exactly the same flexibility, which makes the certification scheme attractive for local implementation. Similar observations were made in the case of energy calculation software which implements standardised ways of modelling and predicting building energy use and which according to Zapata-Lancaster and Tweed (2016) through their flexible use enable communication within interdisciplinary design teams as well as the communication of energy performance aspects to non-experts. Even though not directly sustainability related, we see the same processes at work in Bresnens (2010) study of 'partnering', a set of contractual and practical arrangements that was proposed to overcome competition driven, rigid divisions of labour in construction.

These analyses of how the new standards and tools enable collaboration in (sustainable) construction show a large degree of ambivalence between binding capacity and interpretative flexibility that resembles more the back-and-forth between dividing specificity and uniting generality of boundary objects than a standard.

Taking up this line of thinking, in the next section we present an in-depth analysis of a transdisciplinary research centre that has as goal to move the whole sector towards even more ambitious environmental goals. Based on what was written so far we will focus on how collaboration across social worlds was enabled there.

Introducing The Norwegian Research Centre on Zero Emission Buildings (ZEB)

The Norwegian Research Centre on Zero Emission Buildings (ZEB) was one of eleven Research Centres for Environmentally Friendly Energy founded in 2009 in reaction to a broad coalition of almost all

parliamentary parties' decision to dramatically increase research funding in renewable energy. ZEB involves commercial actors from the whole construction value chain, as well as public actors and the largest building research groups in Norway. At the time of writing it has reached the last year of its eight year funding period and has received some 30 million Euro funding split between traditional research funding through the Research Council of Norway and various non-academic partners.

ZEB is clearly an example of an arena in which members of different social worlds meet 'around issues of mutual concern and a commitment to action', more specifically, the creation of "buildings that have zero emissions of greenhouse gases related to their production, operation and demolition".¹¹ With an university as its main hosting organisation (Norwegian University of Science and Technology) the ZEB centre is part of the trend towards the proliferation of links between academic research and industry (Godin and Gingras 2000).

When transdisciplinary research is categorized by the strength of its commitment to boundary spanning, the ZEB centre falls in the category which shows the highest integration. Knowledge was not only exchanged between the disciplines and between the non-academic partners and scientists; indeed, the scientists felt very much compelled to produce the problem definition together with their non-academic partners. Thus, the ZEB centre's work is best understood as a collaboration in which an epistemic arena is temporarily shared (Felt et al. 2016, 19). In the terms used by Cherney (2015), it is an integral partnership (as opposed to just addressing industry partners as formal supporters or responsive audiences) and what Turnhout et al. (2013) would call a facilitating knowledge broker (as opposed to supplying or bridging brokers). The ZEB centre's work also has all the characteristics of successful 'deep' collaboration that were described in the literature; for instance, with its long funding period (eight years) it is able to transcend short project cycles in the sense of Etzkowitz and Leydesdorff (2000, 117–8), and it is able to deepen pre-existing relations between actors from policy, industry and researchers, which are known to produce a sense of interpersonal trust (Bouty 2000; Cherney 2015).

At the time of writing, the ZEB centre, which has its headquarters in Trondheim, Norway, has just entered its final year of funding. During the first seven years of its existence it has produced 104 journal papers, 130 conference papers, 255 conference presentations, eight books, 100 reports and 139 popular science articles and media contributions authored by ca. 290 authors from different disciplines. This was enabled by some 30 million Euro funding which was split between funding provided by the Research Council of Norway and contributions from industry actors from the whole construction value chain. Collaborations between the academic and non-academic partners and between the disciplines involved (above all: building engineering, architecture, physics, chemistry, and sociology) are at the core of the centre's activities, which comprise a broad variety of arenas such as the "creation of new physical facilities, consultancy and contract research, joint research training, and meetings and conferences" (D'Este and Patel 2007: 1309).

The daily work and research structure at the ZEB is organized in work packages. Each work package employs researchers and students working. Representatives from the business partners are invited to involve themselves at least once a year when the annual research plan is circulated and presented in a common workshop. A part of the industry's funding takes the form of in-kind funding, i.e. the industry partners commit part of their work time to topics of interest for ZEB. This, however, does not mean

11 From the ZEB homepage, <http://zeb.no/index.php/about-zeb/about-the-zeb-centre>, visited 17 March 2016

that the work is co-located on a regular basis. A more common pattern of collaboration is workshops in which research topics are defined and results are discussed and disseminated. Similarly, even though the centre disposes exclusively of a physical office landscape at the university campus with some 20 work spaces, most researchers remain at their original offices and meet to monthly “lunch meetings” and coordination meetings.

Work package leaders compose the leader group of ZEB, and half of the ZEB board consists of non-academic partners. In addition, regular partner workshops are held to generate research questions, present results and discuss prevailing challenges with the ZEB participants.

One of the work packages was tasked with the development a definition of ‘zero emission building’. This work turned out to be more demanding than expected but resulted after seven years in a corpus of standardised input values and calculation methods (Fufa et al. 2016).

Despite its project-like structure, there are several similarities between the ZEB centre and other institutions that are tasked to provide a common direction for a fragmented construction sector such as the Building Research Establishment (BRE) or the Passive House Institute (PHI). There is first the unusually long funding period - eight years (with a midterm evaluation after five years) which created ample opportunity to create lasting social networks as well as following construction projects from inception to early use phase. Second, these networks and pilot buildings included extensive industry collaboration, even though its depth varied according to the partners' strategic and functional characteristics (Barbolla and Corredera 2009). And third, and probably most importantly in the context of a fragmented sector, the centre had the ambition to provide a set of standards and routines that would be useful for the whole Norwegian construction sector.

Empirical observations

Context and methods

This paper was written by two authors working as researchers within the ZEB centre. The direct outcomes of this work are documented elsewhere¹². Here, we will report specifically on three empirical studies carried out as part of the centre's self-evaluations and their outcomes as they were directly related to the exploration of the creation of shared meaning across the boundaries between the involved disciplines and the non-academic partners. First, as part of the five-year mid-term evaluation, we circulated a short questionnaire authored by the funding agency among the partners which contained questions about their preferences and experiences with the centre. Of the 21 non-academic partners of centre, two did not respond (Snøhetta, DiBK) and three did not fill out the open questions (Dupont, Isola, Nordan) analysed below. While the answers to the standardised part of the questionnaire – where the partners were for example asked to quantify their financial gain from participating in the centre - did not yield any useful results in the context of this article, the sometimes extensive answers to the open questions about the partners’ experiences and motivation turned out to be directly relevant. To explore complexes of these evaluations, we used measures for co-occurrence (with paragraphs and our codes as units of analysis). Second, around the same time, we asked the five academic work-package leaders of the centre to describe their goals and ambitions for the centre in writing and employed the same analysis strategy. Third, and as a final step, in 2014 and 2015 one of the authors of this paper interviewed 18 senior officials primarily within or related to ZEB

12 There is a searchable publication database published here: <http://zeb.no/index.php/publications>

representing the most active academic and non-academic collaborators, as well as a prominent critic of the centre's work. The interviews were based on a semi-structured interview guide and were transcribed and analysed, again using open coding. The analysis was performed comparing the answers to the same questions among all the respondents, identifying clusters of codes. After categorizing the data in this way, similarities and differences were identified both between the academic disciplines involved and between academic and non-academic partners.

	N	Year	Topics	Data	Analysis	Scope
Survey among non-academic partners	16	2013	General evaluation	Short, written statements	Open coding strategy, co-word analysis	Collaboration across the academic – non-academic social worlds
Survey among academic work package leaders	5	2013	What is important to research on and what is to be achieved with the centre's research?	Short, written statements	Open coding strategy, co-word analysis	Interdisciplinary collaboration
Interviews	18	2014/5	What does "robustness" mean for the centre's work?	Semi-structured interviews, transcribed verbatim	Open coding strategy, axial coding	Transdisciplinary collaboration

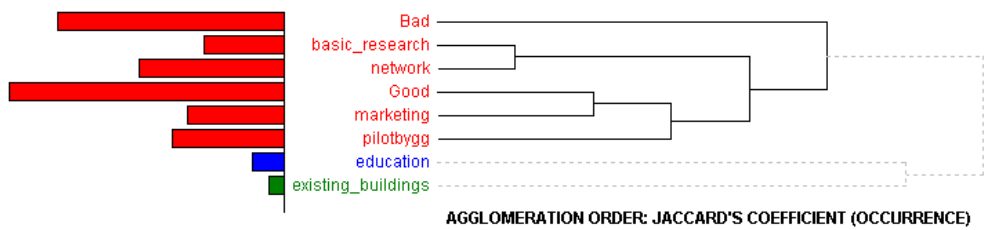
Table 1: The empirical material used in this study

One of the authors has actively contributed to parts of the data which are analysed here. This is less problematic for the survey analysis, as the analysis is based on identifying overall trends that are, moreover, based on material produced three years ago. We decided, however, to exclude his interview from the material used in the qualitative analysis.

In the next section we describe the results of the two smaller surveys. The interview study, which is presented in the following section, was based on these results.

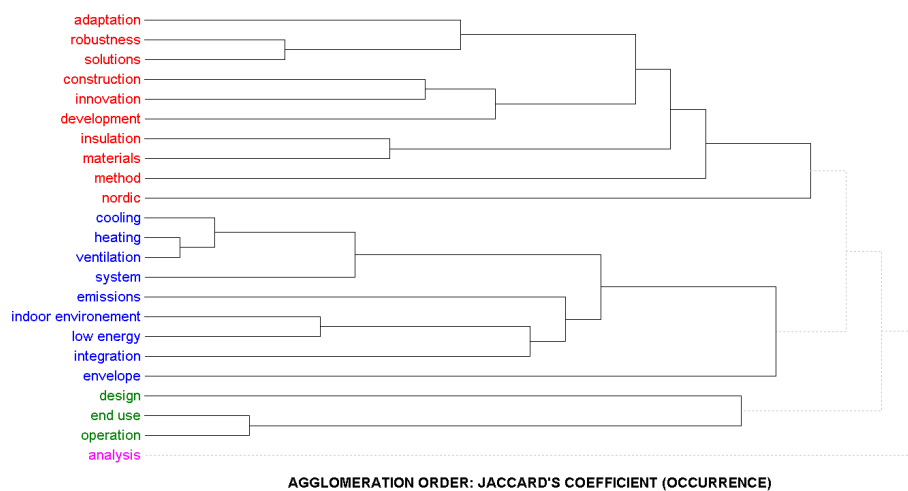
The meaning of ZEB after five years of collaboration

The statements made by non-academic partners in reaction to open questions about their positive and negative experiences with the research centre's work circled around a very limited set of issues. While negative appraisals (category "Bad") were equally related to all mentioned concerns, positive ones ("Good") were more often related to descriptions of "marketing", especially in relation to the centre's pilot buildings ("pilotbygg" in Norwegian). When basic research was mentioned as a concern, it was related to statements related to networking.



Clusters of concerns among the partners (with an indication of their relative occurrence on the left)

When the five work-package leaders were asked to describe what they wanted to see as the main outcome of the centre’s work after its completion, a very diverse picture emerged. The pilot buildings as such were hardly mentioned; instead, a broad array of concerns consisting of materials research, daily user practices, technical system integration, and building constructions was mentioned, mirroring the respective disciplinary belonging of the person answering the survey.



Clusters of concerns described by the lead researchers

In fact, only two concepts were mentioned by more than three work-package leaders: “robustness”, and that the centre should contribute with “solutions”.

The prevalence of pilot buildings in the partners’ responses clearly indicates that there is a potential for these objects to act as boundary objects, enabling the heterogeneous group of partners to collaborate across their respective social worlds. In fact, in the course of the materialization of these eight pilot buildings in Norway, they acted as locales of multiple contacts between the various centre participants, for instance in workshops held at or close to the buildings sites, official openings, and guided tours both for centre insiders and outsiders organized by the centre and research activities.

In this context it is worth noting that at the time of the particular survey answered by the researchers only a small group was actively involved in the actual design of the buildings. Later, in the course of more buildings being finished and occupied, this group was extended considerably in extensive

evaluation activities that covered technical and non-technical aspects of the buildings. Thus, we did not find the kind of demonstrations which were described by Rosental (2013) as not only a tool of persuasion but also as crucial in social negotiations between different researchers and between researchers and research managers during the development of a technology.

Mirroring the absence of explicit concern for pilot buildings in the researchers' survey responses, there was no expression of explicit concern for robust solutions among the partners while it was the only concept around which the interdisciplinary group of researchers seemed to be able to coalesce. We have no reason to believe that partners like, for example, big contractor firms or that architecture firms are *not* interested in robust solutions. Are partners taking this for granted? And can it still be an object that spans the boundaries not only between different academic disciplines but also between partners and between partners and researchers? This question was the starting point for our interviews with researchers and partners conducted in 2014/15.

'Robust solutions' as a boundary object?

The ZEB centre takes a life-cycle approach to emission accounting, including planning, transport and building materials, construction, operation of the building, maintenance and repairs, demolition and waste, as well as recycling. It builds on the Norwegian version of the German passive house standard, focusing on passive measures to be able to construct a highly energy-efficient building (Müller and Berker 2013). In addition to passive measures and a life-cycle approach, the centre builds on the idea that the renewable energy supply on or nearby the building should compensate for whatever emissions are left (Marszal et al. 2011). According to the informants, this approach introduces three sources of added fragility to a building:

1. The building has to maintain a certain degree of airtightness during its whole existence to reduce heat loss. Appropriate construction technologies and materials have to be robust against decay and possible moisture.
2. On-site or nearby renewable energy production adds a whole new group of possible failure sources and have to be designed in a robust manner.
3. With a life-cycle approach, changes during the building's existence become relevant for achieving a zero emission balance when it is demolished. The design of the building has to be robust in the sense that it is not affected by these changes.

According to the informants, a potential fourth added source of fragility is connected to increased automation in the building. These measures not only increase the energy efficiency of the building by reducing inefficiencies but also make the building more independent from occupants' actions and judgements. While the first three aspects of fragility are necessary to achieve zero emission buildings and have to be dealt with, the fourth one is a potential secondary fragility that results from attempts to minimize the overall fragility of the system by "delegating" control to machines (Latour 1992).

According to the interviews, robust means that a building is durable and can last for a long time. In addition, it must be strong to be able to withstand storms, heavy rain and extreme temperatures. Abnormal weather is expected to occur more often in the years to come because of the effects of climate change. Therefore, all buildings should be built with this in mind. Furthermore, a building and its systems should be flexible with respect to changes so that a building could be easily adapted to tenants with different requirements. Additionally, a building should be flexible or forgiving to

differences in use and perhaps “incompetent” users. In summary, according to the interviewees, robust in connection with buildings means the following:

Durability: Long-lasting.

Flexibility: Building and systems can easily be changed.

Forgivingness: Tolerates incompetent use and misuse.

Strength: Withstanding violent wind, weather and abnormal temperatures.

Asked directly about non-technical aspects of robustness, all informants, academic or not, referred to the centre’s interdisciplinary structure:

“We were very focused on technical robustness. We were hunting for solutions that would make it possible to achieve zero emission buildings. However, to get them onto the market we have to keep the other aspects of robustness in mind. We are very much engaged with technical research and we are also rather active when it comes to social aspects, users and architecture [...]” (Birte, academic informant)

This quote is representative of how all academic informants (excluding the social scientist) have described the relation between technical and non-technical robustness. The solutions first have to be technically robust. Politics, economy, and social aspects come only into consideration when the solutions enter society. Since the explicit goal of the research centre was to get zero emission buildings implemented in society, robustness as comprising technical and non-technical aspects became the boundary object that the different disciplines could work with together.

In this sense, the academics among the informants assessed robustness as a positive concept. Mirroring the findings of the survey among the non-academic partners reported above, where robustness played no role, non-academic interviewees evaluated “robustness” in a less positive manner. One of the interview objects who represented a non-academic ZEB partner even dismissed the concept as cliché:

“I would like to delete the word “robust”. For now. It has become a cliché and you cannot define what it is. When you cannot define it you should not use it.” (Zara, non-academic informant)

Other non-academic partners were less outspoken and described robustness, rather, as something that was the 'bread and butter' of their work and not as a special goal that the ZEB centre should strive to achieve.

Despite these appraisals, with few exceptions, our informants agreed that robustness implied quality and vice versa. The combination of durability, flexibility, forgivingness, and strength was then described as deriving from an overarching quality that defines a building that is well built.

Summary of empirical observations

Our report, based on three evaluations of sustained collaboration between different disciplines and across the science-society boundary, has focused on boundary objects that have facilitated collaboration. We have shown that neither of the two most promising candidates for such a meeting of social worlds, the pilot buildings and the concept of robustness, was able to span all boundaries involved in the centre’s work. The pilot buildings appeared more central for the non-academic partners. Their expressed intention to use these buildings to showcase their greenness and innovative

capacity is, indeed, potentially in conflict with the academics’ interest in research on new and by implication not quite market-ready solutions. Moreover, the corporate imperative in marketing is to implement one’s own products in the building, which in the eyes of academic or other non-academic partners may not necessarily be the best or most appropriate solution. This, in fact, has led to tensions in one pilot project (Meistad and Strand 2013).

These limitations notwithstanding, pilot buildings were a useful materialization of the ‘issues of mutual concern and the commitment to action’ that characterized the ZEB centre. As we have shown, the concept of robust solutions did more work for the collaboration across disciplinary boundaries than across the science - non-science divide. The researchers from different fields could instead agree on the goal to create something that would be durable, flexible, forgiving and strong. Compared to this, for the non-academic partners, there was no particular meaningfulness to gain from the fact that the solutions were supposed to be robust; this they took for granted, in one case even calling it a ‘cliché’.

Tools for transdisciplinary collaboration

We want to use the remainder of this paper to show how two boundary objects – the pilot buildings and robust solutions - interacted with each other and how this observation contributes to further the study and practice of transdisciplinary collaboration.

While they do their main work orchestrating different social arenas, the concept of robustness and the pilot buildings also complement each other. Researchers interested in research that produces robust solutions will be more likely to see actual buildings as valuable research objects than their more theoretically inclined colleagues. Meanwhile, non-academic partners that actually want to build zero emission buildings to signal their green competence will be more likely to rely on academic input since they have no other place to obtain the necessary knowledge to do so. And here the circle closes, since academics that actually are able (and willing) to provide robust solutions will naturally be the ones these non-academics turn to. With other words: The risk connected to innovative solution that are perceived as adding fragility to the building is mitigated by the promise that these solutions are robust. And the robustness of buildings, the ‘bread and butter’ of constructing and selling buildings provides the specific challenge that the different academic disciplines commonly relate to. In this sense, the two objects, even though they have different specific meanings within the different social worlds do work together to enable collaboration also across the academic – non-academic boundary.

	Academics	Non-academics
Pilot buildings	(Arena for evaluation of new solutions)	Marketing
	Green innovation	
Robust solutions	Common goal of interdisciplinary collaboration	(“Bread and butter”)
	A building that works in real life situations	

Table 2: Boundary objects and their meanings and uses

This finding of a reinforcing combination of a two boundary objects sheds new light on transdisciplinary collaboration.

The materialization of the common goal provided a fixed point that could be visited and revisited during the course of the centre’s lifetime. With continued engagement, abstract spaces become meaningful places (Parkes and Thrift 1979) which can still bear different meanings for their different

visitors. In our case this was specific buildings, but it could also be a river (Wesselink 2009), a habitat for an endangered species (Goldstein 2010) or an estuary (Bremer and Funtowicz 2015), to mention only a few examples.

While researchers and society both deal with abstract environmental problems, it turns out that one answer to the challenge of transdisciplinary work is to gather around a meaningful object and to commit to improving it together. In this process two zones of indeterminacy (Lainer-Vos 2013) are created, one around the object itself which means different things to the participating parties, the second one around how 'improvement' is defined. Thus, it is no problem if there is not only one but two or maybe even more boundary objects enabling collaboration across different boundaries - as long as they complement each other.

The construction industry has a bad reputation for its lack of innovation and its traditional and fragmented structure. The inherent complexity of buildings as composite infrastructures of everyday life has for a long time slowed down coordinated change in the sector. The case of zero emission buildings that was presented here as part of a larger shift towards green construction leaves a different impression. It represents a stable and productive collaboration between members inhabiting a large number of different social worlds. The more manifold the boundaries that are to be spanned, the more important the work becomes that is done by and with the help of boundary objects. In the case studied here even a working combination of multiple boundary objects was necessary.

In the case studied here we found 'a well-functioning building' combined with a commitment to 'robust solutions'. In other cases we may see some other object or commitment, depending on which 'mutual issues and commitments to action' are at the centre of each specific transdisciplinary collaboration. We expect, though, that both specific, widely visible material objects that are crafted during the collaboration and the commitment to these objects' qualities represent an important combination of boundary objects that should be considered in all kinds of transdisciplinary collaboration.

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Paper 2: The power of buildings in climate change mitigation: The case of Norway

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Abstract

Centralized power production mainly from fossil fuels is increasingly challenged by decentralized power production from renewables. This is a trend caused by the greening of the European power grid which is to be carbon neutral by 2050. As a part of this trend, the number of power-producing buildings is growing. Even in Norway, which has a highly centralized power production based on hydropower, buildings are increasingly equipped with solar power panels. The introduction of cross-sectoral innovations like power producing buildings is likely to encounter resistance, as the conventional system and its powerful actors are challenged. The strategies to either promote or block the growth of power producing buildings in Norway have been explored employing the Strategic Niche Management framework.

For this paper, 32 interviews were conducted with decision-makers and experts, both advocates and opponents of power-producing buildings. It has been found that narratives have the potential to work as a *bridging device* between the niche and the regime. If the narrative supporting power-producing buildings should become a bridging device, it would have to address challenges as defined by the regime incumbents. In Norway, this would be equivalent to addressing the challenge of peak load.

Keywords

Power-producing buildings, niche, empowerment, resistance, narratives, bridging device

Abbreviations: see footnote¹³

1. When buildings become power stations

*“Make it, dammit. It is not exactly rocket science. It demands something from the power industry, of course, but they think differently and that is probably some of the problem”.*¹⁴ Entrepreneur

Europe is greening its power system which is due to be carbon-free by 2050 (The European Climate Foundation, 2010). Buildings in Europe are responsible for about 40% of total final energy requirements and 36% of its CO₂ emissions (European Commission, 2016), and the challenges, in particular, are to increase energy efficiency and to decarbonize the power system (The European Climate Foundation, 2010). The decarbonization of the power system is part of an even larger transition towards a low-carbon society. Power-producing buildings, mainly utilizing solar power, are part of this trend towards more renewable production and also more local, small-scale production. As

¹³ EPBD - Energy Performance in Buildings Directive

NVE- The Norwegian Water Resources and Energy Directorate

RED - Renewable Energy Directive

ZEB - The Research Centre on Zero Emission Buildings

ZEN – The Research Centre on Zero Emission Neighbourhood

¹⁴ All quotes from the interviews have been translated by the author.

buildings are major energy consumers, it is a great energy potential in the building stock if less energy is used, or produced locally. Buildings tend to have a fairly predictable energy profile and in cold climates, peak power demand is related to low temperatures and household activities like for example cooking. Solar power production is low during winter which means buildings will rely on power from the grid. In addition, the development of energy efficient equipment does not necessarily focus on reducing peak load which is a main issue when optimizing the grid capacity. These are issues that are challenging to the electric utilities and add to other concerns, such as loss of income due to lower demand. Resistance is a likely reaction.

This study explores the introduction of power-producing buildings in Norway. A recent White Paper on energy (Ministry of Petroleum and Energy, 2015-2016), the first major policy document on the topic in 17 years, did not lay out any solar power policy. The solar power potential was discussed but seems to have been downplayed. At the same time, Norway's construction related policies aim at the imminent market break-through of zero energy/emission buildings – which in most cases implies local renewable energy production on the building.

1.1 The Norwegian case

Nearly all Norwegian electricity production is based on hydropower (Ministry of Petroleum and Energy, 2015), and electricity is therefore perceived as clean. However, since the late 1980s, there has been a general consensus in the Norwegian Parliament that the period of great hydropower development projects is over, due to the demands of nature conservation. Norwegian households are world-leading in their use of clean energy, as electricity – predominantly hydropower – amounts to 80% of domestic energy use, a large portion of which is used for heating (Bøeng, 2014). Since electricity is inexpensive, there is low economic motivation for energy efficiency projects and other sources of renewable energy production that struggle to compete without support schemes. However, electricity demand is increasing as electricity is replacing other and more polluting energy sources, for instance in the transport sector. Norway has the largest fleet of electric vehicles (EVs) per capita in the world, achieved through extensive use of incentives (Holtmark and Skonhoft, 2014).

The implications of the European objective to decarbonize the power sector are less obvious for Norway than to most other countries, since nearly all electricity is renewable already. The formal reasons for advocating building concepts that include power production are found in particular in two EU directives: the Renewable Energy Directive (RED) and the Energy Performance in Buildings Directive (EPBD) (The European Parliament and the Council, 2010). The EPBD is still not fully adopted into Norwegian legislation, and it is vital that the concept of 'nearly zero energy' and the 'renewable sources produced on-site or nearby' objective in the EPBD are defined in the Norwegian context. Building concepts that include power production are normally also particularly energy efficient and will therefore contribute to additional available power by using less energy. This makes it beneficial to the requirement in the RED of an increased *share* of renewable energy. Excess power could be used to electrify the sectors that are responsible for Norway's per capita CO₂ emissions that are on a par with the rest of Europe. However, the increased electrification in Norway as well as in other countries leads to increased strain to the power distribution grid.

In this context, leading actors in the building industry, supported by generous governmental R&D funding, are advocating building concepts that are power-producing entities, most notably with the use of distributed generation of solar power (photovoltaics/PVs) or in some cases local cogeneration in combined heat and power (CHP). To achieve this, the relevant concepts demand innovative solutions that are challenging to the industry, but they represent incremental rather than radical change (Slaughter, 1998). The notion of power-producing buildings is an opportunity for the building industry to contribute to climate change mitigation and at the same time position for new business domains.

Energy-generating buildings have been part of Norwegian energy and climate policy for more than a decade; they have been assisted through investment support schemes on selected technologies like heat pumps, which recently have been extended to include solar power among other technologies (Enova, 2016a). There are a few examples of investment support for buildings that generate an intermittent power surplus, such as the Powerhouse Kjørbo pilot project (Enova, 2016b). The absence of an explicit inclusion of renewable local power production in energy policy, as described above, stands in contrast to the existence of state-supported projects. There is ambivalence on the policy level towards power-producing buildings and the distributed energy production they represent. This is a common situation when new technologies are introduced (Kemp et al., 1998).

1.2 Perspective and previous research

The potential for solar power production, or lack thereof, is frequently given as an explanation as to why authorities in Norway are reluctant to advise households and other building owners and developers to invest. The allegedly limited potential is due to the geography of Norway, where it is generally colder and darker than most of Europe, and where solar power production would be highest in summer although energy needs peaks in the winter. However, any prospects for solar power are highly dependent on assumptions regarding prices of electricity, solar panels and installations, in addition to lifetime costs, solar panel efficiency, storage technology and more. According to the aforementioned White Paper (Ministry of Petroleum and Energy, 2015-2016), the calculated solar power potential is 1.5 TWh by 2020 and 3.8 TWh by 2030, if suitable roof area is utilized when buildings are erected or renovated. In relation to the total power production in Norway,¹⁵ this is rather insignificant. However, there has been substantial growth in installations on *existing* roofing in 2016,¹⁶ but existing roofing and detached production sites are not included in the calculated potential. Furthermore, even though Norway extends through 13 degrees of latitude, the majority of the population lives in eastern and southern Norway, areas that have the same solar irradiance as for example Northern Germany (Andresen, 2008). The potential is thus bigger than suggested by the government, yet how big is not known.

A payback time of between 18 and 23 years for installations in 2016 was calculated, sinking to between 8 and 15 years in 2030, disregarding any subsidies (Zaitsev et al., 2016). Depending on further development and cost reductions regarding solar panels, in the foreseeable future they could make a cost-effective contribution to the Norwegian energy system.

¹⁵ In 2015, the total power production in Norway was 145 TWh, according to Statistics Norway.

¹⁶ According to an interview with Otovo in October 2016, around 500 solar power installations on existing household roofs had either been installed or were planned to be installed during 2016.

Little research has been done on the societal implications of the transformation of the Norwegian energy system so far, with some exceptions, (e.g. (Christiansen, 2002), (Gullberg et al., 2014) and (Skjølsvold et al., 2013)). Transformation of the building sector has been studied in Nykamp as well as in Ørstavik (Nykamp, 2016, Orstavik, 2014). Studies on transformation in other national frameworks may also be relevant (e.g. (Geels et al., 2016), (Hess, 2013), (Konrad et al., 2008), (Smith et al., 2005) and (Verbong and Geels, 2010)). This article extends the literature, in particular by focusing on narratives and anti-narratives in the latter phase of the development of a niche (Raven et al., 2016). Linking the niche of power-producing buildings to a regime environment also illustrates that niche empowerment is a highly political process involving power and antagonism. The transformation of power systems is about to take place all over Europe, and issues of decentralized power production are therefore also relevant in other settings.

In this article, in order to limit the extent of the discussion to politics and strategies located within and around the niche of power-producing buildings, a boundary has been drawn around the supply side including the policy measures for implementation, thus excluding the demand-side issues, which should be given attention in a subsequent article.

The rest of the paper is structured as follows: the next section summarizes the conceptual foundations in this paper as well as the methodology. Section 3 presents empirical findings which primarily enlighten the arguments and actions by advocates and opponents of power-producing buildings. In section 4, the empirical results are analysed and discussed. This section also looks at how power-producing buildings could develop to become an essential part of the sustainable transition that lies ahead. Finally, conclusions and policy implications are drawn.

2. Conceptual framework and method

2.1 *The regime and its incumbents*

The regime concept has been cultivated in particular by Geels through the Multi-Level Perspective (e.g. in (Fuenfschilling and Truffer, 2014) (Geels and Schot, 2007, Geels, 2011, Geels, 2002)) as well as within the Strategic Niche Management framework (Schot and Geels, 2008, Raven et al., 2010, Kemp et al., 1998). A regime is understood as a dynamically stable structure consisting of actors, networks and institutions.

Regime actors have vested interests in regime preservation and can resist and block pressures to change. Hence, the implementation of a potential path-breaking innovation is typically resisted according to Geels (2014) and Hess (2014). By not only consuming but also producing power, buildings turn into *prosumers* of energy; and become at the same time a potential path-breaking innovation (Raven et al., 2016, Schot and Geels, 2008), which aims at changing the present regime through altering the selection environment (see explanation in the next subsection). In the context of this paper, path-breaking innovation refers to power producing buildings that influence the evolution of the power system.

The incumbents and their relation to the political level and other actors do not constitute *one* single regime but rather several adjacent regimes. In this case, *a part of* the building sector, together with related trade associations, policy actors, etc., could be described as the building regime. And the same

goes for the power sector: the power sector and related trade association(s) can be linked to certain actors on the policy level, and in turn, they constitute a power regime. To focus only on the building regime would give a rather one-dimensional picture, since context and interaction with the power regime would be downplayed (e.g. (Raven and Verbong, 2007, Raven and Verbong, 2009, Smith et al., 2010)).

2.2 A sustainable transition

A transition can be conceptualized as the process of moving from one stable socio-technical regime to another in such a way that the structure of the regime has fundamentally changed (Smith et al., 2010, Verbong and Geels, 2010). The changes needed for a transition to take place involve several interrelated actors, networks and institutions. Transitions are systemic by nature and therefore also hard to initiate and manage. Distributed energy production is part of a large-scale transformation that is referred to as *socio-technical* since the changes that are needed will not only imply changes of a technological character but also changes in policy, markets, user practices and cultural meanings (Geels, 2004) (Unruh, 2000).

Transition theory is developed from evolutionary economics and constructivism, which means there is focus on variety, selection and retention but also emphasizes that the selection environment is wider than users and markets (Geels, 2002, Geels, 2010, Rip and Kemp, 1998). A selection environment consists of several features of the regime, such as industry structures, markets and dominant practices, the established knowledge base, dominant technologies and infrastructures, cultural significance and public policies and political power (Smith and Raven, 2012). Changes in the selection environment can destabilize a present regime and make the introduction of a niche innovation more or less successful.

2.3 Niche innovation

Solutions like power-producing buildings that might challenge the power regime and its incumbents are often developed in *niches*, which are outsiders or sites where innovations can be nurtured and mature (Kemp et al., 1998, Smith and Raven, 2012). According to Kemp et al. (ibid. 1998 p 186), “niches are platforms of interaction; they emerge out of a process of interaction shaped by many actors”. Successful niche innovation is dependent upon a balance between protection and exposure to the selection environment (Smith and Raven, 2012). The development of the power-producing building niche and consequent interaction with the regime(s) will be discussed within the framework of niche protection as presented by Smith and Raven (2012), among others.

Niche protection

Niche protection is broken down into three components: shielding, nurturing and empowerment. Shielding is defined as “processes that hold at bay certain selection pressures from mainstream selection environments” (ibid. p 1027). Nurturing refers to processes that supports technology development within the niche (Boon et al., 2014). It implies interacting processes that focus on learning, networking and the articulation of technological expectations (Raven et al., 2016). The least developed of the protection strategies, according to researchers, (e.g. (Smith and Raven, 2012) and (Raven et al., 2016)), is how niche empowerment is working and complementing the other strategies.

Empowerment strategies are working at changing the selection environment to make it easier for the niche to enter the regime.

Niche management

The empowerment of protective spaces can be achieved in two ways, according to Smith and Raven (2012): firstly, the niche can be developed so that it fits into and conforms to a moderately changed selection environment. This is referred to as *fit and conform* empowerment. Alternatively, empowerment can imply that the niche itself is able to change its selection environment, rather than be subordinated by it. Such empowerment is referred to as *stretch and transform*. The process of empowerment will be decisive as change will be resisted. This resistance materializes in different forms of power exercise, described by e.g. Geels (2014).

Niche protection strategies could be inwards as well as outwards looking (Smith et al., 2014). By looking inwards, it is oriented more towards knowledge creation and networking. Alignment of experiments in a research centre could be another example. When facing the broader selection environment in the latter stage of niche protection, outward looking processes involve actors in for example lobbying and narrative work. According to Smith et al. (ibid.), outward-oriented narratives are used to expand the space for niche development and their associated socio-technical configurations. The narrative work of niche advocates also involves the countering of anti-narratives, as will be illustrated in section 3.

Based on this literature, the research questions can be drawn. In this paper, the interaction between niche advocates and niche opponents will be studied in the case of power-producing buildings. Consequently, the analytical questions that will guide the discussion are: **What niche empowerment strategies – and counterstrategies – are implemented in the case of power-producing buildings? How can the policy ambivalence regarding such buildings be understood given the narratives that are established? And in what way could narratives function as a bridging device in this context?**

2.4 Method

The empirical material was collected through 32 qualitative interviews with expert representatives. The experts were from the building sector (five from the private and five from the public sector); the power sector (three); trade associations (six); one environmental organization; academia and research institutions (four); and the policy level, including central authorities (eight). Their roles were as advisors or senior advisors (12), leaders ranging from project leaders to managing directors (17), and academic staff in research/academia (three). Since Norway is a relatively small country, the size of the community with knowledge and an understanding of the impact on the development of power-producing buildings is limited and transparent. It could be described as a close community which, according to Guy and Shove, permits interaction across disciplinary and sectoral boundaries (Guy and Shove, 2000).

Interviewees were chosen because of their knowledge of, experience with or their position regarding power-producing buildings. From the building and the power sector, the interviewees had knowledge of or, more commonly, experience from relevant projects. At the policy level and within the trade

associations, most interviewees had positions with a high influence on policymaking and/or implementation regarding power-producing buildings.

The qualitative method is preferred when there is insignificant research-based knowledge on the area in focus (Kvale and Brinkmann, 2009). It allows the researcher to adapt to new knowledge and encourage thick descriptions. Experts are chosen as interviewees, as the research focus is not part of general knowledge and few people have any experience with the problem to be addressed (Littig, 2009). At first, the selection strategy was to include experts from the building regime to do a system analysis of zero emission buildings. However, once the interviewing had started, power and resistance became evident as major obstacles to the wider diffusion of power-producing buildings. This led to a shift in focus where actors from the power sector were included. The interviewing continued until new arguments ceased, following the principle of saturation (Mason, 2010).

The interviews were based on a semi-structured interview guide, which was slightly adjusted during the process. The political nature of the topic favoured a situation where open-ended questions were required. Each interview lasted approximately one hour and was transcribed with the exception of two shorter interviews (lasting about 30 minutes each) that had a more supportive character. The respondents did not, in general, seem to take any notice of the recording of the interview, although in one particular interview the respondent made it clear that recording would alter their responses. In this case, we made a deal to turn off the recording after the main part of the interview and the dialogue continued thereafter. Both the recorded and unrecorded parts of the interview are included in the empirical material. In general, the policy level seems more concerned about the prospect of being quoted on politically sensitive questions. Because of this, most quotes in this paper are anonymized. After the interviews were transcribed, they were analysed using open-ended coding focused on finding patterns within or across the regimes (Corbin and Strauss, 2014).

3. Strategies of niche empowerment

In line with the conceptual framework presented in the previous section, the introduction of a potentially path-breaking niche will induce resistance from the power regime incumbents. This section studies which niche protection strategies are chosen in the latter stage of the niche development. It is evident from the interviews that representations of the same reality result in different narratives which can be used to make the public oppose or be in favour of a particular development. The material elaborated upon in this section is mainly drawn from the interviews. However, in particular the anti-narrative finds support in policy documents. This is unsurprising as the power sector is of major significance to the Norwegian economy. The supporting versus blocking narrative to respectively advance or hinder niche development is explored and illustrated in the following sections.

3.1 Supporting narrative

The role of buildings in climate change mitigation is generally accepted. However, as will be illustrated, this standpoint is mainly confined to energy efficiency measures and, to some degree, also the reduction of embodied energy, i.e. energy used in the process of producing materials. Power production on the building site is less commonly advocated in its own right, but is instead seen as part

of an overarching narrative of Norway's role in a future European power system mainly shared by the proponents of the niche.

When exploring the narrative in favour of power-producing buildings, the most prominent arguments are the *alternative use* argument and arguments that portray the building sector as clever and solution-oriented, whereas opponents are seen as primarily protecting their own business interests.

Emissions are global, and Norway has a responsibility to contribute to reducing emissions. Energy that is saved or produced in buildings could be used for alternative purposes and thereby contribute to much larger emission-saving potential than in the building itself. Alternative uses could, for example, be in the transport sector, industry or for export. This argument focusses on the global effect of emissions. Households in Norway allegedly only contribute 1.4% of domestic emissions (Ministry of Petroleum and Energy, 2015-2016). This is due to the extensive use of electricity from hydropower, which is regarded as emission-free, and the narrow focus on the *operational* phase of the building. However, saving or producing power in buildings gives the opportunity to reduce emissions in other sectors, as illustrated by these quotes:

"I think it is a bit strange: the world is not exactly overflowing in clean energy ... It seems odd that we can waste it; why should we not be able to share this energy with others? You need not save much energy in the building sector to be able to electrify the whole transport sector". Trade association 2

"You can export power in two ways: either by cable or by aluminium, to put it simply".
Academia/research 1

These quotes illustrate that indirect effects are seen as an important motivation for the building sector to participate in the sustainable transition. As the building sector uses 23% of the domestic end use of energy (Ministry of Petroleum and Energy, 2015-2016), the potential is significant, and it would be even greater if all buildings produced their own energy.

Another aspect of the supporting narrative focusses on the ability to build these concepts. The building industry has demonstrated that it is possible to build power-producing buildings, and that it is in fact not particularly difficult:

"Technically, we are able to make such buildings. ... And if you look at Powerhouse, a zero emission building by definition, it was not particularly challenging. And we are getting more and more solutions, and prices are going down. If we know where we are going, the achievement is technically obtainable".
Trade association 3

Innovative building concepts like power-producing buildings represent a challenge to the building industry, but the innovation that is needed is incremental and does not threaten to alter the structures of the industry. However, excess power needs to be stored or exchanged. Some actors argue that barriers to power exchange are exaggerated, and they expressed a suspicion that the alleged difficulties were due to business interests, as this quote illustrates:

"It is exaggerated and mostly nonsense. Norway has a well-developed power grid; we can do it. Germany has a much more challenging system. I think it is ridiculous that people are pointing at this as

a problem in Norway. Thermal energy is much more complicated to exchange, but power, dear me! It should just have been done. I think this reluctance is due to business interests; they [a specific company in the power sector] said that they were terrified of small power producers". Academia/research 2

This demonstrates that the niche opponents are assigned protectionist motives by the niche advocates, and this is viewed as the primary reason why power-producing buildings are problematized.

3.2 Anti-narrative

The supporting narrative is countered by an anti-narrative which aims to block the niche development. How do the opponents of power-producing buildings express their doubts?

The anti-narrative lies close to the official energy policy in Norway. However, here the ambivalence becomes visible as there are both state-supported projects and absence of a vision that includes power producing buildings. The most prominent arguments against the niche are that electricity supply is already clean and abundant, and that the notion of power-producing buildings is not an answer to the challenges that the power system is facing. Opponents argue that the existing electricity supply is abundant and cost-efficient, whereas distributed power production is the opposite. The current power system simply possesses superior qualities compared to the alternative technologies. Neither power-producing buildings nor solar power is currently part of any national policy. Many respondents were puzzled by the prospect of a future with a substantial number of power-producing buildings as it is more costly and the grid can offer cleaner energy as well:

"If you build new Norwegian hydropower, this accounts for 6 g/kWh [CO₂ equivalents]. Is it better to build solar power on the building that counts for between 40 and 70 g/kWh than building hydropower that counts for 6 g/kWh?" Trade association 1

These numbers have been confirmed by several studies. Furthermore, the interviewee expressed some frustration about how the building sector interprets emissions calculations from buildings:

"My experience is that the building sector does not take seriously that it is actually a framework that regulates emissions from production. It doesn't matter to them; they don't care. They make their own regulations. But I think we have a duty to contribute to the achievement of national emission targets". Trade association 1

Interestingly, this actor focusses on 'national emission targets', whereas the building sector focusses on 'international emission targets'. This suggests that these targets are contradictory or open to interpretation.

Under the anti-narrative, it is also argued that power-producing buildings are not contributing to alleviating the (some might say principal) challenge of securing the supply of electricity by reducing the peak power demand from these buildings. Rather, they create new challenges, for example by producing power mainly in periods when demand is low. The risk of blackouts is typically a wintertime problem, related to low temperatures and patterns of behaviour (Ministry of Petroleum and Energy, 2012). The focus on reduction of energy use has led to the invention of new products, for example on-

demand water heaters, typically coinciding with user patterns in general. This reduces the overall energy use but increases the peak power demand:

“Some of these energy efficient solutions require relatively a lot of power. The power peaks are not reduced as a consequence of these buildings with a low energy need”. Policymaker 1

In addition to these arguments, the overall solar power potential is portrayed as minor:

“It will take much to give a significant contribution to the energy supply in Norway. It takes a lot of roofs, and the contribution is largely restricted to the summertime”. Policymaker 2

How to get rid of surplus energy is also a challenge, both selling it back to the grid company and selling it to a neighbouring building, as is uncompetitive battery technology. Delivering to one’s next-door neighbour is problematic, because building a grid is the responsibility of the grid monopolist. Neighbourhoods are areas where several buildings or constructions can be seen in relation to one another and are planned as such. When establishing infrastructure to distribute energy between buildings/constructions, it is referred to as a microgrid. The Norwegian Water Resources and Energy Directorate (NVE) explains why microgrids are undesirable:

“In NVE’s opinion, it is most serviceable if everyone has access to the [power] market by having a choice from whom to buy power. Therefore, it is not, as of today, permitted to establish a grid in a neighbourhood and instruct customers to buy from the owner of this grid. We think it is right that the customer is attached to a neutral grid company and can choose [a] power company freely. The grid company should own the grid and supply everyone. If a building owner wants to sell to the neighbour building he quickly becomes a monopolist”. (NVE Fladen, 2016)

Among other things, the responsibility of NVE is to ensure an efficient power trade and a cost-efficient power system (NVE, 2016). As the present system functions well, there is no incentive to insert measures that could alter the very foundations of the system. As a regulator, NVE possesses great jurisdictional power. This power is working at present against the introduction of power-producing buildings, and illustrates how the anti-narrative coincides with national policy. However, not all respondents thought it necessary to uphold the current system, and the idea of self-sufficient areas was brought up:

“In Norway, many grid companies would be willing to pay for customers to go off-grid. Not within the city, of course, but the area need not be very sparsely populated before it becomes expensive to operate a grid.” Power company

The last quote illuminates an important point: the grid’s customers pay for the service of a power cable to their door. If buildings produce their own power, without going off-grid, there will be fewer consumers to share the cost of further grid development and maintenance. This indicates that a shift in demand caused by, for example, distributed power production and more energy efficient buildings could be expected to have a large effect on the income of the grid companies. This could lead to a potential restructuring of the business, and hence the development is met with resistance.

The next subsection explores how politics affect the protective space dynamics.

3.3 Politics in protective space dynamics

The niche actors perform their niche understanding by not only forming alliances and networks, but also by developing narratives which could be an effective measure in political work to increase (or decrease) support for a specific niche (Raven et al., 2016). The supporting narrative presented in section 3.1 was arguing that saved or produced energy has an alternative use. This argument has a logic that is nevertheless contested by representatives from national authorities, as in the case of this interviewee:

“We cannot say that saving 1 TWh can be used in the transport sector or another sector, because it is not our area of responsibility. In the public sector, we are careful not to interfere with each other’s responsibility”. Policymaker 3

Other interviewees belonging to the policy level marginalized the alternative use argument as political rhetoric. Since this is the preferred argument of the niche proponents, it punctuates the debate before it has even started. In the interviews, niche advocates stated that they have to interpret the direction of the development in the building sector largely by themselves:

“The building industry has shown, for a long time, that the industry itself has been leading the development, ahead of the authorities, for example by developing BREEAM-NOR¹⁷ and such things. It is always the industry, at least the cleverest part of it, that is pushing the development, rather than the authorities”. Trade association 4

The niche proponents claim to take climate change seriously by showing what is possible, thereby pushing the limits for building codes and regulations. One of the interviewees argued that the authorities and the power industry simply do not want more energy efficient buildings because of their vested interests:

“The building sector is working every day to increase the focus on energy efficiency in buildings, but the Ministry of Petroleum and Energy and the Ministry of Finance are not very fond of us because of that. ... It is difficult to increase the focus on energy efficiency in buildings ... [as] the energy industry is not very interested in energy saving”. Trade association 2

This reinforces the assumption that policymakers are in favour of the anti-narrative. The lack of enthusiasm regarding largely uncontroversial energy efficiency measures was explained by some of the interviewees as being due to the interdependencies between the power sector and the authorities. The power sector is closely connected to the public authorities in several ways, not least because of the revenues it generates and ploughs back to its public owners. There is a lack of autonomy between the power sector and government authorities which, according to Hess (Hess, 2013), makes it difficult to resist attempts by the incumbents to block a transition or the introduction of a particular innovation.

¹⁷ A Norwegian green label certificate which builds on the British label BREEAM.

3.4 The niche development process

The niche development process has been fragmented and suffered from the lack of a common thread. Although buildings have been energy producers for some time, there is reluctance among the authorities to institutionalize power producing buildings. Narratives in line with the anti-narrative have worked to downplay the potential of the niche over many years, and these conceptualisations of reality are deeply entrenched in society. However, authorities are responsive of pressure from the increasing number of such buildings as well as the improvement of the technology itself, among other things. Knowledge and learning have accumulated in particular through a research centre on zero emission buildings (ZEB) established in 2009. The recent establishment of a research centre on zero emission neighbourhoods (ZEN) as well as public support schemes launched by the state-owned enterprise Enova are indications of a more receptive selection environment. As is common when new technologies are introduced, contradicting forces appear to be present, and this results in an ambivalent policy. Strategies have nevertheless shifted from emphasis on inward-oriented strategies towards more outward-oriented but conflicting strategies offering competing views about the niche.

On the whole, within the interviews, representatives from the building regime advocate the supporting narrative, whereas interviewees belonging to the power regime advocate the anti-narrative. The success of the niche is affected by the ability to form a narrative that is in line with assessment criteria used by the public authorities. It is worth noting that the anti-narrative is part of the current national energy policy. This makes it even more resilient and harder to challenge. Being able to link the niche to a broader socio-political agenda seems imperative for the niche to succeed (Raven et al., 2016). So far, the niche advocates have not succeeded in getting acceptance for their narrative, although strategies that align to (fit and conform) national policies have been seen, for example with the support for the electrification of the transport sector. This is clearly also in accordance with the alternative use argument. However, linking the narrative in favour of power producing buildings to the challenge of peak power demand is likely to be a more efficient strategy.

This section has dealt with strategies of niche empowerment, when the niche is increasingly exposed to its selection environment. This has been highlighted by drawing from interviews with actors representing both niche advocates and niche opponents.

4. Not simply a question of implementation

The previous section presented empirical findings that illustrate how niche protection materializes and that niche empowerment is in fact a highly political process. In this section, the findings are analysed further to comprehend the policy ambivalence regarding power-producing buildings. Additionally, how could narratives function as bridging devices in this context?

When introducing a niche that also could be a path-breaking innovation, its spread is not merely a question of users and markets, but a wider selection environment must be taken into account. The forms of power and resistance towards power-producing buildings materialize in different ways, and narratives and anti-narratives are formed as part of the discourse. The niche-supporting narrative could become a bridging device between the niche and the regime if addressing challenges as defined by the regime. Generally, fit and conform strategies have a larger chance of succeeding than stretch

and transform strategies, although a combination has proven to be even more successful (Raven et al., 2016).

4.1 The materialization of power and resistance

As evidenced for example by the financial support provided for the installation of heat pumps in Norwegian households, energy-producing buildings have been part of Norwegian policy for many years. Within the theoretical framework described above, niche development is part of a socio-technical transformation that is affected by protected space dynamics through the global context, networks and alliances, technological and market development and more. There are different strategies of protection through the development process of a niche. Friction arises when the shielding is removed and the niche faces the selection environment. This often results in the exercising of different forms of power and resistance which materializes in a number of ways, for example through narratives and lobbying. Even if outward-oriented activities are growing, inwards-oriented activities are still needed, as experiments and knowledge creation have to be acquired in the actual environment. This socio-political process that aims to create a productive relationship between niche- and regime-processes could be described as a negotiation. However, it is an uneven one, as the niche opponents have access to more forms of power compared to the niche advocates. Actors on both sides reveal a lack of trust in one another and a suspicion that the opposing party is merely interested in protecting its business. Both are claiming to advocate sustainable solutions through narratives. According to Smith and Raven (2012), the existence of different narratives is expected when a niche emerges from its protected space, because institutions are weak or there might also be institutional void.

The regime which is challenged resists change, not only by producing anti-narratives but also by using its institutional power to hamper the development of power-producing buildings, for example through legislation. In addition, it downplays the potential and basically every other aspect of the niche in the arenas that are available. For instance, as seen in the White Paper on energy (Ministry of Petroleum and Energy, 2015-2016), the calculation of the potential for solar power production selectively chose not to include existing roofing or detached production sites.

The development of power-producing buildings could take place without any support from the government and largely be driven by a rising demand side due to environmental concerns and new actors seeing business potential. For the time being, the incumbents in the power industry seem to be awaiting the development. The advantage of being first is not clear, and a “waiting game” begins (Parandian et al., 2012), which is the main danger in the situation described as follows: the extension of renewable energy production becomes part of the waiting game.

4.2 Narratives as bridging devices

Although ambivalent policy is rather normal in connection to the development of new technologies (Kemp et al., 1998), ambivalent policy is nevertheless an important barrier. However, when challenging a stable regime, ambivalent policy could also be interpreted as an outcome of policies that are supporting the niche development. This gives a window of opportunity in which the selection environment could be altered to be more receptive to the niche.

Government, firms and other actors tend to form alliances due to interdependencies (Geels, 2014), but firms and industries depend on government to provide a favourable environment for development. Government possesses a power superior to the other actors, although it is not omnipotent. Ambivalent policy could be harmful in several ways. The development of less favourable solutions is one consequence. The insecurity upheld by ambivalence in policies leads to reluctant approximation, and opportunities can be spoiled. In order to reduce the ambiguity, this subsection explores whether narratives could bridge the distance between the regime and the niche, and, if so, how?

The nurturing and empowering activities by both regime and niche actors can be interpreted as a possibility for niche growth. As long as the regime is not using its institutional power to completely block the niche, it is possible that it will prosper, even if regime actors do not seem thrilled. One development favourable to niche growth was the recent public support for the research centre ZEN which demands that niche advocates and opponents negotiate further development of the niche in close interaction. Another development is the extensive discussion of solar power in the much referred to White Paper on energy (Ministry of Petroleum and Energy, 2015-2016). Even if the calculation downplayed the potential and no strategy was laid out, the solar power potential was discussed in detail. Hence, solar power and thereby power producing buildings are about to be taken seriously.

The supporting narrative is backed by these recent developments as well as indirectly through the support for electric vehicles. Raven et al. (2016) suggest that if a narrative succeeds in framing the developing technologies as solutions to specific regime challenges, it has a greater chance of succeeding. Following this logic, niche proponents should be more focused on the role of buildings in alleviating the risk of blackouts, which is a primary concern for the authorities. If power-producing buildings could represent a solution to problems as defined by incumbents, this could result in regime actors embracing the niche instead of resisting it. In this way, the narrative could function as a bridging device.

One development that would render powerless several objections to power-producing buildings would be if there was a competitive battery technology to handle the surplus energy. This might be the situation in the near future, but it is not yet. Storage technology, in particular batteries, has improved immensely over the last few years (Norwegian Climate Foundation, 2015). Batteries are available, and costs are likely to decrease. Also, the market diffusion of electric vehicles offers a potential battery for the building. Competitive battery technology is apparently reducing the conflict as buildings can produce and use their own energy as they like. Yet, if this were to become a widespread solution, it would very likely threaten the income structure of in particular the grid companies. We would therefore see the need to reorganize not only the structure of the business, but also the income basis. As part of the niche narrative, the prospects of competitive battery solutions should therefore be framed as a possibility to reduce power peaks, which is perceived as a challenge to the power regime. In this way, the narrative could be bridging the interests of the regime actors and the niche proponents.

The extensive national and partly international power grids have been immensely important to the development of the industrialized world. Despite this successful project, or rather in addition to its

further expansion, an increased focus on microgrids in the coming decades seems likely. Driven by environmental concerns and/or EU regulations, distributed power production is of growing significance to the total power production. The aforementioned support for the ZEN research centre is a signal that further development of microgrids will be explored. This is reinforced by financial incentives supporting conceptual development plans for areas. This could also be framed as areas that could be more or less self-sufficient and thus also contribute to reduced power peaks as well as reducing strain on further development and maintenance of the electricity grid.

5. Conclusion and policy implications

Power-producing buildings could be seen as a path-breaking innovation and be described as a *niche*. In this paper, niche protection strategies – and counterstrategies – in the latter stage of a niche development have been explored. Government policy is ambivalent towards the niche, and its proponents and opponents have developed different narratives to persuade the ‘public’ about the (dis)advantages of the niche. Largely, the narratives are developed from the interviews. However, the anti-narrative finds resonance in policy documents as the power regime partly overlaps the policymakers. Finally, the paper explored in what way the supporting narrative could function as a bridging device between the regime and the niche.

The power of buildings in climate change mitigation is disputed in Norway, mainly due to the clean and abundant supply of hydropower. Yet, building concepts that result in intermittent surplus of distributed power production are developed mainly with a reference to environmental concerns. These power-producing buildings represent a potentially path-breaking niche that can take on different strategies in the development process. In this paper, the latter part of niche development has been studied where the shielding of the niche is removed, and it becomes exposed to a wider selection environment. Actors backing the niche are developing strategies to enable the niche to break through by advocating the advantages of the niche through a supporting narrative, network building and other empowerment activities, whereas niche opponents are developing counterstrategies like anti-narratives (Boon et al., 2014).

The supporting narrative portrays power-producing buildings as a measure that could cut emissions, in particular if the power produced were used to reduce emissions from the transport sector, industry or for export. In addition, power-producing buildings are not very difficult to build.

The anti-narrative stresses the superior qualities of the current power system and emphasizes that there are virtually no emissions from the building sector. Furthermore, the niche opponents argue that power-producing buildings do not alleviate the principal problem which is to reduce peak power demand; rather, they only create more.

Ambivalent policies are common in connection to new technology developments, and they could be interpreted as an outcome of policies that support niche innovation that depart from the stable regime structure. It is nevertheless important for the pace and direction of the development that policies become unified. Ambivalent policies create insecurity, and action may be delayed or misguided. The sectoral responsibility in politics is likely to contribute to the ambiguity as different ministries have separate areas and are careful not to interfere with the responsibility of others. This

makes it even more challenging for a niche that crosses different regimes and therefore relies upon actors with divergent interests to unite.

However, there is a possibility that the supporting narrative could function as a bridging device between the power producing niche and the power regime, in particular. As suggested by Raven (2016), the possibility for this would increase if the supporting narrative addressed problems perceived by the niche opponents – primarily actors within the power regime. If the narrative were able to bridge the differences, the niche would have a greater chance to grow. For clarification; if the supporting narrative embraced one or more of these arguments, it could work as a bridging device:

- If battery technology improves, this would limit the objections concerning production and deliverance in a period of low power demand (mainly summertime). Buildings could store power for their own use but would probably still need to be connected to the grid. The reduction in power demand that this would cause is likely to alter the income structure of the grid companies. However, as a result of competitive battery technology, peak power could be reduced.
- The return to the microgrid is a trend caused by the decarbonization of the power sector in many regions of the world, including in the EU. This is adding to the pressure of the power-producing building niche due to rapid development in solar power technology and reduced prices. If microgrids were accepted, this could reduce the development costs of the grid infrastructure at large. In places with very few people, self-sufficient areas could be erected. Microgrids would also contribute to reducing the power peaks.
- Solutions and products should not only focus on the overall energy use, but also on reducing peak load.

These arguments would be in line with the challenges as defined by the power regime incumbents, which make them more likely to succeed as bridging devices between the niche and the regime. However, if demand for solar power panels rose sharply due to environmental concerns or the development of more cost-efficient products, this could be a challenging situation. It would call for a change of the ‘rules of the game’ and could therefore be described as a *stretch and transform* strategy. According to Raven (2016), research indicates that a combination of both fit and conform and stretch and transform strategies would have the most empowering effect on the niche.

The ambivalent policy regarding power-producing buildings could be sustained by an unsuccessful narrative that has not been sufficiently convincing about the benefits of the niche. To gain acceptance, the narrative should target challenges as perceived by the regime. In doing so, it could work as a bridging device between the niche and the regime.

5.1 Policy implications and suggestions for further research

Niche actors promoting power-producing building concepts have underestimated the need to work on a convincing narrative. Being a potential bridging device, narratives are of political significance. The interplay between narratives and anti-narratives has not been widely researched and could be further investigated.

Grid companies would likely be willing to pay for areas to go off-grid in the future because it is expensive to develop and maintain a well-functioning grid in a sparsely populated country like Norway.

This requires increased research on zero energy neighbourhoods that could be self-sufficient. Another possible implication of power-producing buildings is that energy will be paid per kW instead of per kWh. The implications of this development should be further researched.

The demand-side issues connected to power-producing buildings have not been explored in this paper. This should be done in a subsequent paper, for example by exploring the motivation to invest in solar panels among the population of more than 500 households that have already installed or have concrete plans to install such equipment.

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Paper 3: Challenging the status quo: business models as a force of sustainable transition

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Abstract

This paper analyse the dynamics of green business models in the interface between the building and the power sectors of Norway. Unsustainability and instability in society may be interpreted as business opportunities that could ultimately lead to a transition. The increased focus on business models indicates a belief in systemic approaches as a way of anticipating and possibly guiding this transition. Three business models have been analysed to assess their potential contribution to a sustainable transition. It is found that business models are influenced by landscape pressures, even without intermediation at the regime level. Furthermore, it is found that in terms of commercialization, closeness to the regime is a significant factor. However, for a transition to take place, business models are dependent on institutional development and interaction.

Keywords: Business model, innovation, sustainable transition, building sector, power sector

Abbreviations¹⁸

1. Introduction

Unsustainable business practices do not change by accident, but as a part of conscious leadership, placing sustainable innovation at the core of the organizations' business models (Schaltegger et al., 2016). To achieve such inclusion, it is worth understanding what drives business model innovation and what the most promising models look like. Often, the motivation to orient towards sustainable market transition is to gain a competitive advantage as a frontrunner (Loorbach and Wijsman, 2013). Societal transitions can create opportunities for businesses, but businesses can also bring about sustainable change by embracing sustainability in their innovation targets.

In this article, three green business models (BMs) that represent solutions to a broad range of challenges in the interface between the building sector and the power sector in Norway are presented and analysed. The key question is whether BMs can significantly alter the markets in which they intervene, and in this respect, be a force of sustainable transition. The implementation of Energy Performance Contracting (EPC) is examined, along with its prospects for changing the energy-efficiency market. Furthermore, leasing of solar panels (LSP) has emerged as a rapidly growing business area, with new as well as established actors entering the market. Distributed energy production is part of an international trend that is linked to the greening of the power sector

¹⁸ AF: AF Energi & Miljøteknikk

AGR: The Aggregator Role

BM: Business Model

EPC: Energy Performance Contracting

GHG: Greenhouse Gas

LSP: Leasing of Solar Panels

NVE: Norwegian Water Resources and Energy Directorate

TIS: Technological Innovation System

TM: Transition Management

(European Climate Foundation, 2011). The third BM described in this paper is referred to as the aggregator role (AGR). New technologies increase the possibility of utilizing demand-side flexibility, which can reduce the need to reinforce the distribution grid.

Norway has adopted the same emissions reduction goals as the EU (Norwegian Ministry of Climate and Environment, 2015). Therefore, Norway's challenges and strategies for alleviating the consequences of climate change will be comparable to those of other countries. However, the energy system in Norway is different from most other countries. In addition to being a major oil and gas exporter, Norway has hydropower generation that covers nearly all its domestic electricity use. Since electricity is cheap and regarded as clean, electricity is used for purposes such as heating – where thermal energy could otherwise have been used. In line with development elsewhere in Europe, Norwegian society is increasingly electrified as a part of a greenhouse gas (GHG) abatement strategy (NVE, 2016). A compelling example from Norway is the ongoing electrification of the transport sector (Ryghaug and Toftaker, 2016) (Holtmark and Skonhoft, 2014). Until recently, there has been a cross-political agreement to preserve water systems from new hydropower developments in the interests of conservation of nature. This contributes to increased strains on the grid and encourages the development of new BMs.

Development of green BMs concerns firms and innovators all over the world. The evaluation of how these BMs work and what prospects they have to be significant in the forthcoming green transition is crucial not only for the businesses – that might be in it mainly for the profit – but even more so for the society as a whole and in particular for policymakers that possess power to influence the external conditions, including the institutional frameworks, that allow a BM to prosper. To elaborate policy-relevant issues and potential solutions, a transition management framework supplements the BM theory in the analyses of the three case studies. This article investigates whether BMs could be a transformative force in the forthcoming low-carbon transition. This article also asks, in what way could the transition management framework complement the BM theory when assessing BMs?

2. Theoretical approach

The way in which an invention finds its way to the market is little explored and even less so in connection to the field of sustainable innovation (see (Teece, 2006), (Chesbrough, 2007) and (Schaltegger et al., 2016)). In recent years, several studies have linked BMs to socio-technical innovations, e.g. (Wainstein and Bumpus, 2016, Bolton and Hannon, 2016, Bidmon and Knab, 2014). Some studies have also linked BMs to transition management theory, e.g. Loorbach and Rotmans (2010) and Loorbach and Wijsman (2013). However, within the Norwegian context, there has been little research on this topic so far. Some exceptions are the study of success factors of EPC (Nord and Sjøthun, 2014) and the overview of EPC in the Nordic Countries (Lindseth, 2016) as well as a recent thesis on demand-side flexibility (Ottesen, 2017), which analyse two of the current BMs without directly bringing in the issue of sustainable transitions.

In this section, the conceptual framework is outlined and related to the case studies.

2.1 *Business model theory*

Although the concept of business models is old, it is only recently that it has been widely researched by academia (Gronum et al., 2016). There are still a number of definitions of a BM, and there is a need to distinguish it from other business-related concepts like, for example, strategy. According to Casadesus-Masanell and Ricart (2010), "An organization's business model is the reflection of its

realized strategy” p 205. A green BM adds another perspective: in addition to generating value that customers are willing to pay for (or perhaps as a part thereof), the product or services provided are “green”, or less harmful to the environment than the alternative. The EPC BM is green due to its energy use reduction approach. The LSP BM is green since it contributes to the production of renewable energy and the AGR BM is green since exploiting demand-side flexibility helps to offset investments in grid infrastructure.

Inertia to the development of new BMs has been cited as a reason why established firms are suddenly facing serious challenges. An example of this is the challenges faced by the large energy companies due to the German “sun energy revolution”, or what Germans call “die Energiewende” (see, for example, (Wainstein and Bumpus, 2016) and (Richter, 2013)). BMs have gradually been recognized as a source of market disruption, irrespective of the underlying product (Chesbrough, 2010, Teece, 2010). Furthermore, Boons and Lüdeke-Freund (2013) point at business models as a source of competitive advantage by means of BM innovation. The primary aim of a business model is to create and capture value. According to Osterwalder and Pigneur (2010) the BM “canvas” consists of nine building blocks that can be illustrated like this:

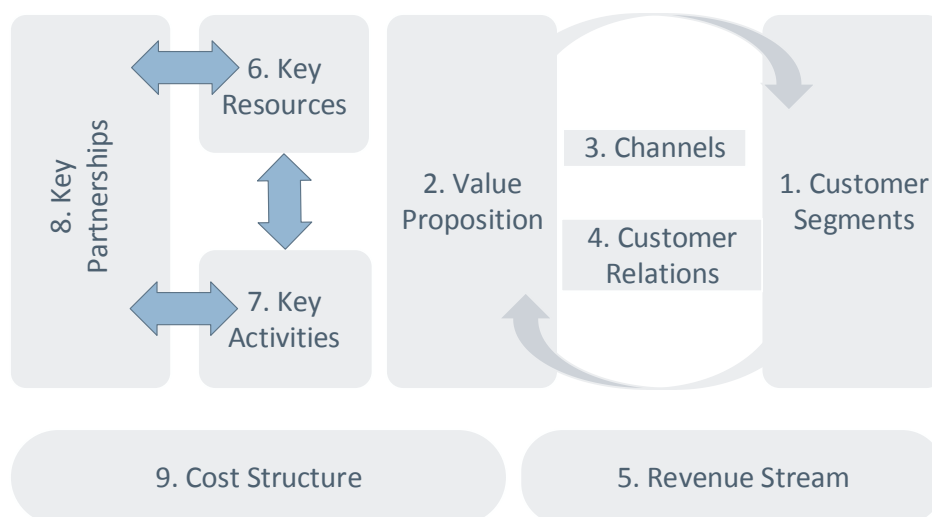


Figure 1: Building blocks of a business model (adapted from (Osterwalder and Pigneur, 2010))

First, it has to be decided who the value is created for; who are the most important customers? Second, what needs are satisfied through the BM? It has to be decided how to reach the customers; which channels are working best and with acceptable costs? Choices connected to customer relations are important as well; from a distanced impersonal relationship to a closer, perhaps co-creating relationship. Willingness to pay, pricing, as well as a system to handle payment logistics must be decided upon and established. Furthermore, key resources, activities and partners are required, all of which are guided by the chosen value proposition. Finally, the cost structure is important to the BM, with two classes of cost structure commonly distinguished: value driven and cost driven. In a cost-driven cost structure focus is mainly on minimizing costs in every possible way. Value-driven cost

structures demand that the product or solution offered has some kind of added value to distinguish it from potential competitors.

Dominating technologies and prevalent infrastructure have potential lock-in effects that reinforce established BMs and hamper the introduction of innovative BMs that challenge the present order (Unruh, 2000). By highlighting some empirical examples of green BMs, this article illustrates how different BMs could challenge more established BMs of energy efficiency and energy production in Norway.

2.2 *Transition management*

Often, transition management is explained along the lines of multiple levels to picture the different processes happening. Experiments are undertaken at the micro level, in outlying niches or sites where innovations can nurture and mature (Smith and Raven, 2012). The actors, networks and institutions that are dominating the status quo of the world are referred to as “regimes”. Typically, there is inertia in the regime towards change. According to, for example, Geels (2014) and Hess (2014), this can be due to resistance by the prevailing dominant actors, also referred to as “incumbents”. The macro level – the “landscape” – consists of overarching elements that are most notably hard to change or inevitable, like institutions, climate change or more sudden incidents or crises like a war or an earthquake.

Transitions are changes that affect a larger part of the society and are happening over a long time span, perhaps a generation or more. Transition management is a governance approach taken up by, for example, the Dutch government that aims to facilitate and accelerate sustainable transitions through visioning, learning and experimenting (Rotmans et al., 2001, Meadowcroft, 2009). Transition management is a strategy that ensures that long-term visions are embedded in short-term policy:

Transition management should be seen as complementing rather than conflicting with current policy, bringing added value by placing it in a more long-term perspective. It is a proactive, anticipatory strategy that is particularly sensitive to grassroots innovation. (Rotmans et al., 2001) p 24

The idea is that visioning should guide the selection or development of experiments and that these experiments should be learned from with improvements made. Built on Rotmans et al. (ibid.), visioning aims to establish an alternative future state that represents what the final transition would look like. This could be several alternative but not mutually exclusive visions. Furthermore, a collective transition objective should be agreed upon and interim objectives must be formulated. Finally, social support should be engaged. This implies a shift from one equilibrium to another, which means challenging the status quo represented by the regime. There are a number of ways in which society might be trapped in sub-optimal outcomes (Meadowcroft, 2009). Transition management seeks ways to break out of these system lock-ins.

2.3 *BM in the transition management framework*

The understanding of the dynamics of transitions is increasingly influencing the way in which experiments are set up, with the aim of influencing their speed and direction (Loorbach and Rotmans, 2010). Experiments in the early phase were mainly taken by governments according to Loorbach and Wijsman (2013). However, this is about to change as businesses are increasingly exploring the transformative force of their markets (ibid.).

Emerging BMs could be seen as experiments at the niche level. A BM may have a more or less regime-friendly output. According to Bidmon and Knab (2014) it could be easier to commercialize a new product or solution if it lies close to the current regime. However, it would likely not induce any radical changes. Unsustainability and instability in society could be interpreted as business opportunities that could also contribute to a transition (Loorbach and Wijsman, 2013). The increased focus on BMs indicates a belief in systemic approaches as a way to anticipate and possibly guide this transition (ibid.).

Taking on the role as a niche actor, companies and their BMs could be termed key loci of focus to characterize the interactions within and between the levels in a transition (Wainstein and Bumpus, 2016). Niches have been found to function as a translation device between the niche and the regime (Bidmon and Knab, 2014). Furthermore, according to Smith (2007) niches have been found to have direct interaction with the landscape pressures, also without intermediation at the regime level. The three case studies are analysed in this respect in Section 4.

As illustrated by Loorbach and Rotmans (2010), there is a surprising diversity of transition management practices. These include regional, sector-specific, international and industry- and business-specific practices. Business can contribute to the development of a shared vision by demonstrating the feasibility of certain solutions (ibid.).

[The carbon lock-in literature] “exposes the central role that the private sector has in sustaining the current energy regime. In fact, its resilient trajectory can be interpreted as a lock-in at the BM level.” Wainstein and Bumpus (2016) P. 574.

By failing to develop innovative BMs, the current equilibrium will be sustained and the status quo continued.

3. Methodology and data material

This section describes the process and considerations related to data collection and analysis. By applying technological innovation system (TIS) analyses of highly energy-efficient buildings, three challenges in the interface between the building sector and the power sector were identified (see findings in Section 4). A TIS analysis is a system approach that has been successful in analysing technological change and determining where intervention is likely to matter the most (Hekkert et al., 2011, Jacobsson and Bergek, 2011). It has provided insight and revealed challenges that have been further explored by applying the case study BMs to each challenge to see if they can offer viable solutions.

The TIS analysis builds on qualitative interviews of 32 expert representatives¹⁹, and subsequent analysis of the material. The size of the community with knowledge and an understanding of the impact on the development of highly energy-efficient buildings is limited and transparent, since Norway is a relatively small country. It could be described as a close community which, according to Guy and Shove, permits interaction across disciplinary and sectoral boundaries (Guy and Shove, 2000).

¹⁹ The experts were from: the building sector (five from the private and five from the public sector); the power sector (three); trade associations (six); one environmental organization; academia and research institutions (four); and the policy level, including central authorities (eight). Their roles were: advisors or senior advisors (12), leaders, ranging from project leaders to managing directors (17), and academic staff in research/academia (three).

Interviewees were chosen based on their knowledge of, experience with, or their position regarding highly energy-efficient buildings. From the building and the power sector, the interviewees had knowledge of or, more commonly, experience from, relevant projects. At the policy level and within the trade associations most interviewees had positions with a high influence on policymaking and/or implementation regarding energy-efficient buildings.

The selection of the case studies resulted in seven additional interviews. AF Energi & Miljøteknikk (AF) was interviewed as one of around six suppliers of EPC in the Norwegian market, and Melhus municipality was interviewed as one of their customers. Otovo and TrønderEnergi were interviewed as suppliers of LSP. Otovo is a small start-up company that is supplying solar panels to a large part of Norway, whereas TrønderEnergi and a handful of other energy utility companies have launched pilot projects. The AGR BM was researched through an interview with the only market-based supplier: LOS Energy. The interview was supplemented with the interview of a PhD candidate (now PhD) writing a thesis on the aggregator role, as well as one of the customers of LOS Energy: Saint Gobain. While including a customer perspective in the EPC and AGR cases, there was no interview with a customer of the LSP BM. Since there are several hundred customers of this BM, a small set of interviews would carry the risk of misrepresenting the diversity of the customers. Instead, studies that included the customer perspective from other countries were included (Strupeit and Palm, 2016, Balcombe et al., 2014, Leenheer et al., 2011).

The case studies referred to in Section 1 represent three BMs and were selected to correspond to three challenges identified through the TIS analysis (see Section 4). A case study is a frequently used method to develop a deeper understanding of specific cases. In particular, this method is useful when rich data is sought on current issues (Flyvbjerg, 2006). Which cases to study and how these cases are identified can be important. According to George and Bennett (George and Bennett, 2005), when there are only a few cases, the result will be more skewed if selection is random.

The interviews were based on a semi-structured interview guide, which was slightly adjusted during the process. For the TIS analyses, each interview lasted approximately one hour and was mainly personal. The seven BM-specific interviews lasted, on average, 45 minutes and were primarily made by telephone. The respondents did agree to their interviews being recorded. After the interviews were transcribed, they were analysed using open-ended coding focusing on finding patterns (Corbin and Strauss, 2014).

4. BMs and the low-carbon transition

The orientation towards sustainability issues makes firms redefine their own business and develop new business models. In this chapter, the three case studies are presented and related to the challenges that they are providing solutions for. Their relation to the BM framework and the levels in the transition framework are presented, with particular focus on risk evaluation.

4.1 Challenges to be addressed

During the initial TIS analysis of highly energy-efficient buildings, principal challenges in the interface between the power system and the building sector were identified. The challenges identified and the BM providing a solution to the challenges are:

1- Energy-efficiency projects: there is a need to reduce the overall energy use both in new and existing buildings. It is commonly acknowledged that energy use, in particular in existing buildings, is

too high. Despite this and despite the fact that many projects are also economically viable, they fail to be carried out. This is known as “the energy-efficiency gap” (Allcott and Greenstone, 2012). The EPC BM seeks to alleviate this challenge through the outsourcing of technical and financial risk. To improve energy efficiency is uncontroversial, but there is, nevertheless, no political will to quantify or in other ways induce forceful politics in order to intensify actions. This has been criticized by the Federation of Norwegian Construction Industries (BNL, 2016).

2- Energy generation on or near to building sites implies the introduction of distributed power generation, which is also a growing trend outside Norway, as Europe is greening its power system (European Climate Foundation, 2011). LSP is attempting to target this challenge but is not only facing a rough selection environment, but also institutional barriers as well as resistance from the incumbents/regime actors (Kvellheim, 2017). However, this is a controversial topic in Norway, not only among power sector representatives and a few policy actors. Firstly, it may require changes to the power sector and its structure. Secondly, it has a controversial rationale, since the power system in Norway is, by and large, based on hydropower. Nevertheless, an increasing number of solar panels are installed on Norwegian roofs.

3- A third challenge to the energy system is the capacity of the grid. Peak load during winter is, in some areas, close to the maximum capacity of the grid, and the threat of a blackout is imminent. This task is increasingly important as new areas have been established where fossil fuel could be replaced with electricity, such as the transport sector. At the same time, there are no plans for further hydropower developments due to nature conservation, although the current government has proposed that this practice should be dissolved (Olje- og energidepartementet, 2015-2016). To avoid expensive intervention in the environment, demand-side flexibility is one option and the AGR BM is offering a solution for this. This BM faces barriers, in particular related to the national main grid owner and operator, Statnett. It has not yet set up a marketplace for this service, and an efficient BM depends on this.

4.2 Energy Performance Contracting (EPC)

EPC is targeting the energy-efficiency challenge and is a market-based model that is well documented, including in the Norwegian context (see, for example, (Nord and Sjøthun, 2014, Lindseth, 2016)). Energy efficiency is largely uncontroversial, but not forcefully advocated. This is probably because energy efficiency in Norway contributes less to climate gas reductions than in countries where the energy supply is based on coal-fired power stations and other fossil energy sources (Olje- og energidepartementet, 2015-2016). However, it says, efficient use of energy can contribute to an economic and environmentally sustainable energy system (ibid.). In what way is not further described. The value proposition of EPC is to reduce the energy bills of its customers, mainly municipalities, and in addition to offer a possibility to reduce maintenance timescales, which is a general challenge among municipalities. EPC is promoted by public enterprises like Enova and the local municipalities organization (KS) and in 2014 a Norwegian standard was released that describes how the model is to be implemented (Standard Norge, 2014). As a likely consequence of this, there was a small boom in the EPC market in 2015, with the total number of EPC tenders increasing by 12 projects in one year to 60 (Lindseth, 2016). Customer relations are co-created, as each municipality has different challenges in their building stock.

A typical EPC has three phases: the first is an analysis of the potential. For this phase, an entrepreneur is pre-selected and does an analysis that can be extensive and therefore also costly. However, the municipality has an option not to perform the suggested measures. Phase two is when the municipality has decided to implement the measures, and phase three – the operational phase – is typically 7–12 years, but can be as long as 25 years, depending on net present value and whether or not a call option is included. In the Norwegian market, there were around six active and experienced EPC providers in 2015 (Lindseth, 2016).

According to an International Energy Agency (IEA) report on BMs in the built environment (Würtenberger et al., 2012) the risk is low for the customer when using this model. However, the supplier has high upfront costs before contract assignment. Also, the procurement regulations add risk to the supplier and discourage direct marketing. In the case of Melhus, the municipality was presented with the BM by a supplier of EPC who eventually, after the open tendering process, lost the assignment to the competing entrepreneur, AF. Even after this, AF was not guaranteed the whole assignment before the municipality had approved phase 1. According to the municipality, it was content with the contract and recommended it to other municipalities without reservations. In particular, it appreciated the ability to reduce maintenance timescales, which is a problem for many municipalities due to a large building stock and a limited budget. When asked what they thought was the reason why relatively few municipalities entered into EPC contracts, the interviewee responded:

It is hard to say. The risk for the municipality is virtually zero, at least economically. I think that this way of carrying out projects is not well known. As we were discussing, there are few actors on the supply side and their marketing capabilities are limited.²⁰ Melhus municipality.

When asked the same question, AF responded that the smaller municipalities do not necessarily know much about EPC, whereas the larger municipalities have more resources and plan to accomplish such projects by themselves. Furthermore, on the question of marketing, AF responded:

No, we are not really marketing EPC. We made a brochure the other year, but did not get much of a response on this. EPC is sold through Enova²¹ and [named mediator]. KS²² is also heavily involved. AF Energi & Miljøteknikk.

The EPC model is targeting a largely uncontroversial but also unquantified national target: to increase energy efficiency. Therefore, AF expects that the EPC model is marketed by public organizations. In addition, the risk is unequally distributed as the supplier, in this case AF, bears most of it. Perhaps this could explain why there are relatively few suppliers. This BM lies close to the regime as energy efficiency is promoted by public organizations like KS and will not change current practice in a disruptive manner. There is subtle landscape pressure through EU and UN strategies, but with reference to the clean hydropower electricity production, Norwegian authorities are reserved in their approach.

4.3 Leasing of Solar Panels (LSP)

The LSP BM targets the need to increase the share of renewable energy. The Norwegian private market on solar energy tripled²³ in 2016, but is still a minor contribution to the energy system with a

²⁰ All quotes are translated by the author.

²¹ State-owned enterprise providing financial support for energy projects

²² The municipalities organization.

kWp in 2016 of 26,687²⁴. The share that is connected to the grid has a stipulated electricity production of 10 GWh/year whereas the total electricity production was around 148 TWh²⁵ in 2016. More renewable energy production is needed to be able to electrify new areas of energy use in society and comply with requests from the EU, but solar power has so far not been included in any national strategy (Olje- og energidepartementet, 2015-2016).

The target group is first and foremost households. The value proposition is the advantage of producing your own energy and the experience of a degree of self-sufficiency. The lease that is paid covers more or less everything, from installation to maintenance and repairs. However, this is a long-term arrangement of around 20 years. If the customer wishes to withdraw from the agreement after, for instance, five years, he or she would have to pay for the solar panels; they are not to be returned to the supplier. The product is promoted through social media and other media publicity. In addition, Otovo is actively seeking established partners in order to both reach more customers and to ensure financing. The customer relationship is distanced and the product and solutions are as standardized and automated as possible.

There are a few energy utility companies that have introduced pilot projects on LSP, using their customers to examine if there is an interest in the product. In addition to this, and with much more ambitious goals and enthusiasm, the small start-up company, Otovo, is addressing the private market with exactly the same product. These are potential competitors, but the risk they are taking is vastly different. TrønderEnergi, the energy utility company that was interviewed, selected 15 pilot customers and uses these cases to explore the effect on the grid and the potential for selling additional products such as batteries and energy communication devices. It sees a business potential, but does not perceive solar power as any threat to their main business area, so far. TrønderEnergi is clearly not taking any substantial risk by exploring this new product. Otovo, on the other hand, is challenging the very structure of the power system by also promoting a product such as “neighbour-electricity” where their customers can sell and buy to and from their neighbour. However, this is, for the time being, not possible due to regulations. They bypass this “minor obstacle” by registering as an energy company and buying the electricity themselves. Even though Otovo has a full-scale model, it charges a lower price than the energy utility company does in its pilot project. On asking Otovo about the risks in connection to its BM it responded:

“What can I say.... The biggest risk for Otovo, not in probability but in consequence, is if a competitor enters the market with the same product, but manages to offer it in a better and cheaper way. Another risk is if external conditions and regulations should make it more difficult or less profitable to install solar power panels. [...] We don’t think this will happen as our impression is that NVE²⁶ is positive towards solar power and other local power production.” Otovo.

This risk analysis from Otovo stands in contrast to the responses in an interview with the regulator, NVE, as a part of the TIS analysis. In this interview, NVE expressed that the current system is, first and

²³ https://blog.otovo.no/2017/03/20/tredobling_solceller_i_2017/ Accessed 24th March 2017.

²⁴ <http://solenergi.no/wp-content/uploads/2015/10/Akkumulert-solcellekapasitet-i-Norge-2016.png> Accessed 30th March 2017.

²⁵ <https://www.ssb.no/energi-og-industri/statistikker/elektrisitet/maaned/2017-03-03?fane=tabell&sort=nummer&tabell=298174#tab-tabell> Accessed 30 March 2017.

²⁶ The Norwegian Water Resources and Energy Directorate (NVE) is the energy regulating public body in Norway.

foremost, rigged to ensure energy security and effective production, transfer and sale of electricity. Small scale solar power production is not perceived to contribute to either of these. According to an IEA analysis (Würtenberger et al., 2012) the primary risk/threat and opportunity connected to the LSP BM is related to changes in national regulations.

This BM is spurred by international development towards more decentralized power production (Sims and Schock, 2007, The European Parliament and the Council, 2010). The growth in solar power production has led to a significant improvement in technology and reduced costs. It is challenging the powerful BM of the regime, namely centralized power production, and is hence likely to meet resistance, in particular due to vested interests (Hess, 2016, Geels, 2014).

4.4 The Aggregator Role (AGR)

This BM is addressing the challenge of peak load, which is perceived as an increasing threat to energy security. The demand for electricity is increasing as more areas are electrified; the transport sector is a prime example. The number of critical incidents has increased and the risk of a blackout is imminent in periods of particular strain to the grid. AGR is one of several emerging BMs to use demand-side flexibility to avoid a capacity crisis in the distribution grid and the model has been analysed in a recently defended PhD thesis (Ottesen, 2017). The only commercial actor that is dealing with this product in Norway is LOS Energy, a subsidiary of Agder Energy (an energy utility). LOS Energy is dependent upon trust from the national main grid owner and operator, Statnett, as their service is of vital importance to society in a critical situation. The customers of the AGR BM are grid operators, including Statnett. LOS Energy utilizes medium to large-size end-users of electricity, such as retail stores and industries, to access available loads. The end-user agrees to let the aggregator overrule their power consumption preferences within certain guidelines, and for this it receives a reduced overall energy price. To enter the AGR BM you need to access the loads of electricity users (for example, by operating as an electricity supplier) as well as specific software and energy trading competencies. As LOS Energy is the largest electricity supplier on the corporate market²⁷ it has access to a significant customer base as a channel for product promotion. Customer relations are distanced as the product is regulated through a standardized agreement.

The legitimacy of this business model is founded in the fear of blackouts, as the strain on the existing infrastructure is increasing. This is caused by different developments such as more electrification, for example of the car park, as well as more energy-efficient products that use less energy overall, but contribute to higher power peaks as they need more power for a shorter period. It would be cheaper and more sustainable if the flexibility already inherent in the system could be exploited. This is how LOS Energy explains how it works:

I think I can turn off the freezers of [a customer] for 15 minutes. And so on. Some of these loads are more interesting than others. The point is, if we can take some of your load consumption for a period when you will not notice, then I can take that load – and here we are unique – and aggregate all the energy load from [the customers] ... Then, I take the entire load that I can gather for 15 minutes and I ask the grid operator: “How much are you willing to pay for this?” LOS Energy

²⁷ www.losenergy.com Accessed 14th April 2017.

This BM is explained by my informant from LOS Energy as more or less inevitable: “This is a European movement, it comes like a supertanker; it does not move fast, but it is difficult to stop.” LOS Energy is not making money on this BM yet, but hopes to have an advantage in a few years by being first. They express great enthusiasm about what they are doing: “There are a lot of loads here that nobody has thought of before, which are flexible. This is simply supercool, you should know that.” LOS Energy.

This risk LOS is taking must be seen in relation to national priorities. It is dependent on a willingness to rely on this model and to change accordingly, which requires industry change in areas that are primarily the responsibility of Statnett. There is no BM at the regime level taking care of this except for the surveillance and incentives that Statnett is in charge of. It is targeting energy security issues, which is high on the agenda. This, in addition to the landscape pressure (with reference to the supertanker) makes the prospects promising for this BM.

4.5 A brief summary

The variables affecting BM development are drawn from the BM framework and transition levels, which give input to a risk evaluation. The main variables considered can be summarized by Table 1:

Variables / BM	EPC	LSP	AGR
Challenges	Energy efficiency	Renewable energy	Peak load
Customers	Municipalities	Households	Commercial electricity end-users
Value proposition	Reduced energy bill and maintenance update	Producing your own renewable electricity	Payed for disconnection of spare electricity
Channels	Through public organizations like Enova and KS	Social media, general publicity and strategic partnerships	Already established customer relationship
Customer relations	Evolving into a co-creating relationship	Distanced	Distanced
Cost structure	High up front	High up front	Low to medium
Regime BM	Building codes and public support schemes	Centralized electricity production	None so far
Landscape pressure	Weak	Medium	Strong
Risk assessment (to further BM development)	Low	Medium high	Medium

Table 1: Comparison of BM characteristics, transition levels and risk assessment

The variables have been sorted into categories by colour codes. The BM variables included are light grey and the transition theory variables are light red. The interplay between transition levels could indicate how the BMs will evolve further. At the regime level, one could suggest an instability caused by a major landscape pressure from anthropogenic climate change. This pressure is particularly relevant to the power sector, which needs to become carbon-free by 2050 according to EU strategy (European Commission, 2011). Other landscape pressures stem from EU directives, for example the Energy Performance in Buildings Directive as well as market development of commodity prices and improvement of products.

5. Discussion and conclusion

The dynamics of sustainable BMs was illustrated in the previous section. This section discusses how BMs can contribute to the forthcoming low-carbon transition. Since current BMs have contributed to man-made climate change, BM innovation is needed in order to include sustainability issues. The three case studies are used to gain a better understanding of the risks and opportunities associated with the BMs. The role of BMs in transition management will be investigated further before the conclusions are made.

5.1 Business model innovation

The challenges identified in the interface between the power sector and the building sector have different origins and distance from the current regime practices. Some are fairly uncontroversial, although still not forceful, such as the EPC model. Others stem from EU directives or trends and technology/market development, like the drive towards distributed power production. Demand-side flexibility mechanisms are emerging as a promising tool to avoid the risk of blackouts and exploit the capacity of the grid to a greater extent. Besides, demand-side flexibility mechanisms are targeting energy security issues, which are a high priority for regime actors.

EPC has been pushed by public organizations that ensure legitimacy and initiate the building of institutions. Little translation is needed between the niche and the regime since EPC is in line with regime concerns. The Norwegian standard on EPC was the first standard developed among the Nordic countries and the standard has contributed further to the credibility. Other BMs approaching the same challenge, for example green leases, are experiencing more difficulties. Regarding EPC, it seems that credibility, provided by public actors, has been key. The next step would be to monitor and evaluate and see if the model could be expanded to a larger share of the market. However, the lukewarm approach to energy efficiency at top policy level indicates that the drivers must come from elsewhere.

LSP has been neglected by the public support system until recently when, due to improved technology and falling product prices related to solar panels, the technology has been included in some support schemes. However, it is clear that LSP has developed mainly despite the lack of public support system. Here, the rising number of projects could act as a demonstration of feasibility. However, as discussed in Kvellheim (Kvellheim, 2017) the argument for power-producing buildings would be stronger and more persuasive if it was made in line with concerns by regime actors. The leasing model has eradicated the upfront investment barrier and remaining barriers seem to be mainly institutional, in addition to further improvement of the technology. As revealed in the papers on customer incentives to invest in LSP (Strupeit and Palm, 2016, Balcombe et al., 2014, Leenheer et al., 2011), there are diverging results. A study from the Netherlands indicates that the primary reason to produce your own

energy is for environmental reasons. Other studies indicate that financial incentives are more important.

AGR is in an early phase and relies on adjustment and goodwill from the authorities and the state-owned grid operator, Statnett. It is one of several potential models to exploit demand-side flexibility, and builds on excess loads from the non-residential sector of medium to large energy users. According to the interviews, there is a substantial potential and more suppliers are likely to enter the market once confidence is established, alongside a marketplace. This model is targeting issues that have a high priority by the regime, but it is also addressing a vital function for society, which could lead to comprehensive regulation. Therefore, the “experiments” initiated by LOS provide important information to the public authorities. However, further development of this BM is dependent on support from the regime actors, as well as the development of supporting institutions.

All case studies can be traced to landscape pressure, although for the LSP and the AGR this is more direct than the EPC BM. The main suppliers (Otovo and LOS Energy) of these two BMs are willing to take considerable risk and invest years of low or no profit. This indicates a strong belief in the future development as every BM, including sustainable ones, is dependent on profit in the end. On the other hand, the EPC BM is promoted by the authorities and even if risk is skewed, there are a few commercial actors ready to take on more projects. In general, the suppliers of EPC earn a profit from their projects. Regardless of this, there is still a substantial growth potential but the suppliers lean on the authorities to promote the product/service contract.

5.2 BMs in the transition management framework

How could these BMs be a force of sustainable transition? The transition management (TM) framework is introduced to explore whether the BM and TM theories could be complementary. According to Loorbach and Rotmans (Loorbach and Rotmans, 2010), business could contribute to the development of a shared vision by demonstrating the feasibility of certain solutions. In this way, the BM could function as a translation device between the niche and the regime (Smith, 2007, Wainstein and Bumpus, 2016). As each of the BM case studies could be framed as experiments within niches, the question would be how were these initiated and by whom? Was it as a result of an established transition arena and a shared vision, or rather despite such a background?

The relation between risk assessment and regime distance could be an indicator of BM prospects in terms of market development. Related to the three case studies, it could be illustrated as in Figure 2.



Figure 2: Business models related to regime distance and risk assessment

As indicated in Section 2, there is a lower risk in the BMs that are closer to the regime. However, the EPC is unlikely to bring about any radical change, but rather incremental change if any. Hence, the potential transitional force of the EPC is minor. The AGR BM is placed at some distance from the regime as there are institutional barriers that must be removed before it can prosper and grow. If a marketplace for trading excess loads was established, then this BM could have some success. However, it is in line with regime priorities and is likely to reinforce the regime or bring about incremental rather than radical change. The LSP BM is the BM at the furthest distance from the regime. The LSP BM is facing institutional barriers such as the inability to sell excess energy to your neighbour and the downplaying of the solar energy potential by the government (Olje- og energidepartementet, 2015-2016, Kvellheim, 2017). It faces high risks, primarily since it could be shut out of the market by new regulations or a likely restructuring of the power sector. Furthermore, the market is immature, both in terms of what price to expect if you sell energy to a power company as well as the continuing development of the technology and the products.

Relating to the LSP and AGR BMs in particular, the pressure from the landscape level seems obvious. Both models are related to the greening of the power systems in many regions, including in the EU (European Climate Foundation, 2011). Due to this development, distributed generation has been encouraged, which has resulted in the growth in and subsequent improvement of solar power technology. Since electricity is expected to be of increasing importance in the green transition, the scarce grid capacity is an issue that Norway shares with many countries. Demand flexibility mechanisms are likely to be developed and implemented in various ways in the coming years. It has been demonstrated that BMs have taken up the challenges presented by the landscape pressure and led the way without any intermediary role played by the regime, which was also earlier illustrated by Smith (Smith, 2007).

5.3 Conclusion

This paper has investigated whether business models could be a transformative force in the forthcoming low-carbon transition. In answer to the question of whether business model theory and transition management theory can complement each other when assessing business models, it is of vital importance to understand BM innovation, as a shift is needed towards more sustainable BMs that can contribute to the transition. Looking at the case of Norway, three challenges in the interface between the building sector and the power sector have been identified. Furthermore, three green BMs that address the challenges have been studied in search of the drivers of BM innovation. The question of whether businesses could take on the transformative force that originally belongs to the authorities is explored using the transition management framework.

The chosen BMs were elaborated in Section 4 and quotes from interviews were used to illustrate the perceived risk and future potential of the models. Furthermore, the empirical results were related to the challenges identified: energy efficiency, renewable energy production and peak load reduction. The BMs were illustrated in a figure that depicted the relationship between risk and regime distance and it was discussed what aspects affect the risk assessment and what it would mean to future development.

BMs can be seen as experiments within niches. They can also function as translation devices between the niche and the regime, and thereby help to demonstrate the workings of a specific BM innovation. It is not crucial to a BM whether or not it is initiated or supported by public authorities. However, public authorities possess institutional power and are able to hamper or perhaps block any of the three BMs by a stroke of a pen. BMs can, however, as can niches, be directly affected by landscape pressure and respond to this. When doing so, they contribute with demonstration projects that increase knowledge and learning for all actors, including those within the regime.

The EPC BM is addressing a seemingly uncontroversial challenge, namely to increase energy efficiency. It is supported by public support schemes and an institutional framework is built around it. This distinguishes it from other measures targeting the same challenge; for example, green leases. This means it has a transition arena and experiments and frontrunners are present. Still, shared visions are somewhat lacking with reference to, for example, the reluctance to establish an energy-efficiency target. Such a target has only been applied by a small part of the potential market and suffers from lack of knowledge at the demand side. It is close to the regime and suppliers are earning a profit from engaging in the EPC BM. However, energy efficiency is not forcefully advocated, likely because it does not contribute directly to the reduction of emissions since the power system in Norway is based on hydropower.

The LSP BM is furthest away from the regime, and only recently has modest public support been received. However, this BM has grown despite the lack of public support. The power sector does perceive LSP as a threat due to the dim consequences of a massive development. There is no established transition arena nor shared vision developed in which this BM is a major part. Rather, the experiments are likely to demonstrate the feasibility of the BM and challenge the regime to deal with it. However, it could grow based on consumer demand if not blocked by any institutional barrier.

The AGR BM is distant from the regime as there are still institutional barriers such as lack of a marketplace. The BM shares a vision with the regime, namely to ensure a secure energy supply. However, it is dealing with a function that is vital for the functioning of society and is dependent upon

trust and the establishment of a marketplace. There are also several other BMs addressing the challenge of energy security and peak load, but this is the only one implemented – so far.

As BMs represent a vital function (experiments) in the transition management framework, it is useful to include both BM and TM theory when examining how BMs can contribute to the forthcoming low-carbon transition. The contextualization brought in by the notion of niches, regimes and landscapes is helpful when evaluating the prospects of a business model. The take-up of signals from landscape pressure by the BMs and the solutions developed provide valuable learning for all actors, including the regime. This could eventually lead to the development of transition arenas – making BMs a weighty force in challenging the status quo. However, the role of business models in sustainable transitions is still insufficiently researched and more empirical and theoretical studies should be encouraged.

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