

Torill Randi Meistad

# **Sustainable building – From role model projects to industrial transformation**

Thesis for the degree of Philosophiae Doctor

Trondheim, October 2015

Norwegian University of Science and Technology  
Faculty of Engineering Science and Technology  
Department of Civil and Transport Engineering



Norwegian University of  
Science and Technology

**NTNU**  
Norwegian University of Science and Technology

Thesis for the degree of Philosophiae Doctor

Faculty of Engineering Science and Technology  
Department of Civil and Transport Engineering

© Torill Randi Meistad

ISBN 978-82-326-1196-6 (printed ver.)  
ISBN 978-82-326-1197-3 (electronic ver.)  
ISSN 1503-8181

Doctoral theses at NTNU, 2015:270

Printed by NTNU Grafisk senter

## Sustainable building

– From role model projects to industrial transformation

Title: Sustainable building – From role model projects to industrial transformation

Main supervisor: Marit Støre-Valen

Co-supervisor: Thomas Berker

## Abstract

### Background and purpose

Improving energy efficiency and sustainability is a challenge for the construction industry. The United Nation's environment programme (UNEP) and the EU's Energy Performance of Buildings Directive require a change in building practices. The challenge is how to facilitate the transformation.

The purpose of this PhD research is to increase the understanding of how the Norwegian construction industry is transforming towards sustainable building.

Four issues have been studied in this thesis to provide new knowledge relating to this question, as follows:

- Management of innovative energy-efficient building projects
- Usability of modern energy-efficient office buildings
- The role of facility managers in the planning process of ambitious projects
- Mechanisms in the industrial system affecting implementation of sustainable practice

### Methodology and methods

Pioneering projects have proved that an outstanding energy and environmental performance can be achieved on a voluntary basis by owners and industry partners setting themselves ambitious goals. Eight Norwegian so-called role model projects have been studied to explore the processes and effect mechanisms that lead to the extraordinary results.

The material includes 55 interviews, observations of buildings when they are being used, project documents and written and oral presentations of the projects. The grounded theory approach has been used to perform case study analysis of this material.

### Major findings

Ambitious tenant organizations represent a pull from the market and a knowledge resource for the development of sustainable buildings.

Facility managers are a source of practical experience that feed forward knowledge about the operation and energy performance of existing buildings to new projects.

Life cycle cost analysis provides information on long-term operational and maintenance costs, improving communication between property managers and decision makers and contributes to improving economic, community and environmental sustainability.

Enthusiasm is a driver for innovation and outstanding performance. Enthusiasm enables experienced owners, project managers and teams to find methods and solutions to bridge system barriers that resist change in industrial practice.

R&D partners provide new knowledge and reduce risks in initiatives for innovative sustainable building.

Usability is a key to the implementation of sustainable building. This includes area efficiency, an improved indoor climate and aesthetics, and functionality and adaptability for dynamic user organizations. Added value gained from exploring the synergy effects in energy-efficient building concepts is the key to increasing the demand for sustainable buildings from the market. At the

moment, immature technology for indoor climate control is hampering the transformation of the construction industry.

#### Value of the research

The originality of this research is the analytical approach to sustainable building, namely the organizational dynamics. This approach illustrates how the organizing of relations between individuals in teams and between enterprises in projects affects the result, namely the energy performance of the final buildings.

The socio-technical system perspective provides new insight into the interplay between technology and human beings. Existing studies have shown how this interplay affects the actual energy performance of buildings when they are being used. This research adds insight into how management practice affects social processes that are relevant to the final energy performance of the building. And the research adds insight into the competition between existing industrial regimes and the emerging regimes of sustainable building.

#### Conclusions and suggestions

Research presented in this thesis can be summarized in four major conclusions:

1. The Norwegian construction industry is able to develop highly sustainable buildings. There are stakeholders within the industry that can be characterized as “innovators” and “early adopters” who explore the potential for energy efficiency in construction projects.
2. The organizing of the planning and construction process has been decisive for achieving the extraordinary results. Crossing the borders of organizational units, roles and the division of work in various phases has made it possible to pool knowledge, share risks and find innovative solutions to meet new expectations for sustainable building.
3. Currently, buildings with energy and environmental qualities higher than the mandatory technical regulations are exceptions to the rule within the construction industry. Sustainable building is being developed as a niche market. It still remains to be seen whether sustainable building will become standard practice.
4. The role model projects demonstrate that there is a win-win potential in sustainable building: exploring the synergy effects in a search for energy efficiency reveals options for buildings with added value for users and owners as well as the environment and the community.

The following are the author’s suggestions for strategies for further development of and transformation towards sustainable building:

- To develop building and refurbishment projects as part of a strategic business/organizational plan for the user organization/enterprise.
- To arrange for broad participation and early integration in project planning for the purpose of exploring the synergy effects of the energy performance, operation and usability of the final building
- To focus on the purpose of the building and the users. This supplements conventional technology orientation in project development.

- To explore the principles for reflexive governance in a further development of strategies for transformation towards sustainable building.

A suggestion for further research is to focus on the implementation of sustainable building concepts and solutions from role models and other niches into ordinary practice in the Norwegian construction industry. Two issues are suggested for further exploration:

- Organizational learning from role model projects
- Stakeholder benefits from sustainable building – the potential for win-win effects

Key words:

sustainable building, energy-efficient performance, construction industry, role model projects  
innovation, organizing, project management, integration, collaboration, partnering, transformation





## Acknowledgements

This research work would not have been possible without contributions, support and collaboration from others. This includes supervisors, colleagues and professionals in the industry, family and friends.

First of all, I am thankful to my main supervisor, associate professor Marit Støre-Valen, who introduced me to construction industry and the challenges, possibilities and paradoxes related to sustainability in the built environment. She has introduced me to her professional network, sharing her credibility within the Norwegian industry as well as the international research community. Throughout the process of this research work, Marit has been a good sparring partner, challenging me to explore further the puzzling patterns while at the same time kept an eye on the whole. Sharing time with you has been like an oasis for reflection and growth. Marit, you are a great team player!

Secondly, I am thankful to my co-supervisor, professor Thomas Berker, who immediately volunteered to look over my research works from the social science perspective. Thomas introduced me to the ZEB community. He invited me to the monthly PhD study group seminars and gave me opportunities to present my works at lunchtime seminars and workshops. The feedbacks which I got from that community have been very useful and used as an inspiration to complete this research. Thanks to Lillian Strand, Krishna Bharathi, Liana Müller, Andreas Eggertsen, Håkon Fyhn and all the rest!

Thomas has been my inspiration to explore the processes of innovation, reminding me about the nature of human beings when I got carried away by glittering ideas of some kind of technical fix to the problem. Thomas, you have been the perfect match to my supervising team!

Colleagues have been my best supporters in my daily work. This includes everybody at Department of Civil and Transport Engineering at NTNU, greeting me every morning, and showing interest and care. Especially I appreciate “the boys at the office”, professor Ole Jonny Klakegg and assistant professor Hallgrim Hjelmbrække. We have had a number of spontaneous colloquiums throughout the years. We have shared frustrations, jokes and laughs, and inspired each other towards “the ultimate answer” for building processes and project management. Dear colleagues, sharing office and time with you has been a luxury!

I am also grateful to everybody at NTNU and SINTEF who have opened their doors, spent time with me and offered such thoughtful, candid reflections on different questions. This includes professor Tore Haavaldsen and the late professor emeritus Alf Tørum at BAT, professor Siri Blakstad at the Centre for Real Estate and Facilities Management, Jan Alexander Langlo at SINTEF Teknologi og samfunn and Prosjekt Norge, Berit Time at SINTEF Byggforsk, my recent colleagues at Department of Architectural Design and Management, and many more. To all of you: thanks a lot!

Thanks to the many professionals within construction industry who have shared their experience and reflections with me. This includes co-writers at Rambøll and Faveo, and the informants in key positions involved in pioneering projects and also in conventional planning and production. These meetings have broadened my insight and been an inspiration for further efforts. Hopefully the experience have been mutual!

There is also a historical line of inspiration worth to mention. The late professor Sigmund Borgan, at the present Norwegian University of Life Sciences at Ås, introduced me to the subject of resource economy, the Club of Rome and the Brundtland report in the 1980s. And more recently the network of pioneering female leaders within construction industry, including mentors and adepts with

ambitions to renew industrial practice: The project “Kunnskapsringen” supported by the Building Cost Program in 2005-2010 gave a boost to diversify culture and practice in the industry, and I am most grateful to be part of it.

I am also grateful to my family. To my father for teaching me the pleasure of working with the soil, use my hands and brain, to my mother for always being interested in my work, and to both of them for inspiring me to be curious and learn from life. To my sister for a friendly competition towards our individual doctoral ambitions. You won this time, Astrid, but finally we made it, both of us!

A special thanks goes to my dear husband Sigbjørn, who as an educated intellectual and smart practitioner brought my ideas down to earth or lifted them up in the sky whenever there was a need for a counter balance. Thanks for being my best friend and for always believing in me!

Good friends and professionals have contributed during the finishing stage, with layout work and proof reading. Thanks a lot to Shiferaw Asmamaw Tadege, Elisabeth Dixon and to Beverley Sykes at Superscript Proofreading (UK)!

And finally, for the official record, the PhD scholarship has been financed by NTNU, Department of Civil and Transport Engineering, where the majority of this work has been written. A minor part has been written within the Research Centre on Zero Emission Buildings (ZEB). I gratefully acknowledge the support from NTNU, the ZEB partners and the Research Council of Norway.

Trondheim, September 2015

## Abbreviations

AEC	Architecture, engineering and construction industry
BIM	Building Information Modeling
BREEAM	Building Research Establishment Environmental Assessment Methodology
CII	Construction Industry Institute
CSR	corporate social responsibility
DBOM	Design-Build-Operate-Maintain
ECTP	European Construction Technology Platform
EIA	Environmental impact assessment
ENOVA	the Norwegian Energy Fund
EPBD	European Union's Energy Performance of Buildings Directive
ESPC	Energy Saving Performance Contracts
ETP	Energy Technology Perspectives
FM	facility management
FME	National Centres for Environment-friendly Energy Research
GHG	greenhouse gas
ICT	information and communication technology
IDP	Integrated Design Process
IEA	International Energy Agency
IED	Integrated Energy Design
IPCC	Climate panel
LCA	Life Cycle Assessment
LCC	Life cycle cost
LEED	Leadership in Energy and Environmental Design
PPP	Public private partnership
R&D	Research and development
RM	risk management
TBL	the Triple Bottom Line
TQM	Total Quality Management
UNEP	the United Nation's environment program

WLC            Whole Life Cost  
ZEB            the Research Centre on Zero Emission Buildings

## Papers and declaration of authorship

The thesis consists of an overview and the following seven papers:

<b>PUB. NO.</b>	<b>PAPER</b>	<b>DECLARATION OF AUTHORSHIP</b>
1.	Meistad, T. and Valen, M. S. (2012): "Adding value and sustainability by involving facility managers in design phase. A preliminary study of Norwegian pilot projects of energy efficient buildings", CIB Conference "Delivering Value to the Community", Cape Town, 22–25 January 2012.	The first author conceptualized, planned and wrote the paper along with Valen. The first author collected the data, partly together with Valen. Valen presented the paper at the conference.
2.	Meistad, T., Valen, M. S. and Lohne, J. (2013): "Use of collaborative working in construction projects with high energy ambitions", 7th Nordic Conference on Construction Economics and Organization, "Green urbanization – implications for value creation", 12–14 June 2013.	The first author conceptualized and planned the paper along with Valen. Valen and Lone contributed with feedback and suggestions during writing. The first author collected the data and presented the paper at the conference.
3.	Meistad, T. (2013): "Partnering for the development of an energy-positive building. Case study of Powerhouse #1", 7th Nordic Conference on Construction Economics and Organization, "Green urbanization – implications for value creation", 12 – 14 June 2013.	The author conceptualized the paper and collected the data together with Lillian Strand. The author wrote the paper and presented it at the conference.
4.	Meistad, T., Valen, M. S. and Klakegg, O. J. (2013): "Three stories describing the impact of research on the development of Norwegian Construction industry". The 19th CIB World Building Congress, Brisbane 2013: Construction and Society, 5-9 May 2013.	The first author conceptualized the paper with Valen. The first author collected the data, wrote the paper and presented it at the conference. Valen and Klakegg commented on drafts.

5.	Meistad, T. (2014): "How energy efficient office buildings challenge and contribute to usability", <i>Smart and Sustainable Built Environment</i> Vol. 3 Iss: 2.	The first author conceptualized the article with Støre Valen. The first author collected data, performed the analysis and wrote the article. Valen, Haavaldsen and Blakstad commented on drafts.
6.	Meistad, T. (2015): "Developing energy efficient buildings –the organizational challenge", <i>Engineering Construction and Architectural Management</i> , submitted March 2014.	The author wrote the article based upon papers 2 and 3. The author collected supplementary data and performed additional analysis.
7.	Meistad, T., Valen, M. S., Brattås and Gissinger, H. K. (2012): "LCC as a decision tool for strategic development of the public building portfolio. A Norwegian study", IALCCE 2012 Conference, Vienna, Austria, October 3–6.	The first author conceptualized the article with the co-authors. An existing study by Brattås and Gissinger contributes to the material and analysis. The first author collected data, performed the analysis and wrote the article. Valen, Brattås and Gissinger commented on drafts. The first author presented the paper at the conference.

Presentation of co-authors and contributors:

Marit Støre-Valen is an associate professor at NTNU in the Department of Civil and Transport Engineering. She is qualified' civil engineer and has a PhD in building constructions. Her latest research is on property management and sustainability. Støre-Valen is the main supervisor for this PhD research project.

Lillian Strand is a PhD student at NTNU in the Department of Architectural Design, History and Technology. Strand is associated researcher at the Research Centre for Zero Emission Buildings (ZEB). Her academic background is in economics, political science and international development studies. In her PhD, she uses analytical frameworks from sustainable transitions analysis to explain the conditions influencing innovative green value chains based on local products, such as wood, in the construction industry.

Ole Jonny Klakegg is a professor in Project Management at NTNU in the Department of Civil and Transport Engineering. His research interests include the governance of projects, construction management, partnering, stakeholder management, process management and other project management issues.

Tore Haavaldsen is a professor in Building Technology in the Faculty of Engineering Science and Technology at the Norwegian University of Science and Technology. His recent research focuses on the intersection between technology and the long-term utility of designs and requirements in the societal context.

Siri Blakstad is a professor at the Centre for Real Estate and Facilities Management at the Faculty of Architecture and Fine Arts at NTNU and Vice President of Division for Engineering and Architecture, Land, in Reinertsen. Blakstad's specialties are management and organizational development. Research interests include knowledge workplaces, usability and adaptability in office buildings, building processes and economics.

Jardar Lohne works as a researcher at the Department of Civil and Transport Engineering, NTNU. Since finishing his doctorate, he has specialized in coordinating scientific production. He holds a coordinating role within Project Norway, a national arena for the exchange of experiences of project expertise.

Hans Brattås is a qualified civil engineer and has had a long career working in municipal planning and industrial development, as a newspaper's chief editor, chief municipal executive and as a consultant, and is currently a chief executive in county administration. Brattås' expertise includes, among others, public property management.

Håkon Kvåle Gissinger is a senior FM consultant at Rambøll and an assistant professor at NTNU. Areas of expertise include facility management consultancy and maintenance planning. Among his recent work is the development of a guide for introducing life cycle cost analysis into municipal property management.





SECTION I

INTRODUCTIONARY ESSAY



## Table of Contents

Table of Contents .....	1
Table of figures .....	7
1 Introduction .....	9
1.1 Background of the thesis .....	9
1.2 Approach .....	11
1.2.1 An organizational approach .....	11
1.2.2 Actors and levels of analysis .....	12
1.2.3 Sustainable building .....	15
1.2.4 Innovation .....	19
1.2.5 System theory .....	21
1.2.6 Characteristics of the construction industry .....	28
1.3 Role model projects .....	30
1.3.1 Theory on role models .....	30
1.3.2 Role model projects challenge the socio-technical system .....	30
1.3.3 Role models as the empirical approach .....	31
1.4 Focus of the study .....	31
1.5 Objectives of the thesis .....	35
1.6 Research questions .....	36
1.7 Contributions from research .....	38
1.8 Structure of thesis .....	39
2 Literature review .....	41
2.1 Structure of the chapter .....	41
2.2 Integration .....	41
2.2.1 Organizing for integration .....	42
2.2.2 Working methods for integration in construction projects .....	44
2.2.3 Experienced effects .....	45
2.3 Collaboration .....	46
2.3.1 Organizing for collaboration .....	46
2.3.2 Experiences on collaboration in the construction industry .....	48
2.3.3 Project-based and strategic partnering .....	49
2.3.4 Trust and risks, motivation for collaboration .....	50
2.3.5 Effects on innovation .....	51

2.3.6	Effects on energy and the environment.....	52
2.4	Attitudes to and handling of risks in innovative building.....	52
2.4.1	Attitudes to risk in construction teams .....	52
2.4.2	Implications for research.....	53
2.5	Motivation for innovative sustainable building .....	53
2.5.1	Motivating individuals .....	53
2.5.2	Leaders and managers as motivators.....	55
2.5.3	Motivating for sustainability .....	55
2.5.4	Implications for research.....	56
2.6	Project management for innovation .....	56
2.7	Involving facility managers.....	57
2.7.1	The relevance of facility management .....	57
2.7.2	FM competence.....	58
2.7.3	Exploiting FM knowledge in the development of sustainable building .....	59
2.7.4	Implications for research.....	60
2.8	Usability of sustainable buildings.....	60
2.8.1	Definitions of usability.....	60
2.8.2	Dimensions of the usability of buildings .....	61
2.8.3	Perspectives on usability .....	62
2.8.4	Evaluating usability.....	63
2.8.5	Usability of energy-efficient buildings.....	63
2.8.6	Implications for research.....	65
2.9	Life cycle cost analysis .....	65
2.9.1	Performance measurement using LCC .....	65
2.9.2	Implications for research.....	66
2.10	National and international policy for sustainable industry.....	66
2.10.1	The market pull for sustainable building.....	66
2.10.2	Public policy for sustainable building .....	67
2.10.3	Research-based industrial development of sustainable building .....	68
2.10.4	Diffusion of knowledge.....	69
2.10.5	Sustainable transition.....	71
3	Methodology and methods.....	75
3.1	Research design.....	75
3.1.1	Design approach .....	75

3.1.2	Role model projects.....	76
3.1.3	Case studies.....	78
3.1.4	Data collection.....	79
3.1.5	Data analysis.....	79
3.2	Materials.....	80
3.2.1	Selection of projects for case studies.....	80
3.2.2	Selection of informants.....	81
3.2.3	Literature search.....	82
3.3	Evaluation of the research design and material.....	83
3.3.1	Case study design.....	84
3.3.2	Advantages and disadvantages of case studies of role model projects.....	86
3.3.3	Evaluation of the selection of informants.....	86
3.3.4	Evaluation of the researcher's role.....	87
4	Findings in the papers.....	91
4.1	Structure of the chapter.....	91
4.2	Relevance to the thesis.....	92
4.3	Papers on the effects of collaboration and partnering.....	94
4.3.1	Use of collaborative working in projects with high energy ambitions (paper 2).....	94
4.3.2	Partnering for developing an energy-positive building (paper 3).....	96
4.3.3	Developing energy-efficient buildings – the challenge of management (paper 6).....	98
4.3.4	Summary of papers on the effects of collaboration and partnering.....	101
4.4	Papers on facility management, property management and usability.....	102
4.4.1	Involvement of facility managers during planning phase (paper 1).....	102
4.4.2	Life cycle analysis in municipal property management (paper 7).....	105
4.4.3	Summary of papers on facility management and property management.....	108
4.4.4	How energy efficient office buildings challenge and contribute to usability (paper 5).....	109
4.5	Paper on the impacts of R&D.....	113
4.5.1	Three stories describing the impact of research on the development of Norwegian construction industry (paper 4).....	113
5	Discussion.....	115
5.1	Discussion of organizing for innovation in building projects.....	115
5.1.1	Integration and knowledge development.....	115
5.1.2	Collaboration.....	116
5.1.3	Informal collaboration and social mechanisms.....	116

5.1.4 Mechanisms of the socio-technical system .....	117
5.2 Discussion of selected actor groups and their relevance to sustainable performance .....	119
5.2.1 The role of the owner .....	120
5.2.2 The role of facility managers and property management .....	121
5.2.3 The role of the users.....	123
5.2.4 Summary.....	126
5.3 Discussion of the implementation of sustainability in the construction industry .....	127
5.3.1 Diffusion from role model projects .....	128
5.3.2 Organizational learning from prize-winning projects.....	130
5.3.3 Transformation of construction industry from green niches.....	132
5.3.4 Implementation from open innovation.....	132
5.3.5 Implementation from a socio-technical perspective .....	134
5.3.6 Summary.....	137
6 Implications and suggestions .....	139
6.1 Perception of sustainable building.....	139
6.2 Broadening the concept of sustainability in the construction industry.....	140
6.2.1 Adding value from usability.....	141
6.2.2 Adding value from area efficiency.....	141
6.2.3 Measuring added value .....	142
6.3 Implementing sustainable building .....	142
6.3.1 A resource management hierarchy .....	142
6.3.2 A new breed of managers .....	143
6.3.3 A new breed of policymakers and decision-makers.....	143
7 Conclusion .....	145
7.1 Conclusion on the overall purpose.....	145
7.2 Conclusions on research questions .....	145
7.3 Challenges and suggestions for further development towards sustainable building.....	151
What does it take? .....	152
What is the major value of sustainable building, in particular energy-efficient buildings?.....	153
In summary.....	153
8 Further research .....	155
8.1 Organizational learning from role model projects.....	155
8.2 Stakeholder benefits from sustainable building .....	157
8.3 Implementation of sustainable building practice.....	157

References ..... 159





## Table of figures

Figure 1: Construction industry and its surroundings .....	12
Figure 2: Actors in role model projects .....	13
Figure 3: Theoretical and empirical approaches .....	15
Figure 4: Socio-technical system perspective .....	24
Figure 5: Socio-technical perspective on industrial systems.....	26
Figure 6: The three levels of analysis .....	35
Figure 7: Approaches and levels of analysis in studies included in the thesis .....	37
Figure 8: Multi-stakeholder network (based upon the figure of Feige et al, 2011, p 507) .....	43
Figure 9: Conventional and integrated design processes .....	45
Figure 10: The triple helix model for innovation policy, based upon Etzkowitz and Leydesdorff (2000) .....	69
Figure 11: "The research wheel" (based upon the figure of Johnson and Christensen 2004).....	75
Figure 12: Thematic groups of papers.....	91
Figure 13: Dynamics of relations at project level.....	93
Figure 14: Dynamics of relations between the construction industry and the surrounding community .....	93
Figure 15: Innovative organizing and the effects on energy.....	102
Figure 16: Involvement of facility managers .....	108
Figure 17: Challenges of innovative sustainable building from a socio-technical perspective.....	119
Figure 18: Role of users in buildings when they are being used .....	124
Figure 19: Construction industry from a socio-technical perspective .....	134
Figure 20: Internal and external dynamics of the construction industry.....	152



# 1 Introduction

## 1.1 Background of the thesis

There is an increasing concern about climate change and an increasing demand for energy. As the largest consumer of energy and natural resources internationally, the building sector is being challenged to develop sustainable alternatives (UNEP 2009). Increasing energy efficiency is identified as priority number one.

As a consequence of European regulation, above all the redrafting of the Energy Performance of Buildings Directive (EPBD) from 2002 (Directive 2010/31/EU), national parliaments are now implementing laws that push the industry to increase energy efficiency considerably. The question is how energy-efficient practice can be implemented in construction in a way that facilitates a transition towards a sustainable construction sector.

What does it take to create a change towards energy-efficient and environmentally sustainable construction practice? How can the Norwegian construction industry make the shift to sustainable building? What are the driving forces of the ongoing processes, and what are the challenges? To address these questions, this PhD study was developed to explore how sustainability in construction projects can be achieved. **The overall purpose is to increase the understanding of how the Norwegian construction industry is transforming towards sustainable building.** This study provides new empirical and theoretical insight beneficial for the industry and political decision makers.

Energy-efficient building in practice can be achieved in a number of ways. Many examples exist all over the world, and some of them have produced outstanding results. In Norway, there are pioneering projects, so-called "role model projects", in which owners, together with industry partners, have set themselves very ambitious goals. Goals for these projects are set voluntarily and not because of the new mandatory regulations. What can the Norwegian construction industry learn from its role model projects? Lessons learned from role model projects will open the door to the study of the transformation towards industrial sustainability.

In Norway, public requirements for energy efficiency in buildings have gradually increased. In 2010, the government stated that the ambition is for energy requirements to be at the level of the passive house standard from 2020. This is in accordance with the EU Energy Performance of Buildings Directive (EPBD). Since 2010, various programmes have been developed supporting ambitious initiatives to improve energy and environmental performance. Two examples of these are Cities of the Future (Regjeringen.no 2008-2014, Regjeringen.no 2011) and the Low Energy Programme (Lavenergiprogrammet 2007-2015). Other means of support include financial contributions, research and development programmes and the honouring of buildings that use innovative solutions or have an exceptional performance.

Technological development and market mechanisms are being used as driving forces for change towards environmental sustainability. The technology and market approach is recognized in national and international strategies. This is the case in relation to the UN and EU policies to reduce greenhouse gas emissions, which include strategies for the development of low-emission technology

and which are supported by the Norwegian government (Miljøverndepartementet 2014 - 15). It is also the case in relation to the OECD strategy for a knowledge-based industrial development (OECD 1996) which includes supporting research, education and innovation, and this is implemented by the Norwegian government.

However, the strategies are being questioned. Among other effects, a rebound effect from the use of modern energy-saving technology has been identified (Sorrell 2009), public procurement regulations are found to hamper innovation in the construction industry (Håkansson and Ingemansson 2013) and “technology forcing” as an implication of the EU EP strategy is being disputed (Schot and Rip 1996, Gann, Wang et al. 1998). In other words, regulations, technology and market mechanisms are not sufficient for an industrial shift towards sustainable building.

This thesis will address this knowledge gap, exploring alternative mechanisms for an industrial change, namely an organizational approach to innovation and industrial change.

The organizational approach draws upon theories of the dynamic of professional relations in projects, teams and industries. Studies within the construction industry and other industries are shedding light on how organizing, formally and informally, affects the behaviour of the individuals and enterprises, and thereby the result of the work, including effects on sustainability.

A socio-technical system model is introduced as a supplement to the “engineering approach” that dominates models for industrial innovation (Bresnen and Marchall 2000). The socio-technical perspective on organizing for innovation draws attention to trust, motivation, mutual learning and professional values as driving (or counteracting) forces for innovation, thereby supplementing previous studies on the role of formal partnering, tools for integrated design, evaluation models and other organizational techniques expected to promote sustainability.

The organizational approach also draws on the author’s education in organizational development and in research practice in industrial innovation and readjustment processes.

The organizational approach provides a model to analyse role model projects on two levels:

1. at the project-level, the facilitation of innovative development processes, and
2. at the industrial level, mechanisms supporting and hampering the transformation from conventional to emerging construction practices.

From the beginning of this research, it was expected that organizing was a key to innovative projects and sustainable development: the organizing of projects, team processes and the industrial system. During the process of carrying out the research, it became clear that the social implications of organizing are crucial, and have been underestimated in previous studies. This introductory essay presents how this new insight has emerged.

In the following, this chapter presents the theoretical approaches to the purpose of the research, including the theory on sustainability, innovation and socio-technical systems, and the empirical approaches, including the characteristics of the construction industry and case studies of role model projects. The chapter sets out the focus of the study, the objectives and the research questions, and

finally the chapter includes an overview of how the research papers contribute to explaining the overall purpose.

## 1.2 Approach

Transformation towards sustainable building is approached as an issue of organizing processes. The organizational approach is explained in section 1.3.1. The selection of actors and levels of analysis is explained in section 1.3.2.

Further, the purpose of the thesis is approached partly from a theoretical perspective and partly from an empirical perspective:

- Theoretically, sustainable building is approached as an industrial innovation issue. This approach will be examined later in the thesis partly as an issue relating to organizing for innovation (section 1.3.4), and partly as an issue relating to stability and change in industrial systems (section 1.3.5).
- Empirically, the issue of sustainable building focuses on the energy performance of the building. This is fully explained in section 1.3.3. The approach involves exploring prize-winning sustainable building projects. A selection of so-called role model projects has been studied to exploit experiences from case projects that have succeeded in developing innovative concepts for high-performance sustainable buildings. The role model approach will be introduced in section 1.4.

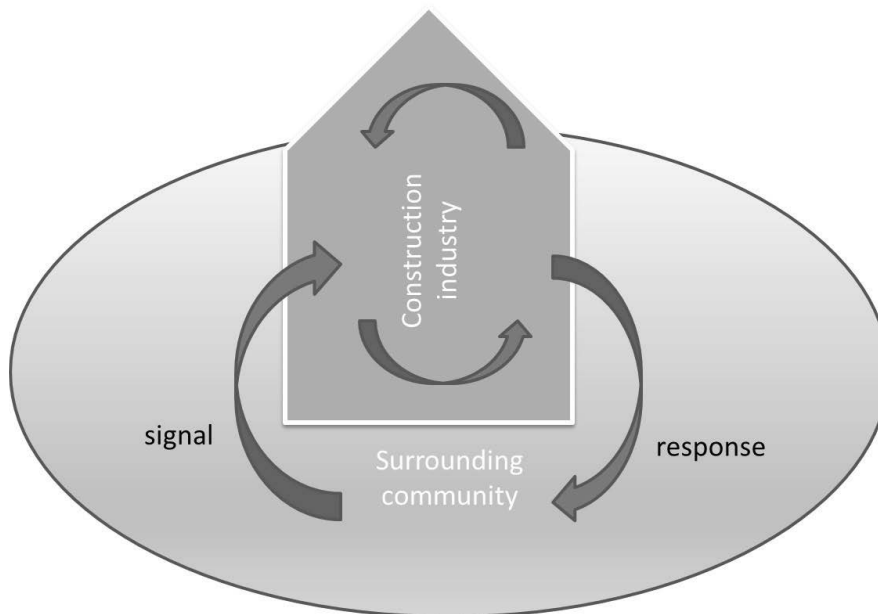
Using these theoretical and empirical approaches, the overall purpose of this thesis is explained in a set of research questions (section 1.6) which has been explored in individual studies presented in the papers included in Part II of this thesis.

### 1.2.1 An organizational approach

An organizational approach will be used to examine the issue. The rationale for this approach is that it provides a contribution from the social sciences that supplements that of the technological sciences in the efforts to develop sustainable building. An organizational behaviour approach (Roethlisberger 1977, Buchanan and Bryman 2007) is applied for the purpose of this PhD research. This implies using social theories to analyse organizations as subjects (or actors) that are interpreting their surroundings and acting upon them (Clegg, Hardy et al. 1996). Organizational studies provide an insight into the rationality of these subjects and the relations among them and to their surroundings. The studies included in this thesis apply an interpretative approach rather than a normative approach to the organizing of projects and industries (Buchanan and Bryman 2007). The focus of the attention is on the processes of organizing to achieve innovation and sustainability – the dynamics as well as the structures of the system.

The organizational approach to examine the industrial transformation towards sustainable building implies studying the construction industry as a system of actors. These actors are enterprises, institutions and other organizations operating within the value chain, and together they constitute the construction industry. The industry is related to its surrounding environment, which includes the market, international and national politics and other factors. Companies in the construction industry

are sensitive to changes in their surroundings. Similar to organizations in general, there is a mutual dependency between the enterprises operating within the construction industry and the financial and political institutions and markets which this industry relates to. When external conditions change, enterprises and organizations within the industry will respond. This creates a dynamic within and among the organizations. According to modern organizational theory, this should be considered as a continual, ongoing process of change.



**Figure 1: Construction industry and its surroundings**

The basic model in figure 1 illustrates the organizational approach to the purpose of the PhD project, including internal and external dynamics:

The external dynamics deals with the construction industry and the surrounding community, while the internal dynamics deals with the relations between actors within the industry. The construction industry is receiving signals from the surrounding community to increase environmental sustainability. The role model projects with outstanding energy performance represent a response from the construction industry to these signals. The organizational approach to the internal dynamics provides a theoretical model for analysis of the industrial actors organizing the processes to create innovative and sustainable buildings. The organizational approach to the external dynamics provides a theoretical model for analysis of formal and informal structures affecting transformation of the industry.

#### 1.2.2 Actors and levels of analysis

In accordance with the organizational approach, the analysis will explore which actors (stakeholders) are involved in sustainable building projects, and also their roles and agendas and their input and output in relation to the processes. At the project level, the analysis will explore the internal dynamic

between the actors and how the dynamics affect the sustainability of the resulting building (see figure 2).

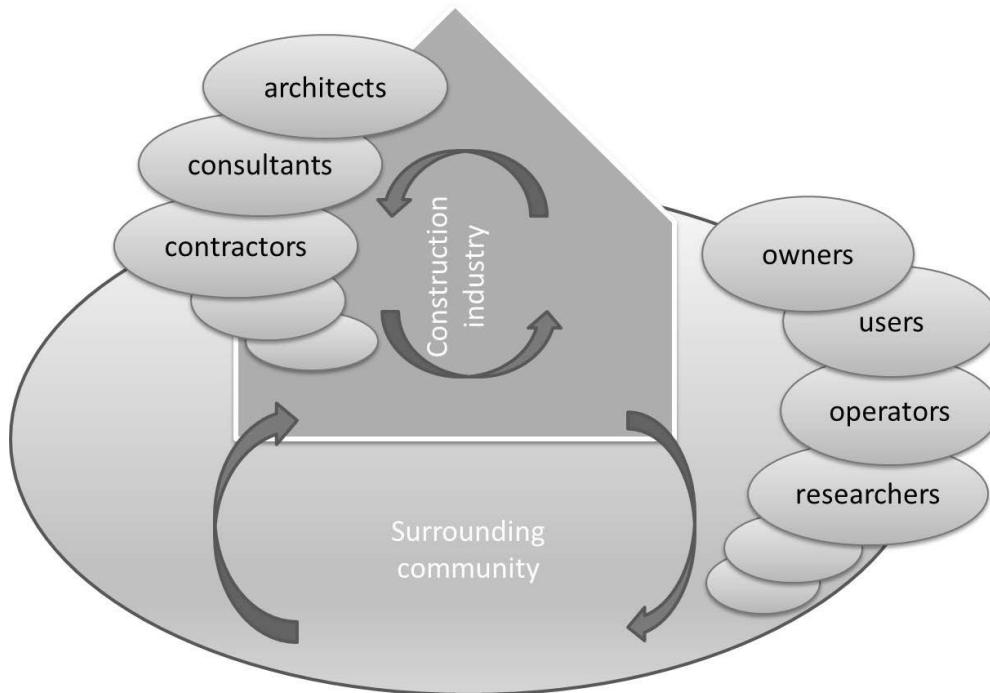


Figure 2: Actors in role model projects

This thesis will include analysis of development at two levels, namely the industry level and the project level. Key actors in the process of developing sustainable building include both industrial actors (enterprises) and actors in the surrounding community, as suggested in figure 2. Architects, consultants and main contractors are expected to play key roles among the industrial partners, while owners, end users and operators are expected to play key roles in the surrounding community. In addition, research institutions are expected to play a key role, due to the innovative aspect of sustainable building.

Arguments for selecting these actor groups are as follows:

- Owners have a key role as strategic decision makers regarding the purpose of the building, and thereby represent the demand side of the market.
- Architects have a key role in developing the owners' requested purpose for the building into a concept for the built facilities.
- Consulting engineers contribute to alternative solutions and specifications for construction. Analysis of energy performance and environmental impact are among the contributions of engineers to the decision-making process.

- Contractors represent the production chain that transforms plans into reality, and thereby have a key role in following up on the quality of the work and the materials being used, including in relation to subcontractors and suppliers.
- The users have a key role in terms of the actual performance of buildings. Users' behaviour, whether as user organizations or individual occupants, has been identified as a major challenge to the sustainability of the performance of buildings (Grini, Mathisen et al. 2009, Newsham, Mancini et al. 2009).
- Facility managers have key roles in the operation of the buildings, which amounts to the major part of energy consumption during service life of the buildings. Property managers have a key role in the maintenance and refurbishment of building portfolios, and thereby play a key role in sustainability of buildings from a lifetime perspective.
- Researchers have a key role regarding innovation and change in practice within the construction industry. Education and research are vital instruments of international strategies for industrial and economic development.

This selection of actor groups for analysis will be further argued for, and partly modified, as a result of what is discussed in literature review presented in chapter 2.

Two phases in construction projects are selected for special attention in the analysis of innovation, namely the planning and the occupation and operation of the final building. The arguments for selecting these phases are as follows:

- The early planning (concept) phase is when goals for the facilities, including the qualities of sustainability, are transformed into design, materials and solutions for the building.
- The occupational phase is when the users experience the performance of the building, including sustainability.

Table 1.1 gives an overview of combinations of actor roles and the levels of analysis covered in this thesis, partly in the included papers (P1-7) and partly in the discussion (chapter 5).

Table 1.1: Actors and levels of analysis covered in this thesis

Actors	Project level		Industry level
	Early planning phase	Occupation and operation phase	
Clients/owners	P1, P2, P3, P6	P6	Discussion
Architects	P2, P3, P6		
Consulting engineers	P2, P3, P6		
Constructors	P1		
End users	P5	P5	Discussion



Facility managers, property managers	P1	P7	
Researchers			P4

The following sections further explore the concepts that form the theoretical and the empirical approaches to the purpose of this thesis. The theoretical approaches include the concept of sustainability (section 1.3.3), the concept of innovation (section 1.3.4) and the system theory approach (section 1.3.5). Next, there will be further examination of the aspects that are included in the empirical approach of the thesis, namely the organizational characteristics of the construction industry (section 1.3.6) and the rationale for studying role model projects (section 1.4). The approaches are illustrated in figure 3.

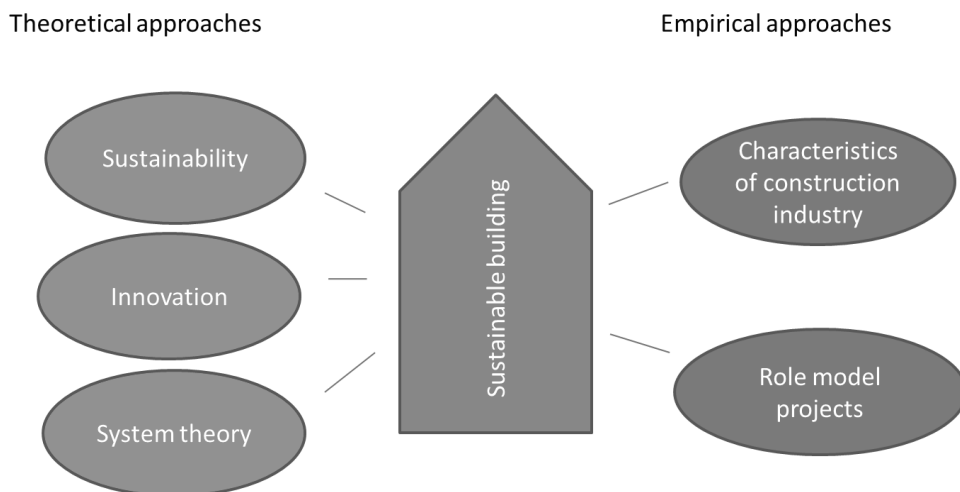


Figure 3: Theoretical and empirical approaches

### 1.2.3 Sustainable building

“Sustainability” is a concept that has various meanings depending on the context. The following section explores how sustainability relates to buildings and the construction industry. The purpose is to find a fruitful approach to analysis of industrial development of sustainable building.

The interest in sustainable building is caused by the global concern about climate change. The International Energy Technology Perspectives 2012 (ETP) focuses on the goal of limiting the global temperature rise to 2°C: “If no action is taken to improve energy efficiency in the building sector, energy demand is expected to rise by 50% by 2050. The 2°C Scenario would require an estimated 77% reduction in total CO<sub>2</sub> emissions in the building sector by 2050 compared to today’s level” (IEA

2013). The strategy for decarbonisation in buildings suggests a reduction in energy demand, an increased use of renewables and, most importantly, a decarbonized power sector.

Sustainability deals with the carrying capacity of natural systems regarding human activities. The term was introduced in the book *Limits to Growth* as a response to the concern for the development of the global economy and the growing population that was exploiting natural resources (Meadows, Meadows et al. 1972).

The World Commission on Environment and Development (UN 1987) used the term to indicate the direction that sustainable development ought to take: “Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

The term has been further developed for strategic and practical purposes. The concept of “the triple bottom line” (Savitz and Weber 2006) acknowledges three pillars of sustainability: the economic, the environmental and the social. The triple bottom line has become the United Nations standard for urban and community accounting (2007) and the dominant approach to public sector full-cost accounting. Similarly, in the private sector, commitment to corporate social responsibility (CSR) implies some form of triple bottom line reporting.

#### *Sustainability and industrial development*

For an industry or business actor, energy efficiency and other forms of environment-friendly use of resources are possible only within the framework of economic sustainability for the actors. Recent times of economic pressure have exposed inefficiency in business processes and practices in a number of industries, and thereby have revealed a lack of long-term sustainability in industry practices.

Some contributors claim that sustainability is a matter of the ability to consider change in a boom time and to be prepared for the future (McLeod 2008). This became an issue that was discussed in the recent period of economic pressure, in the UK construction industry and in other areas (McLeod 2008).

There have been initiatives that explore economic opportunities in more environment-friendly production and consumption. These include OECD’s strategy for green growth (OECD 2011), which proposes a policy framework with a focus on “innovation, investment and competition that can give rise to new sources of economic growth – consistent with resilient ecosystems”. I also include the UN strategy for a green economy, which suggests how further development of human well-being can be decoupled from resource consumption (Fischer-Kowalski, Swilling et al. 2011). In Norway, the national strategy for sustainable development is based upon a combination of regulations, taxes and the financing of research and education (Nærings- og handelsdepartementet 2008-2009).

To summarize, the above implies that for the purpose of analysing the development of sustainable building in the Norwegian construction industry, environmental sustainability has to be considered within the framework of economy for the industry and the requirements for infrastructure in the community.

#### *Sustainability in the construction industry*

The building sector is the largest energy-consuming sector, accounting for over one-third of final energy consumption globally; it is an equally important source of carbon dioxide (CO<sub>2</sub>) emissions (IEA

2013). The building sector also accounts for a similar portion of the exploited natural resources, especially wood, metals and cement (UNEP 2009).

Concerns about climate change have resulted in intensified efforts in the development of solutions for environment-friendly construction and refurbishment. These include the United Nations Environment Programme's Sustainable Building and Climate Initiative (UNEP 2009), which suggests strategies for different actors, including government, investors, insurance companies, property developers and buyers/tenants of buildings.

Sustainability is high on the international research agenda, including that of the European Construction Technology Platform (ECTP).<sup>1</sup> The agenda includes the vulnerability of critical infrastructure, and future materials and technology for construction.

Worldwide, there are national initiatives involving industry partners and research partners, partly supported by governments. For an overview, see (Hampson, Kraatz et al. 2013).

In Norway, a group of national Centres for Environment-friendly Energy Research (FME) has been established. Eleven centres contribute to the development of technologies for environmentally friendly energy. One of the centres is The Research Centre on Zero Emission Buildings (ZEB), which is working not only on technology and building materials and products, but also on the challenge of implementing new practice in the Norwegian construction industry.<sup>2</sup>

To summarize, buildings are acknowledged as important for built infrastructures in our communities, and a broad spectrum of actors, in addition to the construction industry, is being challenged to contribute to sustainability.

#### *Sustainable buildings*

Environmental sustainability includes a number of variables and aspects. Life cycle assessment (LCA) analysis has become recognized as useful in building projects with ambitions for environmental sustainability. Databases are being developed internationally to include CO<sub>2</sub> values for increasingly more resources and more aspects of buildings' life cycle. The usefulness of LCA analysis is due to models that measure environmental effects in numbers, which implies that there is the potential for comparing alternative designs, materials and building solutions in individual building projects. "Embodied energy" is being introduced as a concept to grasp the energy spent during all stages of a process in manufacturing and transporting building materials.

Voluntary certification programmes for buildings have been developed, such as Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Methodology (BREEAM) and Green Star. Such programmes translates the principles of LCA analysis into a practical analysis of the construction. These programmes also supplement LCA analysis by addressing the surrounding community, especially transport solutions.

Independent of measuring methods and models, energy is given special attention in environmental analysis. Energy is relatively easy to measure. And energy draws attention to the lifetime aspect of

---

<sup>1</sup> [www.ntnu.no/indecol/research/infrastructure](http://www.ntnu.no/indecol/research/infrastructure)

<sup>2</sup> [www.sintef.no/Projectweb/ZEB/About-ZEB/](http://www.sintef.no/Projectweb/ZEB/About-ZEB/)

buildings, since 80-90% of greenhouse gas emissions result from energy spending in buildings during its use and operation (UNEP 2008). Energy analyses includes not only energy consumption, but also draw attention to recovery of heat, to localization of the plot, to effects of alternative designs, and to generation of energy on buildings. Improving energy efficiency in buildings is considered the most important factor for delivering significant and cost-effective greenhouse gas emission reductions (UNEP 2009).

Research and development of sustainable building is based upon the UN Kyoto protocol on greenhouse gas emission reduction (UN 1997) and the 3R principles for reducing the carbon footprint; reduce – reuse – recycle. Various methods and calculating tools have been developed for the purpose of designing buildings with low or net zero energy consumption, including the Energy Triangle (Haase and Amato 2005) and the Kyoto Pyramid (Dokka 2005). These methods are based upon the Trias Energica model (Lysen 1996), suggesting a stepwise approach, starting with energy saving (applying passive means), then maximising the use of renewable energy sources and finally use fossil fuels efficiently.

The forefront of the industrial development has gradually changed the priority from energy- saving (the passive house concept) to energy production (the active house concept), and from waste-handling to low-emission buildings. This is reflected in the focus of building concepts, where low energy and the passive house are becoming recognized and preferred among an increasing number of clients. The innovative forefront of change now includes developing concepts for active house and zero emission buildings.

This rapid development is recognized among the case projects covered in this thesis: year by year, pioneering projects have improved energy performance and broadened the spectrum of environmental aspects taken into consideration.

An internationally approved definition of “sustainable building” is provided by ISO 15392 as follows: Sustainable development of buildings and other construction works creates the required performance and functionality with minimum adverse environmental impact, while encouraging improvements in economic and social (and cultural) aspects at local, regional and global levels” (International Organization for Standardization 2008). This definition emphasizes the three pillars of sustainability, and also points to the planning phase as the key to sustainable building.

A simplified definition is that “sustainability ensures the smallest possible strain on resources and the environment, and contributes to a sustainable society as a whole” (Hovde 2004, Hovde 2008). This definition draws attention to the entire product life cycle, including not only the construction of new buildings, but also their use, maintenance and refurbishment, and the final demolishing and recycling of resources.

#### *Sustainability of the buildings when in use*

Recent contributions points to the fact that producing and using sustainable products does not by itself generate sustainable outcomes. The argument is that it is users developing new practices involving products and technologies that results in sustainability. Ozaki et al. (Ozaki, Shaw et al. 2013) argue that “the effectiveness of environmental strategy, which meets demand for sustainable outcomes, can be only understood through the appreciation of how organizations, and their products and customers, are implicated in, and co-produce, the processes and practices that deliver

sustainability". Environmental sustainability is seen to be the result of "co-produced sustainability" or "negotiated consumption" (Ozaki, Shaw et al. 2012, Ozaki, Shaw et al. 2013).

Similarly, for built infrastructures such as buildings, environmental sustainability depends only partly on the physical construction itself. Transformed to relate to the issue of sustainable building, this perspective implies that analysis of the construction industry must include how organizations/enterprises and their customers negotiate and co-produce the buildings and practices that deliver sustainability.

For business operations in general, it is recognized that to be sustainable in the long term, they need to reduce waste and use natural resources more efficiently (Pitt and Tucker 2008). The facility management (FM) profession is becoming acknowledged as significant for "green practice" in business organizations, and also for productivity and reputation. In other words, operators and facility managers represent key competence in co-producing sustainability of buildings, and will therefore be included in the empirical analysis.

#### *Implications for the approach*

This overview has the following implications for the analysis of case projects that engage in sustainable building:

- Analysis must consider the triple pillars of sustainability to understand the agendas and behaviour of the various actors involved in the industrial transformation towards sustainable building.
- Analysis must include the industrial actors developing and constructing the buildings, the clients and actors representing changing demands from the surrounding community, and also the occupants and operators that will be using the buildings during their lifetime.
- Analysis of sustainable building projects must include both the planning and design phases and the buildings when they are being used.

#### 1.2.4 Innovation

Improving environmental sustainability in buildings requires innovation and a change of practice within the construction industry. The ability to develop and improve the quality of products and services is crucial for any industry in a community paying increasing attention to sustainability. Innovative "green alternatives" represent new business opportunities and are gaining shares in the market, e.g. in relation to energy and transport.

#### *Theory on innovation*

The interest in innovations is related to expectations that the new products and services will make contributions to the development of the human community. Historically, the focus has been on innovative technology and on the purpose of saving labour in production (industrialization). Economists have highlighted the role of technological change in economic growth (Schumpeter 1943). Currently, information and communication technology has proved to have a vital role in the knowledge-based economy. And there are high expectations for innovative technology in improving the environmental performance of the global community, as presented in the OECD's strategy for green growth (OECD 2011).

Traditionally, studies of innovation have focused on the creation of new products and on the individual inventor, company or research department. Later studies and theories contribute with knowledge about innovative processes that are responses to changes in the surrounding community and how innovations are related to the rest of the production chain and to the implementation and diffusion of innovations.

The research area of innovations has been broadening as more perspectives have been added to the field of knowledge. Four aspects are of special relevance for identifying the approach of the analysis in this thesis:

- a) A shift of focus from the novel product to the innovative system
- b) Awareness of social and cultural aspects of innovation
- c) A shift of focus from the creation of innovations to implementation and diffusion
- d) Awareness of the relevance of process innovations

While a classic definition presents innovations as a deterministic, linear progression, later theoretical and empirical work reframes innovation as a complex interaction between users, producers and intermediaries located in (and shaping) an institutional context (Whyte and Sexton 2011). The complexity relates not only to the fact that innovation is a collective action but to the dynamics among the actors in the networks.

The “open innovation” model (Chesbrough 2006) is evident in such co-evolutionary processes, suggesting that in today’s information-rich environment, companies can unlock economic value in the market by combining their own ideas and technology with external sources. In this perspective, the development of innovative sustainable building is a complex process, and involves interrelated networks of enterprises throughout the whole value chain, including end users and operators, and also research and education.

#### *Diffusion of innovations*

The theory on the diffusion of innovations focuses on how and at what rate new technology and ideas spread throughout the community. Diffusion is the process by which an innovation is communicated through certain channels over time among the members of a social system (Rogers 1962 / 2003). Innovators and early adopters are the first groups to adopt an innovation. With the next group, the early majority, diffusion accelerates. Late majority adopters are sceptical and adopt later, while “laggards” is the group resisting change the longest. Innovators are the most risk tolerant, and early adapters represent opinion leadership. Innovations are challenging the existing products and technological systems, and only very few are able to reach a critical mass for adoption.

Studies of technological development have moved from being studies of diffusion to studies of interaction (Håkansson and Ingemansson 2012). As various kinds of technology become more interrelated, the relevance of interaction between various involved enterprises is about to become recognized. Development of a product or a process cannot be done by an individual company, but needs relevant counterparts. The client or user can be such a counterpart, as can suppliers of materials or products or research and development (R&D) organizations. This points to the long-term dynamics between new technology and its users, that is, the co-evolution of technology and society.

#### *Implications for the approach*

To summarize, the challenge for more sustainable building is a two-fold one for innovation in the construction industry. The need to develop innovative designs, materials and technical solutions is one part of it. Another part is the need to organize innovative working processes. This thesis focuses on the second part of the challenge.

At the project level, innovation for sustainable building implies focusing on the process of developing the individual building, from early planning and into early occupation of the final building, while at the industrial level, innovation for sustainable building implies focuses on relations between the industry and its surroundings, namely initiating innovation and implementation/diffusion.

Theory of diffusion of innovations emphasizes the inclusion of both the supply side (innovations) and the demand side (user environment) in the analysis of innovations.

#### 1.2.5 System theory

The challenges for sustainable building were presented in figure 1 as signals to actors within the construction industry from the surrounding context. However, response time varies. The general experience is that changes do not happen quickly within the construction industry. Among the explanations for the slow change of practice is the close interdependency within the production chain (Christie, Donn et al. 2011). Also, other characteristics of the construction industry are found to restrict the industry's ability to develop and change.

The following section will introduce the system perspective to create a clearer understanding of the dynamics of stability and change within the construction industry. A system perspective, when used in the analysis of innovations, provides a framework to analyse processes involving the chain of actors in construction projects. The socio-technical system model will be introduced.

This section also presents how characteristics of the construction industry that can be understood in the system perspective, and suggests implications for the analysis in the research contributions that is presented in this thesis.

#### *The construction industry as a system*

System theory originates from natural sciences, and predicts that balance is the ideal for any system. This approach contributes to understanding mechanisms for stability and evolutionary change in the construction industry as well as in other industries. Sustainable building practice can be analysed to explore the driving forces behind innovative initiatives, and also to identify the barriers to change that are embedded in the industrial system.

According to traditional approaches, organizations deal with changes in their surroundings one at a time. Models for strategic planning, organizational development and other types of change represent the underlying idea that changes in the surroundings disturb stability in the organization, and that to develop a new strategy and structure is supposed to result in a new stability. This can be considered as a stepwise organizational development. In other words, change is the exception and stability is the norm (Clegg et al. 2011).

However, in many industries the reality is rather that there are continual changes going on, as responses to signals from the market, competing companies, introduction of new technologies, changes in the global economy, political changes or sudden events. These might be changes that start internally in the organization or externally, which soon affect other organizations, and the organization has to decide if and how to respond to them. The development of ICT implies that organizations have a broad relation network and that information is communicated quickly. Every organization has a high number of signals to consider, and responses have to be quick. The construction industry is facing an increasing number of signals, including the challenge to improve environmental sustainability, and need to develop structures that can deal with continual development.

The perspective of “industrial systems” focuses on how innovations relate to the community surrounding the production chain. The infrastructure includes not only technology but politics, economy and finance, social systems in the community, education, applied research, and users and others. There is network of various actors in the value chain of an industry, and the innovative activities are underpinned by an institutional framework (Asheim and Coenen 2005) including universities, research institutes and development programmes. From this perspective, innovations are perceived as co-evolutionary processes, implying that the “success of innovation depends on weaving a seamless web between these domains into a functioning whole” (Geels 2004 p 898). Construction is, to a high degree, related both to the market and to the government, and is therefore sensitive to changes in public regulations, finance and preferences in the market.

Industrial systems may be defined in terms of competence networks and flows of knowledge rather than flows of ordinary goods and services (Carlsson and Stankiewicz 1991). This perspective is found to be especially relevant to following up and evaluating the effects of industrial policy and national strategies for knowledge- and research-based innovation (see chapter 2).

The system perspective contributes to this thesis by clarifying how actors and processes in any organization, whether it is an enterprise, an industry or a community, are interrelated. Relations develop over time and create a pattern, including formal and informal structures, and the members act according to this pattern. The system perspective originates from natural sciences and has diffused from biology and ecology to technical and social sciences. Two major characteristics of systems are of interest:

- The tendency to search for balance and stability
- Circular processes

Applying a system perspective to the construction industry contributes by revealing the interdependency between the enterprises. Even if they often consider each other as competitors, they are part of the same value chain and relate to the same market, regulations, education system and natural resources, etc. Of special interest is the dynamics of change and stability within a system. A change or initiative in any part of the system (or its surroundings) will trigger a reaction. In this perspective, incentives for developing more sustainable building practice are such an external change triggering the construction industry. And, in a system perspective, role model projects may be interpreted as a response from the industry to signals from the surroundings for the purpose of re-achieving balance with the external community. Each individual construction project can be



interpreted as a circular process in which actors within the industry respond to current signals from other internal and external actors.

*The construction industry as a socio-technical system*

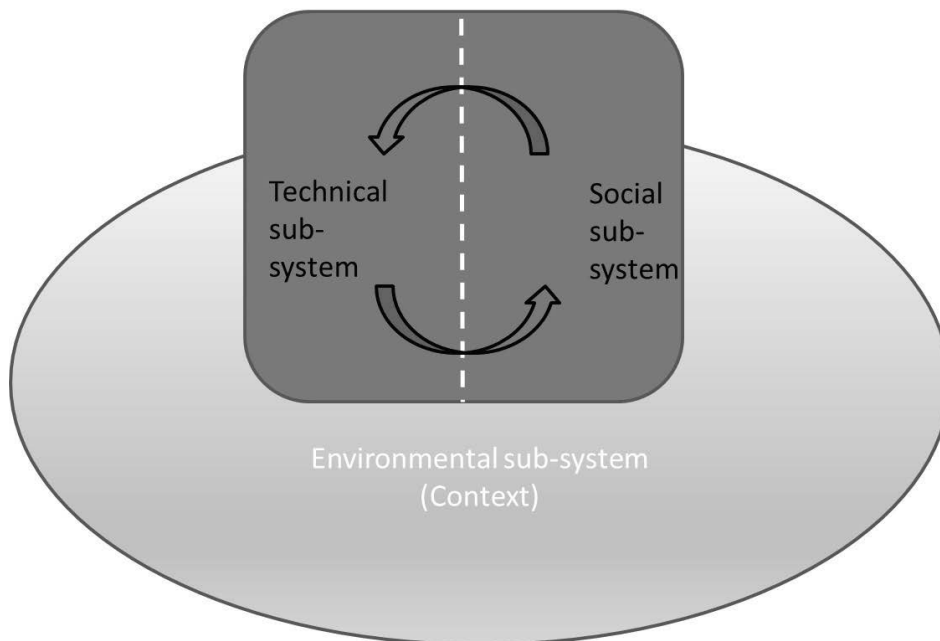
Efforts to improve the sustainability of constructions have been focusing on technology, materials and building solutions. The experience to date is that even if technology, materials and knowledge are available, change of industrial practice is slow (Cole 2000, Cole 2011, Whyte and Sexton 2011) The situation has similarities with the historical background of the development of the socio-technological system perspective. In the middle of the 20<sup>th</sup> century, a number of industries introduced new technology and had high expectations for production efficiency, but experienced resistance from the workforce. Behavioural scientists at the Tavistock Institute developed the socio-technical perspective to analyse the problems that were encountered when trying to implement new technology in industries (Trist and Bamforth 1951, Emery and Trist 1965). In this thesis, the perspective will be explored for the purpose of analysing change and resistance regarding sustainable building.

The “socio-technical perspective” suggests that any organization, enterprise or community can be analysed as a system consisting of two sub-systems, namely the technical and the social. The technical sub-system comprises facilities, tools, devices and techniques that transform inputs to outputs during the performance of the organization, enterprise or community. The social sub-system comprises the knowledge, skills, attitudes and values with which the employees, customers or citizens contribute.

A generic model of a socio-technical system includes the following (see figure 4):

- The *social sub-system* consists of formal and informal structures and the actors who are members of the system.
- The *technical sub-system* consists of the technology (including buildings) and the tasks (work, activities) being achieved in the system.

In addition, there is the context in which the system exists: the *environmental sub-system*. In the case of an enterprise or similar system, this consists of customers and suppliers and the rules and regulations, formal and informal, which govern the relations of the organization with society at large.



**Figure 4: Socio-technical system perspective**

The socio-technical perspective provides additional insight for analysing the dynamics of implementing the innovative solutions and technology in ordinary building practice. This perspective is relevant in the analysis of change in and stability of the construction industry, because it combines technical/physical and social/cultural aspects of building activities. In this way, the socio-technical perspective includes the actors, their agendas and resources in the analysis.

The socio-technological system perspective contributes to this thesis by highlighting the interrelations between technology and people. It indicates that:

- The activities in an enterprise in an industry, in a community or in a building, include both a technical sub-system and a social sub-system.
- Best performance is reached when there is a balance between the two sub-systems.
- There is a need for “joint optimization” during the implementation of new technology, emphasizing a consideration for technical performance and the quality of people’s lives. For this purpose there are developed a set of socio-technical design principles (Cherns 1976 , Clegg 2000).

The perspective contributes by revealing the dynamics of development and change, and drivers and resistance. It supplements the industrial system perspective by revealing the strength of the social sub-system in processes of development.

Analysis of sustainable building in a socio-technical perspective can be applied at multiple levels. For the purpose of this thesis, the analysis will include two levels, namely the project level and the

industry level. The following sections illustrate how a socio-technical approach can be applied to the research questions and studies included in this thesis.

*a) The project in the planning phase from the socio-technical perspective*

The planning processes of role model projects can be analysed as socio-technical systems. The socio-technical systems in question includes the client, architects, consultants and other stakeholders involved in the planning phases. The technical sub-system consists of existing and innovative management means, including, for example, partnering contracts or integrated design, while the social sub-system consists of the many professionals and representatives involved in the process, including their various cultural backgrounds, skills and motivations.

Chapter 5, Discussion, provides a re-analysis of the findings in papers 1, 2, 3 and 6, and explores the development of a joint optimization of the project's organization that results in innovative sustainable buildings.

*b) The building when in use from the socio-technical perspective*

Energy-efficient buildings can be seen as a new technology introduced to improve production in the user organizations. In a socio-technical perspective, this can be interpreted as new "technology-in-use" meeting the existing culture and organizational structures of the user organizations, and thereby a new "fit" for people and tasks in their daily activities is developed.

The socio-technical systems in question are the user organizations. The new buildings represent a change in the technical sub-system of the user organization. The socio-technical perspective implies exploring how this change affects the social sub-system and whether a new fit that balances technical performance and the well-being of the relevant people has been achieved.

Chapter 5, Discussion, provides a re-analysis of the findings in paper 5 on the usability of energy-efficient office buildings.

*c) The construction industry from the socio-technical perspective on*

An industry can be analysed as a system that includes three dimensions and the dynamics between the dimensions (Geels 2004, Geels 2006), as illustrated in figure 5.

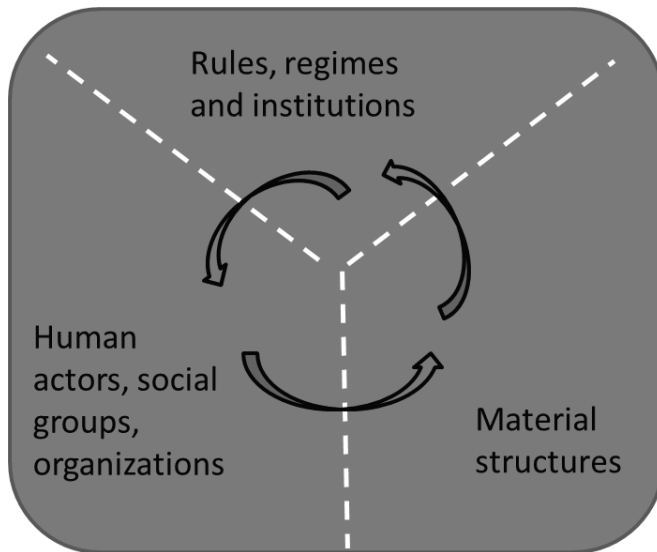


Figure 5: Socio-technical perspective on industrial systems

The first dimension includes rules, regimes and institutions. Rules and regimes are guiding actions and perceptions. Both formal and informal rules are included: cognitive, normative and regulative ones. When actors operate according to the rules and also reproduce the rules, they become *institutionalized* (Berger and Luckmann 1967). Alignment between the rules implies that it is difficult to change one rule without altering some of the others. The construction industry is an example of a system in which the participants – enterprises, organizations and individuals – act in accordance with institutionalized informal guidelines which affect the behaviour of individuals and enterprises as if they were physical structures (Scott 2004). Studies of the construction industry reveal how cognitive routines make engineers and designers look in particular directions and not in others (Nelson & Winter 1982, Dosi 1982). Skills and knowledge are “cognitive capital”, and it takes a lot of time to build up new competence. Learning builds upon existing knowledge, and thereby contributes to “path dependence” and “lock-in” (Arthur 1994, Sydow, Schreyögg et al. 2009).

The second dimension includes actors and enterprises embedded in interdependent networks. Once networks have formed they represent a kind of “organizational capital”, e.g. knowledge of who to trust and who to call upon. This can be a source of competitive advantage (Black and Lynch 2005). The mutual dependencies between buyers, suppliers and financial backers contribute to stability (Gadde and Dubois 2010).

The third dimension is the material structures of the system. Complementarities between components and sub-systems are an important source of inertia in complex technologies and systems (Kash and Rycroft 2002). The material networks and the artefacts are found to almost acquire a logic of their own (Walker 2000) and are hard to change.

System theory contributes to an understanding of the informal mechanisms and structural characteristics that are challenging innovation in the construction industry.

A summary of this section is that the purpose of this thesis can be redefined according to the socio-technical perspective: introducing sustainable building (solutions) can be considered as a redesign of the industrial system of the construction industry:

- What impacts does such a change in the technical sub-system have on the social sub-system?
- For the purpose of making a system of sustainable building achieve superior results, how can it be ensured that the sub-systems are working in harmony?

#### *Sustainable innovation from a system perspective*

Traditionally, innovative organizations are described as small, autonomous work units (Dougherty 1996). The alternative system approach focuses on the network of companies, organizations and other parties active in developing and making products and in utilizing technologies. Industrial system theories on innovation emphasize that there are a number of different agents involved in a production chain, and that changes in production within a single company will have consequences both for relations with the various suppliers and for relations with the market (Geels 2004). The construction industry is characterized by close relations between a large number of actors, and a system approach is relevant for studies of innovation and change in practice.

The innovative system perspective system implies that the scope of analysis has been broadened from artefacts (the product) to systems and from individual organizations/enterprises to networks of stakeholders, and also includes relations with the surrounding community/context.

Studies of innovations traditionally focus on the supply side of the innovative system. However, theories on diffusion highlight the demand side of the system, supplying information about the role of the users of the products and the market, and thereby acting as a reminder that innovations depend on competition and selection by market mechanisms. This is highly relevant regarding a shift to more environment-friendly solutions and products.

Energy-efficient buildings can be seen as innovative technological systems. Using the industrial systems perspective in analysis of innovation implies including not only a generation of technology, but also diffusion and utilization of this technology. "Technological systems" may be defined as "networks of agents interacting in a specific technology area under a particular institutional infrastructure to generate, diffuse and utilize technology" (Carlsson and Stankiewicz 1991). This definition focuses on implementation as being crucial for the survival of innovations.

Studies of innovative systems have a strong focus on the development of knowledge and technology and pay less attention to the diffusion and use of technology. The perspective of socio-technical systems broadens the analytical focus even further by including the social aspects of technology and innovation. The analytical focus is on the interaction between people and technology, and contributes by showing how work and well-being are affected by products and their users. The socio-technical system perspective contributes by highlighting the implementation and utilization of innovations, impacts and societal transformations. A widening from industrial systems of innovation to socio-technical innovative systems This implies that the fulfilment of societal functions, such as

housing, transportation, communication and others, becomes central (Geels 2004). As for sustainable building, the socio-technical system perspective implies that analysis must include qualities experienced by the user and the functionality of the facilities, and not just the buildings themselves.

#### *Implications for the approach*

Theories on innovation and industrial systems contribute with elements of analysis relevant to understanding how and why (or why not) more sustainable (environment-friendly) constructions are being built. The following aspects will be included in the analysis:

- relations between networks of firms interacting and cooperating
- the user side/role of innovations (co-producing, co-evaluating)
- the flow of knowledge and competence related to sustainability
- diffusion and utilization of innovations in the context of innovations and change, including policy and markets

#### 1.2.6 Characteristics of the construction industry

The construction industry is characterized by a large number of small and medium enterprises operating in complex production chains. Production is a one-of-a-kind project. Participation in each project is based upon what competition there is in the market. These characteristics are crucial to an understanding of the dynamics of stability and change in the industrial system, including the dynamics of developing sustainable building.

Studies on the construction industry internationally have explained the system mechanisms. The following are examples from published literature.

- The production chain has been interpreted as a temporary organization: for each project, a new organization is assembled, consisting of partly new actors: buyers, entrepreneurs and various subcontractors. These are individuals that have not worked together before. They represent different values and procedures and have different roles and responsibilities (Orange, Burke et al. 2000).
- The construction industry is also found to be a loosely coupled system: the pattern of couplings among activities, resources and actors is differentiated between individual projects, permanent networks and collective adaptations in “the community of practice” (Dubois and Gadde 2002).
- The industry is segmented into silos of interests. There is little alignment of objectives among the silos; each is optimized for its own interests (Jonassen 2010).
- The industry is characterized by competition. Competition is intensified by procurement regulations.

Even if terminology and analytical approaches vary, these and other studies share the concern about the implications regarding the ability to develop and respond to changing expectations from the market and the community. The following examples illustrate this:

- The pattern of loose couplings favours short-term productivity while hampering innovation and learning (Dubois and Gadde 2002).

- Each segment is optimized for its own interests. There is poor and discontinuous information flow between parties (Jonassen 2010).
- Current business models and contracts reinforce barriers to collaboration and integration. Recent studies indicate that procurement regulations counteract development within the industry (Håkansson and Ingemansson 2012).
- There is little attention given to evaluating the performance of buildings. As a result of the project-based activity, participants in one project continue to the next one without an evaluation of the outcome. This is an obstacle to learning and the transfer of knowledge from innovative (sustainable) design/solutions to further projects and other organizations within the industry.
- There exists a “blaming circle”, in which the actor groups blame each other for limited innovation, such as the limited supply of sustainable buildings (Warren-Myers 2012).

These characteristics of the construction industry represent a paradox regarding developing sustainable building. On one hand, the project-based activity and one-of-a-kind production imply that in principle every single project is an opportunity for innovation. On the other hand, the continual reconstruction of teams and lack of evaluations and follow-up studies imply that there are limited learning effects (Meistad and Obolonska 2010, Bakker, Cambré et al. 2011, Hampson, Kraatz et al. 2014).

Theories and models on industrial systems and socio-technical systems are useful to show how the system resists change to a significant degree. Geels emphasizes that “[t]his system interdependence is a powerful obstacle for the emergence and incorporation of radical innovations” (Geels 2004 p 911). The theoretical models may also be useful for exploring incentives and driving forces for the development of sustainable building.

#### *Implications for the approach*

The system approach has a number of implications for studies of the development of sustainable building. The following will be included in studies covered by this thesis:

- The industrial system model reminds us about the variety of enterprises and organizations that are part of the system. However, only a selection of stakeholder types/groups will be included in studies covered by this thesis.
- The socio-technical system reminds the researcher to include the formal and informal rules and perceptions that the various stakeholders are guided by. For the purpose of the studies included in this thesis, these include the roles, professions and interests of the selected stakeholders.
- The socio-technical system reminds us to include the material conditions, rules and regulations that form a context for action. For the purpose of this thesis, the incentive programmes for energy-efficient building will be analysed.
- The socio-technical system reminds the researcher to include the dynamics between the actors, the perceived rules and the technical possibilities. For the purpose of this thesis, the analysis will focus on the knowledge and experience of innovative alternatives for sustainable building.

### 1.3 Role model projects

The motive for studying role model projects is to learn from examples that have succeeded. The projects selected for case studies have been honoured as prize winners due to their energy performance and environmental qualities. However, what is of interest for this thesis is that during the processes carried out during the projects, innovative means have been used to achieve outstanding results.

There is a lack of evaluations within the construction industry of knowledge transfer that has come from role model projects. Among the few exceptions is the Norwegian State Housing Bank's support of construction projects with outstanding environmental and energy qualities. A recent evaluation indicates that in particular the financial support for competence building is making a difference. The conclusion is that since this funding is used to buy research and development services, there would have been less development activity without this support (Nordvik 2011).

#### 1.3.1 Theory on role models

Ideas about how behaviour is affected by role models build upon the basic ideas of social learning theory. We may be attracted or repelled by what we observe and experience but we do learn from it and we individually construct our own behaviour in the light of it (Bandura 1986). Role models are found to be key players regarding environment-friendly behaviour. There are examples of how this also applies to owners of private homes. A recent survey on attitudes towards the refurbishment of a housing cooperative reveals that what is most important for the informants is what is being done in other housing cooperatives (Hauge, Thomsen et al. 2011).

Social learning theory emphasizes the relevance of model–observer similarity. This implies that an observer is more likely to seek to emulate the model because of their shared characteristics (Bandura 1986), as exemplified in the refurbishment survey. Similarly, within the tradition of organizational learning, referring to others within the same community of practice is found to be a key to explaining the transfer of new knowledge between organizations (Nonaka and Takeuchi 1995, Wenger 1999). The potential and limitations of case studies in relation to knowledge transfer from role model projects will be discussed in chapter 3.

#### 1.3.2 Role model projects challenge the socio-technical system

Political initiatives for developing sustainable building have to deal with the resistance to change that exists within the socio-technical system of the construction industry. The situation has been summarized like this: changing buildings requires changing the context in which buildings are being developed, designed and operated, and also the role that various stakeholders play within the process (Cole 2011).

Initiatives for sustainable building represent such an alternative context, such as programmes for industrial innovation, including Bygg21 (Norway) and Constructing Excellence (UK), financial support for research programmes, and also honouring ambitious projects by awarding them prizes and giving them status as role model projects. Therefore, it is of interest to explore prize-winning role model projects, what barriers (in the institutionalized system) they meet during the development process and how they are able to overcome some of them.



### 1.3.3 Role models as the empirical approach

There are studies indicating that some cases are of special relevance to human learning. Among professional adults there is found to be a difference between the rationality and behaviour of beginners and that of experienced practitioners. While the beginner relies on theoretical knowledge and the rules of operation, the expert performs more fluently based upon tacit knowledge. The experience they have gained from a number of cases within their area of expertise is the basis for handling future cases (Christensen and Hansen 1987). Professionals who have gained experience from role model projects are therefore informants of special interest for studies covered in this thesis.

Research on learning shows that context-aware knowledge is necessary to allow people to develop from being rule-based beginners to becoming experts. Accordingly, the context-awareness of case studies should be seen as a potential to the research approach used in this thesis.

### 1.4 Focus of the study

Limiting the scope of the study has been a part of the research process. The process of focusing the study includes the following major issues:

- The first relates to the research questions: choosing and formulating fruitful research questions.
- The second relates to operationalizing the study: choosing which actors and stages in the value chain to focus on.
- The third relates to the methodological approach: what data are available and which methods of data collection and analysis are useful in further understanding the research questions.

The following section presents the main steps in the process, including which alternatives were considered and the reasons for the choices that were made.

#### *Step 1: Operationalize the phenomenon of sustainability*

I made a decision to focus on *energy* as the major criterion for sustainable buildings. In 2011, at an early stage in the study, energy was highlighted by the UN (Intergovernmental Panel on Climate Change – IPCC and the Kyoto Protocol) and the EU (the Energy Efficiency Directive and the Energy Label system) and in Norwegian policy initiatives (TEK 10, ENOVA support programme and the Low Energy Programme). Energy was the most developed criterion as far as measuring is concerned. There are models to calculate the effects of passive energy means, and also the energy consumption of and production of technical systems in buildings. Equipment for regenerating heat was reaching high performance levels. Since my work started, the concept of energy in constructions has been elaborated further to include energy embodied in the materials and construction processes. ENOVA role model projects were measured according to a calculated energy performance (see NAL Ecobox at [www.arkitektur.no](http://www.arkitektur.no)).

More recently, measuring models for other aspects of sustainability have been developed further. These include, in particular, materials, focusing on greenhouse gas (GHG) emissions and energy

consumption during the manufacturing of the materials. Also included are the indoor environment in the buildings, emissions from materials and the heat-buffering qualities of massive materials, etc.

Energy efficiency is therefore the most important criterion in the selection of construction projects to be included in the analysis. Where other aspects of sustainability have been in focus, they are considered in the analysis.

*Step 2: Selecting methods and material for analysis*

I decided to focus on construction projects as units for analysis. Projects with outstanding ambitions regarding energy and environment were selected for this purpose. There are three reasons for this decision.

The first reason is that the purpose of the research project implies an explorative approach to the issue. Case studies are suitable for this kind of research. This issue is elaborated further later in chapter 3 on methodology and methods.

The second reason is based in theories on the diffusion of innovations. Pioneering projects are developed by actors that are sensitive to changes in the environment (public regulations, trends in the market, etc.), and respond by being innovative (or early adopters of innovations). Motives, methods and experiences from these projects are of interest for both the purpose of the research and the innovation of more environmentally sustainable construction practice.

The third reason is that pioneering projects receive a lot of attention from the rest of the industry and from the public. Demonstration projects and role model projects imply a contribution of extra resources, both from project owners and from development programmes. Analysing processes and experiences from these projects is of interest for the industry and the community.

*Step 3: Selecting the most critical phases of the construction process*

Two phases were selected to focus on: the early planning phase and the early operation phase.

*The early planning (concept) phase* was selected due to its importance in developing sustainable (energy-efficient) concepts. This phase is the phase at which it is fruitful to explore the mutual energy implications of architecture, the building envelope, materials and technology. This planning phase is also the phase during which ambitious owners are able to demonstrate the ability to keep their ambitions high in situations with conflicting goals. The early planning phase was selected as a focus for the analysis regarding the methods and effects of multi-professional collaboration (papers 2 - 4).

*The first period of occupation and operation* of newly constructed buildings is of special importance in modern energy-efficient buildings. This is partly because high-performing buildings are complicated to operate, and it takes time to fine-tune systems and routines, and partly because actual energy performance to a large degree depends upon the behaviour of the users of the buildings. Most people have little or no experience of highly-energy efficient or passive-house buildings, or of fully automated indoor environmental control systems. The first period of occupation

of newly constructed buildings was selected as a focus for the analysis on the usability of modern energy-efficient buildings (paper 6).

*Step 4: Operationalize the organizational approach*

Organizing for innovation and sustainable building is being addressed at project level and industry level.

At project level my first intention was to study how innovative concepts have been arranged for in the role model projects. This included the use of formal contracts, as I expected frequent use of partnering contracts, and it included the working methods in project teams as performed by project managers. As I discovered the criticism to the engineering approach to innovation and the potential in the socio-technical system perspective, I also included studies of human relations into the analysis. The human relation perspective explores motives and resources, rewards and risk considerations among the individual participants, and the model of analysis will be further developed in chapter 2.

At the industrial level, my first intention was to do a survey to study diffusion of highly energy efficient building concepts from role model projects to other projects. However, as the buildings were completed within the last few years, it was too early to expect any results. Therefore I made a study of impacts of research in three Norwegian construction projects with innovative sustainable concepts (paper 4), and also made a discussion of findings in the studies included in this thesis in the light of literature on transformation to sustainability (see chapter 5). I found the socio-technical perspective fruitful to explore the inter-organizational relations and dynamics within the construction industry.

*Step 5: Considering sustainability from a long-term perspective*

Traditionally, the construction industry focuses on how to plan and erect buildings, and eventually it also focuses on refurbishment and demolition. These stages represent, however, a minor period of the service life of buildings, compared to the period when the building is in operation and used for its purpose. Also, considering the economic aspect, investments represent a minor part of the total costs and income that are represented during the total lifetime of a building. Lifetime considerations is a concern for developers and managers of non-residential property. This is why I have chosen to study non-residential buildings, and also why I have been studying life cycle cost considerations of building portfolios in Norwegian municipalities (paper 7).

Similarly, in the perspective of sustainability, the long-term implications are of major importance in terms of the overall effects of the standard of the building portfolio on a community. This includes energy performance, greenhouse gas emissions and other aspects affecting the natural environment. As a consequence, refurbishment of existing buildings is a major part of the policy for improving the sustainability of built environments. It may therefore have been natural to select refurbishment projects for case studies. However, pure refurbishment projects are exceptions among those honoured as role models by ENOVA. The sustainability of buildings depends on the degree to which they fulfil their purpose. For non-residential buildings this implies some kind of production. Therefore the studies of energy efficient case projects must discuss not only the environmental effects but the

social and economic implications. Of special interest is the experience of the users of the buildings, employees and others, who are performing their daily activities facilitated by energy efficient buildings. Therefore this thesis will include an analysis of the usability of buildings developed from role model projects (see paper 5).

The knowledge of facility managers, cleaners and operators is crucial in the planning of new buildings. Therefore, I have been studying the effects of the involvement of FM personnel in planning energy-efficient buildings (paper 1).

*Step 6: Selecting key roles/stakeholders in the value chain*

Project owners, architects, consultant engineers and main contractors were selected as key informants at an early phase of the research process.

*Owners* have a key role as clients who decide on the purpose of and goals for the construction project. My interest has been in exploring project owners' motives for high energy and environmental ambitions, and in how they handle situations with conflicting goals. The project owners' role is especially explored in the study of collaboration in planning processes (papers 2, 3 and 6) and is also one of the aspects analysed in the study of the usability of modern energy-efficient buildings (paper 5).

*Architects and consultant engineers* are in focus due to their key role in the planning phase and the concept and design phases. During the research process, my interest in integrated planning processes has increased, due to their potential for improving energy effects and environmental performance. The roles of consulting engineers and architects are explored especially in the case study about the energy plus concept project (paper 3) and also in the other papers on collaboration (and integration) (papers 2 and 6). During the research process, I have become aware of energy and environmental consultants, which are a type of specialist consultant used in role model projects.

*Main contractors* are key actors due to their coordinating role in actually erecting the building according to specifications, budgets and timetables agreed on in contracts. Contractors are often subject to procurement bids. Traditionally, price has been a key criterion in the bids. How contractors handle energy and environmental goals in situations with conflicting goals is one of my interests, which has been explored especially in two of the papers on collaboration (papers 2 and 6). During my research period, partnering contracts came to make up an increasing proportion of construction contracts. This implies a strengthening position for main contractors, who also coordinate and make decisions on behalf of subcontractors. I have explored how partnering contracts affect the status of energy and environmental ambitions (especially in papers 2 and 6). I also explore which working methods main contractors use in their relations with subcontractors and suppliers to achieve the energy and environmental key performance indicators that are agreed on in the pioneering projects (especially in paper 6).

During the research process, two more key roles were identified: the operators and the users.

*Operators*, or rather facility managers, were identified due to their role during fine tuning of indoor environment technology in new buildings, and due to their role in performance of buildings during service life, as presented in step 3. *Users* were identified due to their key role during the occupation

of the buildings, also as presented in step 3. Therefore, these two groups were added to the list of informants. The roles of facility managers and users are explored in papers 1 and 5 respectively.

Three more key roles have been identified during the research process: the government, universities and product manufacturers. These were identified during the analysis of R&D uptake in the construction industry, as presented in paper 4.

### 1.5 Objectives of the thesis

The purpose of this research, as presented in section 1.1, is to study the ongoing change of industrial practice to improve environmental sustainability. The following two objectives are addressing this purpose:

- a) To provide new empirical insights into management practise in projects with outstanding energy performance.
- b) To provide new theoretical insight into the challenges of industrial transformation towards sustainable building.

Three levels of analysis have been used to meet these objectives. This is illustrated in figure 6.

- Level 1a includes studies of organizing of innovative planning and design processes.
- Level 1b includes the performance of the completed buildings. Focus of analysis is on how organizing of the projects (level 1) affects sustainability of the final buildings. Analyses includes
  - the organizational means being used, and
  - effects on the energy efficiency of the buildings.
- Level 2 includes a discussion of how the prize-winning highly energy efficient buildings are affecting the overall practice within the construction industry. Focus is on the transition of the industry by implementing experiences from role model projects.

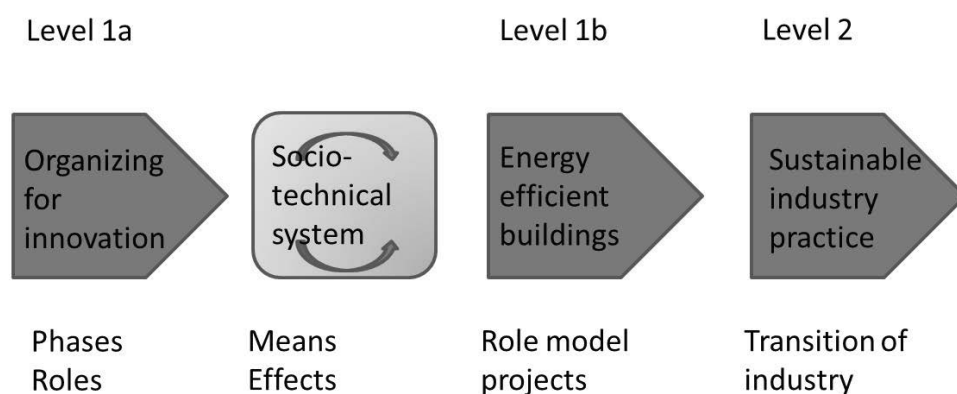


Figure 6: The three levels of analysis

## 1.6 Research questions

The research objectives have been developed into a set of research questions. The research questions were developed in accordance with the theoretical and empirical approaches presented in sections 1.3.3–1.3.6 and 1.4 (see figure 3) and in accordance with the three levels of analysis presented in section 1.5 (see figure 6). Figure 7 illustrates how the approaches are applied at the three levels of analysis:

- Level 1a: Studies of organizing for innovation have been approached using innovation theory and data from case projects with outstanding energy efficiency. Data on the organizing of the role model projects has been compared to the characteristics of the organizing of conventional projects. Research questions 1 and 2 relate to this level of analysis.
- Level 1b: Studies of the energy efficient buildings and how the results relate to the organizing of the planning and design process. The studies are based upon data from role model projects and have been approached using additional theories on sustainability. Research questions 3, 4 and 5 relate to this level of analysis.
- Level 2: Transformation of the industry towards a sustainable practice. This thesis includes a discussion of how experiences from role model projects can contribute to this industrial transformation. The discussion (see section 5.3) develops the findings from analysis at level 1a and 1b by drawing upon system theory and international studies (literature) on the characteristics of the construction industry. Research questions 6 and 7 relate to this level of analysis.

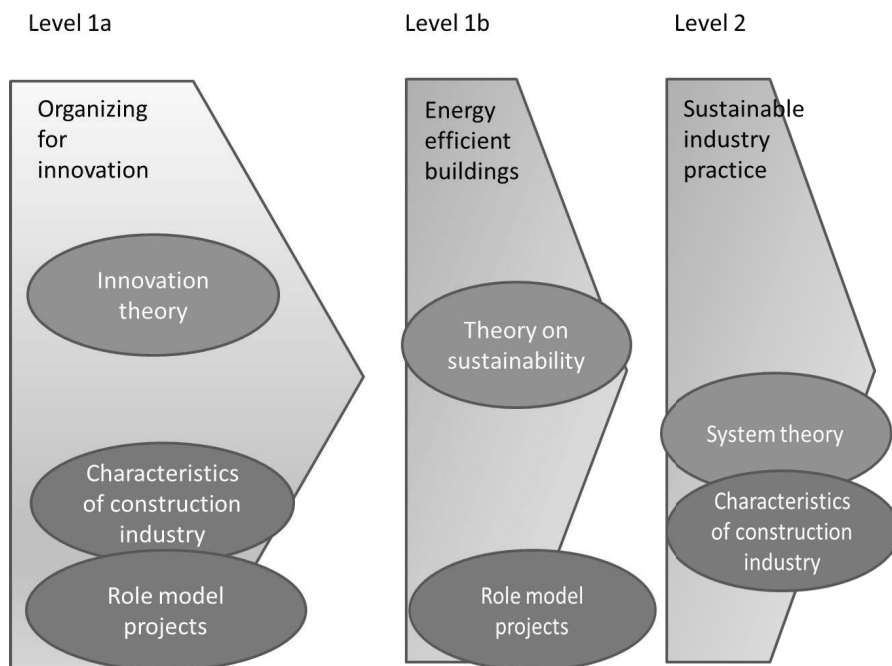


Figure 7: Approaches and levels of analysis in studies included in the thesis

The research questions are as follows:

1. What characterizes the interaction process of projects with high energy and environmental ambitions?
2. What are the innovative aspects of the organizing of role model projects in various project phases?
3. How do the working methods used during the planning phases affect the energy performance of the resulting buildings?
  - a. Involvement of facility managers during early planning
  - b. Integrating the processes during concept and design phases
  - c. Partnering in the value chain
  - d. Industry and research partnering
  - e. Use of LCC analysis in portfolio management
4. What benefits do clients (owners/developers) experience from constructing modern energy-efficient buildings?
5. What benefits do user organizations experience from occupying modern energy-efficient office buildings?
6. How are relations between the industry and research contributing to transitioning towards a more sustainable construction industry?
7. Are experiences and solutions from the role model projects being implemented into the Norwegian construction industry?

## 1.7 Contributions from research

The main contributions of the research can be summarized as follows:

- A. Showing that involvement of facility managers in the design phase of construction projects has a positive effect on the energy performance of the buildings (paper 1)
- B. Exploring the use of collaborative working models in construction projects with very high ambitions relating to energy performance (papers 2, 3 and 6)
- C. Analysing and illustrating policy and practice for research and innovation in the Norwegian construction industry (paper 4)
- D. Exploring how tenant user organizations experience and value the usability of modern energy-efficient office buildings (paper 5)
- E. Revealing how clients and contractors have experienced benefits for their companies by introducing means for improving environmental performance and saving energy (papers 2 and 6)
- F. Understanding the use of LCC analysis in the practice of Norwegian municipalities' (paper 7).
- G. Understanding how sociotechnical mechanisms in the industrial system is hampering implementation of an environmental sustainable practice (Discussion)
- H. Suggesting strategies for accelerating the transition (Implications and suggestions)



## 1.8 Structure of thesis

*Chapter one* have introduced the purpose, approaches, objectives and research questions of this thesis.

*Chapter two* is a review of published literature relevant to the research questions. The review provides an overview of the state of the art in international research.

*Chapter three* presents the research design. The chapter focuses on the rationale for selecting the material and the methods that have been used. The strengths and weaknesses of the design are discussed. Also the trustworthiness (validity and reliability) of the analysis and the conclusions being drawn in this thesis are discussed.

*Chapter four* summarizes the findings of the individual studies.

*Chapter five* discusses the findings, presented in chapter four, in relation to existing research and relevant theories, presented in chapter two.

*Chapter six* presents the implications of the findings and the discussion, presenting suggestions for further development and the implementation of sustainable building.

*Chapter seven* draws conclusions regarding the overall purpose of the study and the individual research questions.

*Chapter eight* suggest issues for further research on developing and implementing sustainable building.

The individual studies (papers) referred to in this introductory essay are presented in *section II* of this thesis.



## 2 Literature review

The purpose of this chapter is to provide an overview of the state of the art in international research regarding industrial development of sustainable practice. The review includes international research on industrial development mechanisms in general and on sustainability and the construction industry specifically.

### 2.1 Structure of the chapter

The literature covered in this review covers two major topics, namely organizing for innovation and organizing for sustainability.

- a. *Organizing for innovation.* This tradition includes research on the means that are expected to favour innovative activities in industries in general and in the construction industry in particular.
- b. *Organizing for sustainability.* This tradition includes literature on sustainability as a theoretical concept, and also research on sustainability in the construction industry, other industries and in the community in general.

The selection of these research traditions is in accordance with the choice of approaching the construction industry as a socio-technical system. The reviewed literature addressing the project level includes literature that discusses the organizational means in use throughout all phases of building projects. The review considers literature on organizing for integration (section 2.2) and organizing for collaboration, including partnering (section 2.3), on risk handling in relation to innovative building (section 2.4), on motivation as a driver for sustainable innovation (section 2.5), and on management for developing innovative building projects (section 2.6).

Some actor groups are selected for special attention. This in accordance with the system approach and the life cycle aspect of environmental sustainability presented in chapter 1, Introduction. The literature review focuses on the role of facility managers during planning phases (section 2.7), the role of the users during planning and the in-use phase, including the usability of sustainable buildings that is experienced (section 2.8), property managers and their use of methodology for life cycle cost analysis (section 2.9), and the role of researchers in the development of environmentally sustainable construction (section 2.10.3).

The reviewed literature addressing the industrial level includes literature that discusses national and international policy and strategies and initiatives for sustainable development (section 2.10). The focus is on the implementation of environmentally friendly building practice and industrial transition towards sustainable building.

### 2.2 Integration

The literature review on innovation emphasizes that it takes a multidisciplinary team to address the issue of sustainable innovations. Contributions have emphasized the relevance of common goals, understanding and trust to enable organizing for innovation to occur. The conventional practice of

using a sequential design process in the construction industry is found to generate suboptimal buildings with higher costs (Larsson 2002).

The need for careful planning at the start is emphasized in construction projects, since options for changes later in the project will be limited and costly (Blyth and Worthington 2010). This implies that ambitions for energy performance and other environmental ambitions must be considered during early planning, and thereby draws attention to the brief and design phases. Improvements and changes for optimizing energy performance are gradually more difficult as the process unfolds, and may even be disruptive (Sartori and Hestnes 2007, Andresen and Hestnes 2009, Attia and De Herde 2011, Attia, Gratia et al. 2012). Life cycle considerations relating to energy, greenhouse gas emissions, operation and refurbishment add to the complexity during planning, and also, potentially, contribute to improving sustainability.

Various forms of integration have been suggested to meet the challenges of an industrial system that is both fragmented and interdependent. The concept of integrated design is of special interest due to the focus on early planning, which is the phase of building projects which is most relevant to innovative decisions. The following list gives an introduction to theoretical models and models that can be applied for integration, namely:

- Integrated Design Process (IDP)
- Integrated Energy Design (IED)
- model of co-configuration
- multi-stakeholder network approach

#### 2.2.1 Organizing for integration

In the literature on innovations, it is suggested that establishing teams in which the members are from culturally diverse backgrounds brings fresh ideas and new approaches to the problem. The challenge is that they also introduce different understandings and expectations regarding team dynamics and integration. There is also a suggestion that with increasing complexity, the importance of the management of relations within a team is increasing (Morris and Pinto 2004, Aarseth 2012).

Feige, Wallbaum et al. (2011) suggests a “multi-stakeholder network approach” for the purpose of managing the multiple stakeholders involved in sustainable construction. This approach has a certain issue as its focal point, and brings together various stakeholders that are affected by the issue. Often the issue that is being addressed is too complex to be handled effectively without collaboration (Roloff 2008, Feige, Wallbaum et al. 2011). The multi-stakeholder network approach is relevant to sustainable building, due to its complexity and the need for innovative solutions. The approach focuses on the need for multiple perspectives that result from sharing concerns and pooling knowledge on the issue in question (see figure 8). This model therefore meets the requirement for an inter-organizational approach to sustainable innovation/building.

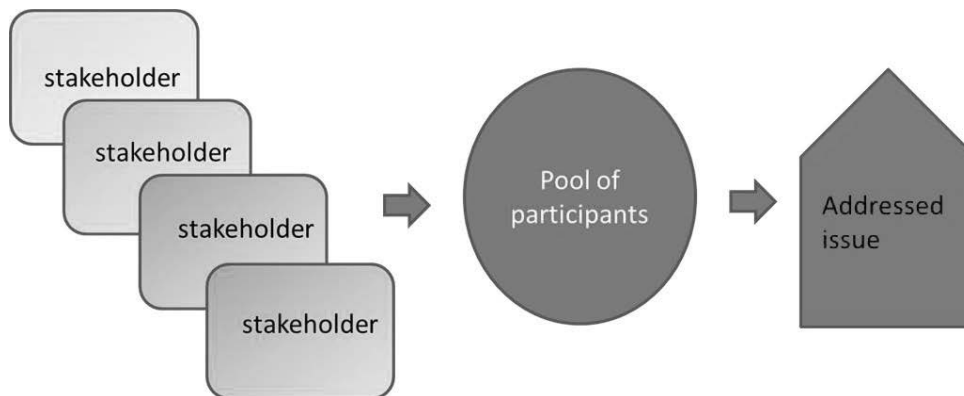


Figure 8: Multi-stakeholder network (based upon the figure of Feige et al, 2011, p 507)

IDP and IED methodology represent a multi-stakeholder-network approach that is of interest for innovative sustainable building projects. The following elements characterize a multi-stakeholder network:

- All actors are treated as equal partners. This creates an opportunity to develop a vision of potential solutions and actions based upon common interests (Cordano, Frieze et al. 2004, Onkila 2009, Feige, Wallbaum et al. 2011).
- A pool of stakeholders represents the concerns of a much wider set of stakeholders. Therefore, it is possible to reduce the number of stakeholders involved in solving an issue, and thereby shorten the time taken in discussion and making decisions (Feige, Wallbaum et al. 2011).
- A global point of discussion can become part of a firm's business (Frooman 2010).

“Co-configuration” is a concept that has been developed to illustrate collaboration in temporary teams, similar to those in typical construction projects. Co-configuration work is characterized by the creation of a complex and adaptive product, constructed through collective efforts of multiple actors in collaboration with the customer. The work is performed by a temporary collective of partners that come together to focus on a common product or service to be created (Victor and Boynton 1998, Engeström, Engeström et al. 1999, Engeström 2004, Engeström and Kerosuo 2007).

Studies of collaborative working have identified characteristics of co-configuration within health-care and legal settings (Engeström, Engeström et al. 1999), education systems, public works design projects and also within the construction industry (Bishop, Felstead et al. 2009). The findings are that the team develops innovative ways of working in order to accomplish the objective more effectively. The team members move from a position of simple coordination according to traditional roles to full cooperation and open communication that is focused on re-conceptualizing the shared problem (Engeström, Engeström et al. 1999, Marsick 2009). IDP and IED methodology facilitate processes of co-configuration and re-conceptualizing that have the potential to be used in relation to innovative sustainable building.

Expectations have been high that ICT will support integration and collaborative working processes. Building Information Modelling (BIM) is among the promising tools. BIM provides information about the entire building and a complete set of design documents, and data are stored in an integrated database. In a study of the use of BIM in Finland there was found that BIM has been adopted fairly generally for design use. However, the old ways of collaboration seem to prevail, especially between designers and between designers and building sites. BIM is found to provide new demands and means for collaboration, but BIM is not found to be used to provide new interactive processes across professional fields (Hannele, Reijo et al. 2012, Kerosuo, Mäki et al. 2013).

#### 2.2.2 Working methods for integration in construction projects

“Integrated design process (IDP)” has been introduced in the construction industry to meet the challenges of designing sustainable buildings. It has been used in manufacturing industries since the 1980s for the development and construction of new, complex products. IDP is described as “A collaborative process that focuses on the design, construction, operation and occupation of a building over its complete life cycle” (Larsson 2002). The process includes the client and other stakeholders, and allows the development and realization of functional, environmental and economic goals and objectives. It requires a multidisciplinary team so that all the skills needed to address every issue flowing from the objectives are included.

“Integrated Energy Design (IED)” is a special variety of IDP focusing on the energy performance of the building. IED is based upon the passive energy design principles developed from the Trias Energica strategy, in which the major environmental contribution lies in the reduction of energy demands. Considering the whole life cycle of a building, energy consumption during its operation represents by far the largest share. IED focuses on the energy-synergy effects of various elements in the construction and on optimizing energy performance during the whole life cycle of a building (Andresen and Hestnes 2009).

Various models of IDP and IED share the basic organizational characteristics (Löhnert, Dalkowski et al. 2002, Andresen and Hestnes 2009, Forgues and Iordanova 2010):

- Involvement of actors from all stages of a building’s life cycle from the start, from design and construction to use and operation
- Establishment of a multidisciplinary team. IDP emphasizes the collaborative skills of the team, while IED emphasizes knowledge of energy and sustainability
- The entire team is involved in decision-making
- There are iterative processes with feedback loops
- A process facilitator replaces the role of the design manager

IED specifies the development of a “quality assurance programme” and a “quality control plan” for following up throughout the project.

IDP can be compared to conventional design processes, as illustrated in figure 9. One major difference is the front-loading of IDP, where a broad team is involved from the start. This differs from the conventional sequential process in which the problems are distributed among people that

develop systems within their speciality and meet only for coordinating purpose. While members of the project team will change from phase to phase in conventional processes, the same team is involved from the start of the brief to the completion of working drawings in IDP (Larsson 2002). Another major difference is that in contrast to the mainly linear structure of the conventional design process, IDP is flexible, with no preordained sequence of events, iterative processes and feedback loops. This includes evaluations of in-use performance in IDP (Guren 2013).

The principles of IDP are used in the case projects included in this thesis.

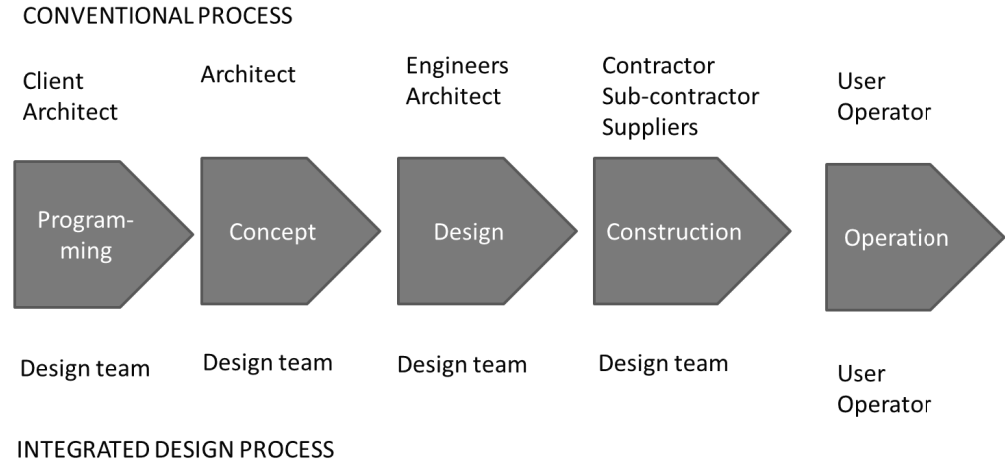


Figure 9: Conventional and integrated design processes

2.2.3 Experienced effects

The literature reveals mixed experiences with integrated design and effects on innovation, sustainability and energy performance.

The lack of existing integrated teams within the construction industry is found to be a challenge for integrated design and for gaining the energy effects of whole systems thinking (Forgues and Koskela 2009). An analysis has compared experiences in the construction industry with experiences in manufacturing industries. There was found that expectations when introducing IDP into the construction industry were similar to the expectations relating to manufacturing industries: to improve the quality of the final product and to speed up the development process. The basic idea was to assemble, integrate and harness all the collective skills and capabilities of clients and their supply chains. However, the project teams within the construction industry cooperate only on a project basis, while teams in the manufacturing industry usually had experience from a series of projects (Forgues and Koskela 2009). As participants from various organizations in the production

chain represent different cultures, introducing IDP implies a risk that design collaborations may not perform as well, or may even be dysfunctional (Moore and Dainty 2001).

The analysis of case projects has been explored whether suggestions from previous studies correspond to experiences in the Norwegian role model projects.

### 2.3 Collaboration

In the construction industry, as in other industries, collaboration between organizations exists at the same time as there is competition between them. However, in the case of the construction industry, a number of studies reveal that competition is hampering development in the industry. The large number of professions involved in the production chain, project-based teams and the large number of small enterprises are found to be barriers to lean production (Egan 2002) and innovation (Valen, Klakegg et al. 2010). The production chain is a temporary organization: for each project, a new organization is assembled, consisting of partly new actors, individuals that have not worked together before, representing different values and procedures and having different roles and responsibilities, etc. (Orange, Burke et al. 2000). The characteristics of the industrial system (see section 1.3.6) commonly imply conflict, hostility and litigation between contractors (Bishop, Felstead et al. 2009). As a result, over the last couple of decades the construction industry has developed a backlog in terms of quality and efficiency compared to other industries. This issue has been addressed by Latham (Latham 1994) and Egan (Egan 1998), among others, and there have been reports in the UK and a report by Byggekostnadsprogrammet in Norway.

Collaborative working is suggested as a means to overcome the challenges. According to theory, formal collaboration is established to reduce uncertainty, acquire resources and solve problems (Emery and Trist 1965). In other industries, collaborative working models have proved to be useful in solving new problems. For instance in the oil industry partnering is used as a tool for stimulating performance gains and innovation (Barlow 2000). Industrial and regional networks are found to be of vital importance for development of enterprises, as illustrated by studies of Silicon Valley (Cohen and Fields 2000) and the regional clusters of small enterprises in North Italy (Porter 1998). In general, collaboration is found to be beneficial in complex construction projects (Aarseth 2012).

#### 2.3.1 Organizing for collaboration

The notion of collaboration covers a wide range of organizational forms. In general, collaborative working implies that there are models for various actors (persons or enterprises) working jointly. This can be a formalized partnership or informal cooperation such as in social networks. In the context of the construction industry, the concept covers models that differ from the traditional serially organized design process.

“Partnering” relates in general to an agreement between organizations or people to work together (Construction Industry Institute 2015). Further, partnering may be defined as “Establishing a long term win-win relationship based on mutual trust and teamwork, and on sharing of both risks and rewards. The objective is to focus on what each party does best, by sharing financial and other



resources, and establishing specific roles for each participant” (BusinessDictionary). “Joint venture” and “strategic alliance” are examples of business partnerships.

The Construction Industry Institute (CII) defines partnering as “A long-term commitment between two or more organizations as in an alliance or it may be applied to a shorter period of time such as the duration of a project. The purpose of partnering is to achieve specific business objectives by maximizing the effectiveness of each participant’s resources” (Construction Industry Institute 2015). This definition differs from the general one by differentiating between project-based partnerships, which are limited by time and their objective, and strategic partnerships between enterprises with a long-term purpose.

Using partnering was among the suggestions for improving the progress and quality of construction projects in UK in the 1990s. Since then, the number of public–private partnering (PPP) contracts has increased, and they have also been introduced in other countries, including Norway.

In Norway today, partnering has developed within the construction industry. Partnering contracts are gradually becoming common between the client and the main contractor, and they are often combined with turnkey contracts. In addition, PPP projects have been introduced. In Norway, there has recently been a discussion about whether to introduce standard contracts for partnering projects (byggejuss.no , Standard Norge 2013).

The UK initiative for partnering started with public clients of large construction projects, where the government promoted client-driven change as a means to champion better performance. The Latham Report (Latham 1994) suggested a review of procurement and contractual arrangements, and was followed by Egan’s HMSO report (Egan 1998, Egan 2002), which specified the types of practices the construction industry should adopt, including team-working, supply-chain integration and a quality-driven agenda. The concept of partnering was inspired by the Japanese management revolution Kaizen, which focuses on total quality management (TQM) (Alderman and Ivory 2007), as well as by other similar examples.

From a political viewpoint, for the purpose of benefiting the community there are a number of expectations of partnering in relation to improving contributions from the construction industry. Initially, it was the increasing complexity of large construction projects that triggered the demand for reform of the contractual arrangements, with expectations for improving quality and completion time. Later, mega-projects with structural complexity and many interfaces have maintained the expectations for partnering models (van Marrewijk, Veenswijk et al. 2014). Further, there are expectations that partnering should include better communication and more informed decision-making, leading to improved learning and continuous improvement and innovation, including in relation to environmental sustainable practice. This is because inter-organizational issues are especially challenging for innovation and renewal (Gadde and Dubois 2010, Håkansson and Ingemansson 2012). The intention of partnering contracts is to focus on continuous improvements rather than simply meeting the minimum needs of the legal contract (Bennett and Jayes 1998).

In the context of an industry, any kind of business relation is based upon contracts between the parties involved. In a building project, the formal contracts are essential in defining roles and responsibilities in each single relation in the production chain. In addition, there are aspects of informal agreements involved in business relations. The concept of the “social contract” (Hobbes

1651 / 1999, Rousseau 2002, Boucher and Kelly 2003) explains the ways in which people form and maintain social order. It can also be thought of as an agreement by the governed on a set of rules by which they are governed. Applying this to the construction industry, there are always tacit expectations of a balance of give and take in the relationship between property developer, contractor and subcontractors. These are in addition to agreements included in the formal contracts. If the mutual benefits are being misused by one of the parties, this will be considered as a threat to the other party and could possibly start a chain reaction of less flexibility and short-term and selfish decisions that may result in a lower quality or higher costs of the total project.

Partnering contracts differ from conventional contracts in terms of both formal and social aspects. Partnering contracts provide joint objectives and encourage the contracted parties to work together to solve problems. Partnering contracts include financial incentive systems rewarding the parties equally for success and penalizing them for failure (Bennett and Jayes 1998). The principles of win-win profit sharing and mutual risk sharing are crucial for initiatives implying a change from established solutions and practice. Further, partnering represents an alternative to the hierarchical organizational structure with “top down” management (Naoum 2003 ), and thereby should result in equality among the partners and stakeholders. In addition, trust and an open, no-blame culture are attributes related to partnering. In fact, these aspects of a social contract were part of the initial definition of partnering presented by the Construction Industry Institute’s (CII) Partnering Task Force (Construction Industry Institute 1991): “ The relationship is based on trust, dedication and common goals, and an understanding of each other’s individual expectations and values.”

According to these characteristics, partnering meets the criteria proposed for a multi-stakeholder network suggested by (Feige, Wallbaum et al. 2011) for the purpose of organizing for innovation. And it is therefore of special interest for the purpose of studies of improving sustainable construction.

Partnering, especially the second and third generation of partnering (Bennett and Jayes 1998), is underpinned by a set of management actions enabling construction firms to meet the demands of their customer:

1. Strategic actions
2. Membership
3. Equity
4. Integration
5. Benchmarking
6. Project processes
7. Feedback

The analysis of Norwegian role model projects will explore whether such management actions are being used for the purpose of improving energy performance in the buildings.

### 2.3.2 Experiences on collaboration in the construction industry

In general, collaboration is found to be beneficial in complex construction projects (Arge and Hjelmbrekke 2012, Berker and Bharathi 2012). Partnering is also found to stimulate research uptake in the construction industry (Bygballe, Jahre et al. 2010, Reve and Sasson 2012). However, research

on organizational cooperation in project management is, in general, scarce (Morris and Pinto 2004, Winter, Smith et al. 2006). This is also the case for the construction industry, where research focuses on project management rather than on strategic cooperation and long-term development (Aarseth 2012).

The effects of partnering in the construction industry are found to be limited compared to high expectations for it. Among the explanations for this is the long history of competition which has created a culture of hostility and mistrust within the industry (Bishop, Felstead et al. 2009). Contributions made by organizational studies have uncovered the strength of such informal systems, that is, organizational culture as a tacit code of practice, e.g. in conflict management in the construction industry (Valen, Klakegg et al. 2010). Mutual trust is also considered a crucial basic element of all industrial relations, as expressed in the term “social contract” in the field of business ethics (Weiss 2008) and in studies within the construction industry (Klakegg, Valen et al. 2011). However, social and informal aspects of relational development have attracted little attention in practical experiences of partnering (Bresnen and Marchall 2000, Marshall 2006). The literature on experiences of partnering reveals that tools and techniques to design relationships are emphasized at the expense of the social aspects, such as shared understanding and trust (Bresnen and Marchall 2000, Bygballe, Jahre et al. 2010).

Studies of collaborative working reveal that there are challenges facing multi-professional collaboration. A major challenge is communication, due to professional divisions, ingrained practices, habits and identification boundaries (Engeström, Engeström et al. 1999). Another major challenge is that actors may have very different aims and be committed to different objectives (Avis 2007, Bishop, Felstead et al. 2009). These tensions are embedded in the structural relations between the actors, and there are challenges in encouraging actors to work together even if they are essentially committed to the same object (Young 2001).

Critiques of partnering in construction highlight the resistance to change that exists within the socio-technical system. Theoretical models tend to assume a common goal between all parties and a willingness to engage in collective knowledge-sharing and problem-solving. This contrasts with the tradition of hostility and mistrust. Bishop, Felstead et al. (2009) argues that these theoretical models do not adequately take into account the historical, cultural, and social and economic contexts within which such “new” practices must operate. In the construction industry, the adoption of such (unfamiliar) ways of working would entail a fundamental cultural and structural shift that could not happen overnight. The whole industrial system would be required to undergo a wide-ranging transformation. A move towards more collaborative modes of working would require and promote heightened levels of skill and knowledge transfer (De Vilbiss and Leonard 2000, Cheng, Li et al. 2004), open communication, and collective learning and knowledge-sharing between partners (Engeström, Engeström et al. 1999).

### 2.3.3 Project-based and strategic partnering

Project-based partnering has gained the most attention within the construction industry. This includes the increasing number of public-private partnering (PPP) projects. Strategic partnering has gained little attention, although this is commonly used in other industries, for example within the offshore industry (Bygballe, Jahre et al. 2010).

Studies of fruitful innovation processes have revealed how the participants move from a simple coordination according to occupational scripts to cooperation and open communication (Engeström, Engeström et al. 1999). Partnering may therefore be a strategy for change in practise, learning and innovation e.g for further sustainability in buildings. Feedback to capture the lessons learned are among the characteristic of the “second generation partnering”. The elements of equity and the project processes that embody best practice and reward everyone involved are also among these characteristics (Bennett and Jayes 1998). This implies that strategic partnering is of special interest for innovative sustainable building.

The industry is taking steps to develop more cohesive teams in the form of new procurement mechanisms such as partnering arrangements or public-private partnerships, which take advantage of long-term relationships and promote better collaboration in relation to value return (Bygballe, Jahre et al. 2010). Procurement has a key role in sustainable construction. Inter-organizational relationships are given first priority recommendation, due to the need to incorporate the whole supply chain in encompassing the triple bottom line of sustainability (Meehan and Bryde 2011). The EU is currently considering a new version of the public procurement directive. The main purpose of the audit is making improvements for public clients with regard to environmental concerns and innovation.

#### 2.3.4 Trust and risks, motivation for collaboration

Scholars have been discussing factors that influence the development of trust and cooperation in client-contractor relationships in construction projects (Kadefors 2004). Based on the general theory on trust it is suggested that formal contractual rules, contractual incentives and close monitoring of contractor performance may induce opportunism. It is argued that a higher level of trust would improve project performance. Partnering practices are found to have a potential to influence trust and creative teamwork. However, little research explicitly relates to trust in the context of construction projects (Bresnen and Marchall 2000).

Authors have stressed that not all partnering projects do well, and that there are no “quick fixes” or methods that guarantee success. Thus, “for inexperienced partnering candidates, the risk of ending up in quite traditional roles and relationships still seems to be substantial” (Kadefors 2004 p 175). Due to the breaking up of conventional regimes it takes skills and trust to contribute in partnering. Partnering contracts require a high level of commitment from suppliers, and their potential failure must be regarded as a source of risk. It is suggested that project actors, particularly those occupying commercially weak positions in the relationship, take a hard look at the risks as well as the benefits (Alderman and Ivory 2007).

Dealing with uncertainty is a major motive for collaboration in innovation. Tools for risk management (RM) in projects are being developed and allocation-based risk approaches have long been popular research topics. New collaboration-based project delivery approaches such as alliances and partnering have opened up opportunities for shared risk management.

Multi-organizational project collaboration is partly a source of uncertainty: as modern organizational environments are becoming more complex at an increasing rate, this means that uncertainty also increases, and the ratio of externally to internally induced changes is also increasing (Scott 2001).

Multi-organizational collaboration might also be a resource for reducing uncertainty. While risk management is traditionally allocated to a selected participant, there are arguments for shared approaches to risk management (Lehtiranta 2014). Scholars propose to involve a multidisciplinary team to deal with risk identification, analysis, and response (Lichtenberg 2000), and a joint RM to unify the efforts of all major contracting parties (Rahman and Kumaraswamy 2004).

Research into collaborative performance improvements within architecture, engineering and construction (AEC) industry have centred upon operational improvements or technological advances. Scant attention has been paid to behavioural approaches (Dainty, Moore et al. 2007, Shelbourn, Bouchlaghem et al. 2007, Gorse and Emmitt 2009, Love, Davis et al. 2011, Barrett, Goulding et al. 2013). However, recent studies explore design theoretically as a social and collaborative process. Examples of these are mapping of social networks in construction projects (Pryke 2004, Pryke 2005) and a description of design as a social process of interaction and negotiation (Bucciarelli 2002).

### 2.3.5 Effects on innovation

Collaboration for innovation is the basic idea of “open innovation” (Chesbrough 2006), namely innovating with partners. Extensive customer interaction, especially in the design process, is one of the other techniques used in the software industry. This allows companies to incorporate customer input and user criteria into the product. An additional advantage is that the customers become closely involved in the product management cycle. Studies have also revealed the advantages of this approach as being reduced cost of conducting research and development, an increase in the accuracy of market research and customer targeting and the potential for synergism between internal and external innovations (von Zedtwitz and Gassmann 2002, Bowns, Bradley et al. 2003, Leiponen 2012). Open innovation is also associated with a number of risks and challenges, including the potential for an enterprise to lose its competitive advantage as a consequence of revealing intellectual property (West and Gallagher 2006, Cheng and Huizingh 2014).

Of special interest for this thesis is that models of open innovation offer the promise that enterprises can achieve a greater return on their innovative achievements and their knowledge (intellectual property) by loosening their control over both (Chesbrough 2006).

Within the construction industry evaluations of public-private partnership projects (PPP) reveal that PPP contracts have proved to have a very good effect on timely delivery and costs, both in Europe (Bougrain 2012) and North America (Chasey, Maddex et al. 2012).

Even if PPP projects are often portrayed as more innovative, there is literature contradicting this. Bougrain (2012) finds three major explanations for this finding, which is based on the studies he reviews:

- The regulatory framework is the same for all projects, including PPP projects. Specific design and requirements are a barrier to innovative behaviour.
- Collaborative working between designers, contractors and operators is not systematic.
- Private partners tend to favour tried and tested solutions to limit the risk exposure.

### 2.3.6 Effects on energy and the environment

PPP can be considered as a way for the public client to reach its environmental targets, such as reducing climate gas emissions from buildings. Energy Saving Performance Contracts (ESPCs) are partnerships between a client and a provider where investments in an energy-efficiency improvement measure is paid for in relation to a contractually agreed level of improvement (European Parliament 2006). Using PPPs is considered as a way to develop the market for ESPCs. The success of such contracts are found to require that the public client has a good knowledge of the status, occupational level and energy consumption in their buildings (Bougrain 2012). Information disclosure in ESPCs contributes to creating trust among the partners and reducing uncertainty (Bougrain 2012).

## 2.4 Attitudes to and handling of risks in innovative building

Discussions of risks and trade-offs of risks are a part of decision-making in built environment design. According to the model of the construction industry as a socio-technical system, there is a “social order” at work in design teams, which influences their ability to produce innovative design ideas. In a literature review, Barrett, Goulding et al. (2013) explore how work in the field of social psychology contributes to understanding these mechanisms. These mechanisms are also expected to be relevant to innovative sustainable building design.

### 2.4.1 Attitudes to risk in construction teams

In general, in an industry historically concerned with lawsuits or legislation (Latham 1994), innovation struggles to exist within the risk-averse and adversarial culture that it generates. The existing literature suggests that project participants are more likely to take risks if they are part of a cohesive team which promotes psychological safety and adopts a shared value of risk acceptance (Barrett, Goulding et al. 2013).

Innovation thrives where there is a team which exhibits a willingness to share risk and clear, potential rewards for subsequent innovation in the construction product or process (Russell, Tawiah et al. 2006). It is therefore true to say that innovation is more likely to occur when a risk-tolerant climate is achieved (Egbu 2004). Teams perform more effectively when a “no-blame culture” is employed (Baiden, Price et al. 2006). This contributes to the risk-tolerant, non-adversarial and positive team climate facilitated by the client and maintained in the project team’s interactions (Harris, Romer et al. 2003).

Dealing with risks is part of the task for leaders of project teams. Group interaction is found to reduce uncertainty, which in turn reduces risk in decision-making. The presence of high-risk takers is found to “release” individuals from their individual norms of cautious behaviour within a group setting (Pruitt 1971). The “relevant argument theory” suggests that risk taking leaders will use the group to elicit arguments supportive of higher risk strategies rather than to gain a balanced view of the pros and cons (Barrett, Goulding et al. 2013). This might be the case for innovative and ambitious project owners of the role model projects.

#### 2.4.2 Implications for research

Collaboration and partnering is one of the strategies for risk-handling, being explored in section 2.3 in this chapter. Another option is a limited pilot production while larger sets of production are maintained as constant (Dougherty 1996). Role model projects involving outperforming energy-efficient buildings are examples of a pilot production strategy.

Risk handling is among the issues being explored in the case studies included in this thesis.

#### 2.5 Motivation for innovative sustainable building

Motivation for innovation is a broad research issue. The selection of literature presented in the following section relates to three relevant aspects:

- a) Motivation for actors within the construction industry to innovate in general, and to develop sustainable buildings in particular
- b) Motivation for individuals to be innovative
- c) Motives for green or environmental sustainable behaviour

One of the special issues of *Building Research and Information* (2011) focuses on ways of motivating stakeholders to deliver environmental change. A need is identified for stakeholders to understand each other's particular motives and drivers. A series of studies on the issue demonstrates "varying degrees of engagement, fragmented and risk averse, shaped by a general lack of awareness of the seriousness of environmental issues and their potential for affecting positive change" (Cole 2011 p 432).

##### 2.5.1 Motivating individuals

Motivation among employees in an organization or enterprise is an important driver for their work and therefore for the total production. As individuals, the (knowledge) workers desire acknowledgement and social relations, opportunities for development and self-fulfilment (Spurkeland 2009).

Self-determination (Ryan and Deci 2000) is among the characteristics of working processes in knowledge-based enterprises. Some degree of self-determination is found to have a positive effect on motivation and achievements among knowledge workers (Kuvaas 2008). An increased degree of autonomy is found to release the creativity, competence and energy that are traditionally under-exploited in enterprises, and this contributes to the formation of value creation for clients, owners and colleagues (Johannessen and Olsen 2008).

There are two types of motivation: intrinsic and extrinsic. *Intrinsic* motivated behaviour is defined as actions stemming from the self, human nature, such as curiosity. Intrinsic motivation is found to be essential for knowledge workers to succeed and flourish in their work. Intrinsic motivated activities are found to occur when the working tasks are experienced as meaningful and interesting. Intrinsic motivated activity is found to occur depending on the basic psychological conditions being present, namely the need to belong, be competent and have self-determination (Ryan and Deci 2000).

*Extrinsic* motivated behaviour is driven by external rewards, such as status, fame or money (Ryan and Deci 2000).

Alvesson (2011) argues that intrinsic motivation is a more positive driver for the individual employee than economic incitements. This is especially the case in knowledge-based enterprises. Alvesson (2011) suggests developing a suitable mix for motivating the employees.

Baiden, Price et al. (2006) and Dai, Yang et al. (2008) analyse factors that impact knowledge-based employees that are motivated by green factors. The authors propose to combine green material motivation with green psychological motivation. This suggestion is based upon Herzberg's two-factor theory of motivation (Hackman 1976): green material motivation represent the "hygiene factors" (factors that do not give positive satisfaction or lead to higher motivation, though dissatisfaction results from their absence), and green psychological motivation represent the "motivators" (factors that give positive satisfaction, arising from intrinsic conditions of the job itself). Motivators make employees eager to achieve psychological well-being, healthy emotions and harmonious interpersonal relationships.

The literature on motivation for knowledge-sharing in teams is also relevant to innovative and sustainable building projects. Osterloh and Frey (2000) analyse various organizational and motivational devices with regard to their suitability for making use of explicit and tacit knowledge, and focus on organizational forms that can crowd out intrinsic motivation and thus have determinant effects on the transfer of knowledge. The findings are summarized in a description of three aspects, namely participation, personal relationships and reward for performance. The following elaborate on the social mechanisms and the relevance of motivation for sustainable building:

- Participation is found to signify an agreement on common goals. Participation raises the perceived self-determination of employees and therewith strengthens intrinsic motivation. This finding supports the concept of management by using objectives as a process of joint goal-setting between a principal and an agent (Osterloh and Frey 2000). In construction projects, this might be a parallel to the relation between a client and a team during the concept phase.
- Personal relationships significantly raise the intrinsic motivation to cooperate. Team-based structures enable personal relationships and are a precondition for establishing psychological contracts based upon emotional loyalties, often called team spirit (Osterloh and Frey 2000). A network of interlocking teams raises intrinsic motivation based upon psychological contracts (Likert 1961, Paul, Niehoff et al. 2000). This implies that successful team-building supports motivation for innovative building.
- Reward for performance can crowd out intrinsic motivation. Piece-rate incentive plans are found to produce counterproductive behaviours (Lawler III 1990). Variable pay-for-performance is suggested in situations that need high intrinsic motivation (Jensen and Murphy 1990, Güth 1995). As for sustainable building, the element of competition might be triggering intrinsic motivation among the participating professionals and enterprise managers, due to the potential recognition and publicity and the contracts that are entered into following involvement in a prize-winning project.



Other scholars contribute by analysing the reward structure as an aspect of motivation. The nature of the reward/risk package and the way it is distributed among the design team influence group behaviour. Performance is found to be affected by its perceived levels of equity and fairness. Perceived rewards prompt varying levels of willingness to explore alternative design options or to expend efforts on modifications that would improve the design or add value (Love, Davis et al. 2011). However, performance incentives are not usually important in relation to the role of design consultants, except in prime contracting (Pryke 2004).

#### 2.5.2 Leaders and managers as motivators

Similar mechanisms for motivation are at work in enterprises. The literature emphasizes the role of leaders as motivators. Rose and Manley (2010) and Rose and Kim (2011) point to the client's role in construction projects. Clegg, Kornberger et al. (2011) refers to McGregor's concepts of Theory X and Theory Y regarding the management of human resources. Osterloh and Frey (2000) discuss the balance between the intrinsic motivation that might be provided by an enterprise and the extrinsic motivation that is supported by monetary rewards (price incentives) from the market.

Studies on the construction industry suggest that companies failing to adopt and diffuse the innovations presented may act as a demotivator to their employees, becoming a barrier to innovative activity in the future (Steele and Murray 2004).

#### 2.5.3 Motivating for sustainability

International policy for meeting climate change targets often suggests using national policy instruments to motivate industry actors to improve sustainability. Cole (2011) points to the challenge of meeting the diverse motives of the complex and fragmented stakeholder network involved in construction. Analysis reveals that stakeholder groups are very heterogeneous, whether they are architects or developers, financial institutions (Lützkendorf, Fan et al. 2011) or suppliers. Progress in motivating the various stakeholders must move away from broad generalization and develop a more refined understanding of their diverse make-up (Cole 2011).

Strategies for Green Growth (OECD 2013) and The New Climate Economy (The Global Commission on the Economy and Climate 2014) are based upon the argument that improving sustainability has clear potential economic benefits. According to theory, enterprises have to develop and innovate to remain competitive in the market, and green innovation is a smart strategy. Still, markets remain slow to engage emission reduction-related investment opportunities. Scholars suggest that even in a market-based industry such as construction, growth may not be the only motivation. In small project-based firms, the motivation for innovation may instead be to get past a survival mode of operating and to achieve stability by satisfying clients (Barrett and Sexton 2006). In such small firms, the market is relatively niche, the owners play a key role and, due to the lack of slack resources, innovation is closely tied to operational activities (Whyte and Sexton 2011). This implies that intrinsic motivation for sustainable building has a potential in supplementing the basically extrinsic incentives used in governmental policy instruments.

#### 2.5.4 Implications for research

The review of the literature on motivation has implications for studies of sustainable building. One implication is that intrinsic motivation ought to be considered as a driving force for developing innovative building projects. Another implication is that organizing, management and incentives are of vital importance for motivating team members in innovative problem-solving, such as sustainable building.

#### 2.6 Project management for innovation

The literature presented so far implies that there is a potential for innovative sustainable building to focus on collaboration and integration in problem-solving and, in relation to the influence of motivation, on trust and attitudes to risk. The following section presents relevant literature on the management of such processes in innovative projects.

The Integrated Design Process and the Integrated Energy Design include a methodology that focuses especially on the concept and design phase. Early involvement of a broad spectrum of professionals and stakeholders is emphasized. Suggested methods include workshops and brainstorming, preferably guided by a facilitator. The methods also emphasize sharing knowledge and experience and the parties learning “expansively” from each other (Engeström, Engeström et al. 1999, Bishop, Felstead et al. 2009).

Within the fields of business, government and education, there is widely recognized work on the social environment as a driver of creative performance. There are also contributions exploring creative performance in the AEC sector.

Some studies emphasize the importance of working face-to-face. Those involved in non-routine design are found to rely heavily on face-to-face conversations with other designers for solving problems and developing new, innovative ideas (Salter and Gann 2003). Intrinsic factors such as a sense of professionalism are considered relevant, as are extrinsic, organizational and project-based factors which allow opportunities for innovation. Other extrinsic motivators are the act of creating a new structure, satisfying client needs and the social rewards of working in a team. Therefore, with this in mind, design managers who wish to enhance innovative performance must therefore endeavour to establish a collaborative, face-to-face culture which fosters the intrinsic motivation to be creative and minimizes the extrinsic barriers to idea generation and flow (Amabile 1996, Nijstad, De Dreu et al. 2010).

The literature emphasizes the difference between the creative phase and the decision phase. “Prosocial behaviour” implies that individuals are working towards the collective success of the group, while with “pro-self behaviour” the individual is seeking to “win” at the expense of group consensus or harmony. In collaborative teams it is expected that collaborative behaviours (such as information-sharing, communication of goals and principles and giving and making concessions) will enhance performance (De Dreu and Weingart 2008). Counter-intuitively, the presence of pro-self behaviour has been found to enhance collective results in the long-run (De Dreu and Beersma 2005). Individuals attempt to create further value in a competitive environment. This contributes to more original ideas being created through the processes of idea generation. However, when integrative

behaviour is required, such as during decision-making and project execution, it is the convergence through processes that is needed because the goal is the usefulness rather than the number of ideas.

A study of architects and engineers in design teams identifies four critical success factors for increased motivation for innovative work (Oyedele 2010):

- favourable working conditions for the project, including the psycho-social and organizational working environments
- organizational support, including feedback on performance and career opportunities
- efficient design process, e.g. harmonious working relationships and communication within the team
- effort recognition and rewards: innovative solutions are not fostered where there is a lack of motivational rewards

Acknowledging the role of motivation and knowledge among professionals in the construction industry has implications for leadership and management of enterprises and projects. It becomes crucial to know what motivates each individual employee. Accordingly, it is implied that management must create meaning, a framework and space, making it possible for the individual professional/co-worker to utilize his or her potential and creativity (Nordhaug, Hildebrandt et al. 2008).

The literature presented here draws upon theories on management in knowledge-based enterprises. In knowledge-based enterprises, the working processes and structures of responsibility differ from those in production-based enterprises. Knowledge workers are partly performing tasks that were traditionally carried out by the management, including decision-making. Leadership differs from the traditional role that was based upon the position of the employee in the organizational hierarchy. In knowledge-based organizations, leadership is rather about involving others in their goals and tasks by being a visionary, leading the way for the rest, and by supervising and facilitating the process (Clegg, Kornberger et al. 2011). These are the characteristics of a human relation-oriented type of leadership, which contrasts with and supplements the task-oriented type of management (Spurkeland 2009).

Project management in the construction industry has traditionally been task-oriented and less oriented towards human relations (Andersen 2011). This implies that development of innovative sustainable building represents a challenge for project management practices.

## 2.7 Involving facility managers

Facility Management (FM) is understood in various ways. A European standard defines FM as the integration of processes within an organization to maintain and develop the agreed services that support and improve the effectiveness of the core activities (CEN 2006).

### 2.7.1 The relevance of facility management

Traditionally, building projects have a clear distinction between the project phase (design and construction) and the user phase (management, operation and maintenance). This is because of the

economics of the situation, where decisions about alternative investments and alternative operations are made according to different criteria and may even be subject to the decisions of different departments or stakeholders. However, concerns about the lifetime economy, energy consumption and carbon footprint of the project direct attention to whole-life considerations of buildings. This is because during the life cycle of the facilities, expenses for operation and maintenance may far exceed the initial costs. As for energy, the proportion used during construction multiplies many times during 50–100 years of operation, and so do greenhouse gas emissions.

The limited degree of learning from experiences of use and operation of existing buildings is one of the challenges in the building industry (Emmitt 2007, Jensen 2009). Even if the idea is generally approved, studies reveal that practice is limited. There were expectations that information technology should have made the knowledge transfer easier. However, evaluations conclude that the necessary initiatives were lacking (Bröchner 1996).

Knowledge transfer can be made in two ways. One way is to give feedback about the operation of a building to the design team responsible for designing that particular building, as discussed in section 2.8.4. An alternative is to “feed forward” (Gray and Ferrell 2013, Cathcart, Greer et al. 2014) from the operation of existing buildings to the design of new buildings. Facility managers represent a valuable source of experience from currently operating buildings, which can be fed forward via involvement in the early phases of new construction projects.

#### 2.7.2 FM competence

Decisions made during the planning stage strongly affect the operation of the building. Incorporating knowledge on maintenance and operation at an early stage will therefore make a difference in the long run (Dahl, Horman et al. 2005).

Internationally, there is a tendency that has been identified for the facility management profession to progress from being involved in a narrowly defined set of functional tasks to adopting an integrated management approach. In this new role, facility managers perceive themselves as significant determinants of corporate goal achievement (Pathirage, Haigh et al. 2008) .

As providers of experience of the operation and maintenance of buildings, facility managers have increasingly become recognized as key competence holders. Their knowledge is regarded as important for good performance of the facility in terms of its purpose, and also from an investment point of view. As it is becoming recognized that green construction and maintenance principles contribute to better production and services (Dahl, Horman et al. 2005), interest in FM knowledge is growing and there is a need for further studies to document these effects.

Recent literature acknowledges the value of FM knowledge. The studies reveal that companies are exploiting the value of FM information (McLennan 2000). A study on how FM knowledge is generated and utilized within FM organizations reveals that there is potential but that there are also barriers. Knowledge and specialization are high among FM personnel, and willingness to share knowledge is good. However, there is a lack of formal training opportunities. And due to the existing structures of FM organization, the personnel lack interaction with those outside (Baharum and Pitt 2009).

In a knowledge management perspective, FM knowledge is recognized as being in the initial stage of development. It still needs greater internal and external coherence in many organizations; it has few secure methods of its own to underpin good practice and is insufficiently supported by an adequate knowledge base (Baharum and Pitt 2009).

### 2.7.3 Exploiting FM knowledge in the development of sustainable building

This review includes published studies on the implications of considering operation and maintenance in the early planning phase of a construction project. While some of the studies focus on how to involve FM personnel in the process, others focus on the effect for the long-term value, costs and environmental sustainability of the facility.

The main picture that emerges is that there are three types of issues that the literature covers. The issues deal with a) knowledge regarding operation and maintenance, b) structures for construction projects, c) methods used for decision-making during the process and d) communication among involved actors.

Studies on FM knowledge are concerned with its lack of status and officially recognized competence. In general, the caretakers and cleaning personnel do not have a high status in the facilities where they are working. These functions are often outsourced, and personnel are treated as easy to replace. One of the reasons for this is the lack of formal training (Damgaard and Erichsen 2009). The specific FM knowledge that has strategic value is the understanding of the relationship between the performance of the physical resources and their impact on the customer being served by these resources (McLennan 2000). This type of knowledge can be difficult to access since it is often tacit and experimental in nature. Among the suggested solutions is to provide more formal training opportunities (Baharum and Pitt 2009).

Construction projects are complicated processes, covered both by formal regulations and by traditions regarding participation and decision-making at different stages. A fragmented construction process with many actors involved at different stages is found to hinder effective interaction between the parties involved (Valen, Klakegg et al. 2010). Also, the one-of-a-kind nature of the projects and the procurement rules are among the identified barriers (Damgaard and Erichsen 2009). Among the potential solutions suggested by scholars are that project models should consider the operation of the building and its long-term perspective. The Design-Build-Operate-Maintain (DBOM) delivery system and other partnership models are expected to bring critical operations and maintenance knowledge into the design (Dahl, Horman et al. 2005, Damgaard and Erichsen 2009).

To include FM and environmental considerations, there is a need to broaden the basis for decision-making early in the process. As building owners increasingly see the value of incorporating sustainable principles into their buildings, design professionals have turned to sustainable design standards as an integral component of the design process for new buildings or the renovation of existing structures (Hicks 2011). New methods have been developed and provide new standards for total economy considerations, such as Leadership in Energy and Environmental Design (LEED) and BRE Environmental Assessment Method (BREEAM).

Ineffective communication and collaboration is found to be among the barriers to achieving quality and efficiency in the construction industry. This is a challenge due to the fragmented process that includes a number of actors with partly varying priorities. Shared objectives, openness and clear responsibilities/roles are suggested as possible improvements (Valen, Klakegg et al. 2010). Within project management, there is increasing interest in the relational aspects of professional team processes. Relations based upon trust and shared understandings are particularly important to be able to exploit tacit knowledge, such as FM experience (Damgaard and Erichsen 2009).

#### 2.7.4 Implications for research

The literature implies that there is a potential in drawing on FM knowledge in the development of sustainable building. The research included in this thesis explores which working methods are being used for FM involvement, and what effects there are on the performance of the final building (see paper 1).

## 2.8 Usability of sustainable buildings

Sustainability of buildings relates not only to their impact on the natural environment, but also to qualities relevant to the users. This section includes literature on definitions of usability and dimensions of the usability of buildings. Further, it includes literature on usability from the perspectives of key actor groups, and literature on evaluating usability. Finally this section covers literature specifically on usability of energy-efficient buildings.

### 2.8.1 Definitions of usability

Usability is defined in the ISO Standard on Ergonomics of Human System Interaction (ISO 9241-11) as the effectiveness, efficiency and satisfaction with which specified users can use a specified product to achieve specified goals (International Organization for Standardization 1998). The user organizations that are considered in this study are those for which the new buildings are the products being used to achieve their business goals. According to the ISO definition, usability for a building can be elaborated further: “effectiveness” concerns adding value to the services, activities and production of the organization by using the facilities. “Efficiency” relates to the quality of the outputs compared to the costs of the facilities, including the intensity of use, the amount spent on energy and other operational costs. “Satisfaction” is the users’ perception, safety, health and well-being.

The interaction between the building and the people occupying the building is the essence of usability, as buildings are seldom an end in themselves. Instead, they are tools to support the activities taking place within them (Hansen, Blakstad et al. 2011). The concept of usability deals with buildings’ ability to support an organization’s professional and economical goals, i.e. creating value in a broader sense (Hansen and Knudsen 2006).

Usability is related to functionality; however, functionality alone does not make a certain building usable. Nor does its theoretical potential to deliver a certain effect automatically make it usable in the real world (Granath, Hinnerson et al. 2005). As a result of increased complexity of the building concepts, modern energy-efficient buildings are more fragile in their performance. It is therefore of particular importance that building facilities and occupants work well together (Leaman and Bordass 2007).

Usability depends on the situation and the context in which the building is used. As contexts change over time, this implies that usability for a building also changes over its service life (Granath, Hinnerson et al. 2005). For example, information and communication technology (ICT) has transformed most industries in a way that has radically changed the usability of office buildings. Similarly, political concerns for the global climate have increased the concern for corporate environmental responsibility, which implies that organizations are more conscious of how their built facilities promote the values and their business profile (Cajias, Geiger et al. 2011, Geiger, Cajias et al. 2013).

#### 2.8.2 Dimensions of the usability of buildings

“Adaptability” is an additional quality of a building. A building’s adaptability is defined as the ability to change in response to internal or external changes (Blakstad 2001, Larssen and Bjørberg 2004, Larssen 2011). Adaptability is a valuable quality of a building for organizations experiencing frequent shifts in their operational pattern (Støre-Valen, Kathrine Larssen et al. 2014). Adaptability is absolutely essential in relation to the life time of the building, regarding both economic and environmental sustainability.

Scholars have been critical of traditional methods used for assessing built environments, which are mainly concerned with the physical aspects of the environment. Critics have suggested adding the social and virtual dimensions (Nenonen 2005, Rasila, Rothe et al. 2010). Later studies have revealed that there are a number of dimensions involved in the usability assessment of buildings by individual users (Rasila, Rothe et al. 2010), including the atmosphere and social effects, among others.

The dimension of “atmosphere” adds insight to findings from the studies of role model projects included in this thesis. Atmosphere, according to the usability perspective, is made up of the sensual experiences of the environment, including hearing, smelling, feeling and seeing. In modern sustainable buildings, this relates to solutions for air conditioning, lighting, acoustics, the sound environment, aesthetics and the indoor climate (Hansen, Haugen et al. 2005).

“Networks” is suggested as a supplementary dimension of the usability of buildings. The dimension includes organizational networks and social networks (Rasila, Rothe et al. 2010). For business purposes, it is of interest where and how organizational networks may be utilized most effectively. For social networks, whether the built environment supports or hinders interaction is of interest. It can be seen from the findings in paper 5 that the network dimension has been high on the agenda in the strategic process, resulting in new buildings and organization models in both case projects. Developing facilities with a layout and materials that invite networking and collaboration has resulted in solutions that also contribute to creating effective energy performance and environmental sustainability of the buildings in question. This implies that acknowledging “networks” as an additional dimension of usability might contribute to the sustainability of buildings.

Usability is given high priority especially in computer technology and communication systems. The focus is on the human–computer interaction.

Buildings have some similarities with ICT that makes it relevant to explore the approach to usability in the ICT industry. Both computers and modern energy-efficient buildings are complex technologies.

At the same time, both are considered part of everyday life. Studies of user–technology interaction have revealed that people prefer systems that are intuitive to use. Studies of user behaviour on the web have revealed that there is a low tolerance for difficult designs or slow sites. People don't want to wait, and they don't want to learn how to use a web page (Nielsen and Norman 2000). People might have the same expectations of modern buildings. A major difference between buildings and websites is that there is rarely an option to leave and move into another building.

User-orientation in the development of software and hardware has become an alternative to technology-oriented development methods. A user-oriented design paradigm implies that the product is designed with its intended user in mind at all times, while a participatory design paradigm implies that some of the users are members of the design team (Holm 2006). The studies of role model projects included in this thesis reveal that involvement of users has been crucial for reaching the actual energy performance of the buildings in use.

Usability, as seen from the perspective of the ICT industry, implies that any system designed for people should be easy to use, easy to learn, easy to remember and helpful to users (Gould and Lewis 1985). Designing for usability must therefore have an early focus on users and tasks. In addition, iterative design and empirical measurement are suggested. User-centred design within ICT emphasizes considering who the users are and what experience they have with similar systems. Both cognitive and emotional characteristics of users are expected to relate to proposed technology/design. These design principles and methodology might be of interest for designers of modern sustainable buildings.

The dimension of an interface for human–technology interaction is highly relevant as a supplement to the generic definition of usability, and might contribute to the creation of a sustainable user and operating practice for modern energy-efficient buildings.

### 2.8.3 Perspectives on usability

Traditionally, the usability of a building is considered from the viewpoint of three key roles: the owner, the manager and the users of the facilities. This particularly applies in cases where the building belongs to a property developer, there are various tenant businesses occupying the building and an external facility manager operating the building (Olsson, Blakstad et al. 2010). In addition, there are the individual users performing their daily activities in the building – employees, customers and visitors.

From a user organization's perspective, the building should provide productivity and effectiveness. A user organization will consider how the facilities are able to improve the way tasks are carried out and also whether the building is adaptable for the future development of the organization.

From an individual employee's or customer's perspective, the concern relates to "user satisfaction", covering practical, aesthetic and social aspects of daily activities. In general, good usability for employees is found to depend on a robust performance of basic factors such as comfort and space provision (Leaman 2000, Leaman and Bordass 2007).

From an owner's perspective, usability relates to the value the built facilities have for the customers. It has been argued that organizations will adopt sustainable practices in reaction to the rise in environmental legislation and concerns about overall competitiveness (Porter and Linde 1995).



Enterprises and other organizations are expected to create a market that demands more energy-efficient facilities, and property developers are expected to gain a return on their investments.

Understandings of usability have been developed within various traditions. While the engineering tradition focuses on the technical and physical properties of the facility, industrial design studies emphasize that usability includes both functional and aesthetic attributes. For instance, there have been studies on soft interior design in housing and health-care facilities (Daykin, Byrne et al. 2008) revealing that arts, design and environment are relevant to the suitability for and health of occupants, staff and patients (Lawson 2010, Björnfot, Storm et al. 2013). While physical design relates to building codes, floor plans and physical accessibility, etc. (Indraprastha and Shinozaki 2012), aesthetic design includes considering light, colours, design, art, nature and harmony (Caspari, Eriksson et al. 2006).

#### 2.8.4 Evaluating usability

There have been challenges regarding how to measure and evaluate the usability of buildings. Current rating tools for sustainable buildings, such as LEED and BREEAM, focus on technical aspects of the buildings, such as energy consumption and materials. Recently, methods have also been developed for the purpose of evaluating the interaction between users and the building (Hansen, Blakstad et al. 2011). However, there is a general lack of feedback on how the actual performance of the built facilities affects products and services, the value of the production and employees' health, well-being and productivity (Turner and Frankel 2008).

Post-occupancy evaluation is a methodology used to give feedback from users and to adjust building performance to improve the overall usability. As perceived by customers and employees, building performance is analysed in relation to the measured physical performance of the building, thus highlighting the effects of the built environments on the quality of work, productivity and user satisfaction. Mapping is based on questionnaires or structured group interviews, and may also include a walkthrough (Hansen, Blakstad et al. 2011). A full post-occupancy evaluation process also includes a strategy for actions to be taken to improve overall performance (Preiser and Schramm 2002). The growing numbers of intelligent office buildings make use of such methodology.

#### 2.8.5 Usability of energy-efficient buildings

There is a growing awareness of workplaces as crucial corporate assets (Kupritz 2002). For organizations to develop facilities aligned with their overall strategy, methods such as "strategic workplace design" (Blyth and Worthington 2010, Blakstad and Andersen 2011) need to be considered. Built facilities are found to be important for the image of the user organization. This implies that there will also be consideration of whether the building is in accordance with the overall vision and mission of the user organization (Fenker 2005, Arge and Hjelmbrække 2012, Valen and Olsson 2012).

Concern for the global climate is increasing among customers and employees within a growing number of industries. Therefore, presenting a green profile has become a competitive advantage among enterprises (Geiger, Cajias et al. 2013). "Integrated energy design" (Andresen 2008, Andresen

and Hestnes 2009) is a method developed for strategic development of green built facilities. While such methods are gaining interest, research on how modern energy-efficient buildings affect the core activities of the organizations occupying them is still developing.

The number of studies on the actual energy performance of energy-certified buildings is increasing. However, experiences are mixed. For example, it has been found that a quarter of the new and LEED-certified buildings do not save as much energy as their design predicts. Even if the average energy performance of LEED buildings is better than for comparable existing building stock, some are actually doing worse (Turner and Frankel 2008, Oates and Sullivan 2012). The findings have resulted in a debate about the explanations for the findings and the implications for the worldwide initiative on green buildings. Scholars are focusing on the energy models, rating schemes and definitions (Newsham, Mancini et al. 2009, Scofield 2009).

The number of studies on user satisfaction is increasing, with post-occupancy studies focusing on which qualities have the highest priority among users regarding the effect on perceived productivity in the buildings. Overall comfort is found to be number one, followed by temperature, ventilation/air, lighting and noise (Leaman and Bordass 2007). Thermal comfort is a particular concern during cold winters and hot summers, while ventilation is a concern for both adjusting the temperature and getting rid of unpleasant odours. This implies that energy efficiency is rarely the main criterion for choosing the building for the occupants, but it is gladly accepted as a bonus (Thomsen, Hauge et al. 2011, Thomsen, Berker et al. 2013). A study including worldwide examples of commercial and institutional buildings designed according to sustainable principles concluded that the buildings were not functioning optimally according to the plan, with noise and limited storage being the most common sources of complaints (Baird 2010).

The expectations of the users are found to be relevant to user performance in buildings with innovative energy systems. Occupants usually have no previous experience of passive houses or energy-efficient buildings, and are not aware of the consequences for light, temperature and other indoor qualities. New technology is challenging user habits, and is thus influencing usability. Individual users are generally found to be more satisfied if they understand how the new technology is supposed to work, and they are more dissatisfied if they experience being subjected to interventions by technology over which they have little or no control (Leaman and Bordass 2007). Information that is given to employees and other individual users is often an issue in high energy performance buildings (Thomsen, Berker et al. 2013).

User control is another issue. Occupants are found to have a strong desire to be able to adjust their indoor environment, and users tend to take action if they are not satisfied (Nicol and Roaf 2005). This is relevant in energy-efficient buildings. A lack of control is frustrating, especially if there is no information or training in how the concept works, and this causes users to intervene with the planned use (Thomsen, Hauge et al. 2011). Previous studies emphasize that success for energy-efficient buildings is dependent on the individual occupants and their ability to adjust their habits (Baird 2010, Blakstad and Kjølle 2013).

There is an increasing global interest in energy-efficient buildings as investment objects. An analysis of 10,000 US office buildings concluded that buildings with a "green rating" command rental rates 3% higher than otherwise identical buildings, while selling prices are 16% higher (Eichholtz, Kok et al. 2010). An analysis of more than 800 transactions of offices with Energy Performance Certificates in

the UK indicates that there is a significant rental premium for energy-efficient buildings. This is especially the case for the youngest cohort of state-of-the-art energy-efficient buildings (Fuerst, Van de Wetering et al. 2013). As for residential buildings, an analysis of German statistics shows that energy-efficient buildings yield higher returns on investment and higher rents than inefficient buildings (Cajias and Piazzolo 2013).

There is still a lack of studies on how modern energy-efficient buildings contribute to creating value for their users and owners. General business models are found not to express the relationships between green constructions and the business logic of a firm or organization (Mokhlesian 2012). There are contributions suggesting that the organization of offices may be a major contributor to improving both environmental and economic sustainability. Wireless communication and flexible seating are sources of interest (Van den Dobbelsteen 2004).

Currently, there is a lack of studies on how modern energy-efficient buildings contribute to the overall purpose of organizations. In particular, long-term effects on productivity, economy and competitiveness, and health and recruitment are still to be proven. It has been argued that without owners and producers making green building performance visible, many are flying blind (Bordass 2001), which is still the case.

#### 2.8.6 Implications for research

The literature review on usability implies that innovative sustainable buildings should be evaluated not only for their energy performance or greenhouse gas emissions but also for their impact on qualities relevant to user organizations: the production, the employees and the customers. A study included in this thesis explores the usability of energy-efficient buildings developed as part of a business strategy of the user organizations (paper 5).

User orientation in product development is a strategy for competition in the ICT market. What about sustainable buildings?

### 2.9 Life cycle cost analysis

Life cycle cost (LCC) analysis is a method for assessing the total cost of facility ownership. All costs of acquiring, owning and disposing of a building are taken into account. LCC analysis is especially useful in comparing project alternatives that fulfil the same performance requirements, but differ with regard to initial costs and operating costs (Fuller 2010).

#### 2.9.1 Performance measurement using LCC

Standards for LCC analysis are still developing. The European ISO 15686 was introduced in 2008, while the Norwegian standard, NS 3454, is the object of an ongoing audit (Standard Norge). Whole life cost (WLC) analysis is a closely related term. However, in addition to the cost aspects included in LCC, WLC also includes non-construction costs (e.g. administration), externalities and income in the calculations. The question of whether to include environmental costs in the analysis is still being discussed.

LCC analysis has gained renewed interest due to updated European and Norwegian procurement regulations emphasizing that environmental implications and life-cycle costs are mandatory bases in decisions on all public purchasing. In Norway, LCC analysis has been among the requirements for tenders from the two largest public property clients, Statsbygg and Forsvarsbygg, since the 1990s. An evaluation among Norwegian construction companies reveals that the use of LCC or WLC analysis during the concept decision-making process is limited. With a few exceptions, there is no demand from clients (Holte byggsafe 2008).

There is a generally increasing interest in performance measurement in facility management. In addition to LCC analysis of decisions taken about investments, the focus is on optimizing costs and performance during operation and maintenance. Benchmarking is developing as a key performance tool (Pitt and Tucker 2008). In general, there are expectations that increasing the focus on the long-term management of a building portfolio will draw attention to energy consumption and the consumption of other resources, and that the new tools will provide increasing insight for decision makers concerned about the environmental impacts of portfolio management. There are widespread expectations that increasing awareness of and user-friendly tools for improving performance and the economic aspects in portfolio management will be a driving force for innovation (Pitt and Tucker 2008).

#### 2.9.2 Implications for research

This literature review implies that the issue of the effects of LCCA on the development of sustainable building is still to be explored and evaluated. It is of particular interest to explore what the perceived advantages of LCC among various decision makers are, especially among the clients and the property portfolio managers.

#### 2.10 National and international policy for sustainable industry

The challenge of how to make actors (people, enterprises or organizations) change towards a more environmentally friendly behaviour is a general one. Various interventions are being used, from legal regulations to financial support and pilot projects.

This section explores the following approaches:

- market pull for sustainable building
- public policy for sustainable building
- research-based industrial development of sustainable building
- diffusion of knowledge
- sustainable transition

##### 2.10.1 The market pull for sustainable building

Studies have highlighted the strength of established socio-technical regimes and resistance to change (see section 1.3.5). This is found to limit the pull for sustainable building from the market. This is illustrated, among others, by two recent studies of private homeowners, one in New Zealand and one in the UK. The New Zealand study reveals that a large number of the homeowners considered

the risk that green technologies might not be suitable for their house or that they may not be benefit economically in the long run (Christie, Donn et al. 2011). The UK study explored which low and zero-carbon technologies are actually being used. It was found that a narrow range of technologies were selected, and that these choices were made to minimize the disruption to standard design and production templates. Technical efficiency and cost benefits, which were expected to be primary drivers, were found to be mediated by the logic of maintaining the standard templates (Lees and Sexton 2014).

These studies reveal the challenges of the diffusion of innovations. The examples illustrate the persistence of incumbent regimes as opposed to major changes in technology (Geels 2004, Kemp and van Lente 2011, Geels 2014), which in this case are more environmentally sustainable building retrofits. Scholars have suggested that climate change can trigger “radical innovations”, implying a breakthrough of radical innovations due to tensions or mismatches in the existing regime (Geels 2004). The New Zealand and UK studies, however, indicate that sustainable building is developing according to an “evolutionary innovation” perspective (Lees and Sexton 2014). This perspective suggests that there is a variety of processes that is introducing new products and processes, and that there are selection processes whereby particular products are adopted by actors in the market from the variety of offers. In the interaction between variation and selection, some innovations survive and adapt to the environment in which they operate, while others do not. The persistence might be interpreted as uncertainty and avoidance of/resistance to risks.

Other studies illustrate the mechanisms of active resistance in socio-technical (industrial) systems to more sustainable alternatives. Examples include the shift from cesspools to integrated sewer systems, which was motivated by hygiene concerns. In the Netherlands, the transition occurred during a period of 60 years due to a battle between the stakeholders of the different systems (Kemp and van Lente 2011). A more recent example is the ongoing transition of the UK electricity system from coal, gas and nuclear production regimes to renewable alternatives, in which industrial actors use power and politics to resist new low-carbon systems (Geels 2014). The fact that the emergence of new technologies and practices implies the disappearance of established systems (Shove 2012) explains some of the resistance.

Experiences from the last decade reveal that the suggestion of planting and cultivating “niches” of environmentally benign technologies (Elzen, Geels et al. 2004) is not sufficient for a radical change towards sustainable building. There is also a need for co-evolution of policy, infrastructure, regulations and user behaviour in the surrounding community (Schot and Geels 2008). Previous studies show that incentives have to be diversified in accordance with the various driving motivations for the various parties involved in the value chain of construction (Whyte and Sexton 2011). Theory reminds us that self-interest rather than perceived altruism is the driver for environmental activity (Cole 2011, Hunt and Townshend 2011).

#### 2.10.2 Public policy for sustainable building

Studies have also illustrated the influence that institutional mechanisms exercise over building construction and use. Among others, these include public policies, procurement regulations and the financial sector. Based upon an analysis of actors within the property market, finance, insurance and construction, (Lützkendorf, Fan et al. 2011) conclude that the financial sector has a significant

influence on the built environment during all its life phases, and is able to exercise considerable influence on the realization of sustainable development principles.

Based upon a study of housing stocks in Switzerland, Germany and Spain, Nicol (2011) concludes that regimes can motivate users and owners to create sustainable housing. However, change towards sustainability is found to be possible on the precondition that regulations govern the use of all goods and services when these regulations are coherent: “Indeed, no matter how well the uses of housing are individually, unless the coherence between all of the regulations of a regime is high, the right conditions cannot exist for public or private action to promote housing sustainability” (Nicol 2011 p 471).

The OECD strategy Towards Green Growth aims to combine improved resource management with a boost in productivity, and to encourage economic activity to take place where it is of best advantage to society over the long term. Innovation is suggested as the major approach (OECD 2011). An evaluation of the Green Growth initiatives concludes, “Green-growth policies are likely to have beneficial welfare effects in the long term, but short term transition costs have hampered their implementation”. Innovation is expected to be a key to foster green growth. However, as long as trade and financial flows can circulate freely the effects are depending on transfer of knowledge and technology” (OECD 2013). These reflections also seem to be relevant to the construction industry and the development of sustainable building.

### 2.10.3 Research-based industrial development of sustainable building

Innovation policy in most Western countries (e.g. OECD) is based upon a research-based strategy for industrial development. This implies some kind of collaboration between government, industry and universities. This has been described as a triple helix of relations (Etzkowitz and Leydesdorff 2000). This theoretical perspective (see figure 10) acknowledges that progress is carried out through a network of actors in the value chain of the construction industry. Development is underpinned by institutions and measurements constituting the current research and innovation policy (Asheim and Coenen 2005) .

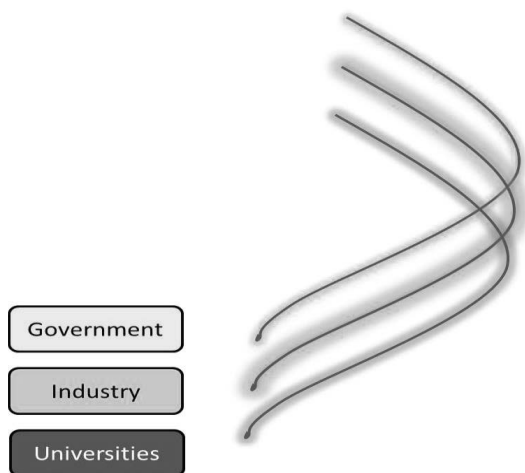


Figure 10: The triple helix model for innovation policy, based upon Etzkowitz and Leydesdorff (2000)

Norway and other Nordic countries have applied a type of the knowledge-based economy strategy that might be characterized as the “learning economy” strategy (Asheim and Coenen, 2005). In a learning economy, innovation is understood as an interactive process which is socially and territorially embedded and culturally and institutionally contextualized (Lundvall, 1992). The learning perspective implies a dynamic notion of innovation, drawing attention to knowledge transfer and collaboration in R&D processes.

The strategy aims to develop a generally high level of education in the population, welfare for employees, resources for science and research and development of industrial design, and also aims to improve copyright patents for the industry. Sustainable innovation and development is the number one priority for all industries (Nærings- og handelsdepartementet 2008-2009).

The Norwegian national programme for development of the construction industry, Bygg21, emphasizes the development of knowledge and working processes as key strategies (Kommunal- og moderniseringsdepartementet 2011–2012). The programme approaches the challenge of implementing research results and innovation into ordinary production, and includes instruments to improve collaborative development between the industry, the government and R&D institutions (Ulseth and Sanila 2013). The programme is in accordance with the national learning economy strategy which is being used in other major industries. The challenge of improving construction processes accords with findings in this literature review that emphasize the challenge of bridging structural and professional borders to focus on the overall and long-term goals.

#### 2.10.4 Diffusion of knowledge

Buildings with innovative solutions or extraordinary design are being used as role models worldwide, and they are often referred to as “demonstration projects”. The purpose of demonstration projects is to build an evidence base for development by sharing experiences of and solutions from projects that are innovative or apply an element of best practice. Demonstration projects are a key activity in

initiatives for industrial development. Relevant examples are the UK programme Constructing Excellence,<sup>3</sup> the US Office of Federal High-Performance Green Buildings<sup>4</sup> and also the Norwegian national initiative Bygg21 (Bygg21 2014). Demonstration projects are used to test technologies and strategies, measure and benchmark performance, identify replicable solutions and disseminate research results.

Demonstration projects are being promoted to gain attention from actors within the construction industry. There are on-site presentations during construction work and also after completion. There are presentations at seminars and articles in magazines and newspapers. Most attention is given to the physical building in terms of the design, materials and technical solutions being used. Less attention is given to the process, that is, how the results have been achieved. Hopefully, my research contributes by illustrating the relevance of the processes leading to innovative project results. My motive for studying role model projects is to reveal the working methods used by them.

Learning theory emphasizes the phenomenon of “situated learning” (Flyvbjerg 2004), which is a model of learning in a community of practice. This term emphasizes that learning is fundamentally a social process – “learning in doing” (Lave and Wenger 2003). People learn from observing other people and from co-constructing knowledge. By definition, such observations/learning takes place in a social setting, a community of practice, where the learners participate. Situated learning allows an individual to learn by socialization, visualization and imitation (Lave and Wenger 2003).

Two aspects of this model are of special interest for studies of role model projects. One aspect is that the model emphasizes the value of “learning in doing”. This implies that the highest learning effect can be expected to apply to the individuals that are active participants in a project, rather than to observers. Another aspect is that the model emphasizes the social aspect of learning. Development of construction projects with outstanding environmental performance might be considered processes of co-learning.

This implies that role model projects can be expected to be of special relevance to developing and transferring knowledge on sustainable constructions as communities of new practice. The findings from the studies included in this thesis indicate that there is a strong learning effect of role model projects on the individuals participating throughout the process. It remains to be seen whether and how this knowledge diffuses to the organizations employing the participants, and to other companies and organizations within the industry.

Situated learning also implies that the intention of becoming a full participant in a community with a certain sociocultural practice is a motive for learning (Lave and Wenger 2003, Lavenerigiprogrammet 2007-2015). Learners inevitably participate in communities of practitioners. And the mastery of knowledge and skill requires newcomers to move towards full participation in the sociocultural practices of a community. A person’s (or enterprise’s and organization’s) intentions to learn are configured through the process of becoming a full participant in a sociocultural practice. This social process includes the learning of skills that require knowledge (Lave and Wenger 2003). This implies that wanting to be among the most green and innovative actors of the construction industry may be a motive for participating in a role model project (or programme).

---

<sup>3</sup> <http://www.constructingexcellence.org.uk/resources/demonstrationprojects/> (last accessed 20.01.2015)

<sup>4</sup> <http://www.gsa.gov/portal/category/105283> (last accessed 20.01.2015)



In role model projects, learning begins with people trying to solve problems. When people explore real-life situations to find answers, learning is problem based (Jonassen and Hung 2008). Studies have revealed how important being social is to learning. If learning is social, it is to be expected that learners who gravitate to communities with shared interests tend to benefit from the knowledge of those who are more knowledgeable than they are (Jonassen and Hung 2008).

Currently, there are a number of communities providing knowledge-sharing that are related to the Norwegian construction industry. In addition to the individual role model projects, there are the coordinated initiatives of the industry (BA2015) and of regional and urban development (Cities of the Future, FutureBuilt), training programmes (Lavenergiprogrammet) and research programmes (ZEB, Treprogrammet), and Bygg 21 and others. Role model and demonstration projects are being used in nearly all the programmes, based upon the expectation that innovation will diffuse and knowledge will be transferred to the rest of the industry.

The literature on the implementation of energy-efficient and sustainable building reports that there is an ongoing process in the industry. An examples of this process is the Norwegian public programme Cities of the Future; the industry has changed its practice due to this programme (Bull-Hansen, Selstrøm Moe et al. 2015).

#### 2.10.5 Sustainable transition

The notion of “transition” is rooted in the systems thinking perspective, which highlights the co-evolution of the technical and the social (see section 1.3.4). In this perspective, the implementation of innovative sustainable building can be perceived as processes of transformation in socio-technical systems.

The term “sustainable transition” is introduced as a notion of a response to major socio-economic challenges. Models of sustainable transition management meet the need for a holistic approach to the challenge of interactions and interdependencies of economic, technical and social systems (Shove and Walker 2007). Scholars have been exploring sustainable transitions in a system perspective using multilevel analysis.

The dynamic between existing and emerging systems is a major issue in the literature. Contributors remind us that the emergence of new systems and practices implies that other systems will be reduced or will disappear. Analysis reveals aspects of persistence of established alternatives, or “incumbent regimes” (Kemp and van Lente 2011). Among others, these include the following:

- The suburban way of living (Shove 2012): the low density housing and well-developed infrastructure for automobility that was created after the Second World War. These structures favour a transport regime dominated by car driving. Similarly, this housing structure is a structural obstacle for sustainable building and energy-saving communities.
- Consumer criteria in relation to preferences between alternative technologies: while previous shifts, e.g. of transport, were competing based upon price, ease and reliability, contributors claim that these criteria are not sustainable due to rebound effects and other impacts (Kemp and van Lente 2011).

- Power relations in the transition of regimes: a shift of regime also implies a shift in power relations. If a transition can be managed, who are the actors and on what authority do they act? The author argues that there is a politics to transition management, a playing out of power concerning when and how to decide and when and how to intervene (Shove and Walker 2007). Power and politics underpin development (Geels 2014).

Contributors point to the challenge of reintroducing environmental qualities into previous regimes, for instance cycling for mass transportation (Shove 2012). The infrastructures of existing regimes (Shove 2012) and consumer perceptions (Kemp and van Lente 2011) are among the social and technical structures resulting in persistent opposition to major shifts.

The process of transformation towards alternative sustainability technologies is another major issue that is addressed in the literature. Scholars exploring the “sustainable transition” approach contribute with critiques of existing policy: policymakers “hope” that green innovation is sufficient. And the literature also focuses on policy and innovation. Critics argue that this alone is not sufficient (Geels 2014). The literature on sustainable transition contributes with suggestions for additional challenges:

- Change in perceptions. Such a change is found to be imperative to new politics for sustainable transition (Kemp and van Lente 2011).
- Regime stability as an outcome of active resistance by incumbent actors. Studies are shedding light on how networks between business actors and policymakers that result in privileged positions for some business actors hinder alternative concepts from developing (Smith 2007).
- Niches in the market are crucial for regime shifts, but are not enough on their own. Many strategies focus on the introduction of technologies, but neglect to highlight the need for co-evolution processes.

*Strategic niche management* is among the contributions made in the transition tradition. The tradition refers to the strategy of planting and cultivating “niches” of sustainable alternatives (Elzen, Geels et al. 2004) or protected areas for the co-evaluation of technology, user practices and regulations (Schot and Geels 2008).

*Transition management* is being explored using the multilevel model developed by (Kemp, Schot et al. 1998) as its basis; the model describes innovation and change as co-evolution and mutual adaption between the macro level (the socio-technical landscape), the meso level (regime) and the micro level (niche of novel products). Rotmans and Kemp (2008) have introduced “transition management” as a governance concept for exploring new paths in a reflexive manner. The concept of transition management has been developed as a cyclical process of searching, experimenting and learning as a response to deterministic methods used during the last decade. The model is used to describe how new technologies emerge within protected niches, and how the niches affect and are being affected by the regimes and landscapes surrounding them.

Some contributions explore how niches and regimes interact and are interdependent (Smith 2007). The translation between green niches and socio-technical regimes has been analysed to explore the different values and cultures, technologies and structures. A gulf is found to exist across every socio-technical dimension in the analysis (guiding principles, technologies and industrial structures) and between green niches (e.g. eco-housing) and conventional regimes. While profit and loss are guiding principles in conventional regimes, green niche building is guided to minimize its ecological footprint.

Contributors suggest that there is a structural technology bias. To overcome this bias, it has been found that there is a need for co-evolution. The bias is embedded in the modernist way of managing the introduction of technology in society, and is therefore a challenge. The bias is found in institutions and culture, and also in the distribution of responsibilities.

There are critics who perceive sustainable transition management as some kind of social engineering, presupposing that individuals and organizations can steer complex systems towards predefined, normative goals. However, the contributors seem to agree that transition management provides an alternative that combines the advantages of planning (according to goals) with those of incrementalism (doable steps which are not immediately disruptive). And that the major contribution is to open up problematic space and solutions space, and also governance arrangements for system innovation. All in all, transition management provides a governance concept for exploring new paths in a reflexive manner (Rotmans and Kemp 2008).

Some scholars calling for a “new reflexive governance model” (Hendriks and Grin 2007, Schot and Geels 2008) to develop sustainability as a basis for a holistic policy on community development. Reflexive governance has been developed in the Netherlands as part of a national policy for transition to sustainability of the Dutch community (Hendriks and Grin 2007, Kemp and van Lente 2011). This has been introduced as a governance concept for exploring new paths in a reflexive manner (Kemp and Loorbach 2006). According to this concept implementing sustainable development implies that actors reconsider their underlying assumptions, institutional arrangements and practices (Hendriks and Grin 2007). Management of sustainable development includes a cyclical process of searching, experimenting and adjusting performance according to experiences.

Experiences have revealed that it is possible to create shifts in dominating regimes by negotiate systems and incentives. Such an example is the waste handling system in Netherlands (Kemp and van Lente 2011). Exploring the potential for increased activity and new business opportunities has been a key to this transformation. The recent Norwegian national initiative for development of the building sector (Bygg21) embrace the challenge for sustainability, among other goals. Based upon research included in this thesis, the author suggests a reflexive governance approach to handle the balance between conflicting goals and interests.



### 3 Methodology and methods

This chapter presents the research design and the data sources used in the research. This includes the choice of case study methodology for the analysis of so-called role model projects, the selection of informants and data for analysis and the use of the grounded theory approach for exploring the material.

Special attention is given to discussing the implications of the methods and materials that have been used in the studies included in this thesis. The discussion on the suitability of the design relates to the explorative strengths and weaknesses. The discussion on the quality of the design relates to the reliability, validity and the overall trustworthiness of the analysis.

#### 3.1 Research design

The research design for the studies presented in this thesis is based upon a combination of case studies and literature studies.

##### 3.1.1 Design approach

The research process was described as a six-step process in section 1.5. There has been a process alternating between induction and deduction, as illustrated in figure 11. The issue has been approached partly by considering data and the observation of case projects, and partly by considering theories and previous research regarding organizing innovation and the development of sustainability in the construction industry.

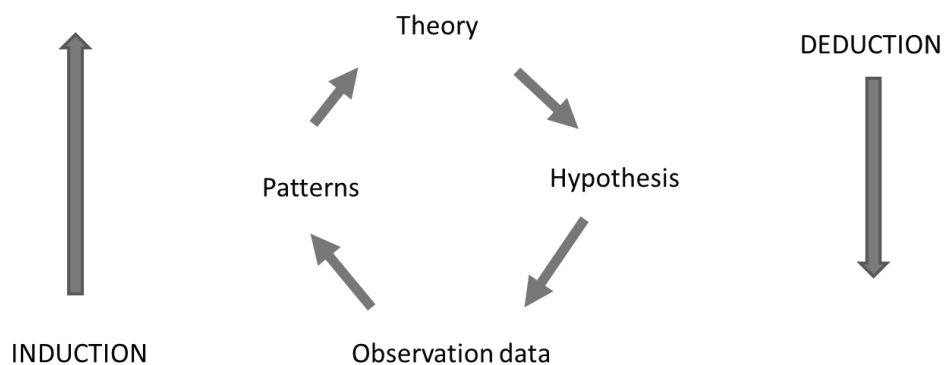


Figure 11: "The research wheel" (based upon the figure of Johnson and Christensen 2004)

Deductive and inductive are two methods of logical reasoning (Kvale 1996, Yin 2009):

- *Deductive reasoning* works from the more general to the more specific. The starting point is a theory about the topic, which is narrowed down to a more specific hypothesis that can be

tested: this is the hypothetic-deductive method. Data from a representative sample are analysed, and statistical generalization contributes to further development of the theory.

- *Inductive reasoning* works the other way, moving from more specific observations to broader generalizations and theories. In “analytical generalization”, theory becomes the vehicle for examining other cases. Analytical generalization may also be described as “inductive generalization”.

The studies presented in this thesis combine the two types of reasoning. They are combined when the “research wheel” is circled twice or more.

General theories (on innovation, organizing and socio-technical systems) are used as a basis for exploring selected case projects via interviews and observations. Material is analysed for patterns and variations. Then inductive reasoning is used to develop a preliminary model of how role model projects work. This represents circling the wheel once.

A literature review is carried out, which explores global findings about energy-efficient and environmentally friendly behaviour. Hypotheses are developed based upon the literature study and the initial theories, and are tested on supplementary interviews and case studies based upon deductive reasoning. The findings from the case studies have been compared to those of other studies, and conclusions are modified or strengthened. This represents circling the wheel twice.

The approach has similarities with the “grounded theory method” (Glaser and Strauss 1967, Corbin and Strauss 2007). The aim of grounded theory analysis is to generate a theory to explain what is central in the data material. This suggests finding a central core category which is grounded (derived from) the material being collected and is also at a high level of abstraction (Robson 2011). This can be done in three stages:

1. Finding conceptual categories in the data material
2. Finding relationships between the categories
3. Conceptualizing and accounting for these relationships by finding core categories.

Qualitative analysis and the grounded theory approach are discussed by epistemologists, who focus on the quality of qualitative analysis. Qualitative analysis is characterized by reflection on the selection of the strategy of the analysis relevant for the subject. Other characteristics are conceptualization and interpretation of data. There is a distinction between interpretation of data and analysis (Kvale 1996). Scholars emphasize that it is necessary to be explicit about the selection of analytical criteria and the fact that they are actually being used in the analysis (Olsen 2002).

The following section presents the strategy for selection and analysis of the data used in this thesis.

### 3.1.2 Role model projects

A design based upon case studies has been used for most of the analysis included in this thesis. Cases are recent Norwegian construction projects with high energy and environmental ambitions, so-called role model projects, pilot projects or demonstration projects.

The term “role model projects” refers to construction projects with ambitious energy and environmental aims. Their status as role model projects is honoured by the national energy fund (ENOVA) because they are construction projects “with forward-looking solutions to obtain low energy consumption and use of renewable energy sources”. Their energy goal must be less than 50% of current practice.<sup>5</sup> ENOVA provides expertise and economic support to a limited number of projects each year. The national housing bank (Husbanken) similarly supports construction projects with outstanding ambitions regarding sustainability and universal design. Documentation for all role model projects is available for the public at the ENOVA website for the purposes of inspiring people and sharing solutions for future projects. Actual energy performance is registered during the first two years of occupation, and the buildings are available for demonstrations and research studies.

Role model projects on sustainable construction have been a success in other countries. Austria is among the leading European countries in terms of the introduction of passive house construction. Role model projects, which have extensive consultation during planning, special training of the workforce and post-occupancy evaluation, have contributed to new practice (Krapmeier 2011).

Throughout the period of the research included in this thesis (2011–2014), the number of role model projects has multiplied. As technical requirements are gradually getting more restrictive, the energy goals for role model projects are continuously improving. Competition for being awarded the status of a role model project is pushing performance to higher levels.

The Norwegian government uses the role model strategy to challenge the construction industry and public and private property owners to develop construction projects with low greenhouse gas emissions. Its motive is the expectation that experiences from these projects will spread to similar/ordinary projects, gradually improving the general performance within the industry. The intention of Framtidens byer (Cities of the Future), FutureBuilt and other similar initiatives is that schools and other public service buildings will be prototype projects and will serve as arenas for sharing experiences and on-site exhibitions as the buildings are being completed. This is in accordance with the national strategy of innovation, in which public actors are acting as demanding customers and role models (Kommunal- og moderniseringsdepartementet 2011–2012).

The motive for analysing role model construction projects is to learn from examples that have succeeded. The case projects are prize winners due to their energy-efficient concepts, which outperform by far other new buildings. However, the focus of the analysis in this thesis is not on the concept as such, but on the organizing of the social process leading to the development of the innovative concepts. The process management is just as innovative as the design and building solutions. According to the theory on learning from role models (Nonaka and Takeuchi 1995, Wenger 1999, Lave and Wenger 2003), lessons learned about management of innovative projects might be just as valuable for the construction industry as the engineering and architectural solutions are for sustainable building.

The major advantage of role model projects is that they are construction and refurbishment projects that are actually being built, and they are available for occupants and others to experience how they

---

<sup>5</sup> ENOVAs støtteprogram for Bolig, bygg og anlegg

perform when they are used. In other words, they prove that sustainable building solutions work in real life.

Role model projects represent outstanding results. In other words, they are exceptions compared to regular building practice, or “niches” compared to current “regimes” in the construction industry (Elzen, Geels et al. 2004, Schot and Geels 2008). This implies that studies of role model projects must be supplemented with other sources for the purpose of exploring diffusion or the implementation of sustainable building practice in the Norwegian construction industry in general.

### 3.1.3 Case studies

Role model projects are of interest due to their high ambitions, and because they result in physical buildings with characteristics that are different from those of ordinary buildings. As real-life buildings, they are of interest to the construction industry and to the public, demonstrating practical solutions and actual performance. Analytical role model projects must be treated as “extreme cases”, demonstrating something unique compared to ordinary projects (Yin 2009). This has implications for the question of the generalization of experiences from role model projects, which will be discussed later on.

Case studies have a general advantage when they are used to investigate contemporary phenomena in a real-life context (Yin 2009). This is the case for the ongoing process of increasing the environmental sustainability of buildings, including improving policy, regulations and research and encouraging pioneering projects in Norway. Case studies also have a general advantage in explorative studies (while the classic hypothetical-deductive model is more useful for explanatory purposes, according to the conventional view).

Explorative studies include the kind of research questions that focus on “how” or “why” a phenomenon works. These are the type of questions being explored in the studies included in this thesis: *How does the Norwegian construction industry respond to the expectations of sustainable building? How is it possible to organize for such development processes? And why are collaboration, integration, involvement of the users and life-cycle analysis, etc. affecting the process?*

A disadvantage of case studies is that the number of cases is limited. This excludes the use of statistical testing in comparing role model projects with ordinary projects. Instead, analysis of the cases is done by relating to previous research and theoretical framework models. Context awareness is important, especially for extreme cases, which is what role model projects are.

The studies included in this thesis combines three sources of information:

- Interviews with informants involved in the projects who have a key role
- Literature review on existing research and theory
- Observation, documents and news articles about the projects



#### 3.1.4 Data collection

The primary source of data has been interviews with key-role actors involved in the role model projects.

Interviews have been based upon semi-structured interview guides. The guides vary for each paper according to the purpose of the research question. The interview guides for four of the studies are included as appendixes to this thesis.

The interviews were partly performed face-to-face and partly by phone or Skype. Interviews lasted from 30 to 120 minutes, with an average of 60 minutes. In some cases there have been additional interviews regarding supplementary questions that were brought up during analysis and comparisons.

All informants received oral and written information about the purpose of the research, and have been guaranteed confidentiality. Consent agreements for two of the studies are included as appendixes to this thesis. During all interviews, the interviewer made notes, which were written out into full sentences within one or two days. The full sentence notes were sent to each informant for confirmation and eventual corrections or supplementation. The analyses are based upon the final version that each informant has confirmed.

#### 3.1.5 Data analysis

The research has an explorative character. The data collected about the case projects are basically qualitative data. A flexible research design was chosen because of the explorative purpose of the research. According to Robson (2011), this implies that design evolves during data collection.

The process alternated between developing research questions, the research design, data collection and analysis, refining research questions and design and supplementing data and analysis. New aspects of analysis have gradually been added as my knowledge of sustainable construction has increased.

Analysis has been performed via a five-step process, as follows:

1. At an early stage, with two to three interviews from the first two cases, information was analysed in a search for certain themes shared among the informants. This analysis is in accordance with the process of induction, as suggested in grounded theory strategy (Corbin and Strauss 2007) and the research wheel illustrated in figure 11.
2. These themes were subjects focused on in the literature review to find experiences, patterns and challenges that had been explored in previous studies and in other countries.
3. A framework model was created based upon common elements in theories on organizing and innovation. This model was used in further analysis.
4. At a later stage, there were interviews with additional informants, from the same case projects and from other ones. The interview guide was more focused to illustrate aspects of the framework model. Supplementary interviews were conducted with the first informants.

5. Data from the case projects were compared, role by role and project by project, to look for patterns.

Finally, findings from the case projects have been evaluated for the purpose of generalization and trustworthiness. Due to the qualitative character of the data, “analytical generalization” is used. According to (Yin 2009), this is achieved by analysing cases according to relevant theories to search for whether my findings are in accordance with established explanatory models.

### 3.2 Materials

This section presents the criteria for selection of case projects, selection of informants and methodology for literature search.

#### 3.2.1 Selection of projects for case studies

Case projects that were selected are among the most extreme examples regarding energy performance of the buildings. The candidates included projects honoured with the status as role model projects by ENOVA or the national housing bank and prize winning projects acknowledged for their energy performance. During the early stage of the research, cases were selected using a pragmatic approach: they were geographically close, so were easy to reach for interviews and visits.

During the first analysis, it became evident that the projects had too many varieties of goals, participants and purposes. It was clear that it would not be possible to draw conclusions about a shared pattern based upon a limited number of cases. There were both private and public clients, and a variety of occupants and activities, etc. In a search for possible saturation, a decision was made to focus on office buildings.

Table 3.1 provides an overview of which case projects were the subjects of analysis in the studies of the individual papers included in this thesis. Six of these projects have been developed for office-related purposes, one is a sports hall and one is currently being developed for the purpose of a housing area. Six of the projects have been realized and honoured as role model projects, while two are still at the concept stage. Table 3.2 provides a description of the eight projects selected for extensive studies, including data on owners and users, size, energy performance and year of completion.

Ten additional projects have been studied less extensively (also included in table 3.1), and interviews with the clients and some of the user representatives have been conducted. Four of these projects have been developed for office-related purposes. The additional material supplements the case studies for the purpose of the discussion in chapter 5.

Table 3.1: Case projects included in the individual studies

Project	Paper #	PURPOSE OF BUILDING	1.	2.	3.	4.	5.	6.	7.	DISCUSSION
SPAREBANK 1 SMN MIDT-NORGE, TRONDHEIM BANK HEADQUARTERS		offices, customer service	x	x			x	x		x
PAPIRBREDDEN 2, DRAMMEN CENTRE FOR KNOWLEDGE AND INNOVATION		education, research						x		x
POWERHOUSE ONE, TRONDHEIM ENERGY-POSITIVE BUILDING CONCEPT		offices			x	x		x		x
BELLONABYGGET, VULKAN, OSLO CULTURAL CENTRE		offices		x			x	x		x
PROFESSOR BROCHS GATE, TRONDHEIM TECHNO PARK		offices	x	x			x	x		x
RANHEIM FRIDRETTSHALL, TRONDHEIM		sports hall	x							x
VENNESLA BIBLIOTEK OG KULTURHUS, VENNESSLA		library				x				x
BRØSET BYDEL, TRONDHEIM		housing area				x				x
TALLHALL, METEROLOGISK INSTITUTT, OSLO		computer based research								x
TROLL, HINNA PARK, STAVANGER		offices								x
RANHEIMSVEIEN 149, TRONDHEIM		housing								x
RÅDHUSKVARTALET, KRISTIANSAND		offices and public services								x
GRONG VIDEREGÅENDE SKOLE		school								x
HUSBY AMFI OG TERASSE, STJØRDAL		housing, rehab.								x
JADARBYGG		housing								x
FRAMTIDENS AKTIVHUS, STJØRDAL		housing								x
GLØSHAUGEN SOLCELLEVEGG, TRONDHEIM		offices, rehab.								x
MYHRERENGA BORETTSLAG, SKEDSMO		housing, rehab.								x

### 3.2.2 Selection of informants

The case studies focus especially on the planning stage of the projects: the concept and design phases (papers 1, 2, 3, 5, 6 and 7). For this reason, the informants that are selected are from among



Table 3.2: Description of case projects

<b>Project</b>	Project 1 Techno Park	Project 2 Bank head quarters	Project 3 Athlete sports hall	Project 4 Centre for knowledge and innovation	Project 5 Energy positive building	Project 6 Cultural centre	Project 7 Vennesla library	Project 8 Brøseth housing area
<b>Owners, clients</b>	Investment and real estate company	Finance enterprise's own property developer	Municipality	Property developer	Property developer	Property developer	Municipality	Property developers
<b>User organisations</b>	Private and public enterprises	Finance enterprise	Sport clubs	University colleges and private enterprises	Enterprises	NGOs and private enterprises	Municipality and the public	Private families
<b>Purpose of facility</b>	Offices and meeting facilities for tenants.	Offices, conference facilities for bank head quarter. Offices and shopping space for tenants.	Athlete sports hall	Laboratories, auditoriums, offices and meeting facilities for education and research.	Offices and meeting facilities for tenants.	Offices and meeting facilities for tenants.	Library and culture centre	Domestic homes. Eco city
<b>Floor area, gross area</b>	16,400 m <sup>2</sup>	20, 260 m <sup>2</sup>	4,750 m <sup>2</sup>	8,500 m <sup>2</sup>	Ca 16.000 m <sup>2</sup>	3,400 m <sup>2</sup>	1,940 m <sup>2</sup>	Dwellings Ca 4000 inhabitants
<b>Total cost</b>	235 mil NOK	550 mil NOK	64 mil NOK			62.5 mil NOK	66.4 mil NOK	
<b>Energy consumption (calculated) And/or other environmental ambition</b>	Total net energy consumption: 114 kWh/ m <sup>2</sup> pr year. Total imported energy: 94 kWh/ m <sup>2</sup> pr year	Total net energy consumption: 100 kWh/ m <sup>2</sup> pr year. Total imported energy: 83 kWh/ m <sup>2</sup> pr year (Measured 66)	(Numbers not available)	Total net energy consumption: 70 kWh/ m <sup>2</sup> pr year. Total imported energy: 58 kWh/ m <sup>2</sup> pr year	Net energy positive building BREEAM Outstanding	Total net energy consumption: 83 kWh/ m <sup>2</sup> pr year. Total imported energy: 68 kWh/ m <sup>2</sup> pr year	Total net energy consumption: 8 kWh/ m <sup>2</sup> pr year. Total imported energy: 58 kWh/ m <sup>2</sup> pr year	Carbon neutral living
<b>Time of completion</b>	September 2009	October 2010	2010	August 2012	(At concept phase)	October 2010	2011	(At concept phase)
<b>Link for more facts</b>	<a href="https://www.arkitekt.no/miljobygget-professor-brochsgaard">https://www.arkitekt.no/miljobygget-professor-brochsgaard</a> 2	<a href="https://www.arkitekt.no/sparebank-1-smn">https://www.arkitekt.no/sparebank-1-smn</a>	<a href="http://www.bygg.no/article/66498">http://www.bygg.no/article/66498</a>	<a href="https://www.arkitekt.no/papirbrodden-2-og-3">https://www.arkitekt.no/papirbrodden-2-og-3</a>	<a href="http://www.powerhouse.no/">http://www.powerhouse.no/</a> In English: <a href="http://www.powerhouse.no/en/">http://www.powerhouse.no/en/</a>	<a href="https://www.arkitekt.no/belonaarhuset">https://www.arkitekt.no/belonaarhuset</a>	<a href="https://www.arkitekt.no/vennesla-bibliotek-og-kulturhus?">https://www.arkitekt.no/vennesla-bibliotek-og-kulturhus?</a>	<a href="https://www.trondhejm.kommune.no/gro-nnbybroset/">https://www.trondhejm.kommune.no/gro-nnbybroset/</a> In English: <a href="https://brozed.wordpress.com/">https://brozed.wordpress.com/</a>

the organizations/actors participating during these phases. They include the traditional key-role actors in the construction process: the owner (client), architect, consultant engineer and main contractor. Specifically for paper 1, the informants also include representatives from facility management. The analysis reveals that additional actors were involved in the planning process, such as specialist environmental or energy consultants and researchers. These participants are also among the informants.

In the study of usability (paper 5), the focus is on the post-occupancy stage, especially the first period of operation. Informants therefore include representatives from the user organizations and the main contractors.

Table 3.3 provides an overview of all interviewees providing material for this thesis. It includes informants from the eight case projects and informants from the projects being studied less extensively (table 3.1), and also property managers providing material on LCC analysis (paper 7).

**Table 3.3: Types and numbers of informants included in the analysis**

<b>Type of informant</b>	<b>Number of informants</b>
Owner's representatives	14
Representative of tenant organizations	8
Manager of construction project, main constructor representatives	9
Facility managers	5
Public property managers	9
Architects and consultants	5
Scientists	2
Others, including representatives of suppliers, non-governmental organizations and politicians	3
<b>TOTAL</b>	<b>55</b>

### 3.2.3 Literature search

The literature review has three purposes:

1. To rationalize the choice of research questions (to identify the need for knowledge)
2. To rationalize the choice of the theoretical approach and the model for the analysis, focusing on the following aspects:
  - a. Barriers to change and drivers/main concerns for actors in the construction industry
  - b. Contributions from the chosen theory and other industries

3. To relate findings to existing studies (to compare results, and discover whether there are similar or contradicting conclusions)

The search for literature on relevant state-of-the-art studies was performed using electronic search generators PreQuest, Google Scholar and Emerald Insight.

The search was based upon the following words/terms:

- construction, building, design, project
- + sustainability, energy efficiency, innovation
- + organizing, management, human behaviour

An additional search was made for literature on facility management, usability and LCC.

The search was done on the content of peer-reviewed journals, published books and key references used in these sources. It focused on literature from 2000 to 2015.

### 3.3 Evaluation of the research design and material

The research design used was selected to meet the requirements of studies based on social science. Even if role model projects can be considered as experimental, they are part of the current community with participants from the real-world construction industry.

Further, the main subject of the analysis is the social relations between human beings, as members, leaders and employees in organizations and enterprises. Even if buildings and case projects are units of analysis, the focus is on the people involved. People are purposive actors who attach meaning to the world surrounding them. And as professionals, they act in accordance with goals and perceived alternatives from their individual perspective, whether as competitors or partners, users or owners, constructors or suppliers, etc. Their behaviour depends on these multiple perspectives. This has an implication for the analysis: the rationale for behaviour has to be interpreted in the light of the rationale of the individual informant and the organization and role she/he is representing. Another implication is that roles in the value chain are key criteria in the analysis of interview data used in the studies included in this thesis. The research design implies a partly relativist approach that emphasizes the complexity of understanding reality. Extreme relativists state that no universal truth exists, but that there are local, personal, community and specific forms of truth (Kvale 1996). Moderate relativists, however, suggest that truth cannot be established by using natural science methods alone.

The following is an evaluation of the research design being used. The purpose of the evaluation is to raise the level of consciousness regarding the strengths and weaknesses of the methods and materials. The evaluation includes the following issues regarding the methodology and material:

- Case studies as a research design, focusing on validity, generalization from role model projects and other advantages and disadvantages of the design
- The selection of cases and informants

- The role of the researcher

### 3.3.1 Case study design

Case studies are to be judged by the same quality criteria used for other social research designs. These criteria can be summarized in the following four definitions: constructive validity, internal validity, external validity and reliability. Dealing with these criteria implies paying attention to certain considerations in designing a study, from the strategic selection of cases to the choice of analytical technique (Yin 2009).

#### *Internal validity*

Internal validity is important when seeking to establish a causal relationship. This is relevant for explanatory studies, when certain conditions are believed to lead to other conditions (Yin 2009).

Even if the research included in this thesis primarily has an explorative purpose, it is tempting to assume that the findings have implications, e.g. for the development of policy. The research design implies that even if extensive collaboration in the planning stage of the role model projects is found, as well as an outstanding energy performance in the resulting building, collaboration does not necessarily explain the result. Even if an association between the two phenomena is identified, there may be alternative explanations: causality might be the other way around (e.g. the interest in innovative projects attracts a lot of highly skilled participants), it might be the result of a third factor being present (e.g. an ambitious client) or it might be a coincidence.

Analytical tactics that can be used to strengthen internal validity in case studies include pattern-matching, explanation-building, addressing rival explanations (Yin 2009) and comparing cases.

- *Pattern-matching analysis* involves comparing empirical patterns with the theoretical predictions in order to investigate differences and similarities between the empirical data and theory. A recent example from the construction industry is a case study of a lean construction pilot project (Eriksson 2010). In the case of the studies included in this thesis, pattern-matching analysis is used in papers 1, 2, 3, 5 and 6, where data from case projects are compared to relevant theoretical models and literature reviews.
- *Addressing rival explanations*: There is a potentially subjective bias in the case study design: the method has a tendency to confirm the researcher's preconceived notions (Flyvbjerg 2004). This is also a challenge in the studies included in this thesis. For instance, in papers 2, 3 and 6, the findings seem to verify the researcher's expectation that collaboration will improve energy performance. However, this question is included in the interview guides, and analysis of the material reveals that collaboration is among the organizational aspects contributing to the resulting building.
- *Multiple case design* has been used in the studies included in this thesis except for in paper 3. Case projects were selected that share some common characteristics, namely that they are prize-winning, energy-efficient buildings, built for the purpose of activities like those that would be carried out in an office and have a private owner or property developer as their client. Working methods and experienced effects have been compared to explore similarities and differences.



*Saturation of data* is suggested as an indicator for the development of a robust theory from qualitative research. This refers to the collection of research data for the purpose of explaining a phenomenon of interest and then constructing theories from the collected data. According to grounded theory, theory construction takes place as the data are being collected. The point of saturation in data collection is when no new or relevant information emerges with respect to the newly constructed theory (Saumure and Given 2008). Hence, a researcher looks at this as the point at which no more data needs to be collected. When the theory appears to be robust, with no gaps or unexplained phenomena, saturation has been achieved and the resulting theory is more easily constructed (Saumure and Given 2008).

As for the case studies included in this thesis, the purpose of including them was partly to explore similarities in organizing for innovative sustainable building. However, the purpose was also to explore the variety in working methods. The limited number of cases included in the series of case studies is considered to satisfy the criteria of saturation according to the general theory, namely that there is an effect of innovative organizing on innovative concepts and outperforming results. From this it is concluded that internal validity among the role model projects is strong.

#### *External validity (generalization)*

External validity is defining the domain to which a study's findings can be generalized (Yin 2009). Since role model projects must be considered as "extreme cases", it is important to discuss to what degree and on what conditions the findings included in the papers can be transferred to and recommended for other building projects.

Generalization is closely involved with theory. Generalization is about relating the specific and individual with the general – to link to a theoretic model. A well-developed theory makes it possible to move beyond the findings of any single research study in search for the general operation of the phenomenon (Johnson and Christensen 2004, Falk and Guenther 2006). Findings should generalize to theory analogous to the way a scientist generalizes from experimental results to theory (Yin 2009). Comparing theory and practice – the general and the individual case – has been described as a "research wheel" as illustrated in figure 11. Johnson and Christensen (2004) suggest that the only difference between qualitative and quantitative research is the starting point on this wheel.

There are three categories of generalization that are based on case studies (Stake 1995):

- Naturalistic: based upon personal experiences
- Statistical: correlation, probability coefficients and other criteria
- Analytical generalization: reasoned assessment of to what degree findings from a study may be used as a guide for what may happen in another situation. Judgement is based upon analysis of similarities and differences between the two situations (Kvale 2006). "Analytical generalization" is a type of generalization in which the inquirer attempts to link findings from a particular case to a theoretical model (Schwandt 2015).

The analysis included in this thesis is to a large degree based upon analytical generalization. The stepwise analysis combining inductive and deductive reasoning is described in the previous section on the design approach. The qualitative approach implies analytical generalization, partly from general theory to data, and partly from data to existing research results. Analytical generalization is

used in both circles of the research wheel to discuss the implications of the findings of the studies of the role model projects.

No statistical generalization has been done. Some naturalistic generalization has been done, drawing upon the researcher's experience, as will be elaborated on later in this section.

### 3.3.2 Advantages and disadvantages of case studies of role model projects

The evaluation of the research design used in the studies included in this thesis has revealed that there was potential for improving the value of the research if time and capacity had allowed. Here, two relevant issues will be commented on, namely the context of role model projects and the development of the hypotheses.

The *context-specificity* of qualitative research is emphasized (Falk and Guenther 2006, Yin 2009). This implies limitations to generalization, as discussed previously in this chapter. However, it is also a major advantage for certain purposes. There is potential to elaborate more on the context of the role model projects. This would improve the understanding of the setting in which they are being developed. For instance, analysing the current market and policy situation for the Norwegian construction industry might be fruitful for the purpose of further development of incentives for energy-efficient building so that they become the preferred practice.

In relation to the development of alternative hypotheses, as part of the second circle in the research wheel, a set of specified alternative explanations for the relation between working methods and the energy results in the case projects might have been developed. This will be explored systematically using the existing material. There is also potential to test the hypotheses on a quantitative data set, which might include both pioneering projects and ordinary construction projects. Such supplementary analysis is suggested in chapter 8 Further research.

### 3.3.3 Evaluation of the selection of informants

The informants included in the studies have key roles in the planning stage of the construction projects. The experience is that this has been beneficial for the analysis as far as exploring how energy-efficient concepts are being developed is concerned. However, the analysis of the planning stage does not explore the process during the construction stage and during the operation throughout the service life of the building. The implication is that the studies included in this thesis are limited to a large degree to the theoretical role model projects, as presented in the concepts, design and calculated models for energy efficiency and environmental sustainability.

The analysis of usability (paper 5), reveals that actual performance may not be fully in accordance with the plans. The selection of informants is not sufficient to explore *why* this is the case. Including more informants from the group of individual users and operators might have given supplementary information. There exist reports on user evaluations. However only the conclusions have been available for the studies included in this thesis. All informants among the users and operators in the study of usability are in management roles, either for the user organization or the property owner. The analysis of the data material indicates that managers tend to focus on the positive aspects of the building and the average result of user feedbacks and are patient regarding the time needed for

adjustments and improvements. Access to the primary data might have provided supplementary information.

In general, achieving objectivity of the data material is a challenge. All informants are considered to be subjective and to have opinions and understandings that depend on their individual perspective. Therefore, it was anticipated that opinions in the projects would be more differentiated among the various informant groups than it was found to be. The overall result is that all participants are positive about the role model projects, although they focus on various aspects of the building and the process. This is in accordance with the expectations: informants will present their experiences in a positive light, due to their involvement in and perceived ownership of the project. Social scientists cannot only observe patterns of behaviour. In addition they ask questions about the beliefs people hold and the meaning they attach to action. The purpose is for the researchers to concern themselves with the inner world of their subjects in order to understand why they act as they do (Elster 2007).

Conclusions from the studies included in this thesis may be affected by the context of the case projects. Since energy-efficient buildings are not the norm, these buildings receive media attention. To reach the top among competing projects, it is the researcher's impression that many of the parties involved in planning and erecting the building have put extra effort into the job, and that users are willing to sacrifice some comfort for the purpose of achieving the ambitions. In other words, there might be a potential Hawthorne effect of energy-efficient buildings. This implies that the positive feedback from occupants may be an effect of extra attention from "interested observers" rather than because of the qualities of the buildings. For instance, even if the hypothesis in the study in paper 5 is that user involvement during planning phases affects energy and user satisfaction, the explanation might well be that involvement has created a sense of ownership which might affect the perception of the final building.

There are examples in the interview material of comments that are critical of the projects. In some cases, these arguments have been moderated by or supplemented with positive arguments during the process of confirmation of the written interview (as described in the paragraph on Data collection in section 3.1.3). One informant has withdrawn from the study at the point of confirmation of the interview, in accordance with the option in the consent agreement. In addition, there are examples of potential informants that, when an interview was requested, recommended that others that have more information on the issue should be interviewed instead, usually implying people in management positions. As a result of this, the variety of informants is limited.

In conclusion, there is expected to be a bias in the material which implies that positive experiences have received more attention than negative experiences.

### 3.3.4 Evaluation of the researcher's role

Qualitative research methods value openness and receptivity of the researcher. This in contrast to quantitative research methods, where the ideal is objectivity and the research design seeks to establish distance between the researcher and the participants. The values of the researcher and of the researched are accepted, and so is the self-awareness of the researcher (Robson 2011). This section reflects on the role of the researcher in the research presented in this thesis.

#### *Researcher's background*

The author responsible for the studies presented in this thesis has a background that is partly in and partly outside the construction industry. Her education and previous research practice is within social science; however it includes studies of industrial change and organizational development processes. Being employed at the Norwegian University of Science and Technology in the Department of Transport and Civil Engineering means that there is a collegial environment and professionals who are highly skilled in terms of their knowledge of materials and construction, and the design and management of sustainable buildings. The research presented in this thesis draws upon the knowledge represented by these colleagues. The insight of the researcher has increased during the research process as new aspects of the research problems in the study were discovered, which has contributed to the researcher being able to elaborate further on the data material.

The author partly represents an outsider and partly an insider to the informants from the construction industry. An advantage of being an "outsider" is having the opportunity to question practice that is tacit knowledge and accepted by "insiders". This implies that informants and research colleagues can reflect on questions and practices that they usually do not consider. And the author also learns about and gains an insight into the complexity and culture of the construction industry. The insider/outsider position is also used to discuss and reflect with colleagues. In relation to the research issue of a change in practice within the construction industry, and the driving forces of and barriers to this, the background of the author has been used as an advantage.

#### *Role in data collection*

In interview situations, the author has been aware of the interaction with the informant. The following list presents two issues that the researcher has been especially conscious of and how they have been dealt with:

- The background of the researcher was presented as part of the introduction to the interviews. As a response, the informants were concerned about explaining their statements, using examples and words other than those used specifically in the construction industry. The interviewer used opportunities to summarize how the answers were understood and to check whether this was correct.
- Some preliminary analysis was done during each interview, using the researcher as "an analytical instrument" (Robson 2011). Exploring the situation and perspective of each individual informant is part of the interview. To some degree, statements were compared with statements from previous interviews. And, if time allowed, supplementary questions were asked to elaborate further on the rationality of the presented statements.

In a number of instances the interviewee concluded that the interview had been a positive experience. There are few opportunities for reflection during daily work, while during the interview their profession or situation were explored from different perspectives. This implies that the interviews acted as a dialogue and source of mutual reflection between the participants, and not only for collecting data from informants to the researcher.

#### *Role in analysis*

The process of developing and refining the analytical approach includes characteristics that can be recognized as a *pragmatic approach* (Robson 2011). The pragmatic approach implies that in

empirical research the meaning of a concept consists of its practical implications. In social research, a pragmatist would use whatever philosophical or methodological approach works best for the particular research problem being dealt with. Hence, truth is simply defined as “what works” (Baert 2005). Among the main features are that different perspectives and conflicting theories are considered useful, human experiences are considered relevant to their actions and theories are valued depending on how well they currently work (Johnson and Onwuegbuzie 2004).

In the analysis process in the research included in this thesis, a pragmatic approach was used in the first, inductive reasoning phase, as data material was analysed in the light of the researcher’s background and previous experience. This implies that the author unconsciously drew upon familiar theories from the social sciences. This will influence which patterns are recognized during the initial explorative analysis. However, the initial analysis and theory development were tested and developed further during later phases of the research.

Scholars emphasize the influence of the researcher’s individual attributes and perspectives on qualitative research. Since the researcher is conducting the interviews and also the analysis, the process involves reciprocity. In other words, the researcher, too, is a subject in qualitative research (Kvale 1996, Kvale 2006). This is the strength and the weakness of the researcher’s role in analysing interviews and observations.

The author, as a participant and an interpreter, have drawn upon her experience at the time of analysis. The insider/outsider position, and the social research background has been used as an advantage for the purpose of the research included in this thesis: The qualitative research method and the author’s background has been an instrument for shedding light on human relations and behaviour in processes of industrial development.



## 4 Findings in the papers

This chapter summarizes major scientific contributions from the papers included in this thesis (papers 1–7 in section II). The presentation focuses on contributions from the individual studies to the purpose of this thesis and the individual research questions in chapter 1.

The papers draw on the theory and existing research included in chapter 2 in this introductory essay, while an overview of the materials and methodology used in the papers' analyses is included in chapter 3.

### 4.1 Structure of the chapter

The papers are presented in three groups:

- I. Papers on the effects of collaboration and partnering
- II. Papers on facility management, property management and usability
- III. Paper on the impacts of R&D

These three groups refers to the analytical levels and approaches presented in chapter 1 and illustrated in figure 7. Figure 12 illustrates how the papers are covering the analytical structure presented in chapter 1.

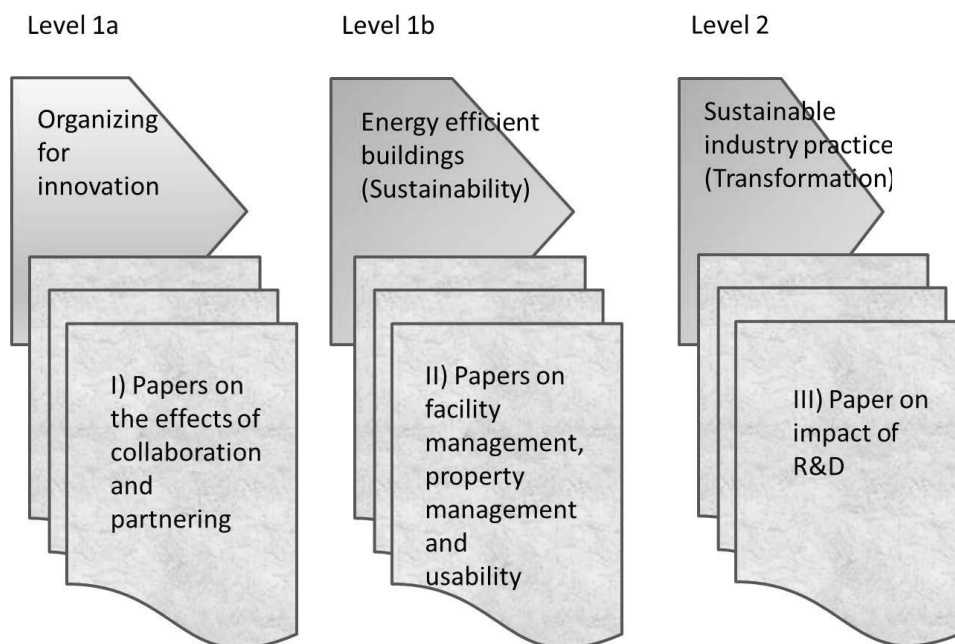


Figure 12: Thematic groups of papers

One or more papers contribute to each group, as follows:

- I. Collaboration and partnering is explored in papers 2, 3 and 6. All three papers explore the methods being used for extensive collaboration in building projects with high energy ambitions. Paper 2 focuses on the participants and working methods during the planning phase, while paper 6 includes all phases of the process. Papers 3 and 6 explore the use of formalized partnering, on the one hand, and the experienced social effects of collaboration, on the other hand. All three papers explore the effects of collaboration and partnering on the energy performance of the final building.
- II. Facility management, property management and usability are approached in papers 1, 5 and 7 respectively. Paper 1 focuses on the facility managers of existing buildings that participate in the planning process of new buildings and the effects on the energy performance of the new building. Paper 7 focuses on how life cycle cost (LCC) analyses contribute to improving the operation of public properties. Paper 5 focuses on how the extensive energy efficiency of the built facilities affects the user organizations. The paper explores the benefits and obstacles of energy-efficient buildings, illustrating how energy goals can add value to occupational enterprises.
- III. The impacts of research on the development of the construction industry are explored in one of the papers. Paper 4 explores three histories of development of innovative building practices, and focuses on the role of collaboration between the industry and research institutions.

#### 4.2 Relevance to the thesis

The papers contribute to this thesis by showing how the Norwegian construction industry is able to develop innovative sustainable buildings. In particular, the papers contribute by illustrating the following aspects:

- The effects of collaboration, including team processes and formal partnering
- The role of owners as strategic clients and property managers
- The role of innovative (unconventional) management practice in the development process
- The effects of extensive and broad involvement, in particular of facility managers, users and research
- The effects of adding value to user organizations from sustainable building
- The dynamic relations between government, R&D, property developers and industry actors

The papers are mainly based upon studies of projects that achieve outstanding energy goals. The papers contribute partly by showing the dynamics of development processes at project level (as illustrated in figure 13), and partly by illustrating the dynamics of the relations between the construction industry and the surrounding community (as illustrated in figure 14).



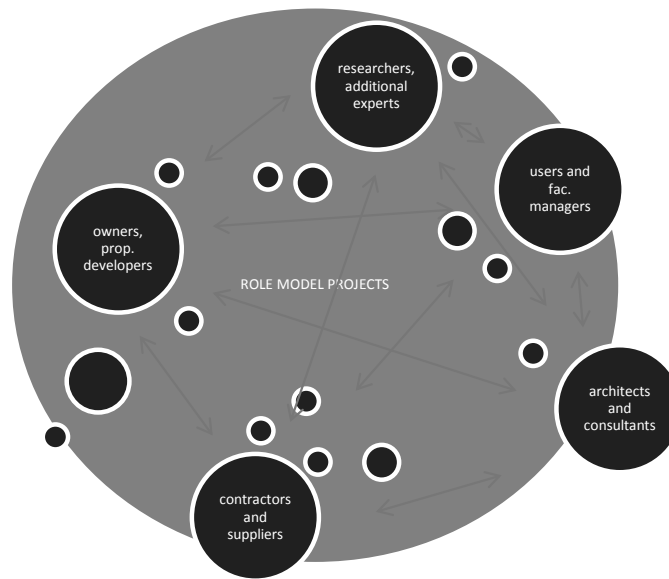


Figure 13: Dynamics of relations at project level

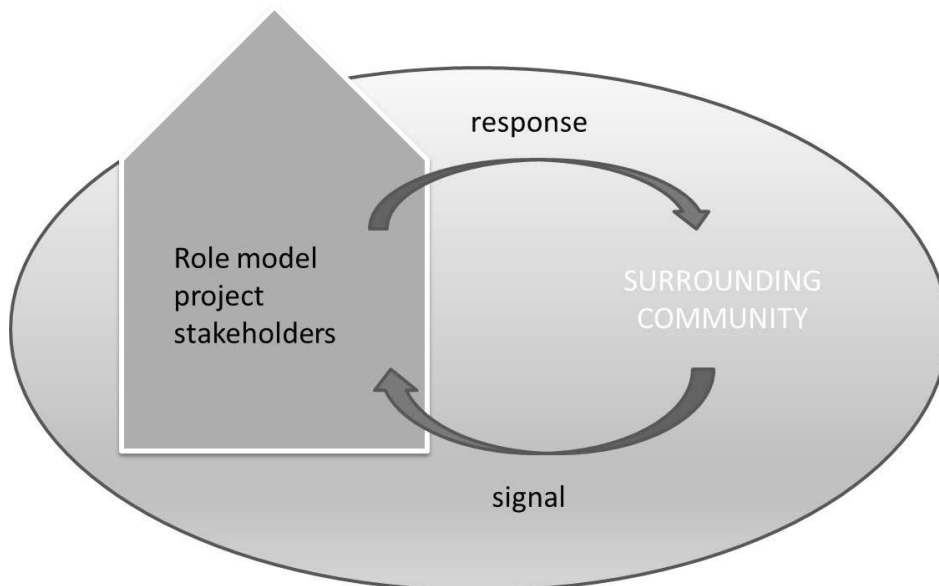


Figure 14: Dynamics of relations between the construction industry and the surrounding community

Each paper is presented in three sections:

- introduction and purpose
- findings in the paper
- relevance to this thesis

#### 4.3 Papers on the effects of collaboration and partnering

##### 4.3.1 Use of collaborative working in projects with high energy ambitions (paper 2)

*Published at 7<sup>th</sup> Nordic Conference on Construction Economics and Organization, Trondheim, June 2013*

*Co-authors: Marit Støre Valen and Jardar Lohne*

###### *Introduction and purpose*

The Norwegian construction industry is challenged to improve energy efficiency. However, changes are slow. Previous analyses of the construction industry have revealed that general development and improvement within the construction industry is being hindered by the general lack of collaborative working among the stakeholders. The study presented in this paper therefore redefines the challenge of energy-efficient building as organizational.

The paper explores the use of collaborative working as a means to improve the energy performance of new buildings. Three aspects from the analysis will be presented here:

- a) The participants
- b) The working methods being used
- c) The effects on the energy performance of the buildings

Analysis is based on three case projects which have achieved outstanding energy performance results. All three of them are office buildings, completed during the period 2009–10, and have been honoured as role model projects by the Norwegian Energy Fund (ENOVA). All clients are professional property developers, and the buildings are occupied by businesses that tendered for them.

The literature suggests *partnering* as an alternative to the conventional production chain, and also suggests an integrated design process (IDP) as a working method for early involvement of actors in all stages of a building's life cycle. IDP and partnering have gained interest internationally due to their potential in relation to the development of sustainable building. Also, within Norwegian construction, there is growing interest in these models as alternatives to conventional planning procedures.

The paper explores experiences of using partnering and integration to develop high-performance buildings. The paper focuses on the concept and design phases.

The paper contributes to the purpose of this thesis by analysing collaboration in projects with extraordinary ambitions. It illustrates the working methods being used to increase collaboration

(research question 2), and how the methods affect the energy performance of the building being created (research question3).

#### *Findings in the paper*

Participation during the planning process is found to be broader than in ordinary projects. Representatives from the businesses that tendered for their building, facility managers, specialized energy consultants and scientists supplement conventional stakeholders. The variety of participants contributes by providing a broad spectrum of expertise and skills which is experienced as fruitful for brainstorming on alternative goals, concepts, technology and designs for the individual building project.

Innovative/unconventional working methods are found to be used for the purpose of improving collaboration. The methods include holding workshops and brainstorming. Thorough modelling by researchers and full-scale lab testing were also used during the exploration of innovative concepts for environmentally friendly building. The characteristics of IDP methodology are recognized in all cases. The paper concludes that the use of collaborative working methods implies that the projects invest more time and resources in the planning process than is usually the case in conventional projects.

Conventional contracts are found to be used during the concept and design phases. Partnering contracts were not used during the planning of the case projects. This finding contradicts the finding in the literature suggesting that partnering contracts are used in projects with extensive collaboration.

Broad, early involvement is found to contribute to the energy performance of the final buildings. This is partly due to the broad knowledge and experiences that contribute to developing integrated solutions to achieve the high energy ambitions. It is also due to the users acknowledging and contributing to the energy goals during their occupancy of the final buildings. The findings are in accordance with those of previous studies that emphasize the benefits of collaboration in developing innovative building solutions to achieve the high ambitions for the environmental footprint and net energy performance.

#### *Relevance to the thesis*

The paper contributes to research question 2 by illustrating what working methods are used to intensify collaboration during the planning phases and by exploring which extraordinary participants are involved.

The paper also contributes to research question 3 by revealing how extensive collaboration during the planning and design phases contributes to improving the energy performance of the final building. The paper concludes that broad, early and intense collaboration has been essential for developing prize-winning buildings with high energy efficiency. Three major reasons are identified:

1. Integrated solutions have been developed as a result of the broad multi-professional planning process. These solutions take into consideration the energy effects of all aspects of design, technology, materials and the use of the building.

2. Supplementary expertise was brought into the project, contributing with a broad spectrum of knowledge and experience. This expertise added to the potential alternative concepts in the creative phase and also to the evaluation in the conclusive phase of planning.
3. Property developers and owners draw on the learning effects of their previous experience of innovative and complex building projects.

The findings in the paper support theories on the relevance of collaboration in innovative projects, namely pooling knowledge and sharing risk in relation to problem-solving. The findings imply that clients and industry partners acknowledge the potential for energy-efficient building practice, and also acknowledge the relevance of extensive collaboration to exploring this potential.

#### 4.3.2 Partnering for developing an energy-positive building (paper 3)

*Published at 7<sup>th</sup> Nordic Conference on Construction Economics and Organization, Trondheim, June 2013*

##### *Introduction and purpose*

The paper presents an analysis of Powerhouse One, which is a project that has been developed to be the first energy-positive commercial building in Norway. The project is of special interest for two reasons:

- the energy ambitions, namely to produce more electricity than is used over the lifetime of the building
- the unconventional organizing of the process during development of the concept

At the time of the analysis, Powerhouse is developed as a concept. Powerhouse One is still waiting to be erected, while a refurbishment project which is based upon the same concept is being completed. The analysis is based upon semi-structured interviews with a selection of professionals participating in the concept phase.

The purpose of paper 3 is to explore the collaborative working process that took place during the development of the concept building. The focus is on the following:

- a. How the concept development process was organized
- b. How the process of collaboration has affected the energy concept for the planned building

The paper contributes by explaining the characteristics of the interaction process (research question 1) and how working methods that encourage extensive interaction affect the energy performance of the resulting building concept (research question 3). Of special relevance is the exploration of the social mechanisms of extraordinary collaboration during the concept phase and the formalized partnership that is established to facilitate the process.

### *Findings in the paper*

Two strategic organizational means are found to be of special relevance, namely the following:

- the established alliance of industrial partners
- the Integrated Energy Development methodology

The industrial alliance includes a property developer, a construction group, an architect's office, an aluminium production company and an NGO working for an environmentally friendly community. The alliance is a precondition for the initiative to develop an energy-positive building concept for a northern latitude, and the ambition is for the alliance to collaborate in the construction of a series of individual energy-positive buildings. Formal strategic partnering is an exception in the Norwegian construction industry, but it is suggested in the literature as a means for innovative construction. Therefore, these aspects are of particular interest regarding the development of sustainable building.

It is also found that the strategic industrial partnership of the alliance has made it possible to invest extra time and resources in the concept development process, due to the long-term plans to use the concept in a series of building projects. This reveals two effects:

- Reuse of the concept in a series of projects provides opportunities to learn from one project to the next.
- Reuse of the core team from the concept phase saves time during design phase.

The Integrated Energy Design (IED) methodology is characterized by broad and early participation of stakeholders: the so-called frontloading of the process. In the case project, this has been organized as a combination of workshops and specialized working teams. The series of five workshops involved up to 50 individual participants, including representatives from members of the alliance, potential suppliers, external specialists and scientists working on energy solutions. A dedicated facilitator led the process. The multidisciplinary workshops were used to brainstorm about alternative energy solutions. In between the workshops, specialized teams of workshop participants performed detailed calculations on the most promising alternatives.

The main finding is that the IED methodology has resulted in an energy concept for an energy positive building. The working process of Powerhouse One is in accordance with the methodology of IED, which aims for the energy supply, thermal storage and daylight systems to be integrated with the architectural design.

An additional finding is that throughout the process the energy ambitions have increased. Part of the concept phase involves operationalizing the criteria for an energy-positive building, and the exploration of optional solutions for the ambitious energy targets have resulted in criteria that are more strict and specified than those in international standards. This implies that the IED methodology has brought the energy ambitions further forward than initially planned.

The findings reveals the value of strategic long-term partnering. Previous studies have enlightened how the project-based nature of the construction activity is a barrier to taking high performance teams further, and to innovative construction in general.

*Relevance to the thesis*

The IED methodology has created an unconventional process affecting the behaviour of the individuals, and has significantly improved collaboration across the borders of professions and the roles of each stakeholder/participant. The following is especially emphasized by the interviewees:

- There has been an atmosphere that encourages suggesting and discussing optional solutions that have previously not been used in this climate zone. Experienced specialists have been open to discussing implications across areas of expertise. All decisions have been made by consensus. This was a new and radical experience for many participants, including the client.
- During the process, shared understanding and respect has developed between the participants. Re-using a core team from the concept phase in the design phase saved time because of the shared understanding that had been established.

The findings in this paper contribute by showing the potential of strategic partnering in developing sustainable building. The case study reveals how an industrial alliance contributes by exploiting innovative concepts and developing a shared understanding and mutual learning, and thereby represents a promising alternative to the traditional restructuring of project teams (and understandings) from one project to the next, which is found to hamper learning processes and innovation.

4.3.3 Developing energy-efficient buildings – the challenge of management (paper 6)  
*Submitted to Journal of Engineering Construction and Architectural Management, March 2014*

*Introduction and purpose*

Conventional project management in the construction industry has been questioned regarding its ability to improve industrial performance in general and to develop sustainable building in particular. Prize-winning energy-efficient buildings are exceptions demonstrating the potential to achieve outstanding results by using unconventional project management methods.

The purpose of the study presented in this paper is to explore the management methods being used in developing projects with an outstanding environmental performance. The focus is on management of the process from early planning to occupancy in terms of the following:

- a) The organizational means being used
- b) The experienced effects of unconventional project management

The analysis is based upon five case studies. All are Norwegian office buildings with outstanding energy performance. Four are prize-winning buildings completed between 2009 and 2012, while the fifth is still at concept stage at the time of writing. This fifth building is included in the analysis because it has the most extreme energy ambitions of all of the case projects and also because it uses the most extensive collaborative working methods.

The paper contributes to the purpose of this thesis by exploring innovative organizing of construction projects (research question 2). The paper supplements the findings in papers 2 and 3 by analysing the

project management throughout all phases of the process, from early planning to post-occupational use and operation.

The paper also contributes by showing how management of collaborative processes affects the energy performance of the final building (research question 3). This paper supplements the findings in papers 2 and 3 by discussing the significance of formal contracts compared to the significance of the social effects of extensive collaboration.

#### *Findings in the paper*

It is found that unconventional management methods are used during all phases of the projects:

- In the concept phase, the clients have created workshops with broad participation and, in some cases, a dedicated facilitator.
- In the design phase, the clients have made extra efforts to create dedicated teams, either by re-using participants from the concept phase or establishing a shared multi-professional office during the design period.
- In the construction phase, two strategies are used by the contractors:
  - Challenging the workers on the construction site, the suppliers and the subcontractors to contribute to further improving the energy qualities of the final building and the environmental performance during construction work.
  - Following up on energy and environmental goals during construction. Systems have been developed to evaluate alternative suppliers and to test completed work on the construction site.

In most cases, the strategies of challenging and following up have been combined.

- The individual users working in the buildings have been involved so that they understand the concept and adjust their daily habits according to the energy ambitions.
- The first year of occupation has been used to fine-tune the operation of the energy system.
- User evaluations and feedback from facility managers were used to adjust systems for light, temperature and ventilation to improve the energy performance. All of the buildings have systems for detailed and continual monitoring of the energy performance of the building in use.

The paper concludes that management that encourages extensive collaboration and broad involvement has made a significant difference to the energy performance of the resulting building. The social atmosphere created during workshops and consensus-based decision-making has created a team spirit and a sense of ownership of the results. Early involvement of users and facility managers has created enthusiasm for achieving the ambitious energy goals and a willingness to adjust daily behaviour to contribute to achieving the goal. Workers on the construction site have been awarded collective bonuses for saving energy and for the high quality of their work affecting the energy performance of the building. Management practice is found to establish “psychological contracts” between owners, users and facility managers, and within the concept and design teams.

As for the formal organizing, it is found that traditional procurement models have been used. Partnering contracts have been used between the client and the contractors in three out of four completed building projects. This is in accordance with the current conventional practice. The

unconventional aspect is that formalized energy indicators have been included in all the contracts. In some cases, a dedicated energy/environment consultant was contracted by the client. This modification may explain why conventional contract models have proved successful. The fifth case is found to be an exception; a formal strategic partnership has been established for concept development. Re-using the energy concept that has been developed is a major argument for using the formal alliance in this case. The paper suggests that in the other cases the client has the key personnel, making them able to harvest experiences and develop the energy concept in future buildings without being involved in a formalized partnership.

In one case, “green tendering contracts” have been introduced as an incentive for sharing the costs and benefits of the energy-efficient building between the owner and the tendering businesses. Such a formal energy contract with the user organizations is an exception, and is found not to replace the psychological contracts with the individual users.

The paper identifies a positive relation between the degree of the energy ambitions and the level of management that encourages collaboration: a pattern is found in that the most recent projects with the most far-reaching energy ambitions have been using the most extensive collaboration methods.

#### *Relevance to the thesis*

This paper contributes to this thesis by emphasizing the value of involvement and collaboration during the development of sustainable buildings. The paper illustrates the innovative aspects of the management of projects with outstanding energy ambitions (research question 2) and the effects of the organizational means used for collaboration on the resulting building (research question 3).

The findings in the paper are in accordance with those of previous studies and theories regarding the effects of collaboration in innovative projects. However, while the existing literature emphasizes the formal aspects of partnering (contracts), the informal management of collaboration has been explored less. This paper contributes by exploring the use of both formal and informal involvement methods.

The findings in the paper imply that it is possible to create innovative processes and develop sustainable buildings without organizing formal partnerships or altering other structures of the industrial system. The paper’s findings imply three vital preconditions:

- a) Explicit energy/environmental indicators should be integrated into the formal contracts
- b) Acknowledgement of the “psychological contract” and the intrinsic motivation of the individuals to contributing to the energy ambition
- c) Ensuring re-use of concepts and experiences from one building to the next

All case projects have given priority to the energy goals. Management throughout all phases of the whole project reflects this. Even if management methods vary, they serve the purpose of focusing on the energy ambitions and involve all stakeholders in the challenge.

In relation to b), the paper contributes by illustrating the value of informal management methods for building a shared understanding and ownership of the project goals. The analysis recognizes that management principles are used in knowledge-based enterprises, such as creating team spirit, honouring initiatives and trusting the project team to make decisions. While the literature on



partnering and innovation in the construction industry emphasizes extrinsic incentives as a driving force for the involved stakeholders, this paper shows the value of intrinsic motivation for the individual participants.

In relation to c), re-use of the knowledge on energy-efficient building is found to be crucial to justify the extra resources invested in the projects. The paper's findings are in accordance with those of previous studies, and emphasize the concept phase in energy-efficient building: the so-called frontloading of the process. While the clients in most of the case projects are property developers re-using the knowledge gained from one building to the next, the stakeholders in the project with the most extreme energy ambition have established a formal strategic partnership to ensure the re-use of the building concept.

The findings in the paper imply that owners and project managers acknowledge the value of collaboration for innovation. The findings indicate that it takes more extensive collaborative methods to develop the most innovative buildings. They also indicate that there is a barrier to formalizing long-term partnering for this purpose, which thereby seems to be the most extreme management tool for the purpose.

Finally, the paper contributes by exploring the role of the clients in building projects with outstanding energy ambitions. The findings reveal a strategic client role in the case projects. Two common characteristics are identified: firstly, the suggestions for high energy and environmental ambitions have come from other stakeholders, including potential tenants, architects, NGOs and politicians. The clients have been open to exploring the relevance of the suggested ambitions to the purpose of the project. Secondly, when deciding on the energy ambition, the clients have been visionary and have supervised the development process; they have also adopted a hands-on attitude in following up on the energy goals. This finding is supplementary to that of previous studies, emphasizing that ambitious clients play the key role in sustainable building. However, the finding is in accordance with the literature on leadership in knowledge-based organizations, in which leadership is about leading the way for the rest rather than about the traditional role that is based upon a particular position in the organizational hierarchy. Thereby, the paper contributes by emphasizing the value of innovative management in sustainable building.

#### 4.3.4 Summary of papers on the effects of collaboration and partnering

Papers 2, 3 and 6 contribute by exploring the organizing of innovative building projects. Based upon studies of the development process of buildings with outstanding energy performance, the papers contribute by illustrating management methods and their effects for the development of sustainable building. The papers are of relevance to three of the research questions:

- Contribute by illustrating the interaction processes (research question 1), especially the social effects
- Contribute by illustrating innovative aspects of organizing role model projects (research question 2), especially broad and early involvement, multi-professional concept and design teams, and systems for following up on the energy goals during construction and post-occupancy

- Contribute by illustrating how the working methods affect energy performance (research question 3), especially the relevance of informal methods creating team spirit and psychological contracts with the individuals

The findings reveal the double effect of organizing to achieve collaboration: it contributes partly by improving the design, the construction the use and operation of the physical building, and partly by creating team spirit, a sense of ownership, motivation and other social effects among the individual participants (see figure 15). A major contribution from multi-professional concept and design teams is the exploration of the synergy effects on the energy performance of the final building. The major contribution from the social relations being built during collaboration is the creation of “psychological contracts” about mutual efforts to increase energy performance. The papers illustrate the relevance of this double effect in projects that succeed in developing buildings with outstanding energy results.

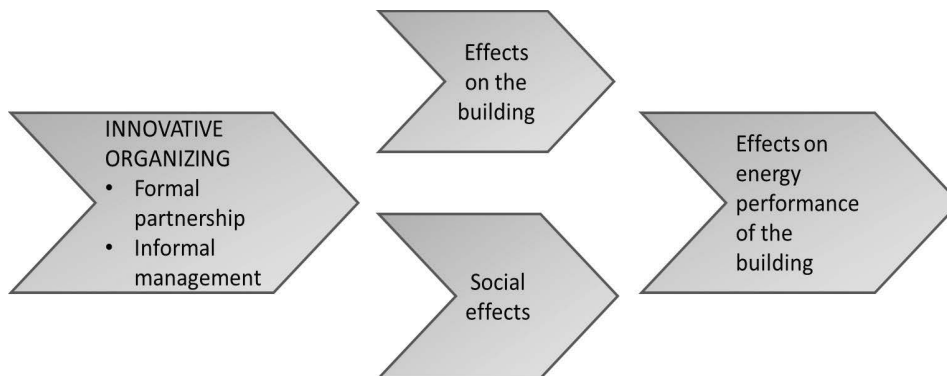


Figure 15: Innovative organizing and the effects on energy

#### 4.4 Papers on facility management, property management and usability

##### 4.4.1 Involvement of facility managers during planning phase (paper 1)

*Paper presented at CIB Conference, Cape Town, January 2012*

*Co-author: Marit Støre Valen*

###### *Introduction and purpose*

Improving the long-term value and performance of built assets is a major challenge for sustainable building. For this purpose, the literature suggests integrating facility management (FM) into early planning of new construction projects. Knowledge of all aspects of facility management is valuable for clients in relation to considerations concerning the life-cycle costs and life-cycle assessments of buildings. Facility managers are recognized as key competence holders for the purpose of improving the energy performance of new buildings.

The study presented in this paper explores the following research question: *How does the involvement of facility managers improve the energy-efficiency results?*

Two sub-questions are explored:

- a. To what degree and in which project phases are facility managers involved?
- b. What are the mechanisms through which facility managers contribute to the energy performance of the final buildings?

The study explores experiences from the perspective of the owners. The analysis is based upon interviews with clients and facility managers in three construction projects resulting in energy-efficient buildings.

This paper contributes to this thesis by showing the potential of involving FM personnel during the development of sustainable building. The paper contributes to two research questions as follows:

- ✓ By describing how FM personnel are involved in the planning processes the paper contributes to research question 1.
- ✓ By describing the effect mechanisms of how FM involvement contributes to the energy performance of the final buildings the paper contributes to research question 3.

#### *Findings in the paper*

Involvement of FM representatives varies among the case projects. There is found to be intense involvement during the planning phases in two out of three projects, while involvement during occupation and operation has been significant in all cases.

A positive relation is found between early and significant involvement of FM personnel and the energy efficiency of the final buildings. In cases A and B, the internal operation departments have had a key role in concept and design teams. The experience of the owners of these projects is that FM competence has been crucial in discussions on the construction concept. In case project C, energy efficiency was handled by the design team without involving representatives from the FM department. The experience of the owner of this building is that the energy solutions are working well and that the energy performance of the building matches the high ambitions. However, buildings A and B, and not building C, have been honoured as energy-efficient role model projects.

A positive effect is also found to result from the involvement of FM personnel in optimizing the energy performance of the final building. In all three projects, facility managers have been actively involved in monitoring and adjusting the operations of the facility. Adjustments have been necessary in all buildings to achieve the calculated energy performance. The experience of the owners of buildings A and B is that the facility managers were eager to find energy leaks and waste, improve routines and performance and to continually optimize the results. FM informants that have been involved during the planning process of projects A and B find that the insight they have gained contributes to their ability to optimize post-occupancy energy performance.

Achieving outstanding energy performance is found to be a major goal for owners of buildings A and B, while it is of lower priority for the owner of building C. This fact explains the extraordinary

collaboration between clients and facility managers in projects A and B, especially during early planning. The findings are in accordance with those of previous studies emphasizing the value of FM knowledge in the planning of energy-efficient buildings. The paper concludes that this value is acknowledged among owners with the highest energy ambitions.

*Relevance to the thesis*

The findings contribute to this thesis by explaining the value of involving FM personnel during the development of sustainable building.

The paper contributes to research question 1 by identifying the early planning phase and the post-occupancy evaluation as crucial project phases for FM involvement.

The paper contributes to research question 3 by identifying two major effect mechanisms for how FM involvement contributes to the energy performance of the final buildings:

- The project draws upon the knowledge and practical experiences of internal/existing personnel to ensure that solutions and design are easy to operate and maintain.
- Participation during planning results in FM personnel learning more about the process and becoming motivated to improve the energy performance of the final building during the occupational phase.

Identification of this double mechanism implies that even if the knowledge of energy and the building's operation can be provided by external expertise during the planning phase, a "psychological contract" with FM personnel in the new building has to be developed through personal participation in the development process.

The paper also contributes by showing how FM involvement contributes by adding value for the owners and users of the final buildings (research questions 4 and 5). It is found that FM expertise has contributed to improving the economic aspect of the project, especially in relation to the life-cycle perspective. FM expertise is also found to contribute to improving the indoor environment by using low-emission materials, noiseless ventilation from an underfloor ventilation system and improving access for cleaning, etc. This paper therefore supplements paper 5 in exploring how energy-efficient buildings add value for the users.

This paper supplements paper 6 by illustrating the relevance of having a high degree of hands-on attitude from the ambitious owner/client. It supplements paper 3 regarding the relevance of an integrated design process. Finally, this paper supplements papers 2, 3 and 6 by explaining the social effects of involvement and participation, which are to build a sense of ownership and competence among key personnel for the in-use service life of the building, and which in previous studies is documented to affect behaviour and habits and to have implications for actual energy use.

#### 4.4.2 Life cycle analysis in municipal property management (paper 7)

*Paper presented at IALCCE Conference, Vienna, May 2012*

*Co-author: Marit Støre Valen*

##### *Introduction and purpose*

The challenges of local public portfolio management relate to the relation between political decision-making and professional property management. The local council makes decisions about investments in buildings and large facilities, and also about the yearly operating budget. However, insight into the long-term economic consequences of investments and maintenance is limited among the decision makers.

In general, investment in new facilities is found to have a higher priority among politicians than investment in the operation and maintenance of existing buildings. However, Norwegian municipalities are constantly being challenged to provide good public services for their inhabitants that take into account economic, environmental and societal sustainability. Management of the building portfolio is an issue gaining increasing attention, and the introduction of computerized tools for life cycle cost (LCC) and whole life cost (WLC) analysis provides assistance in carrying out analysis and making decisions in local public portfolio management.

The purpose of the paper is to explore the status of the use of LCC and WLC analysis in Norwegian municipalities. Two research questions are included:

- a) To what degree and for what purposes are LCC analyses used today?
- b) How do LCC analyses contribute to the building portfolio management?

The analysis draws partly upon a national survey taken by administrative and political leaders in Norwegian municipalities, and partly upon interviews with property managers from selected municipalities.

The study presented in this paper is relevant to the overall purpose of this thesis because it draws attention to the lifetime aspects of buildings, especially the relevance of maintenance (and energy accounting) to sustainable building portfolio management. The findings present LCC analysis as a methodology that can be used to improve the operation and management of existing buildings.

The paper contributes to research question 3 by explaining how the use of whole life cost analysis affect the performance of the buildings. It contributes to research question 1 by illustrating the relevance of good interaction/communication between those at the operational level and the strategic decision makers.

##### *Findings in the paper*

It is found that the use of LCC or WLC calculations in Norwegian municipalities is at an early stage. Such analyses are hardly being used at all for the purpose of optimizing facility management costs for the existing building portfolio. LCC analysis is mainly used in relation to decisions regarding major refurbishment of an existing building or its replacement by a new building. This implies that LCC analysis is associated with investments rather than operation. These calculations are made by external consultants as part of the procurement process, and the use of LCC analysis is limited within

municipal property management departments. About half of the sample municipalities have computer-assisted facility management systems; however, the level of use varies.

Currently, other methods are found to be used for the purpose of the cost-planning of the operation and maintenance of existing buildings: Historical data and key performance indicators are used in more than half of the informant municipalities. Benchmarking with comparable municipalities is also common, and so is energy accounting. Planning and improvement of cleaning and energy use are found to have a higher priority than maintenance of the buildings.

The analysis in this paper explains the paradox regarding long-term management of a public building portfolio: even if all informants (90% in the questionnaire survey and 100% of interview informants) see the potential for improving the long-term economy of operation and maintenance, long-term planning has low priority. These findings are supported by previous studies.

This paradox is the background for the follow-up study presented in the paper. Portfolio managers are found to emphasize three major contributions from life cycle or whole life cost planning to optimize the overall costs per capita regarding public properties:

- 1) Improving the quality and usability of the buildings. This includes improving energy efficiency and area efficiency.
- 2) Improving communication with the municipal council about the implications of policy decisions for operation and maintenance.
- 3) Involving operators, cleaning personnel and users in initiatives for improvement. LCC analysis reveals the potential for improvement and documents effects over time.

The paper reveals that the major challenge for property managers is communicating with the decision makers. There are a number of tools available for property managers, as professionals with a building engineering background, to document, analyse and carry out planning regarding costs and the long-term effects of alternatives for operation and maintenance. The potential value of computerized LCC tools is the ability to visualize the long-term effects of existing policy and also the potential effects of adjustments in budgets and management practice. The paper includes illustrations of examples of how property managers and politicians have achieved major improvements based upon LCC analysis, dialogue about budgets and policy and a yearly report on the effects for users and buildings: visualized analysis is found to be of interest to local politicians in relation to initiating improvement programmes and contributing to the status of and budgets for operation and maintenance of the building portfolio.

The findings from this study are in accordance with those of previous studies (Bjørberg 2007), namely that LCC analysis makes a difference in two ways:

- Optimizing the long-term operation and maintenance efficiency
- Documenting the relation between the cost level and the quality level, and communicating this between the operational level of the organization and the strategic decision-making level, namely the local politicians.

*Relevance to the thesis*

About half of the total Norwegian building portfolio is owned by the public. Most of this is schools, buildings used for health-care purposes and facilities for sport and cultural activities. As representatives of this public ownership, local politicians are elected to make strategic decisions about investments and management. The national concern regarding improving public building management relates to quality and economy as well as wasting energy and other resources. Local municipalities represent a major part of the market for the Norwegian construction industry, and can therefore be a driving force for the improvement of environmentally sustainable buildings.

The paper contributes to research question 3 by illustrating how LCC analyses are being used to analyse and improve building management from a lifetime perspective. The finding that LCC is mainly used in decisions about major refurbishment and investments implies that environmental sustainability is being included as part of the decision-making regarding new buildings and will therefore affect energy consumption in the future. And the finding that similar methods are being used to analyse energy, maintenance and other aspects of the operation of the building portfolio implies that there is an awareness of the potential for improvements in existing buildings.

The paper draws attention to two major challenges for further improvements. One is the challenge of communication between the operational level and the decision makers in the municipal council. This challenge has been documented previously in other studies, and has led to national initiatives to educate local politicians in the basic principles of building portfolio management. The other is the challenge of achieving competence and capacity for long-term analysis and planning in each municipality. The analysis reveals that competence in terms of LCC analysis and giving priority to long-term planning varies considerably among the municipalities. In general, larger municipalities have more competence in property management. However, the paper reveals how an extensive focus on long-term management has led to major improvements independent of the size of the community. This finding is supported by previous studies identifying competence in property management as a key to improving the quality, costs and efficiency of public buildings. The findings indicate that LCC analysis in itself is not sufficient. The ability to communicate the implications to operators and decision makers (professionals and non-professionals) is an additional criterion.

The paper also contributes to research question 1 by emphasizing visualization as a key quality of LCC analysis tools. Visualization is found to improve communication between the operation level and the strategic decision-making level in municipalities. The paper reveals that interaction between these two levels is the major challenge to improving long-term portfolio management.

The paper discusses the implications of municipalities organizing property management in two subdivisions, namely having one unit responsible for the investments, while another is responsible for operation and management. This is to separate the client role in the procurement and design process from the facility management role. Material for this study indicates that the split model is a barrier to whole life cost planning, and especially to implementing experiences from facility management into investment decisions, since the organization model is a hindrance for communication. Thereby, the findings in this paper add to the discussion about the need for collaboration in development and innovation and how procurement regulations may be counterproductive to improving the performance of the construction industry, as presented in the literature review (chapter 2).

#### 4.4.3 Summary of papers on facility management and property management

The two papers contribute by illustrating the challenge of bridging structural and cultural barriers in the construction industry and property management. Separation between the operational level and the strategic decision-making level is identified as a challenge to improving lifetime property management, energy performance and sustainability.

Paper 1 contributes by identifying the potential of the involvement of experienced facility managers in the early planning of construction projects. Facility managers are identified as a link between existing buildings and new ones, representing the potential to feed forward knowledge that is relevant to the long in-use lifetime of buildings at the planning stage.

Paper 7 contributes by identifying the potential of including LCC or WLC analysis of existing buildings into strategic property management. LCC and WLC analysis represents a link between the current situation and the future one, showing the relevance of considering both the investment and the operation in strategic decision-making.

Both papers have a focus on harvesting knowledge of existing operation and management of properties, partly as feedback to improve operation and maintenance, and partly to feed forward into decisions on investments with long-term implications. The findings are supported by theories on the role of evaluation in decision-making. Figure 16, which is based upon a generic model of the evaluation circle, illustrates the involvement of facility managers.

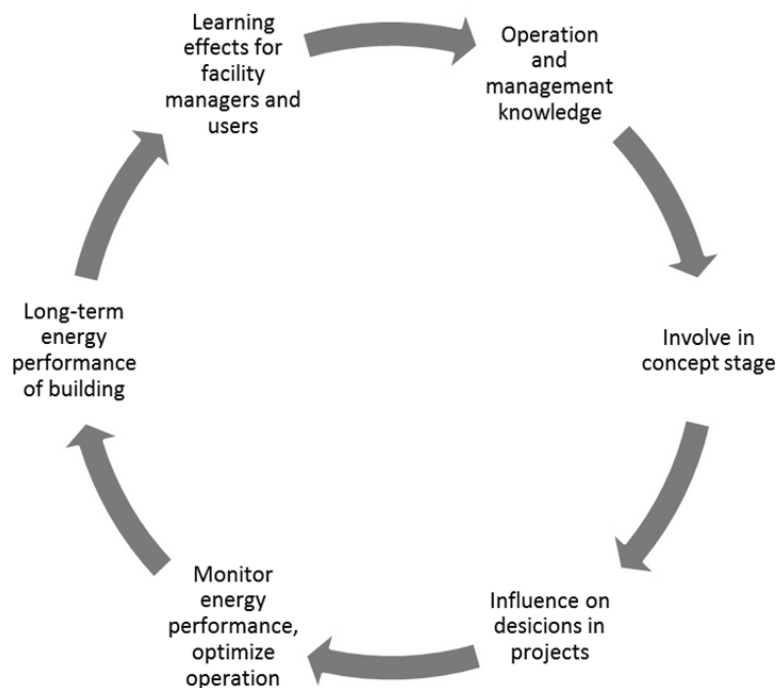


Figure 16: Involvement of facility managers



Closing the evaluation circle is a general challenge in developing sustainable building, due to the fragmentation in the existing system. However, these two papers reveal how personal involvement and tools for systematic analysis contribute to communication across structural borders, roles and professions, and thereby acknowledge the relevance of the lifetime aspects in energy-efficient and sustainable building.

These two papers supplement the papers on collaboration and partnering (papers 2, 3, and 6) by illustrating the double effect of communication and involvement, namely sharing knowledge and developing individual motivation to explore and contribute to improvements.

#### 4.4.4 How energy efficient office buildings challenge and contribute to usability (paper 5) *Published in Journal of Smart and Sustainable Built Environment (Emerald), 2014*

##### *Introduction and purpose*

Energy-efficient buildings are gaining interest among environmentally conscious tenant enterprises. Energy efficiency is also among the qualities considered by property developers to improve competitiveness in the market in relation to office-based and service businesses. The existing literature (see section 2.8) emphasizes that workplaces are crucial corporate assets, since value production for an organization depends on the usability of the facilities.

The purpose of the study is to explore the following question: *How do energy-efficient buildings add value to the enterprises and organizations occupying them?*

Two research questions are included in this study:

- a. *What is the experienced usability of the buildings?*
- b. *How is development of the construction projects related to strategic organizational processes?*

For the purpose of discussing these questions, “value for user organizations” is operationalized by the definition of “usability”. According to the ISO Standard on Ergonomics of Human System Interaction (ISO 9241-11), “usability” is defined as effectiveness, efficiency and the satisfaction with which specified users can use a specified product to achieve specified goals. As a result of the long lifetime of buildings, the aspect of “adaptability” is added to the model of analysis. A building’s adaptability is defined as the ability to adjust it according to changing needs.

The paper contributes to the thesis by illustrating the potential for energy-efficient facilities to add value to user organisations. The findings from the study are relevant to research question 5 regarding the motives for engaging in sustainable building and the benefits of it for the user organizations. The paper is also relevant to research question 1 regarding the interaction process and research question 3 regarding the effects of working methods by explaining the involvement of end users in energy-efficient building projects.

The paper explores two cases of prize-winning energy-efficient office buildings in two Norwegian cities. One building is occupied by a bank head quarter, while the other is occupied by two university

colleges and a commercial research-based enterprise. Professional property development companies are owners of the buildings, while the user organizations have contracts as tenants. The two buildings have been developed for the purposes of the enterprises and university colleges currently occupying them.

The case projects are selected for two reasons. One is their energy performance goals. The other is that both buildings have been developed as part of ongoing strategic development processes within the user organizations. The buildings were completed in 2010 and 2012, which gives three years and one year of experience of occupation respectively at the time of analysis.

The user organizations wanted to develop and expand their activities, banking and finance, and education and innovation respectively. They wanted facilities more suitable for their purpose. The focus on energy and environment is part of strategies to improve services and be more competitive for customers, students and employees. The user organizations wanted to improve internal and external collaboration, and the buildings have been developed according to this. The analysis is based upon interviews of representatives from the user organizations.

*Findings: a) experienced usability*

Post-occupancy feedback reveals that user satisfaction is high, and so are efficiency and effectiveness for the user organizations. The case studies explore the rationality for this result and discover the following:

- User satisfaction is found to relate to the overall quality of the buildings. The new facilities are considered attractive and functional for their purpose, and they represent a major improvement in the indoor climate and general well-being compared to the outdated facilities.
- Efficiency of the new facilities is found to result from a combination of high-quality facilities and efficient working space. There is a high intensity of use of the indoor areas, especially because of open-plan office landscapes replacing individual offices, a free seating system and because of the university colleges and research enterprises sharing specialized laboratories and auditoriums. The extremely low energy consumption contributes positively to cost-saving in both cases and is found not to hamper the quality of work done in the organizations.
- The buildings are found to increase effectiveness. All user organizations registered improved results during the first year of occupying the new buildings. There were high expectations for the improvement of internal collaboration and the sharing of knowledge. The buildings have proved successful in contributing to production by increasing the number of business agreements for the bank, students for the university colleges and research contracts for the commercial enterprise.
- The buildings are highly adaptable to changes in use. This is found to be due to the construction providing large open spaces, with long room spans and a limited number of columns. The inner walls are easy to move due to the use of standard grid systems. Buildings with a high degree of flexibility are appreciated by the user organizations.

The major downside of the energy-efficient building concepts is regulation of the indoor climate, and the automated system that has no manual alternatives is the main negative aspect in terms of user satisfaction. This finding is in accordance with findings in previous studies (see section 2.8.5).

An additional upside of the energy-efficient buildings is the positive effect that is experienced on the images and reputation of the user organizations. The buildings are found to be attractive to customers, students, candidates applying for positions and visitors. This finding is also supported in previous studies.

*Findings: b) relation to strategic organizational development*

The case projects exemplify the dynamic connection between the strategic goals of the user organizations and the development of the new physical environment. The construction projects were initiated from strategic plans within the user organizations, and throughout the planning process there has been mutual exploration of how the buildings and the organizations will interact. The strategic organizational plans include the aims of improving knowledge-sharing and increasing collaboration across units. These aims were transformed into building designs with a high proportion of glass and a limited number of doors and inner walls. The positive experiences of the buildings are supported by previous studies, suggesting that opening the physical environment facilitates human interaction, communication and knowledge-sharing. Thereby the study supports “networks” as a quality of buildings, as suggested in literature reviewed in section 2.8.2.

The high degree of area efficiency is also one of the strategic goals and is a major key to combining energy efficiency and environmentally friendly design and improving usability for the user organizations. Compared to the previous facilities, the floor area has been reduced by 30–50%, but the number of employees, students and customers has increased.

Including energy efficiency in the strategic business plans is found to be crucial to benefit from the synergy effects of energy efficiency and usability. Both the construction projects and the organizational development processes have been governed according to the overall strategy and objectives. As a result, the user organizations have been able to determine the building, and not the other way round, as emphasized in the literature.

The paper illustrates the role of the individual end users in achieving energy-efficient performance of buildings. The involvement of employees has been an issue in all user organizations, during planning and in post-occupancy follow-up activities. However, the degree varies between the two projects. A positive relation is found between extensive and early involvement of employees and their willingness to adjust their behaviour according to what is required by the energy-saving systems. This finding is in accordance with those of previous studies emphasizing that energy efficiency is gladly accepted as a bonus by the users, but not at the cost of indoor comfort, and is also in accordance with studies showing how increasing insight into how the automated indoor climate control system works has impacted on how the users experience the workplace (see section 2.8.5).

*Conclusion – added value for the user organizations*

Even if energy efficiency is the focus of this paper, it is not the first priority of the user organizations. In accordance with previous studies, energy efficiency is found to be considered a bonus or side effect.

The paper concludes that modern energy-efficient buildings add a high level of value to the enterprises/organizations occupying them. The paper reveals that it is the strategic organizational development planning process that has been the driving force of the development of facilities with a high degree of usability. The conclusion is in accordance to the existing literature, which emphasize that the mutual process relating to the development of the organization and the building is found to be of vital importance for adding value to the occupying organizations.

Energy efficiency has indirectly contributed to the results; firstly, by focusing on the natural environment, sustainability arose as a result of the strategic process, due to the importance of demonstrating that responsibility should be taken for the community and the future. Secondly, it has contributed by developing a design and technology that create a building that facilitates collaboration and knowledge-sharing, and thereby contributes to a high degree of area, material and energy efficiency.

#### *Relevance to the thesis*

The paper contributes to the purpose of this thesis by illustrating the potential for sustainable buildings to add value to the user organizations. Two aspects are found to be of special significance to achieve such added value, namely the relation between the strategic development of the organization and the development of the building, and also the involvement of the individual users.

The two case projects have proved that the potential for a win-win relation between environment and economy exists. Both buildings have developed a concept that facilitates network- and project-based user organizations, while at the same time saves energy and materials. Thereby, the new buildings are adding to production and at the same time are saving costs and reducing the lifetime environmental footprint.

The paper shows how sustainable building concepts can contribute by adding value to the user organizations. In these cases, project-based and development-oriented organizations gain value from facilities that also favour the natural environment. Thereby, the paper is relevant to research question 5 regarding the motives for engaging in sustainable building and the benefits of it for the user organizations.

In addition, the paper reveals a process of early and extensive involvement of the individual end-users. The methods used for involvement in planning and evaluation are found to affect the energy results, and this is supported by the existing literature regarding the role of involvement in situations of change in general.

## 4.5 Paper on the impacts of R&D

### 4.5.1 Three stories describing the impact of research on the development of Norwegian construction industry (paper 4)

*Paper presented at CIB world conference, Brisbane, May 2013*

*Co-authors: Marit Støre Valen, Ole Jonny Klakegg*

#### *Introduction and purpose*

Research has a key role in the basic strategy for industrial innovation. This in accordance with the strategy for a knowledge-based economy that is currently being approved by the OECD and the national government. For the construction industry, this implies that technology and specialized knowledge represent an increasingly larger part of the production process at the expense of local materials, traditions, craftsmen and craftswomen.

The purpose of the paper is to explore *how research and development (R&D) is taking the construction industry forward*. The focus is on the uptake process and the exchange of knowledge in the industry. The relevant research questions are as follows:

- a) How are R&D ideas translated into industry outcomes?
- b) What institutional framework is involved in successful R&D processes?

A system approach has been applied to explore the process of industrial development and innovation, as described in sections 1.3.5 and 2.10.3. Three case stories illustrate industrial development in the Norwegian construction industry: the innovative use of wood, innovative energy solutions and ambitious sustainable urban living.

The paper contributes to the overall purpose of the thesis, and specifically to exploring the effects of relations between the industry and R&D actors in the development of sustainable building (research question 6).

#### *Findings in the paper*

The analysis in the paper explores the roles of the institutional framework and the industrial network in the innovative processes.

As for the institutional framework, there are found to be four elements of special significance, namely the following:

- Collaboration via research centres with both industry partners and research partners. The three case stories illustrate how these centres operate as a source for learning for industrial enterprises.
- Support from funding institutions combining financial and expert support, including the national housing bank and the national energy fund.
- Industrial development programme contributes to R&D uptake in the industry. Ambitious clients and visionary politicians have succeeded in triggering the industry in this respect.

- A tradition of collaboration and negotiation between government and industrial organizations in relation to policy development. When public regulations for buildings are being revised, organizations within the construction industry are involved as part of a public consultation process. It is only legitimate to have research-based knowledge underlying new regulations.

As for networks between industrial actors, these are found to be crucial for implementing research in industrial development. One example is the collaboration between a sawmill and a chemical industry partner within the same region, which solved the crucial challenge of fire protection in massive wooden constructions. Another example is the innovative building concept concerning energy that draws on international research on solar energy plants provided by one of the industrial partners.

The Norwegian research and innovation policy model is in accordance with theories describing the dynamics of innovation as a triple helix of relations between universities, industries and government (see section 2.10.3). Innovative projects are explained as crossroads at which actors from the industry, research and government meet to challenge each other, explore common long-term interests and exchange knowledge and resources. The innovation stories presented in this paper are found to be illustrative examples of this.

#### *Relevance to the thesis*

The four elements identified in the institutional framework underpin R&D within the Norwegian construction industry. The framework includes combinations of expertise, financial support, publicity and the gradual upgrading of building regulations. In addition to the general market mechanisms, these elements are driving forces in the policy for R&D in the construction sector.

The paper identifies a network practice that is in accordance with the internationally recognized triple helix model. However, two characteristics are found that are specific for a Nordic context. The first is a variety of the knowledge-based economy strategy that focuses on the dynamics of innovation, including knowledge transfer and collaboration in R&D processes. The second characteristic are the strategic interactions between the industry and government in a “coordinated market economy”, where the state and its government play a more active regulative role in the construction market and are also more active in supporting R&D activities than is the case in liberal market economies. This implies that the findings in this paper partly depend on the national context.

R&D investment impacts should be considered over a long period. Research investments in massive wood have a long history in Norway. Research on energy efficiency has a shorter history than research investments in wood. However, the existing research institutes and universities have been mobilized by extensive research programmes during the last few years. Green urban living, on the other hand, is a new research area, and so far, no research investments exist that are dedicated to this purpose.

## 5 Discussion

This chapter discusses the findings presented in chapter 4 in the light of the literature review in chapter 2. This has two purposes: one purpose is to illustrate how they support or challenge existing studies, and eventually there is a discussion about alternative explanations where there are diverging results. The other purpose is to explore the studies by looking at them from alternative perspectives. The following two major alternative perspectives are explored:

- a) The socio-technical system perspective. This perspective supplements the organizational perspective in understanding mechanisms for the development, change and stability of building practice.
- b) The industry level perspective. The findings from analysis at project level will be explored from an industrial perspective. This contributes to showing how the Norwegian construction industry responds to new, external expectations for sustainable building.

The chapter is organized into three sections, in accordance with the three major aspects of the literature review (see figure 8 in chapter 2) and the thematic groups that relate to the findings in the papers (see figure 12):

- 1) Discussion of organizing for innovation in building projects
- 2) Discussion of selected actor groups and their relevance to sustainable performance
- 3) Discussion of the implementation of sustainability in the construction industry

Analysis in sections 5.1 and 5.2 is on the level of individual projects, while the analysis in section 5.3 relates to the industry level.

### 5.1 Discussion of organizing for innovation in building projects

The role model projects are examples of how the focus on energy efficiency draws attention to the mutual energy effects of all elements of the building, including the locality of the building plot and the activities that will be carried out in the building and the primary users who will be occupying the building after completion.

#### 5.1.1 Integration and knowledge development

Methods for integrated design (IDP and IED) are found to work in accordance with their intentions. They include the principle of broad and early involvement, which is found to improve the exploration of the energy-synergy efficiency of alternative designs. In other words, the “front-loading” of the process.

The findings are in accordance with theory on learning processes, as referred to in chapter 2. Concept and design teams represent “communities of practice” (Lave and Wenger 2003). The studies of role model projects show how the participants have been co-constructing knowledge that has been vital for the projects. As a result of the workshop methodology, the process facilitator, the

design team sharing an office and other methods for multi-professional working, unconventional arenas for situated learning have been created (Flyvbjerg 2004). The findings are also in accordance with those of studies of other industries, where broad and unconventional teams contribute to innovative solutions.

#### 5.1.2 Collaboration

Formal partnering is found to be less important than expected by theory. According to the literature, formal collaboration, such as partnering, is expected to be a focus in role model projects. Theories on innovation suggest that a spectrum of models for enterprise collaboration, from regional clusters to joint ventures and alliances, should be used. Such formal collaboration is recognized in industries with a high level of innovation (e.g. the offshore industry, shipbuilding and fish-farming). The role model projects being studied cover a variety of formal collaboration models. However, the majority of case projects practise project-based collaboration, using design-and-build contracts and partnering contracts, which is in accordance with the majority of current projects within the construction industry. However, among the case studies is one example of a strategic partnership among industrial partners covering major roles in the value chain, namely the energy-positive building alliance. Such strategic and long-term collaboration, established for the purpose of a serial of projects as part of strategic innovation work, is recognized in other and more innovation oriented industries, while, within the construction industry, strategic alliances are exceptions (Bygballe, Jahre et al. 2010).

The frequency of use of strategic and long-term partnering within the construction industry is related to the degree of the focus on innovation. According to innovation theory, clusters and partnering are used as a strategy to exploit shared resources and to reduce or share risks that are associated with innovative work. The low frequency of the use of strategic industrial collaboration identified among the case projects is in accordance with the tradition of competition and project-based activities that characterize the construction industry in general (see section 1.3.5 in chapter 1). Therefore, there must be other explanations for the ability to create innovative solutions and outstanding energy performance as demonstrated in role model projects.

In the following section, and according to literature presented in chapter 2, two alternative explanations will be discussed:

- Informal collaboration and social mechanisms
- Mechanisms of the socio-technical system

#### 5.1.3 Informal collaboration and social mechanisms

The role model projects demonstrate that innovative and high-performing sustainable building is possible within a framework of project-based partnering. The studies included in this thesis shed light on the remarkable efforts being used to improve informal collaboration rather than formal contracts.

The findings reveal that the social mechanisms of collaboration are acknowledged in the industry. Methods for broad involvement and extensive multi-professional collaboration are found to be highly significant for reaching high energy ambitions. Papers 2, 3 and 6 demonstrate how team spirit that develops during the concept and design phase has resulted in the exploration of designs and solutions in which none of the participants had previous experience. The papers also demonstrate



the psychological contracts established through the personal involvement of users, FM personnel and workers on the construction site, which motivated the project and construction teams to produce extraordinary creativity, focus and efforts, resulting in buildings with an outstanding performance.

Extensive informal collaboration is found to affect motivation and human performance in the role model projects. This is in accordance with previous studies emphasizing the importance of establishing face-to-face collaboration and fostering intrinsic motivation for managers who wish to enhance innovative-performing design teams (Amabile 1996, Nijstad, De Dreu et al. 2010). The findings in the papers included in this thesis (especially in papers 3 and 6) shed light on the motivation and incentives triggering the individual participants, especially during the early planning processes. This includes the various specialized consultants, architects and contractors in the project teams. It is also the case for facility managers and users: personal involvement in early planning is found to motivate the individuals to contribute during use and operation to adjusting habits to improve the energy performance of the building (see papers 1 and 5).

Theory also sheds light on the different effects experienced from formal partnering and informal partnering in collaboration in the case projects. It can be seen from the literature on human relation management presented in section 2.5 that there are different motivation mechanisms in operation. Formal partnering contracts relate to the organizational level and include the management level of the partnering enterprises, while informal methods for collaboration and involvement relate to the individual participants in the individual project teams. This implies that for individual projects with high energy ambitions, it makes sense for project owners to put much more effort than usual into informal collaboration to trigger the motivation of the individuals, rather than establishing formal partnerships. In addition, the incentive used in formal partnering contracts is often a monetary bonus. According to Herzberg's two-factor theory of motivation (Hackman 1976), money appeals to the extrinsic motivation of the individual participant, and is more likely to be a hygiene factor than a motivator. In comparison, intrinsic motivation is enhanced in informal situations of face-to-face collaboration. Studies in other industries reveal that intrinsic types of motivation include self-development, the experience of learning and the sense of professionalism. Other motivators include the satisfaction of meeting client needs or contributing to creating a new structure. Similar types of motivation are identified in the studies of the role model projects that are ambitious in relation to energy. Two typical statements from participants in the case projects illustrate this: "We have proved that it is possible. This building is the proof!", and "I am proud to be among those contributing to this pioneering project!"

To summarize, informal collaboration and intrinsic motivation are recognized as driving forces for sustainable building and innovative construction. This finding is in accordance with those of studies in other industries. However, these aspects have been neglected by the literature on construction management and development.

#### 5.1.4 Mechanisms of the socio-technical system

The low frequency of formal and long-term partnering is recognized in the construction industry worldwide. Interpreted from a socio-technical system perspective, this implies that the barriers to collaboration and change in the industrial system are strong. A system barrier represents a major

challenge to the improvement of environmental sustainability. The literature reviewed in chapter 2 suggests that this might be a result of a number of different aspects, including the adversarial culture and a lack of incentives for collaboration. It may also be a result of industrial institutions, including the procurement regulations, which are found to promote competition between enterprises rather than innovation (Håkansson and Ingemansson 2013).

The prize-winning buildings studied in this thesis are all a result of unconventional planning processes. Papers 1, 2, 3 and 6 provide findings on how a joint optimization of the project organization has been developed, a new fit, which has resulted in the development of a new set of psychological contracts among the individual participants and in products with outstanding qualities. The socio-technical perspective provides new insight into these processes, including the following:

- 1) The role model projects are the result of open innovation processes.

The planning processes in the case projects have involved a broad spectrum of participants and have, to a large degree, been open to new initiatives. These characteristics are recognized in literature on “open innovation” models, as referred to in section 1.3.4. Addressing energy efficiency and the ecological footprint has in all case projects been the result of input from the surroundings and not from the client. The environmental challenge has been introduced into the case projects by potential tenant organizations, architects or politicians. This is in accordance with theory characterizing the construction industry as an “open system”, embedded in a surrounding community that affects how the industry operates (Mumford 2006).

- 2) Management of the planning processes draws upon the socio-technical design principles

The findings from the papers illustrate that for architects, consultants and owners it has been a new situation to develop building concepts through decisions that are based on a consensus. The integrated design process (IDP) and integrated energy design (IED) include elements of democracy and self-managing teams, in accordance with the socio-technical design principles, as referred to in section 1.3.5. By applying these design principles, the clients give away some of the control. According to the socio-technical perspective, this implies that it creates a challenge to the risk-aversion traditions of professionals.

- 3) Workers’ rights might be counteractive to the implementation of sustainable building.

The priorities and values of the users of buildings affect the actual energy performance. It is found that the experience of modern energy-efficient office buildings is that the technology used is deterministic for the employees in the user organizations. The automated indoor climate systems create resistance among the employees. The findings indicate that the workers’ rights have a stronger position in negotiations with the owner than the concern for environmental effects. From the socio-technical perspective, workers’ legislative rights might actually be counteractive to the introduction of sustainable building technology and practice. This will be discussed further in section 5.2.3.

These three insights provided by the socio-technical perspective can be illustrated as in figure 17. Tenant organizations demanding environmentally sustainable buildings are actors in the industrial environment who are challenging the conventional socio-technical system of the construction industry (insight 1).

Innovative project management is challenging the norms and cultures of conventional management of construction projects and, as a result of the innovative designs being developed, existing technology and construction practices are being challenged (insight 2). Workers' rights that take the form of legislation are embedded in the industrial environment. These democratic rights are being supported by conventional building technologies and established cultures among professionals within the construction industry (insight 3). However, these rights are being challenged by initiatives for sustainable development of constructions and communities.

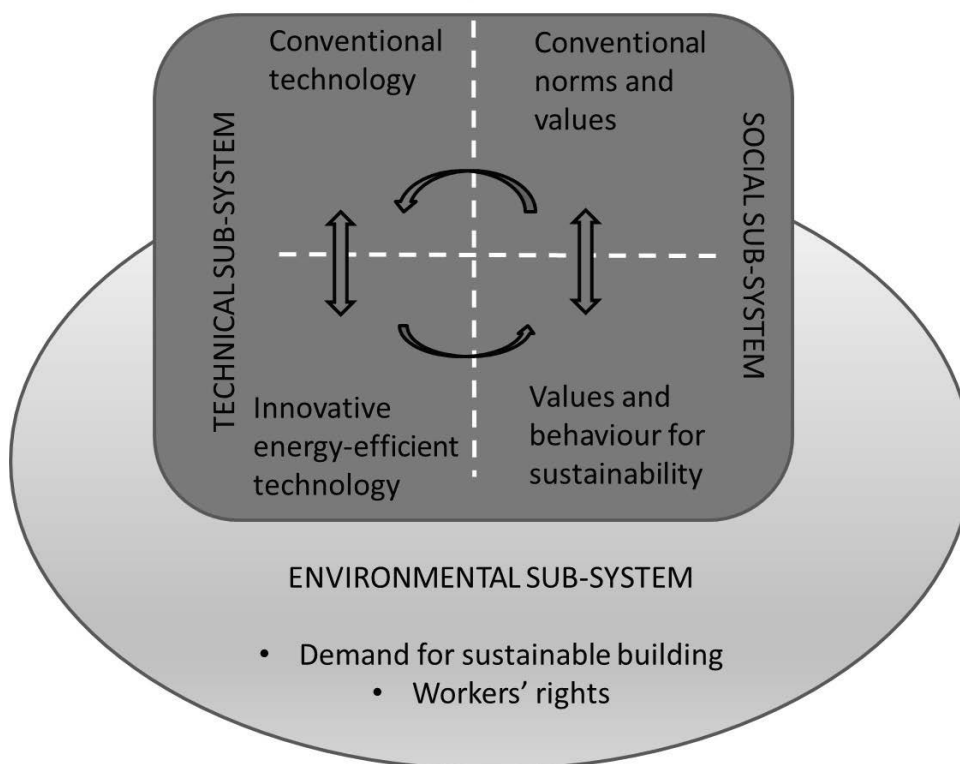


Figure 17: Challenges of innovative sustainable building from a socio-technical perspective

## 5.2 Discussion of selected actor groups and their relevance to sustainable performance

The environmental sustainability of built infrastructures, such as buildings, depends only partly on the physical construction itself. The energy-related and environmental impacts of the building when it is being used accounts for the majority of resource consumption and environmental impacts. Therefore, this discussion will focus on the buildings when they are being used.

In the in-use phase of buildings, three actor groups are traditionally considered, namely the owner, the service provider and the end users (Marja Rasila, Rothe et al. 2009). This part of the discussion

chapter will focus on these actor groups. The papers included in this thesis provide new knowledge about all three actor groups and their role in the development of sustainable building.

Recent literature acknowledges that sustainability is the result of new practices being developed by the users of the products and technologies. Part of this process is that energy consumption is being “negotiated” between owners, operators and users (Ozaki, Shaw et al. 2012) during planning and use of the building. And sustainability is being “co-produced” in the socio-technical relation between the built facility and the users (Ozaki, Shaw et al. 2013).

The analysis in papers 1, 5, and 7 provides findings that will be discussed in the following section. Supplementary evidence is provided by material from all case projects covered in this thesis (see chapter 3). The findings will be discussed in relation to the implications for the development of sustainable building in the Norwegian construction industry.

#### 5.2.1 The role of the owner

The analysis of the case projects reveals that the role model projects are results of the partly unconventional performance of the owner role. While the literature emphasizes the role of the client as the initiative-taker in innovative projects, the studies included in this thesis reveal that the user organizations (tenants) are just as important because they put environmental sustainability on the agenda.

The role of the clients in the case projects is in accordance with the characteristics of “reflexive governance”, as suggested by scholars such as Voss et al. (2005), Kemp and Loorbach (2006), Hendriks and Grin (2007) and others. The owners have approached the projects by exploring new opportunities, experimenting, evaluating and learning from stepwise development from project to project in a cyclical (management) process that explores new paths, as suggested in the literature on transition management, as referred in section 2.10.5. The findings in the studies of energy-efficient role model projects are in accordance with this literature, revealing how clients’ representatives and project managers are performing some kind of reflexive governance: they facilitate multi-professional self-governing project teams (see findings in paper 6) and are open to signals from the market via potential tendering enterprises (see paper 5).

The findings in the studies included in this thesis (paper 6) imply that the strategic approach of the user organization to the construction project is highly relevant to energy performance and for the environmental sustainability of the resulting building. The analysis presented in paper 5 demonstrates how ambitious user organizations (tenants) can be the driving force both for sustainability and for improving the value (usability) for the purposes of the occupant enterprises. Two case buildings illustrate the relevance of the building as part of the business development strategy, implying that there is a need for a thorough evaluation of the need for indoor space and functions and a need to combine organizational development with the development of the requirements for the building (Mosbeck 2004). The implications from the case projects are that production has improved and that the use of indoor space has been reduced, implying positive effects for the three pillars of sustainability included in the triple bottom line (see section 1.3.3).

Active and demanding user organizations are found to be crucial for role model projects. They communicate an interest from the market for sustainable building. From the socio-technical

perspective, tenant enterprises represent new demands of the construction industry from the market, according to the “open system” theory. Demanding user organizations are also found to be active partners in the development of innovative concepts, according to theories on “open innovation” processes, which are discussed further in sections 5.1 and 5.3. Open innovation theory also acknowledges the role of demanding customers, which in the construction industry includes both owners and tenants.

Owners are found to have a key role in negotiating energy performance and sustainability during the in-use phase of constructing role model buildings. The findings in paper 5 can be re-analysed from a socio-technical perspective, illustrating the process of joint optimization of technical and social aspects of modern energy-efficient offices (see section 1.3.4). The two case projects demonstrate varieties in owner roles and performance in negotiations concerning adjustments during the post-occupancy phase. As a consequence of differences in owner performance, sustainability and energy ambitions were protected in relation to the bank building, while sustainability gave way to comfort and democratic rights in the Knowledge and Innovation Centre.

To summarize, this discussion sheds new light on the role of owners in innovative sustainable building: project owners are rarely initiative takers in relation to outstanding sustainable goals, but rather respond to external demands from the market. However, project owners have a key role in maintaining energy ambitions as priorities. The ability to approach and deal with both social and technical aspects of the project is crucial for the success of the energy performance of the final buildings when they are being used.

#### 5.2.2 The role of facility managers and property management

Experience-based knowledge of the operation of existing buildings is of a high value in the planning of new buildings. According to the findings in paper 1, this is acknowledged among clients of sustainable building projects. The findings are in accordance with those of previous studies, emphasizing the value of facility management knowledge for developing buildings with a focus on performance during occupancy (Dahl, Horman et al. 2005). The findings imply that professional FM knowledge and systematic documentation and analysis are recognized among innovative clients and property developers.

##### *A provider of FM knowledge*

Theories on innovation and product development emphasize the value of feedback from users and operators to learn and improve further. This is a challenge in the project-based production of buildings, since feedback from operators and users will come at a time when members of the design team for the particular building has split up (Emmitt 2007, Jensen 2009). The project-based organization of the construction industry is hampering rather than facilitating a standard practice for learning from feedback from recently completed building projects. As an alternative and supplement to this, drawing on FM experience of existing buildings is a valuable source of knowledge in the development of sustainable buildings. The findings in paper 1 indicate that FM knowledge is explored by ambitious clients by organizing processes for FM involvement and the feeding forward of practice-based knowledge (Gray and Ferrell 2013, Cathcart, Greer et al. 2014) from the operation of existing buildings to the design of new buildings.

Innovative sustainable buildings depend on highly skilled and experienced operators to optimize performance. This implies that situated learning (see reviewed literature in section 2.10.4) is also vital for the operators, to gain insight into and enthusiasm for energy efficiency. FM knowledge will be valuable to meet the future challenges for energy-efficient performance, such as the upcoming development of “smart grid” electricity systems. This knowledge source is still to be fully explored by the construction industry.

#### *LCC analysis*

Systematic analysis of the performance and costs of the building portfolio contributes to the sustainability of buildings when they are being used. Paper 7 sheds light on how LCC analysis contributes to the planning of operation, maintenance and major refurbishment or investments. The study provides illustrative examples of how LCC analysis is used to improve the quality of the buildings for their daily users and to combine the performance goal with ambitions for energy and cost efficiency. However, the survey of public property owners documents that the demand for LCC analysis is limited. This finding is in accordance with that of previous studies (Holte byggsafe 2008).

The findings regarding FM knowledge and LCC analysis represent a paradox. On the one hand, the value of such information is recognized among professionals in the industry, while on the other hand, this information is only being exploited to a limited degree in daily practice by clients and their project managers or public owners and their facility managers. This implies that there are system barriers to implementing the tool.

#### *FM knowledge and LCC from a socio-technical perspective*

A system perspective can be used to re-analyse the findings on FM involvement and the use of LCC analysis. The socio-technical perspective (see section 1.3.5) draws attention to the industrial system and its built-in barriers to and potential drivers for increasing the use of feedback and the feeding forward of experiences of performance and the costs for buildings when they are being used. Re-analysing the findings in papers 1 and 6 provides insight into this issue as follows:

1. There are structural characteristics in the system which include barriers, for example:
  - Among public property owners, there is an organizational division between the unit with the client function and the unit responsible for management and operation, as a consequence of procurement regulations.
  - There is little interaction between FM departments across the borders of enterprises.
2. There are also cultural barriers that are relevant, including:
  - Among public property owners, there is limited communication between the professional operators and the decision makers.
  - Traditionally, FM knowledge is based upon practical experience, and FM has not been acknowledged as a profession in its own right (Baharum and Pitt 2009).
3. There are ongoing changes in the industry and its environments, which will have implications for both structural and cultural practice. These include, among others, the following:
  - As public requirements regarding energy performance and sustainability are increasing, there will be an increasing demand for professional FM knowledge and systematic analysis of building costs and performance.

- New training opportunities contribute to upgrading the status of property and facility management.
- There is now increased access to user-friendly professional tools for measurement and analysis of performance and quality of buildings.

Such changes are drivers for increasing the sustainability of buildings.

To summarize the discussion in this section, highly skilled operators, facility managers and building portfolio managers are valuable providers of knowledge about buildings when they are being used. As such, they stand out as key personnel in the attempt to improve the sustainability of buildings.

### 5.2.3 The role of the users

The interaction between the users and the buildings are crucial for a transition towards sustainable building practices. The findings in this thesis reveal that the challenge is two-fold:

- To achieve the energy performance that was planned for the building
- To succeed in achieving the usability goals for the building in terms of the purpose for which it is built

The study presented in paper 5 sheds light on employees' experiences of energy-efficient offices. The challenges relate to a significant degree to the technology and automated solutions for indoor climate control. And the challenges are related to change: new building solutions challenge existing expectations and the habits of the individual users.

The findings are in accordance with those of previous studies, in which lack of user control (Nicol and Roaf 2005), lack of experience with passive house buildings and a mismatch of expectations (Leaman and Bordass 2007) create challenges for usability and energy performance in modern energy-efficient offices.

Individuals' experience of usability is a crucial criterion for the implementation of energy-efficient offices and sustainable building in general, according to paper 5. The findings shed light on why the actual energy performance of modern energy-efficient buildings, to a significant degree, do not meet the expectations of the calculations, as found in previous studies. Users not behaving in accordance with the preconditions are among the suggested explanations in these studies. Therefore, the role of the users is worth discussing further.

The performance of users can be discussed from a socio-technical perspective. The reaction of employees when being introduced to restrictions on indoor climate control in energy-efficient buildings can be interpreted as a reaction by the social sub-system to a change in the technological sub-system (see figure 18). This situation is similar to situations that occurred during the history of industrialization, when the introduction of technology was met with resistance by the workforce, resulting in a failure to achieve the expected benefits (see section 1.3.4).

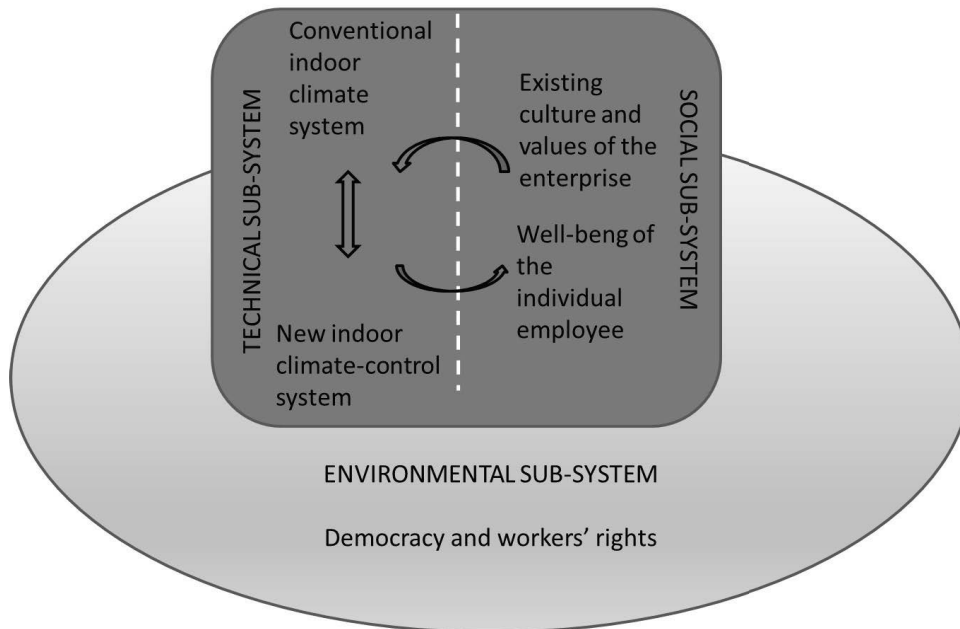


Figure 18: Role of users in buildings when they are being used

Protests from employees working in the two case buildings discussed in paper 5 might be interpreted as resulting from a culture in which employees expect to have influence on their working situation. This right is established in the Norwegian Working Environment Act, which states that workers have a right to a good physical and psychological working environment, including a democratic right to influence it. In the Nordic communities, the historical tendency is that employees in general are getting more freedom to organize their daily work and having more responsibilities for making decisions, according to the principles of “empowerment” (Paul, Niehoff et al. 2000). A fully automated climate-control system, giving the users no opportunity to influence light and shading, temperature and ventilation, might be perceived as being in conflict with worker’s rights. In figure 18, this is illustrated as a general expectation about democracy at work in the environmental sub-system.

If the perceived right to influence the workplace is the reason for frustration over automated indoor climate control, similar reactions to other solutions characteristic of sustainable building might be expected, including open-plan working space replacing individual offices and the elimination of parking spaces for privately owned cars. The case studies included in paper 5 exemplify how negotiations between owners and employees regarding parking spaces can either jeopardize the environmental sustainability of buildings when they are being used or result in a change of user behaviour towards increased sustainability. The findings are in accordance with those of recent studies suggesting that “negotiation of sustainability” is a key to the sustainability of buildings when they are being used (Ozaki, Shaw et al. 2013, Müller 2014 ). The findings in paper 5 are supported by



existing literature on users having a key role regarding energy efficiency and environmental impacts of buildings when they are being used: user behaviour can either contribute to sustainability or be counteractive, regardless of the qualities of the physical building.

User performance and the outcome of negotiations about sustainability are found to differ between the two cases included in paper 5. Energy consumption has exceeded the initial calculations for the Knowledge and Innovation Centre, but measurements from the first few years of operation of the bank building have proved that its performance matches the ambitious calculations.

Why is there this difference? The socio-technical system model sheds light on this question. The model draws attention to three alternative explanations:

- a) Differences in energy-saving technology
- b) Differences in cultures and values within the enterprises/user organizations
- c) Differences in the negotiation process

Figure 18 is illustrative of the analysis.

*Regarding a) differences in technology*

Both of the two modern energy-efficient buildings included in the study in paper 5 use automated indoor environment-control systems. However, the technological concepts differ in the two cases, and priorities among employees' concerns differ too. In the Knowledge and Innovation Centre, sun-shading and temperature tolerance were the main concerns, while in the bank building noise/silence and temperature tolerance were the main concerns. In the first case, persistent problems with the sun-shading system has been compensated for with increased use of air conditioning (cooling and heating of ventilation air). In the second case, the acoustic challenges (caused by the silence of the underfloor ventilation system) were solved by using ceiling sound buffering panels, while temperature fluctuations have been reduced by gradually increasing workers' experience of the operation of the whole climate system of the building.

Both the technological problems and the chosen solutions differ, and thereby so do the implications for energy consumption. While in the first case the problem was solved by technology that increases energy consumption, in the second case the problem was solved using passive technology and gradual improvement in the operation of the climate-control system of the building.

*Regarding b) differences in culture*

The organizations occupying the two buildings have different values and business cultures:

- The bank culture is rooted in the logic of finance and decision-making that is based upon monetary measurements.
- The culture of the university colleges is rooted in values of academic freedom.

The findings in paper 5 can be interpreted as showing that differences in basic values and organizational cultures have had implications for user performance, energy consumption and environmental sustainability of the buildings when they are being used. In the case of the bank building, the strategic business process, including the new facilities and the organization of

production, was based upon an analysis of investment. It is also expected that negotiations regarding the indoor climate have been considered as economic arguments. The results of the negotiations indicate that the arguments were not holding, which in this case favoured the sustainability of the building. In comparison, the strategic plan for the organizational partnership of the Knowledge and Innovation Centre was to build upon arguments regarding collaboration for innovation and knowledge development. Most probably, the arguments in favour of energy-saving and reducing environmental impacts had to give way to ensure the success of the centre as a hub for the partnership of user organizations, implying that priority was given to a high-quality indoor climate and acceptable transport solutions for the users of the centre.

This suggests that the “negotiations” about energy consumption or the sustainability of a building are an indirect rather than a direct effect of negotiations that are based upon the underlying values of the user organization.

*Regarding c) differences in the negotiation process*

From the socio-technical system perspective, negotiations between employees and the owner of the building can be interpreted as a process for “joint optimization” of the technical sub-system and the social sub-system (see section 1.3.5 for introduction of the socio-technical design principles. The automated indoor climate-control systems represent new technology which challenges the existing habits and expectations of the employees.

Paper 5 describes the differences and similarities between the two case projects regarding the involvement of employees throughout the building process, from early planning to the in-use evaluation and adjustments. In the bank building project there was extensive involvement of the employees throughout the strategic business process and planning, resulting in the new bank headquarters. Among the initiatives were the election of “user ambassadors” as representatives of the employees in the planning team. In addition, it was agreed that there would be no complaints for one year about the new facilities, because it was expected that fine-tuning of the operating routines would need time. In the Knowledge and Innovation Centre project, employee involvement has been limited to the in-use phase of the new building, and there are a number of individual tenant organizations and enterprises that have been negotiating with the director of the campus and not with the owner directly.

The processes involve in the joint optimization of the energy performance (the technical sub-system) and the well-being of the users (the social sub-system) gave differing results in the two cases. The findings in paper 5 are in accordance with those of the existing literature, namely that there is a positive relation between the intensity of involvement and the willingness of users to change their behaviour (see section 2.2.1).

This implies that early and extensive user involvement contributes positively to energy-efficient performance and the environmental impact of modern sustainable buildings.

#### 5.2.4 Summary

The following summarizes the discussion on the role of owners, service providers and users regarding the sustainability of buildings when they are being used:

- For the individual user, comfort is considered more important than environmental sustainability. However, early and extensive involvement increases the willingness to negotiate sustainability.
- Tenant organizations/leasing enterprises with environmental ambitions can be a driving force for sustainable building, but this depends on early and extensive participation during project planning.
- Clients and property developers can be a driving force for sustainable building if they are convinced about market opportunities.
- Facility managers and property managers are carriers/holders of knowledge of crucial value for the planning and sustainable operation of the buildings.

According to the above, it is the combination of open-minded owners and demanding user organizations that is the driving force for the implementation of sustainable building in the Norwegian construction industry.

### 5.3 Discussion of the implementation of sustainability in the construction industry

How can lessons learned from role model projects diffuse into ordinary practice in the Norwegian construction industry? This question is one that follows naturally after studies of prize-winning building projects, such as those included in this thesis. The findings in the papers reveal that role model projects have developed innovative processes and solutions that contribute to sustainable building. And experiences, knowledge and skills from successful projects are valuable for the industry and the community in general.

Diffusion of knowledge and practice in energy-efficient buildings have not been studied empirically as a part of this thesis. Therefore, the discussion will be based on the findings from previous studies on industrial transformation and on theories on the diffusion of innovation, as reviewed in chapters 1 and 2. The discussion relates to recognized characteristics of the construction industry, characteristics of role model projects, and ongoing changes in the context surrounding the Norwegian construction industry.

This discussion relates to dynamics at the industry level (as illustrated in figure 1 in chapter 1), driving forces for sustainable transition and the mechanisms for resistance against changes.

The discussion will explore five approaches to implementation, as suggested in the literature presented in chapter 2, namely:

- Role models
- Organizational learning
- Transition from niches
- Open innovation
- Socio-technical perspective

Transforming examples from pioneering projects to sustainable practice in the general market is acknowledged as a challenge (IEA 2010). According to theories on the implementation of

innovations, the new technology has to be accepted by a critical number of “innovators” and “early adopters” to reach a critical mass in the market and for further implementation (Rogers 1962 / 2003, Geels 2004).

### 5.3.1 Diffusion from role model projects

Demonstration projects, in which buildings are used as role models, are made use of worldwide (see section 2.10.4). The prize-winning building projects studied in this thesis are given remarkable resources and publicity for the purpose of being role models. Innovative solutions are developed, tested and measured to identify the potential for sustainable building and demonstrate how it can be replicated. The projects also promote the quality of the services and products available from the individual enterprise contributing to the realization of the building. In other words, role model projects primarily communicate “good practice” among actors within the industry.

Demonstration projects/role models for sustainable building and energy efficiency are presented on public websites, at conferences and in industrial magazines. The kind of information being presented includes architectural design and engineering solutions to meet the purpose of the building and environmental considerations. Information is based upon plans and calculations. When comparing the general intentions of demonstration projects with actual presentations at the public sites of the National Energy Fund ([enova.no](http://enova.no)) or the Norwegian Housing Bank ([husbanken.no](http://husbanken.no)) or the architects’ organization ([arkitektur.no/utvalgt-arkitektur](http://arkitektur.no/utvalgt-arkitektur)), there is a striking lack of information on actual energy performance and feedback from users or other evaluations of the actual performance of the buildings during the occupation phase. This implies that the projects are only addressing to a limited degree the critical questions being debated regarding political goals and the appropriate means for sustainable building. To what degree demonstration projects are adding to or eventually reducing the quality of the facilities for the purpose for which they were intended is not being covered by the Norwegian public sites. Benchmarking is not an issue in relation to usability, economy, energy or environmental assessments made during operation. The lack of evidence on these effects might be a drawback for industry actors and clients looking for convincing designs, especially considering that the major argument in favour of sustainable building is that the extra efforts and costs add value and are paid back in the long run.

As for primary users, there are theories within consumer psychology (see section 1.4.1) acknowledging the role of opinion leadership (Rose and Kim 2011). This approach refers to humans as role models, illustrating how people tend to copy the behaviour, consumption or lifestyle of people that they consider to be idols (Bandura 1986). It is well known that celebrities are trendsetters, for example in relation to fashion. In the Norwegian context, there are examples of public figures promoting a sustainable lifestyle and being recognized among the general public for their conviction. However, the effect on the interests of the public, and of employees, property developers and tendering enterprises, is doubtful. Among the user enterprises of the case buildings covered by this thesis, there is only one actively promoting sustainable offices, namely an environmental activist organization (see paper 6). According to the principle of model–observer similarity, this organization might be a role model for enterprises with a green profile or other activist organizations, but may not appeal to conventional businesses.

As for the buildings themselves, their green qualities are not visible to the general public. The fairly anonymous designs resulting from compact building concepts do not attract attention from passers-by. Modern energy-efficient offices have no “green signature” communicating to the public that this is a building with outstanding sustainable qualities.

Alternatively, role model projects might be interpreted as inspiring challenges for actors in the construction industry. Studies included in this thesis reveal that achieving a high grade in the Energy Label scale or the LEED or BREEAM category is motivating for industry actors, and that prize-winning projects have a competitive advantage in the market. A survey among industry actors concludes that challenging projects are appreciated as an opportunity to develop and improve performance (Faveo 2014). This strategy is being used in Bygg21 (Norway) and Construction Excellence (UK). For parts of the construction industry, challenging projects are attractive, and might result in innovative sustainable buildings, such as the role model projects covered in this thesis. However, it remains to be seen whether sustainable building practices will be integrated into ordinary practice in the industry.

Experience from previous analysis of the learning effects of demonstration projects,<sup>6</sup> suggests two success strategies (Mackley and Milonas 2001):

- Transfer of knowledge which is embedded in technology and tools
- Collaborative learning processes

It seems likely that technology, tools and materials developed as a result of role model projects are functional as carriers of knowledge about sustainable building. The findings from the studies included in this thesis reveal that constructors have been challenging the subcontractors and suppliers for Environmental Product Declarations (EDP) to document the energy consumption on the construction site and to reduce waste and increase recycling, etc. Project management regimes with a focus on environmental key performance indicators have been incentives to suppliers to provide environmental alternatives to conventional products. According to informants from among the contractors, this has resulted in “green” products being more available to the general market. Studies of the diffusion of innovations have revealed that innovations that make tasks easier and represent little risk are more likely to be adopted than innovations that are more complex or disruptive to routine tasks (Dobbins, Cockerill et al. 2001). These findings imply that technology and building techniques developed for sustainable building may be implemented in ordinary construction practice to a larger extent than new sustainable building concepts. Using collaborative learning processes is a strategy that is recognized in the role model projects, especially during the concept and design phases. Management that supports multi-professional teams and mutual learning has proved to be successful for the purpose of developing outstanding concepts (see papers 3 and 6). This implies that role models are good arenas for “situated learning”. As a result of the strength of situated learning, it can be expected that knowledge obtained by the individuals participating in innovative sustainable building projects might be able to make a shift of knowledge “path” (see section 1.3.5).

---

<sup>6</sup> Green Building Challenge, <http://www.iisbe.org/> (last accessed 20.01.2015)

Social learning theory predicts diffusion of knowledge based upon model–observer similarities. However, material from the case studies indicates that even among enterprises within the same branch and professionals with the same expertise, learning from role model projects appears to be limited. Geographical distance is as an obvious barrier, since the client and the main contractor, and often the architect and the consultant engineers, operate within a limited geographical region. An illustrative example is the prize-winning concept of the bank headquarters (see papers 2 and 6), which has been re-used in a local bank building, but not in another regional headquarters within the same banking group. Another example is public hospitals, where innovative solutions for sustainability, quality and efficiency are not being transferred to projects that follow in other regions within the country.

### 5.3.2 Organizational learning from prize-winning projects

Implementing sustainable construction practice in the construction industry can be approached as an issue of organizational learning, focusing on inter-organizational development and the sharing of knowledge. Organizational learning has been used previously in studies of the diffusion of innovations, see section 1.4.1.

Questions about how to share the experiences gained and how to implement solutions developed during energy-efficient role model projects have been included in interviews with the informants involved in the case projects covered by this thesis. Analysis of this material provides two relevant findings, namely:

1. The learning relates first and foremost to the individual participating in the project.
2. Experiences relate to the project phase in which this participant or enterprise is involved. There is rarely feedback from the user phase to the enterprises or individual professionals involved in the planning phases.

Finding 1 is in accordance with the previous literature that emphasizes knowledge as “sticky” and “situated”. The new experiences regarding sustainable concepts and solutions “stick” to the individuals that have participated in the planning and construction teams. There are few options for sharing with colleagues in the enterprises of the architect, consultant, supplier or contractor that are involved. This is suggested in literature as a reason why best practices don’t spread within firms (von Hippel 1994, Szulanski 2002). However, the high mobility of professionals, from project to project, and also between competing enterprises, might contribute to the transferring of experiences of energy-efficient building within the industry.

Finding 2 is in accordance with findings of previous studies of the construction industry, which conclude that the long time span and the fragmentation and loose couplings characterizing the construction industry (see section 1.3.5) are hampering learning, development and innovation. Insufficient time for discussion of experiences gained from projects is a barrier to knowledge transfer (Mackley and Milonas 2001). There are few options or incentives for follow-up studies, evaluations and feedback to the individual enterprise from completed projects (Bakker, Cambré et al. 2011, Hampson, Kraatz et al. 2014).

The findings are in accordance with the literature emphasizing how organizations (and industries) can provide systems that facilitate the transfer of knowledge. When comparing findings from role model projects with those of the existing literature, the following mechanisms are recognized:

- composing templates for solutions
- movement of personnel
- social networks and shared communities of practice

There are other mechanisms, revealed in the literature, which are missing from current practice in the Norwegian construction industry:

- Evaluation and feedback
- Implementation of experience gained into updated routines
- Alliances or other formal collaboration impacting knowledge transfer

Previous studies have revealed that learning is a “path-dependent” process: uptake of new knowledge depends on whether it is compatible with existing knowledge or not (Sydow, Schreyögg et al. 2009). As a consequence of this, sub-optimal solutions may be used, even though a better alternative is available (Woerdman 2004). If this is the case within the construction industry, the learning effect from role model projects may be limited, even within companies that have been involved in the value chain that results in prize-winning energy-efficient buildings. The case projects included in this thesis show how existing knowledge and institutionalized routines for planning processes have been challenging for teamwork among specialized planners and consultant engineers, and how there is a lack of experience in exploring the synergy effects on energy performance (see papers 2 and 6). The individual participants in the role model projects have gained experience of new paths of knowledge and working methods. However, for the rest of the industry the conventional paths of knowledge might be a barrier to developing sustainable building.

One of the preconditions for organizations to learn is that there is some kind of stable organization – a unit of people and some kind of structure – where this knowledge creation and sharing is going on. It is difficult for the construction industry to identify such structures due to the extreme degree of project-to-project-based activity. Other industries using different structures can provide alternative models. For instance, shipbuilding and offshore industries have design and production capabilities in-house. This has proven efficient in complex projects by reducing contract and works specification detailing (Knotten, Svalestuen et al. 2014), and industries with a higher grade of in-house capabilities might also be expected to provide a better framework for knowledge transfer across professional borders compared to the construction industry. Studies in service industries have proved that learning occurs frequently in fixed business models, such as franchising, because of the need for new members to learn about the business model and the brand (Hjalager 1999). The characteristic of loose couplings in the construction industry suggests that it hampers inter-organizational learning.

Organizational learning is a key dynamic embedded in knowledge-driven economic strategy, as suggested by OECD (see section 2.10.3). This is especially the case in the “learning economy” variant which is applied by Norway’s national policy for economic development. Organizational learning is recognized in national programmes for demonstration and role model projects and also in R&D

programmes with industrial and research partners. The issue of learning and the diffusion of sustainable practice in the construction industry is implemented in the national political initiative Bygg21 and in the industrial initiative BA2015, which has been initiated to speed up the process. The major strategy is to establish arenas for joint learning (Bygg21 2014), as suggested in the literature (see section 1.3.3). This strategy is supported by the principle of situated learning, and might therefore contribute to the creation of innovations and new knowledge. However, as an implication of the discussion on diffusion from role model projects, spreading the new knowledge might need an additional strategy that draws on the existing communities of practice within the construction industry. The Low Energy Programme, which disseminates knowledge about low-energy buildings (Lavenergiprogrammet 2014), might prove useful for this purpose.

This issue is of interest for further studies, and is elaborated on in chapter 8 Further research, section 8.1.

### 5.3.3 Transformation of construction industry from green niches

Buildings with low emission and energy performances that are at the level of the passive house standard can be considered as “niche” in the market of the construction industry, since buildings developed with exceptionally good environmental qualities are an exception in the market today. There are models suggesting to plant and cultivate protected “niches” of sustainable alternatives for the purpose of the diffusion of sustainable building into ordinary practice in the construction industry. Models of sustainable transition management is developed to support this approach (see section 2.10.5). This seems to be the strategy for the Norwegian role model projects, which are supported by national programmes.

However, experiences from the last decade reveal that transition of environmentally benign technologies from market niches (Elzen, Geels et al. 2004, Geels 2004) are not sufficient for a radical change (transformation) towards sustainable building. There is an additional need for co-evolution of policy, infrastructure, regulations and user behaviour in the surrounding community (Schot and Geels 2008).

Previous studies illustrate that incentives have to be diversified in accordance with the various driving motivations for the various parties involved in the value chain of construction (Whyte and Sexton 2011). Theory reminds us that self-interest rather than perceived altruism is the driver for environmental activity (Cole 2011, Hunt and Townshend 2011).

### 5.3.4 Implementation from open innovation

The issue of implementation is embedded in the “open innovation” model (Chesbrough 2006), as introduced in section 1.3.6.

The role model projects being studied in this thesis are recognized as externally visible open-source projects, as suggested in open innovation models. Informants working in the case projects agree to the theoretical presumption that pooling knowledge with other enterprises, users and research partners has been crucial in achieving the innovative/outstanding results.



The enterprises contributing to the role model projects also confirm the positive effects of sharing the knowledge in open-source documentation on websites, at seminars and exhibitions and in trade journals: the projects attract attention from potential customers, and experience of energy-efficient buildings is highly valued in a reference in procurement competitions. To the extent that it refers to the dynamic of industrial change (see figures 1 and 2 in chapter 1), the co-evolutionary process in the role model projects favours the diffusion of energy-efficient office solutions both to the market and to the rest of the industry.

Open innovation has some obvious advantages for the purpose of implementing innovative solutions in the industrial community/system. This relates to the collaboration model, whether this relates to partner enterprises in development projects or the involvement of customers/users in the development process. Innovation projects that have many organizations involved imply that a number of enterprises have first-hand insight into the solution or product and can implement the new knowledge in their practice. Similarly, innovation projects with extensive customer/user involvement imply that there are customers with first-hand insight and the best qualifications to use the product, and thereby they ensure success in accordance with the purpose of the new product or service, and also promote it to other customers.

Open innovation processes are recognized in a number of the role model projects studied in this thesis, including the following examples:

- a) The (non-governmental) environmental organization that has a double role, partly as a future tenant of the building being developed, and then, during the process, it also becomes a consultant in the life-cycle assessment and in the discussions about the practical implications for sustainable building solutions (see paper 6).
- b) Researchers contributing to the development of new concepts for low-energy ventilation (see papers 2 and 6).
- c) A political initiative for sustainable urban development that challenges building projects during early planning to increase the ambitions for environmental sustainability and to contribute with its expertise (see paper 5).
- d) First, collaboration between a regional timber mill and a research institute resulted in the development of the glulam technique. Next, a chemical industry partner was added to the network, resulting in the development of suitable fire protection for wood. And finally, triggered by a national competition, the network developed solutions and designs that are now being used in a new era of massive wood buildings worldwide (see paper 4).

All examples are illustrative of the potential of open innovation processes for the purpose of implementing sustainable building. In example a), a tenant organization was active in developing a building concept that fitted with to the strategic plan of the organization. The result was a building reflecting both the green image of the organization and the limited economic resources of a volunteer organization. The resources of the organization were the capacity to develop expertise on sustainable building during the process, and the contribution to an energy concept that included a number of buildings on the same plot. In examples c) and d), a political initiative had a similar role in the open innovation of sustainable building, namely challenging the industry and contributing with their expertise. In examples b) and d), researchers contributed with their expertise.

### 5.3.5 Implementation from a socio-technical perspective

The system perspective illustrates the dynamics related to the implementation of sustainable building in the industry. Driving forces and resistance to change in the socio-technical system (see section 1.3.4) can be listed as follows (see figure 19):

- Sustainable building principles are challenging existing technology and the materials being used in the production of them (technological sub-system).
- Sustainable building principles challenge existing values, priorities and norms for work performance within the various branches and professions (and the rest of the social sub-system).
- Sustainable building is facing the industrial context (the environmental sub-system), including the existing infrastructure in the community and the financial and market situation, and also public regulations and national and international policies.

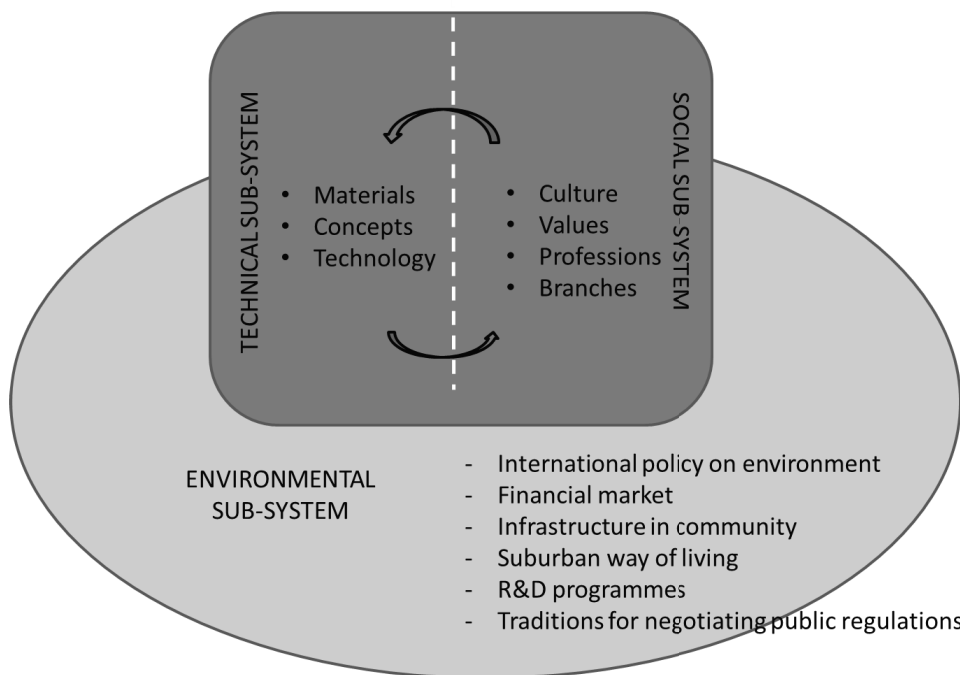


Figure 19: Construction industry from a socio-technical perspective

The logic of the industrial system perspective is that the system supports stability and tends to resist change. Scholars have conceptualized this as something built into the system and a barrier to overcome to achieve transformation. Obstacles to the implementation of sustainable building (see section 2.10.6) that are found include whether green niche building principles are able to meet the volume market, that supply chains must be available (Smith 2007) and the suburban way of living

with its low density housing and private cars as transport (Shove 2012), in addition to habits and perceptions about working methods and lifestyles in general.

Project managers in the role model projects studied in this thesis have experience of these challenges, and have developed strategies for how to make suppliers, workers on the construction site and others provide products and working practices that satisfy the criteria for energy and environmentally high-performing buildings (see paper 6).

Experiences from the case studies included in this thesis include a number of examples of how unconventional solutions and working methods have been challenging the industrial system and its environment. The following part of the chapter discusses some common experiences (see papers in chapter 4) in the light of existing literature (see chapter 2).

Technology:

- Underfloor ventilation: This had to be custom made.
- Materials and products: Requests were made for energy and environmental documentation.

Social and cultural:

- Multi-professional working models used during early planning and design were met with resistance from some of the participants.
- Request from tenant organizations to client/developer for extensive involvement during planning were dealt with by negotiating collaboration, roles and conditions.
- Initiative from main constructor to reduce waste and energy consumption during construction were challenging for subcontractors and workers on the construction site.

The external environment of the construction industry:

- Buildings with energy-producing systems: A request for permission to deliver electricity to the grid in periods of net positive production were rejected by the energy company.
- Extra investment costs for energy-efficient building: Green leasing contracts were established to split costs and benefits between owner and tenant organizations.
- The aesthetic aspects of energy-producing buildings (active houses) challenge the traditional architecture of the neighbourhood and this is dealt with by discussions in public media.
- Local building regulations are developed to meet the building practice of the existing regime. The case project presented in paper 3 experiences the regulations as unsuitable for developing buildings that are designed to function as their own power plant.

The findings from the case studies are in accordance with the literature emphasizing that the introduction of new technologies in itself is not sufficient for a transformation of the mainstream industry's practice. It needs to be supported by a strategy for co-evolution between new technology and the actors, cultures and routines within the industry, and also between the industry, their customers and society in general (Geels 2004, Schot and Geels 2008, Meistad and Strand 2013).

Highly energy efficient and environmentally sustainable building represents a major shift for the industry. The history of community and industrial development demonstrates the dynamic between existing and emerging regimes. Informants involved in the case projects have experienced resistance towards a change in practice in all branches of the industry, while at the same time they have experienced how it has been possible to negotiate solutions and create the enthusiasm needed to achieve the energy ambitions.

Economy is the key to understanding the dynamics of the construction industry. The construction industry is market dependent and based upon competition. The culture of the construction industry has been characterized as guided by the principles of gaining profit and limiting loss (Smith 2007). Every deviation from conventional practice represents a risk of extra costs. As an effect of this, changes are limited to small steps for the majority of projects, while a shift to sustainable building concepts presupposes a willingness, motives and resources to handle the risk.

Cost–benefit considerations are active both in the industry and in the market. Experiences in the case projects are in accordance with the literature, where the industry establishes various forms of partnerships to reduce and share the risk of innovative projects, and where various forms of energy contracts are introduced to split the extra investment costs and the long-term return on investment between the owner and tendering enterprises.

From the producer’s point of view, the question of going mainstream is also a question about the profitability of sustainable building: theories on market niches imply that “green buildings” might be a market strategy. Analysis has revealed that developing an exclusive niche of “green buildings” is attractive to industry actors (Gibbs and O’Neill 2015). This implies that as the mainstream catches up with energy efficiency, there are industrial actors who are likely to shift from the niche of green building to some other niche. From a socio-technical perspective, their strategy is to move to new niches to differentiate themselves from the mainstream (O’Neill and Gibbs 2013). This might also be the case for actors involved in Norwegian energy-efficient role model projects. The impression gained from the case studies is that the motivation for participating in role model projects is that they are innovative and ambitious. There are individual participants and also enterprises that appreciate challenging tasks and have an extra drive for competition and outstanding results. They might be considered as innovators according to theory on the diffusion of innovations (Rogers 2003), and for the time being they find attractive challenges within sustainable building.

From a customer’s point of view, the exclusiveness of innovative and green facilities obviously matters, as revealed in the case studies included in this thesis. The publicity given to the buildings and the environmental image related to them attracts attention from customers, job hunters and business partners (see findings in paper 5). Green leasing contracts draw attention to energy-saving and other forms of cost-saving in modern sustainable buildings.

However, economic calculations among the user organizations included in this thesis draw attention to the value of modern and functional facilities. This relates partly to more efficient work, partly to better services attracting customers and business partners, partly to reduced sickness leave and partly to better area efficiency (see paper 5) (Blakstad and Andersen 2011, Blakstad and Andersen 2013). In one case project, calculations were carried out to illustrate the effects on efficiency as part of the strategic planning in a finance enterprise. Calculations for production efficiency are in accordance with generic theory on investments. However, calculations for the added value for the

production of the user organizations is rarely included in construction projects, but may be part of the factors considered in the strategic decision-making of the owner. Calculating the economic effects on production proved to be crucial in decision-making during the planning phase as well as during the in-use phase in this case. This includes area efficiency, indoor comfort and functionality regarding project collaboration and customer relations, etc.

To summarize, the system perspective reveals that for the industry (and the market) sustainable building is about competitiveness in the market rather than environmental qualities. The focus of interest is on survival for the business rather than long-term responsibility for the community. Therefore, the widespread political strategy of waiting for green innovations to be diffused into the market or for sustainability to transition from “strategic niche management” (Schot and Geels 2008) may prove to be insufficient for the purpose of reaching the climate goals.

#### 5.3.6 Summary

The conclusion drawn from this discussion is that external demand is crucial for the implementation of sustainable building. The role model projects demonstrate open innovation by drawing on resources from the construction industry and external actors. Knowledge and technology for environmental solutions seem to be available on request. However, without the external demand/challenge, there would not have been any incentive to explore the energy efficiency or other environmental qualities of the building projects.

The implementation of sustainable building is dependent on demanding owners and also on demanding users. The studies included in this thesis reveal that demanding user organizations (such as tenants or owners) that are active in a co-evolutionary process represent a strong driver towards more sustainable building. The existing literature characterizes customers of conventional buildings as passive and conservative, while customers of “green building” are active, committed and highly involved in the project (Smith 2007), and thereby supports the active clients in general as a driving force for sustainable building.



## 6 Implications and suggestions

The social aspect of sustainable building is the key to further exploration and implementation of sustainable building. This is the major implication of the research covered by this thesis.

The research provides new insight into the interrelations between humans and technology in the built environment. This includes the development, operation and use of sustainable buildings, where the socio-technical balance is crucial for achieving sustainability.

The research also provides new insight into the dynamics between current and emerging concepts and technologies. This includes risk aversion and enthusiasm as driving forces towards or against innovation. It also includes expectations about what the building can provide to users and owners, and the fit between technology and values and norms in the social community.

The main suggestion is to add a supplementary user-oriented development perspective to the existing technology-driven approach to sustainability. This thesis sheds light on the interrelation between humans and technology and the resulting effects on sustainable building, including the role of motivation and enthusiasm during planning, the ability and willingness of producers and users to learn and adjust behaviour, and also the attention paid to the life-cycle aspects and how sustainable buildings can add value to production and comfort.

The implications and suggestions will be further elaborated on in this chapter. The chapter draws upon the findings in the papers included in this thesis (chapter 4) and the discussion of these findings (chapter 5). It includes implications for theory and implications for policy. The content is organized in three thematic sections, as follows:

- Perception of sustainable building
- Broadening the concept of sustainability
- Implementing sustainable building

### 6.1 Perception of sustainable building

The findings and discussions included in this thesis have implications for how sustainable building is interpreted by owners, users, operators and providers of the built environment.

Consumer preferences are crucial in market-based economies, and therefore also for transformation of industrial regimes. Historically, alternative technologies have been competing within the same basic consumer criteria, namely price, ease and reliability. Scholars suggest that these consumer criteria will not favour environmental sustainable alternatives, due to rebound effects and other impacts.

“Image” is an additional criterion for consumers’ preferences (Kemp and van Lente 2011). It is suggested that a shift in consumers’ perception contributes to the transformation process. Sustainable building needs an image that appeals to a broad spectrum of people, including users (consumers, workers and others) and industrial actors (clients and enterprises in the value chain). For the time being, Norwegian role model projects and sustainable building in general appeal, to a large

degree, to “rational” choices, and to a small degree appeal to social perceptions, as discussed in section 5.4. Sustainable buildings do “show off” a little compared to other buildings. And if they do, it is despite the fact that they use the same type of design and material as other buildings. Sustainable building can be compared to environmentally friendly cars. In relation to the introduction of electric cars, the criterion of “image” added to the existing criteria used for comparing alternative transport. Smart city cars appeal to modesty and private economy, while Tesla has the “wow factor”. What is the Tesla version of sustainable building?

Among the case projects studied in this thesis, Powerhouse One is the most outstanding, both regarding its energy performance and its design. In Trondheim, where it is being developed to be erected, the plans are controversial among the public. The case is illustrative of the different types of rationality: one type is based on the optimization of the environmental and energy performance, and one is based upon feelings and “bounded rationality”. The Sydney Opera House was highly controversial at the phase of planning, but later made the city recognized worldwide. Powerhouse number 1 is challenging social perceptions of “what a building should look like”, and “likes” and “dislikes” from the public can be just as decisive for the implementation of sustainable building as all the research-based arguments for a major shift in building practice.

In accordance with these ideas, another suggestion is to add a fourth element to the triple bottom line of sustainability: a quadruple bottom line which includes social attractiveness or “image”. Some practical suggestions for this aspect are as follows:

- Showing off buildings with environmentally friendly solutions and designs:
  - A yearly “open building day”
  - Guided tours in cities or regionally
  - Energy labels visual at the building
- Sharing user experiences:
  - Establish local advisory and experimental societies of sustainable building users. This would be in addition to “living labs”
  - Establish a system for sustainable building “ambassadors”
- Training of the public. Schools and kindergartens in energy-efficient and environmentally friendly buildings are training a new generation of users in how sustainable buildings work
- Competitions and publicity: a sustainable building grand prix
- Personification of sustainable building: individuals acknowledged by the social community can be role models for and against sustainable building principles.

## 6.2 Broadening the concept of sustainability in the construction industry

The value-adding effects of modern energy-efficient buildings are still to be acknowledged. The following section will elaborate on two selected aspects, which have been illustrated by research included in this thesis:

- Usability
- Area efficiency



### 6.2.1 Adding value from usability

User satisfaction is a crucial criterion for creating further demand for energy-efficient offices. The analysis in paper 5 is carried out in accordance with the ISO standard definition of usability, which is mainly concerned with the physical aspects of the building. Supplementing the analytical model with social and virtual dimensions adds additional insight, as suggested by Nenonen (2005), and Rasila and Rothe et al. (2010). The following explores further the aspects/dimensions of “atmosphere”, of “networks” and of human–technology interaction, as which are all terms that are referred to in the literature referred in section 2.8.2.

“Atmosphere” includes the sensual experiences of the environment, including hearing, smelling, feeling and seeing (Hansen, Haugen et al. 2005). The findings in paper 5 are in accordance with those of previous studies emphasizing that solutions for air conditioning, lighting, acoustics, the sound environment, aesthetics and the indoor climate are critical for experienced usability in modern sustainable buildings (Leaman and Bordass 2007). These aspect of “user satisfaction” are also found to be the most challenging in the two case buildings included in the paper.

“Networks” includes social relations with customers and across and within the departments of the organization (Rasila, Rothe et al. 2010). The findings in paper 5 reveal that facilitating networking has been high on the agenda of the strategic process, resulting in new buildings and organizational models in both case projects included in the analysis, and in both cases it is found that the new built facilities contribute to efficiency in working processes and effectiveness in creating new business relations.

Human–technology interaction is important for users who spend time in a building on a regular basis. Studies of ICT, as referred to in section 2.8.2, reveal that people prefer technology that is intuitive to use. The findings in paper 5 are in accordance with findings of studies of user–computer interaction: there is a low tolerance for difficult designs or a slow response. This implies that increased technological complexity of modern energy-efficient buildings is a major challenge to the experienced usability of the facilities. Further development of sustainable building practice will, according to this implication, gain from improving user–building interaction so that the systems are easy to use, easy to learn, easy to remember and helpful to the users in their ongoing activities (Gould and Lewis 1985).

### 6.2.2 Adding value from area efficiency

Area efficiency contributes to environmental sustainability by reducing the use of building materials and also the amount of energy used for light, temperature and ventilation. Paper 5, on usability, illustrates how the strategic development process of each building has resulted in new facilities, qualities that are suitable for the purpose and a significant reduction in floor area per user (less m<sup>2</sup> and more employers/daily users). The open space design contributes to the reduction in building materials and adjustability for future needs. Previous studies have revealed the tendency to increase space in buildings (domestic homes and industry) as economy allows, and this has implications for increased consumption of energy and natural resources, described as a rebound effect (Sorrell 2009).

Area efficiency is an approach to sustainability that is in accordance with the basic values in the construction industry and the property market, namely calculating economic value, costs and yield on investments. This implies that acknowledging area efficiency as a standard aspect of decisions

that are made in building and major refurbishment projects will contribute positively to sustainability. Area efficiency is still to be fully explored by researchers and policymakers.

In comparison, policies and initiatives for environmental sustainability tend to support technology development rather than low-tech alternatives. The triple-helix mechanism for knowledge-based development supports this tendency. This is partly due to industry/policy alliances which tend to support technology-driven solutions, preferably with the potential to be of use to businesses.

Added value from area efficiency is still to be acknowledged by the construction industry, the scientific community and policymakers. As an implication of the research included in this thesis, the author hereby invites the industry to explore the business potential of sustainable and area-efficient building concepts.

### 6.2.3 Measuring added value

How can usability and area efficiency be measured? How can added value from modern energy-efficient buildings be included in decision-making? Goals and effects have to be able to be measured to be considered. This is embedded in the basic values of the construction industry, and also among those of property developers, owners and tenants. The challenge of measurability may be an obstacle to considering the added value provided by modern sustainable buildings, which implies that attention is given to the extra investment costs but the potential benefits are not included in the calculations. One of the cases included in paper 5 demonstrates that it is possible to make calculations that include the social effects of the built environment, by converting social effects, environmental effects, area efficiency and effects on reputation, etc. into monetary units, and thereby carrying out an analysis of investment which explores the additional and long-term benefits in addition to the saving of energy costs.

### 6.3 Implementing sustainable building

The transformation of existing regimes into sustainable alternatives requires insight into the values and structures of the systems, including the socio-technical system of the construction industry. The findings included in this thesis shed light on how such insight has paved the way for buildings with outstanding energy performance.

The following section will elaborate on some implications from research included in this thesis and present suggestions for further development and implementation of sustainable building. This includes the following suggestions:

- A resource management hierarchy
- A new breed of managers
- A new breed of policymakers and decision-makers

#### 6.3.1 A resource management hierarchy

One suggestion is to develop a “resource management hierarchy” similar to the Energy Triangle, and the waste management hierarchy (Miljøverndepartementet 2013). The purpose of this would be to guide both the construction industry and the users of buildings on considerations relating to the entire lifetime of buildings.

The reason behind this suggestion is the challenge of acknowledging sustainability in the complexity of partly conflicting goals. The hierarchy of aims must include both the benefits and the costs of alternative concepts for sustainable building or refurbishment, as suggested in section 6.2.

### 6.3.2 A new breed of managers

Relation-oriented management is found to be a key to achieving outstanding results. Research included in this thesis provides new insight into this issue, whether it relates to project development processes (see paper 6) or to negotiating the sustainability of buildings when they are being used (see discussion in chapter 5).

The research has provided new insight into the value of relation-oriented management as a supplement to task-orientated management (see section 2.6), especially in relation to innovative problem-solving. The success of developing and implementing new building concepts in the case projects is the result not only of the designs, technology and formal partnerships but is also the result of management practice which exploits and facilitates the intrinsic motivation of humans, creates a good team spirit and negotiates new psychological contracts.

There is a need for a new breed of managers, trained in the art of relation-oriented management, for the purpose of the development and implementation of sustainable building practices. For the purpose of transitioning towards sustainability, scholars have looked at the need for managers schooled in the art of transition and learning from experienced effects of their management style (Shove and Walker 2007)

The research in this thesis reveals that there is a lack of routines for feedback, evaluation and organizational learning within the construction industry. An implication of the insight into the social effect mechanisms regarding innovation and change is that systems for feedback would contribute to increase the intrinsic motivation for transition among actors in the construction industry.

This suggestion is in accordance with the experience of the design of computers and software, along with that of other industries. The involvement of users is found to be crucial for success. In relation to the construction industry, this implies that getting feedback from and educating of users are among the challenges that need to be overcome to succeed with the implementation of sustainable building practice. These tasks are among the challenges calling out for a new breed of managers.

### 6.3.3 A new breed of policymakers and decision-makers

“Reflexive governance” is a concept with the potential for dealing with the socio-technical system of the construction industry for the purpose of a sustainable transition (Hendriks and Grin 2007). The existing literature emphasizes that the ability to explore the potential for increased activity and new business opportunities has been a key to sustainable transformation processes (Kemp and van Lente 2011). The research included in this thesis demonstrates the potential in project owners being reflexive, as discussed in section 5.2.1. Strategic and reflexive clients demonstrate the potential in open innovation processes, in learning from the stepwise implementation of new design and technology and in the analysis of the potential added value for the enterprise occupying the energy-efficient office buildings. These examples prove that there is potential in a thorough exploration of the triple bottom line of sustainability.

Experiences of other industries have revealed that it is possible to create shifts in dominating regimes by negotiating systems and incentives (Kemp and van Lente 2011). The role model projects demonstrate the effect of such negotiations in the individual projects. Following on from this, the author suggests similar negotiations at industrial level and national level to facilitate the transition towards a more sustainable building regime. This requires a new type of policy and decision-makers and a system approach to transformation processes.

The reflexive approach has implications for the formulation of policy instruments. It is suggested that public regulations are to be one element in a double strategy. For instance, the current national technical regulations define a mandatory minimum standard as an incentive for the late majority of actors. As a parallel strategy, voluntary labelling systems give credit to the more ambitious projects. This is in accordance with the findings of previous studies revealing that performance-based requirements are appealing to innovators and early adopters. This double strategy implies a combined push and pull for transformation. At the same time, it facilitates concept diversity regarding sustainable building, and thereby ensures a continuing process of innovation and development of the industry (Axelrod and Cohen 2000).

Reflexive governance implies that the dynamics of the market are addressed and that there is a transition towards sustainable products as a result of demanding customers. The studies included in this thesis reveal that demanding user organizations (tenants or owners) that are active in a co-evolutionary process represent a strong driver towards more sustainable building. The existing literature characterizes customers (user organizations or enterprises) of conventional buildings as passive and conservative, while customers of “green buildings” are active, committed and highly involved in the project (Smith 2007), and thereby support the active clients in general as a driving force for sustainable building. This is in accordance with the discussion in chapter 5, which concludes that without the external demand/challenge, there would not have been any incentive to explore energy efficiency or other environmental qualities of the building projects.

Finally, the author suggests two guiding principles to accelerate the transition towards sustainable building.

1. Explore the potential for win-win effects for all stakeholders. This is for the purpose of triple-bottom-line sustainability: long-term sustainability for environment and society, and long-term economic advantages for owners, users and industry actors.
2. Focus on the long-term return on investment. This includes the potential for saving costs on the investment, e.g. from area efficiency. It also includes saving costs on maintenance and operation over the in-use lifetime of the building (LCC and WLC). This aspect also includes analysis of how sustainable building solutions may be adding value to production.

## 7 Conclusion

This chapter concludes the thesis. First, conclusions on the overall purpose of the thesis are presented. The conclusions on the individual research questions, as presented in section 1.7, follow. The conclusions on research questions 1–7 elaborate on the conclusions on the overall purpose. The chapter rounds off by presenting some challenges of and suggestions for further industrial development towards sustainable building.

### 7.1 Conclusion on the overall purpose

***The overall purpose is to increase the understanding of how the Norwegian construction industry is transforming towards sustainable building.***

#### **Conclusions**

The research presented in this thesis can be summarized in five major conclusions:

Firstly, the Norwegian construction industry is able to develop highly sustainable buildings. There are actors within the industry that can be characterized as “innovators” and “early adopters” who are exploring the potential for energy efficiency in construction projects.

Secondly, the organizing of the development and construction process has been decisive for achieving extraordinary results. Crossing the borders of organizational units and roles and divisions of work in various phases have made it possible to pool knowledge, share risks and find innovative solutions to meet new expectations for sustainable building.

Thirdly, at the moment, buildings with outstanding energy and environmental qualities are exceptions to the rule within the construction industry. Sustainable building is being developed as a niche in the market. It remains to be seen whether sustainable building will become standard practice.

Fourthly, the role model projects demonstrate there is a win-win potential in sustainable building: exploring the synergy effects in the search for energy efficiency reveals options for buildings with added value for users and owners as well as for the environment and the community.

Fifthly, the ability to deal with both the social and the technical aspect is found to be a key to succeeding with innovative sustainable building projects. Role model projects demonstrate the value of managing human relations and exploring intrinsic motivation to succeed in development processes and also in the actual performance of buildings when they are being used.

### 7.2 Conclusions on research questions

The following presents the conclusions on the individual research questions.

***Question 1: What characterizes the interaction process of projects with high energy and environmental ambitions?***

***Conclusions***

Four characteristics are recognized:

- a. Broad and early participation during the concept stage (“front-loaded process”)
- b. Strategic and reflexive clients
- c. Team spirit is developed among the individual participants
- d. Demanding users/stakeholders

Integrated solutions and considerations of the mutual energy effects are the results of the broad involvement from the early planning stage. Multi-professional teams, supplemented with specialist consultants, users, operators and researchers have been involved in extensive collaboration processes. The thesis documents that the methodologies of integrating the design process and integrating the energy design facilitate the exploration and evaluation of innovative concepts.

This thesis adds new knowledge to the field by documenting the co-construction of knowledge and building concepts in the new arenas that establish broad and early involvement.

The thesis also adds to knowledge on the relevance of psychological contracts among the individual project team participants as a supplement to formal partnering contracts between enterprises in project value chains.

The high energy ambitions were not part of the initial requirements of the client. It is an unexpected result to find that the environmental goals developed instead as a result of the broad involvement. This thesis documents that user enterprises, environmental incentive programmes and other participants during the early planning phase have initiated the energy and environment goals. The ambitions for energy efficiency are the result of the involvement of multi-professional teams and early broad involvement, revealing the potential and also convincing clients of the benefits. This conclusion represents new knowledge, supplementing expectations that demanding clients will be initiative takers for sustainable building.

***Question 2: What are the innovative aspects of the organizing of role model projects in various project phases?***

***Conclusions***

Role model projects demonstrate innovative organizing of processes during all phases:

- The concept phase of role model projects is organized to allow broad involvement.
- The design phase is organized to encourage multi-professional teamwork.

- During the construction phase, the suppliers and the subcontractors' craftsmen and craftswomen are challenged in relation to initiatives for improvement.
- In the user phase, the technology and operation of the building are evaluated and adjusted, which implies that there is a negotiation of sustainability.

Special tools and routines are developed to follow up on the energy and environmental measures:

- Key performance indicators are developed to document and evaluate the energy and environmental qualities of deliveries from contractors and suppliers.
- Specialist consultants on energy and the environment are contracted for the design and construction phase.

Quality assurance programmes and control plans for following up on key indicators are existing practice within the industry. The use of indicators and controls for energy and environment is new. This thesis provides new knowledge on the relevance of measurable indicators and detailed follow-up during all phases.

Involving user representatives and facility managers during planning has contributed to sustainability of the planned building. It also improve their knowledge about energy performance of the building and motivation for succeeding in achieving the energy and environmental goals during occupation and the operation of the final building.

The social skills of property developers/owners and project managers have been of vital importance for this success. This is relevant to the ability to exploit the potential for team spirit and intrinsic motivation of the individual participants in innovative projects. Leaving decision-making to autonomous work teams during the planning phase represents an unconventional psychological contract between the client and the team, and the thesis provides new knowledge on the effect of such informal contracts on exploiting innovative solutions.

The role model projects demonstrate how extensive human-oriented management supplements conventional task-oriented management.

Role model projects are used in step-by-step development towards a more sustainable practice. Professional owners and property developers monitor and evaluate energy concepts, feeding forward experiences from project to project.

***Question 3: How do the working methods used during the planning phases affect the energy performance of the resulting buildings?***

The following methods were initially expected to be of special relevance, and have been the subject of analysis, as presented in the papers included in this thesis:

- a. Involvement of facility managers during early planning
- b. Integrating the processes during concept and design phases
- c. Partnering in the value chain
- d. Industry and research partnering
- e. Use of LCC analysis in portfolio management

### **Conclusions**

- a) Involvement of facility managers during planning phases has contributed positively. A double effect causing increased energy efficiency has been identified:
  - Facility managers contribute with knowledge relevant to the planning team.
  - Insight into the energy concept helps the facility managers in the operation of the building during its in-use life.

Professional property developers have an advantage by involving the FM department of existing properties in feeding forward experiences of energy performance into the planning of future buildings for the purpose of further improvement of energy and environmental performance.

- b) Processes for integration are found to be crucial for succeeding in achieving outstanding energy efficiency. Again, a double effect is identified:
  - Stakeholders from the whole production chain have participated from the early planning phase, together with a team of skilled professionals.
  - The focus has been on exploring the synergy effects on energy by using optional alternatives of design, layout, materials and technical solutions, etc.

This conclusion is in accordance with theory on multi-stakeholder networks and relational management. However, integrated design processes are the exception in construction projects today.

- c) Partnering within the value chain is an element of all the case projects. Partnering contributes to energy efficiency by broadening the knowledge base (pooling knowledge) and by reducing the risks associated with unconventional solutions and concepts.
- d) Industry and research partnering contributes positively to energy efficiency. Similar to other partners, researchers contribute to broadening the knowledge base and also by testing innovative concepts and solutions and thereby contribute to risk reduction. Research partners have been involved in all the prize-winning case projects; according to the expectation of the triple-helix model, this is crucial for innovative projects.
- e) Analysis of life cycle costs (LCC) focuses attention on the whole-life perspective of building portfolio management. LCC contributes by linking decisions on investments and



refurbishment with decisions on the operation and maintenance of the buildings, including those on energy costs. LCC analysis provides documentation of the long-term consequences of short-term decisions, which contribute to sustainable decision-making.

Further analysis provides new insight into the basic approaches being used in role model projects, including the following:

Collaboration has proved to be crucial for achieving the results that can be seen in the role model projects. Partnering, early and broad involvement, integrating design processes and LCC analysis all contribute to improving environmental sustainability in construction practice. Exploring the synergy effects of energy during the user phase of the building is a major contribution.

Formalized partnering is among the organizational means used in the role model projects. However, partnerships are (with one exception) formed on a project basis, similar to contemporary conventional practice. This is inconsistent with innovation theory, which emphasizes the long-term perspective of innovative development processes and of strategic partnering. This thesis documents that long-term formal partnering is still to be fully explored by the industry.

The thesis provides new knowledge on the effects of using informal organizational means for collaborative and innovative construction. Particular working processes, including broad and early involvement and consensus-based decision processes have established psychological contracts within teams and intrinsic motivation at an individual level, which have been of vital importance for pioneering work.

The relevance of social processes is in accordance with recent theories on leadership and with management principles being used in knowledge-based enterprises, but is contradictory to the traditional focus on formal contracts within the construction industry. However, the findings are in accordance with those of recent studies of complex industrial projects, which suggests that human-oriented management should supplement traditional task-oriented management with an increasing degree of complexity and innovation.

***Question 4: What benefits do clients (owners and property developers) experience from constructing modern energy-efficient buildings?***

***Conclusions***

Improving their ability to compete in the market is the common driving force for the clients. Developing sustainable or “green” buildings is a strategy of developing a product for a new niche market. The professional clients are motivated by the potential to provide buildings that are appealing to user organizations (enterprises) that want a reputation as business owners who take their responsibility to the environment and the community seriously.

Clients experience how exploring energy-efficient concepts may contribute to other qualities of the buildings. This includes the long-term potentials of area efficiency, an open and flexible layout and

buildings that are placed so that they can easily be reached via public transport. These qualities are major contributors to energy efficiency and to both environmental and economic sustainability.

There are individual property developers with a strategic approach to sustainable building. These clients explore sustainable building principles and evaluate the results from one project to the next, building competence and testing the market step by step.

This thesis contributes with new knowledge on how energy-efficient buildings can contribute by adding value and qualities to the buildings in addition to saving energy and reducing greenhouse emissions.

***Question 5: What benefits do user organizations experience from occupying modern energy-efficient office buildings?***

***Conclusions***

The vital criterion for the user organizations and enterprises is that the buildings provide facilities that support production. Prize-winning energy-efficient buildings provide additional qualities that are crucial for the users and their total experience of the usability of the facilities. Open-plan designs with rooms that are flexible in terms of how they can be used and open-plan office landscapes are attractive to user organizations characterized by networking and project-based collaboration. For such organizations, an open design contributes to the effectiveness and adaptability of the building.

Area efficiency is just as important or more important for user organizations as energy efficiency, due to its contribution to the production and long-term economy of the business.

The indoor environment of the employees is more important to user organizations/enterprises than energy efficiency. The lack of influence on the indoor environment regarding the energy saving technology of modern sustainable office buildings is a major challenge.

Facilities with exceptional environmentally friendly solutions add positively to the reputation of the enterprises and organizations. Inhabiting sustainable buildings gains interest from customers and employees and adds to the organizations reputation for having a sense of corporate social responsibility.

The thesis adds new knowledge to existing knowledge about the relevance of the usability of modern energy-efficient buildings. All of the qualities of a modern and functional building matter to user organizations/enterprises, including the indoor climate and the functionality for the activities to be carried out. Energy efficiency alone is not sufficient.

***Question 6: How are the relations between the industry and research contributing to transitioning towards a more sustainable construction industry?***

***Conclusions***

Research–industry collaboration is crucial for innovative sustainable building. Role model projects provide arenas for joint learning and concept and product development.

Research–industry partnerships contribute positively to innovative sustainable building. Research partners provide expertise and recent knowledge to the industry partners, conduct lab tests and perform modelling on energy and environmental effects. As such research partners represent a guarantor for the quality of new technology and materials presented to the market.

This thesis adds knowledge to the role of research in industrial development towards sustainable building. The findings are in accordance with experiences of other industries and the expectations of the triple-helix model and strategy for knowledge-based industrial development.

***Question 7: Are experiences and solutions from the role model projects being implemented into the Norwegian construction industry?***

***Conclusions***

Knowledge about and concepts for energy-effective building is gradually diffusing into the construction industry, however slowly.

Role model projects are good arenas for situated learning, partly about energy efficient concepts and solutions, and partly about multi-professional team work. However, experiences of the individual participants does not necessarily diffuse into the rest of the industry, due to structural and cultural characteristics of the industrial system.

Price winning projects are inspiring challenges for the most innovative and early adapting enterprises in the industry, and is appealing to the most environmentally friendly profiled customers. For the time being sustainable buildings represent a niche in the market.

Further implementation of sustainable building practices are depending on the demand in the market. For the moment there are few actors in the market appealing as role models among clients and users of office buildings.

Role model projects inhabit characteristics of open innovation. This implies that an increasing number of enterprises have first-hand insight into the solutions, including enterprises and organizations using the final buildings. Depending on their experiences, they are key actors to further demand for sustainable buildings.

7.3 Challenges and suggestions for further development towards sustainable building  
Prize-winning sustainable building projects are the result of a combination of external and internal incentives and also of an ability and willingness to innovate.

Implementing sustainable building practice into ordinary practice in the construction industry is the main challenge. The challenge includes overcoming resistance to change within the socio-technical

system of the industry, the existing infrastructure, the dominating perceptions in the market and a lack of awareness of the value-adding effects of buildings developed with a focus on synergy effects.

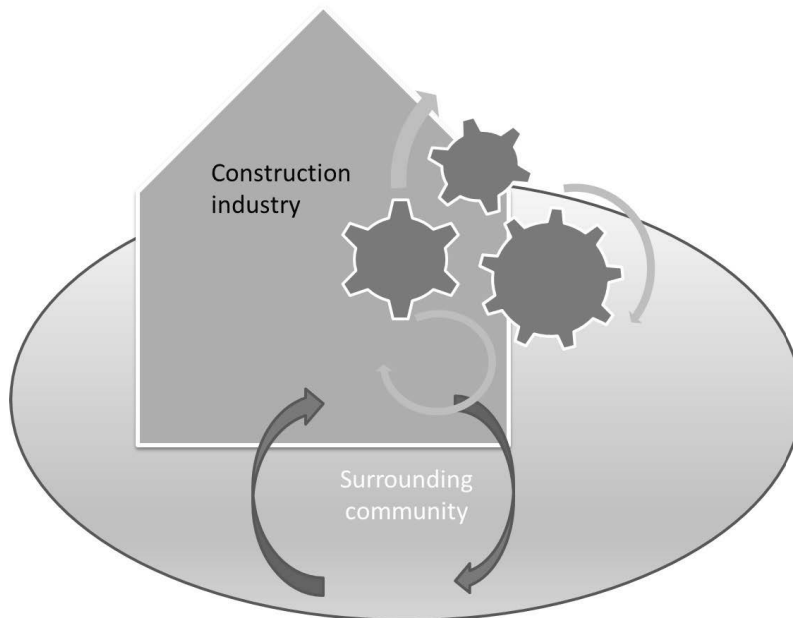


Figure 20: Internal and external dynamics of the construction industry

This conclusion is based upon theories on industrial systems and on the existing literature documenting a) the close interdependency within the construction industry's system and b) the sensitivity of the system towards changes in its surroundings (illustrated in figure 20).

There is a lack of long-term strategies for the industry to use to develop sustainable building practice. This is also the case for most of the enterprises involved in role model projects.

Strategic partnering with other actors in the value chain is an exception in role model projects, as in conventional projects. Organizational learning from role model projects is limited, and there is a lack of routines for evaluation of the feedback on the actual performance of the buildings when they are being used. Such in-built characteristics of the industrial system represent a major challenge for transition towards sustainable building.

What does it take?

To develop buildings with outstanding energy performance, it takes collaboration, ambitious and open-minded clients, and experienced and ambitious teams.

The analysis presented in this thesis can be summarized as a set of prerequisites for innovative sustainable building:

- a) There must be a driving force for sustainable building. This can be an ambitious client or user, an economic gain, publicity or a market opportunity
- b) There must be a system for risk-handling
- c) There must be a system for intense and detailed follow-up of energy/environmental goals during construction and post-occupancy
- d) The development process from the start to occupancy must be organized to achieve integrated building solutions, long-term usability and added value for all parties. The following methods are especially relevant:
  - Front-loaded planning
  - Multi-professional collaboration
  - Contracts favouring inter-organizational cooperation
  - Involvement of stakeholders at all stages
  - Partnerships

What is the major value of sustainable building, in particular energy-efficient buildings? From the perspective of owners and user organizations, it is the value-adding effect to their activities or production provided by the building. Successful projects are a result of strategic processes integrating business development and development of the built facilities.

From the perspective of the individual enterprise in the construction industry, two effects are recognized:

- The value-adding effect in exploring potentials for improvements in production
- A niche market for sustainable building production and services

In summary

Sustainable building must provide a win-win alternative for all stakeholders.

Sustainable building involves triple-win alternatives covering all three aspects of sustainability, namely environment, economy and social/community.



## 8 Further research

The research presented in this theses focuses on which working methods are used in the planning process and how the working method affects the qualities of the final building. The implications of the characteristics of the industrial system have been shown, including the barriers to and driving forces for stability and change.

This chapter suggests further research on the implementation of sustainable building practices into ordinary practice. The following section elaborates on three suggested issues:

- a) Organizational learning from role model projects
- b) Stakeholder benefits from sustainable building
- c) Implementation of sustainable building practice

### 8.1 Organizational learning from role model projects

There is a lack of evaluations of knowledge transfer from role model projects within the construction industry. Among the few contributions is the Norwegian State Housing Bank's support of construction projects with outstanding environmental and energy qualities. A recent evaluation indicates that financial support in particular is making a difference to building competence on sustainable construction. The conclusion is that since this funding is used to buy research and development services, there would have been less development activity without this support (Nordvik 2011). There is also the challenge of transforming examples from pioneering projects into sustainable practice in the general market (IEA 2010).

According to social learning theory, learning from role model projects depends (among other things) on the degree of similarity between the model and the observer (Bandura 1991). Similarly, theories on organizational learning suggest that referring to others within the same community of practice is a key to transferring knowledge between organizations (Nonaka and Takeuchi 1995, Weick and Westley 1996, Wenger 1999). In the construction industry, characteristics such as being within the same market segment or having the same capacity to handle the risk of uncertainty might attract other enterprises and clients to learn and copy from role model projects.

However, even if there are similar characteristics, learning from role model projects appears to be limited. Geographical distance is a barrier, since the client and the main contractor, and often the architect and consultant engineers operate within a limited geographical region. One example of this is the prize-winning the bank headquarter (see papers 2 and 6), from which the concept has been re-used in a recently constructed local bank building, but not in another regional headquarters within the same banking group. Another example is public hospitals, where innovative and successful solutions for sustainability, quality and efficiency are not being transferred to projects in other regions within the country.

The issue of learning from role model projects can be approached in various ways, for example:

- Analyse the enterprises and other stakeholders involved in a selection of role model projects. To what degree have they been re-using the solutions shown in and the knowledge gained

from the role model project? To what degree are they marketing their expertise on sustainable building? Which clients are demanding such expertise?

- Analyse organizational learning within the enterprises involved in prize-winning sustainable buildings. To what degree are experiences, e.g. from concept and design team members, being diffused to colleagues and management within their respective enterprises? And to what degree are the new concepts being adopted by and provided to future clients on a regular basis?

The studies included in this thesis have focused on clients and user organizations as drivers of innovative sustainable building concepts and as actors who demand it. However, the experience of the construction industry<sup>7</sup> is that change and development of building practice is often initiated by the suppliers, who provide and introduce new materials, tools and techniques. The findings from the studies included in this thesis reveal that the main contractors have been challenging the subcontractors and suppliers for Environmental Product Declarations (EPD) to document energy consumption at the construction site, to reduce waste and increase recycling, etc. Further research may explore how suppliers promote sustainable building:

- To what degree do subcontractors and suppliers implement practice from role model projects in ordinary production? And to what degree do subcontractors and suppliers promote environmentally friendly or energy-saving products?

Niches are important as “protected spaces” where radical novelties are shielded from mainstream market selection. A number of different niches have been established during the last few years for innovations within the Norwegian construction industry. FutureBuilt, Framtidens byer (Cities of the Future) and Framtidens bygg (Constructions of the Future), financial and expert support from the Norwegian energy funding body and the research Centre on Zero Emission Buildings (with industry partners) are examples. These are recognized as being involved in the case projects included in this thesis. Unusual relations are established to support projects and reduce risk in projects with innovative concepts.

The role model projects illustrate that they are not protected from the market, but are rather a result of a niche market for green buildings. As found in the case studies, there are clients and tenant enterprises that have been pushing for innovations and for the provision of extra time and resources, especially during the early planning phase. Being able to compete in the market is among the stated goals for the case projects. For this purpose, the clients have established social networks which provide resources and reduce risks. As Geels (2004 p 912) notes, “Actors are willing to support and invest in niches because they have certain expectations about possible futures.”

Niches are also important as locations for learning processes. The niches provide opportunities to deviate from existing regimes, and new paths can emerge. The niche setting implies that rules and regimes from the conventional industry are being challenged and that there are no clear division of the roles. The socio-technical configuration tends to be in flux in terms of what components to use and how to arrange the supplies, etc. There is less structuration of activities. Actors in niches put in extra efforts to uphold the niche so that they can try out different methods and solutions. This is

---

<sup>7</sup> Personal information Byggenærings landsforening.



illustrated in the case studies, where unconventional working forms, contracts and follow-up systems for energy and environmental goals have been tried out (see papers 2, 3 and 6).

## 8.2 Stakeholder benefits from sustainable building

The findings in the studies presented in this thesis reveal the strength of the intrinsic motivation of the stakeholders involved in innovative building projects. However, the primary motive varies among the stakeholders, depending on their role in the value chain and their perception of the market. Previous studies show that incentives have to be diversified in accordance with the variety of motivation driving the various parties involved in the value chain of the construction industry (Whyte and Sexton 2011). Theory reminds us that self-interest rather than perceived altruism is the driver for environmentally friendly activity (Cole 2011, Hunt and Townshend 2011).

Based upon this logic, there is a potential value in analysing the role model projects in terms of the benefits and outcomes they experience as innovative projects:

- What were the expectations among various stakeholders involved in role model projects? What benefits were experienced that are of interest for the enterprise? What potential is seen for exploiting this new knowledge in future projects?

## 8.3 Implementation of sustainable building practice

Theories on the diffusion of innovations illustrate how technological shifts may contribute to the introduction of radical innovations. Whyte and Sexton (2011) suggest that there is an upcoming “wave” taking developments from ICT, biotechnology and digital networks to the next “wave”, which is characterized by green chemistry, industrial ecology, renewable energy and sustainability. Further studies are needed to explore the mechanisms of such a shift. Theories on institutional systems remind us that cultural and social patterns are just as important as technology in such shifts.



## References

Aarseth, W. (2012). An empirical study of organizational cooperation in large traditional and global project execution. Faculty of Engineering Science and Technology. Trondheim, Norway, Norwegian University of Science and Technology. **PhD thesis**: 360.

Alderman, N. and C. Ivory (2007). "Partnering in major contracts: Paradox and metaphor." International Journal of Project Management **25**(4): 386-393.

Alvesson, M. (2011). "De-essentializing the knowledge intensive firm: Reflections on sceptical research going against the mainstream." Journal of Management Studies **48**(7): 1640-1661.

Amabile, T. (1996). Creativity in context, Westview press.

Andersen, E. (2011). Rethinking project management: an organisational perspective. UK, Pearson Education Limited.

Andresen, I. (2008 ). Integrated Energy Design. The 9 steps to a low-energy building, Intendesign

Andresen, I. and A. G. Hestnes (2009). Integrated Energy design IED. A guide to integrated energy design. Integrated Energy Design in Public Buildings. EcoArchWiki.net, intendesign.com.

Arge, K. and H. Hjelmbrekke (2012). Value enhancing processes in building and real estate. Joint CIB W070, W092, & TG72 International Conference on Facility Management, Procurement Systems and Public Private Partnership. Cape Town, South Africa.

Arthur, W. B. (1994). Increasing Returns and Path Dependence in the Economy. Michigan, University of Michigan Press.

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

Attia, S. and A. De Herde (2011). Early design simulation tools for net zero energy buildings: a comparison of ten tools. Conference Proceedings of 12th International Building Performance Simulation Association, 2011, Sydney.

Attia, S., et al. (2012). "Simulation-based decision support tool for early stages of zero-energy building design." Energy and Buildings **49**(0): 2-15.

Avis, J. (2007). "Engeström's version of Activity Theory: a conservative praxis?" Journal of Education and Work **20**(3): 161-177.

Axelrod, R. and M. Cohen (2000). Harnessing Complexity. Organizational Implications of a Scientific Frontier. New York, Basic books.

Baert, P. (2005). Philosophy of the social sciences: Towards pragmatism, Routledge.

Baharum, M. R. and M. Pitt (2009). "Determining a conceptual framework for green FM intellectual capital." Journal of Facilities Management **7**(4): 267-282.

Baiden, B. K., et al. (2006). "The extent of team integration within construction projects." International Journal of Project Management **24**(1): 13-23.

Baird, G. (2010). Sustainable Buildings in Practice: What the Users Think. Abingdon, United Kingdom, Routledge.

Bakker, R. M., et al. (2011). "Managing the project learning paradox: A set-theoretic approach toward project knowledge transfer." International Journal of Project Management **29**(5): 494-503.

Bandura, A. (1986). Social foundations of thought and action: A social cognitive theory. Englewood Cliffs, NJ, Prentice-Hall.

Bandura, A. (1991). "Social cognitive theory of self-regulation." Organizational Behavior and Human Decision Processes **50**(2): 248-287.

Barlow, J. (2000). "Innovation and learning in complex offshore construction projects." Research Policy **29**(7-8): 973-989.

Barrett, J., et al. (2013). "The social life of the novel idea: what did social psychologists ever do for us?" Engineering, Construction and Architectural Management **20**(3): 250-266.

Barrett, P. and M. Sexton (2006). "Innovation in small, project-based construction firms." British Journal of Management **17**(4): 331-346.

Bennett, J. and S. Jayes (1998). The seven pillars of partnering: A guide to second generation partnering, Thomas Telford Publishing.

Berger, P. L. and T. Luckmann (1967). The social construction of reality: A treatise on the sociology of knowledge, First Anchor Books.

Berker, T. and K. Bharathi (2012). "Energy and buildings research: challenges from the new production of knowledge " Building Research & Information **40**(4): 473-480.

Bishop, D., et al. (2009). "Constructing learning: adversarial and collaborative working in the British construction industry." Journal of Education and Work **22**(4): 243-260.

Bjørnberg, S. (2007). Life Cycle Cost (LCC) in Norway. Experience and State of Art. Maintenance Management 2007 - Third International Conference on Maintenance and Facility Management.

Bjørnfot, A., et al. (2013). Assessing construction end user values. 7th Nordic Conference on Construction Economics and organization. Trondheim, Norway, Akademia forlag.

Black, S. E. and L. M. Lynch (2005). Measuring Organizational Capital in the New Economy. Measuring Capital in the New Economy. C. Corrado, J. Haltiwanger and D. Sichel, University of Chicago Press: 205 - 236.

Blakstad, S. H. (2001). A Strategic Approach to Adaptability in Office Buildings. Faculty of Architecture and Fine Art Norwegian University of Science and Technology. **dr.ing.**

Blakstad, S. H. and I. A. Andersen (2011). An objective-driven approach to workplace design, management and use - a case study. 10th Euro FM Research Symposium. Vienna.

Blakstad, S. H. and I. A. Andersen (2013). "Added value from workplace design, management and use? A case study." Corporate Real Estate Journal **2**(4): 340-353.

Blakstad, S. H. and K. H. Kjølle (2013). Workpractice - impact on users' assessment of usability. 7th Nordic Conference on Construction Economics and Organization. Trondheim, Akademia.

Blyth, A. and J. Worthington (2010). Managing the brief for better design. Abingdon, United Kingdom and New York, USA, Routledge.

Bordass, B. (2001) Flying blind? Things you wanted to know about energy in commercial buildings but were afraid to ask.

Boucher, D. and P. Kelly (2003). The social contract from Hobbes to Rawls, Routledge.

Bougrain, F. (2012). "Energy performance and public private partnership." Built Environment Project and Asset Management **2**(1): 41-55.

Bowns, S., et al. (2003). "Measuring the economic benefits from R&D: improvements in the MMI model of the United Kingdom National Measurement System." Research Policy **32**(6): 991-1002.

Bresnen, M. and N. Marchall (2000). "Partnering in construction; A critical review of issues, problems and dilemmas." Construction Management and Economics **18**(2): 229-237.

Bröchner, J. (1996). Feedback for facilities management to design and construction - systems issues. The Organization and Management of Construction, Vol 3. A. Langford and D. A. Retik. London, Taylor & Francis: 238-246.

Bucciarelli, L. L. (2002). "Between thought and object in engineering design." Design Studies **23**(3): 219-231.

Buchanan, D. A. and A. Bryman (2007). "Contextualizing methods choice in organizational research." Organizational Research Methods **10**(3): 483-501.

Bull-Hansen, Ø., et al. (2015). Framtidens bygg. Pilotprosjekter 2009–2015. Klimavennlige bygg og områder. Oslo, Framtidens bygg/ Norske arkitekters landsforbund/Kommunal- og moderniseringsdepartementet: 51.

BusinessDictionary. "BusinessDictionary." Retrieved December, 2014, from [www.businessdictionary.com](http://www.businessdictionary.com)

Bygballe, L. E., et al. (2010). "Partnering relationships in construction: A literature review." Journal of Purchasing & Supply Management **16**: 239-253.

Bygg21 (2014). Sammen bygger vi fremtiden. En strategi for en konkurransedyktig bygg- og eiendomsnæring (In English: Together we build the future. Strategy for a competitive construction and property industry). Norway: 40.

byggejuss.no. Retrieved December, 2014, from [www.byggejuss.no](http://www.byggejuss.no).

Cajias, M., et al. (2011). "Does sustainability pay off for European listed real estate companies? The dynamics between risk and provision of responsible information." Journal of Sustainable Real Estate **3**: 211-231.

Cajias, M. and D. Piazzolo (2013). "Green performs better: energy efficiency and financial return on buildings." Journal of Corporate Real Estate **15**(1): 53-72.

Carlsson, B. and R. Stankiewicz (1991). "On the nature, function and composition of technological systems." Journal of Evolutionary Economics **1**(2): 93-118.

Caspari, S., et al. (2006). "The aesthetic dimension in hospitals. An investigation into strategic plans." International Journal of Nursing Studies **43**(7): 851-859.

Cathcart, A., et al. (2014). "Learner-focused evaluation cycles: facilitating learning using feedforward, concurrent and feedback evaluation." Assessment and Evaluation in Higher Education **39**(7): 270-802.

CEN (2006). CEN/TC 348 "Facility Management", European Committee for Standardization.

Chasey, A. D., et al. (2012). "Comparison of public-private partnerships and traditional procurement methods in North American highway construction." Transportation Research Record: Journal of the Transportation Research Board **2268**(-1): 26-32.

Cheng, C. C. J. and E. K. R. E. Huizingh (2014). "When is open innovation beneficial? The role of strategic orientation." Journal of Product Innovation Management **31**(6): 1235-1253.

Cheng, E. W. L., et al. (2004). "A learning culture for strategic partnering in construction." Construction Innovation **4**(1): 53-65.

Cherns, A. (1976 ). "Principles of socio-technical design." Human Relations **29**(8): 783-792.

Chesbrough, H. W. (2006). Open innovation: The new imperative for creating and profiting from technology, Harvard Business Press.

Christie, L., et al. (2011). "The 'apparent disconnect' towards the adoption of energy-efficient technologies." Building Research & Information **39**(5): 450-458.

Clegg, C. (2000). "Sociotechnical principles for system design." Applied Ergonomics **31**: 463-477.

Clegg, S. R., et al. (1996). Handbook of organization studies. London, SAGE Publications Ltd.

Clegg, S. R., et al. (2011). Managing and Organizations: An Introduction to Theory and Practice. London, Sage.

Cohen, S. S. and G. Fields (2000). Social capital and capital gains in Silicon Valley. Knowledge and social capital: Foundations and applications. E. L. Lesser, Elsevier: 323.

Cole, R. J. (2000). "Editorial: Cost and value in building green." Building Research & Information **28**(5-6): 304-309.

Cole, R. J. (2011). "Motivating stakeholders to deliver environmental change." Building Research & Information **39**(5): 431-435.

Construction Industry Institute (1991). In search of partnering excellence. Special publication Austin, Construction Industry Institute (CII). **17-1**.

Construction Industry Institute (2015). Retrieved December, 2014, from [www.construction-institute.org](http://www.construction-institute.org)

Corbin and Strauss (2007). Basics of qualitative research: Techniques and procedures for developing grounded theory (3rd ed.). Thousand Oaks, CA, Sage.

Cordano, M., et al. (2004). "Entangled affiliations and attitudes: an analysis of the influences on environmental policy stakeholders' behavioral intentions." Journal of Business Ethics **49**(1): 27-40.

Dahl, P., et al. (2005). Evaluating Design-Build Operate Maintain Delivery as a tool for sustainability. Proceedings of the Construction Research Congress 2005: Broadening Perspectives, San Diego, USA, ASCE.

Dai, W., et al. (2008). Research on the green motivation of knowledge-based employees. 11th Joint Conference on Information Sciences, Atlantis Press.

Dainty, A., et al. (2007). Communication in Construction: Theory and Practice, Routledge.

Damgaard, T. and P. B. Erichsen (2009). Implementering af drift i byggeri (In English: Implementing operation in construction), Dyddansk Universitet.

Daykin, N., et al. (2008). "The impact of art, design and environment in mental healthcare: a systematic review of the literature." Journal of Royal Society for the Promotion of Health **128**(2): 85-94.

De Dreu, C. K. W. and B. Beersma (2005). "Conflict in organizations: Beyond effectiveness and performance." European Journal of Work and Organizational Psychology **14**(2): 105-117.

De Dreu, C. K. W. and L. R. Weingart (2008). Groups and organizational teams. International handbook of organizational teamwork and cooperative working. Michael A. West, Dean Tjosvold and K. G. Smith, John Wiley & Sons: 656.

De Vilbiss, C. E. and P. Leonard (2000). "Partnering is the foundation of a learning organization." Journal of Management in Engineering **16**(4): 47-57.

Dobbins, M., et al. (2001). "Factors affecting the utilization of systematic reviews. A Study of Public Health Decision Makers." International Journal of Technology Assessment in Health Care **17**(2): 203-214.

Dokka, T. H., Rødsjø, Are (2005). Kyoto pyramiden. Trondheim, Husbanken Midt-Norge og SINTEF Byggforsk.



Dougherty, D. (1996). Organizing for innovation. Handbook of organization studies. S. Clegg, C. Hardy and W. R. Nord. London, Sage Publications: 424-439.

Dubois, A. and L.-E. Gadde (2002). "The construction industry as a loosely coupled system: implications for productivity and innovation." Construction Management and Economics **20**(7): 621-631.

Egan, J. (1998). Rethinking Construction. UK, The construction task force.

Egan, J. (2002). Accelerating Change. UK, The Strategic Forum for Construction.

Egbu, C. O. (2004). "Managing knowledge and intellectual capital for improved organizational innovations in the construction industry: an examination of critical success factors." Engineering, Construction and Architectural Management **11**(5): 301-315.

Eichholtz, P., et al. (2010). "Doing well by doing good? Green office buildings." The American Economic Review **100** (5, December): 2492-2509.

Elster, J. (2007). Explaining social behavior: More nuts and bolts for the social sciences, Cambridge University Press.

Elzen, B., et al. (2004). System innovation and the transition to sustainability: Theory, evidence and policy, Edward Elgar Publishing.

Emery, F. and E. Trist (1965). "The causal texture of organizational environments." Human Relations(18): 21-32.

Emmitt, S. (2007). Design management for architects. Chichester, Blackwell Publishing.

Engeström, Y. (2004). "New forms of learning in co-configuration work." Journal of Workplace Learning **16** (1/2,): 11 - 21.

Engeström, Y., et al. (1999). When the center does not hold: the importance of knotworking. Activity theory and social practice. S. Chaiklin, M. Hedegaard and U. J. Jensen. Aarhus, Aarhus university Press.

Engeström, Y. and H. Kerosuo (2007). "From workplace learning to inter-organizational learning and back: the contribution of activity theory." Journal of Workplace Learning **19** (6): 336-342.

Eriksson, P. E. (2010). "Improving construction supply chain collaboration and performance: a lean construction pilot project." Supply Chain Management: An International Journal **15**(5): 394-403.

- Etzkowitz, H. and L. Leydesdorff (2000). "The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university - industry - government relations." Research Policy **29**: 109-123.
- European Parliament (2006). Directive 2006/32/EC Directive on energy end-use efficiency and energy services.
- Falk, I. and Guenther (2006) Generalising from qualitative research: Case studies from VET in contexts.
- Feige, A., et al. (2011). "Harnessing stakeholder motivation: towards a Swiss sustainable building sector." Building Research & Information **39**(5): 504-517.
- Fenker, M. (2005). Case study: Technocentre Renault in Guyancourt: The Building La Ruche. Usability of workplaces. CiB Task Group 51, report on case studies. University of Salford.
- Fischer-Kowalski, M., et al. (2011). Decoupling natural resource use and environmental impacts from economic growth. United Nations Environment Programme (UNEP). The Working Group on Decoupling to the International Resource Panel, UN.
- Flyvbjerg, B. (2004). "Five misunderstandings about case-study research." Sociologisk tidsskrift **2**: 118-142.
- Forgues, D. and I. Iordanova (2010). An IDP-BIM framework for reshaping professional design practices. . Construction Research Congress 2010: 172-182.
- Forgues, D. and L. Koskela (2009). "The influence of a collaborative procurement approach using integrated design in construction on project team performance." International Journal of Managing Projects in Business **2**(3): 370-385.
- Frooman, J. (2010). "The issue network: reshaping the stakeholder model." Canadian Journal of Administrative Sciences - Revue Canadienne des Sciences de l'Administration **27**(2): 161-173.
- Fuerst, F., et al. (2013). "Is intrinsic energy efficiency reflected in the pricing of office leases?" Building Research & Information **41** (4): 373-383.
- Fuller, S. (2010). "Life-Cycle Cost Analysis (LCCA)." Retrieved December, 2014, from <http://www.wbdg.org/resources/lcca.php>.
- Gadde, K.-E. and A. Dubois (2010). "Partnering in the construction industry - problems and opportunities." Journal of Purchasing and Supply Management(16): 254-263.

- Gann, D. M., et al. (1998). "Do regulations encourage innovation? - the case of energy efficiency in housing." Building Research & Information **26** (5).
- Geels, F. W. (2004). "From sectoral systems of innovation to socio-technical systems. Insights about dynamics and change from sociology and institutional theory." Research Policy **33**(6-7): 897-920.
- Geels, F. W. (2006). "Major system change through stepwise reconfiguration: A multi-level analysis of the transformation of American factory production (1850–1930)." Technology in Society **28**(4): 445-476.
- Geels, F. W. (2014). "Regime resistance against low-carbon transitions: Introducing politics and power into the multi-level perspective." Theory, Culture & Society **31**(5): 21-40.
- Geiger, P., et al. (2013). "The asset allocation of sustainable real estate: a chance for a green contribution?" Journal of Corporate Real Estate **15**(1): 73-91.
- Gibbs, D. and K. O'Neill (2015). "Building a green economy? Sustainability transitions in the UK building sector." Geoforum **59**: 133-141.
- Glaser and Strauss (1967). The discovery of grounded theory. New York, Aldine de Gruyter
- Gorse, C. A. and S. Emmitt (2009). "Informal interaction in construction progress meetings." Construction Management and Economics **27**(10): 983-993.
- Gould, J. D. and C. Lewis (1985). "Designing for usability: Key principles and what designers think." Communications of the ACM **28**(3).
- Granath, J. A., et al. (2005). Case study: Örebro University Hospital. The O-building. Usability of workplaces. CiB Task Group 51, report on case studies. University of Salford. **Publication 306**.
- Gray, L. and G. Ferrell (2013) Feedback and feed forward. Using technology to support learner longitudinal development. Electronic management of assessment
- Grimi, C., et al. (2009). LECO – Energibruk i fem kontorbygg i Norge. Befaring og rapportering. (In English: LECO - Energy consumption in five office buildings in Norway). Oslo, SINTEF Byggforsk. **48**: 165.
- Guren, E. F. (2013). Håndtering av usikkerhet i tidligfase av bygg- og anleggsprosjekt (In English: Managing Uncertainty in the Early Phase of Construction Projects). Trondheim, Norway, Norges teknisk-naturvitenskapelige universitet (NTNU). **M. Sc. thesis**.

Güth, W. (1995). "Shirking versus managerial incentives of chief executive officers (CEOs): A note on a possible misunderstanding of the principal-agency-theory." Journal of Institutional and Theoretical Economics (JITE)/ Zeitschrift für die gesamte Staatswissenschaft: 693-698.

Haase, M. and A. Amato (2005). Development of a double-skin facade system that combines airflow windows with solar chimneys The 2005 World Sustainable Building Conference, Tokyo: 8.

Hackman, J. R. O., Greg R. (1976). "Motivation through the design of work: Test of a theory." Organizational Behavior and Human Performance **16**(2): 250–279.

Hampson, K., et al., Eds. (2014). R&D investment and impact in the global construction industry. CIB, Routledge.

Hampson, K. D., et al. (2013). Investing for impact: construction a better built environment. Bentley, Australia, Sustainable Built Environment National Research Centre (SBEnc): 28.

Hannele, K., et al. (2012). "Expanding uses of building information modeling in life-cycle construction projects." Work **41 Suppl 1**: 114-119.

Hansen, G. K., et al. (2011). USEtool evaluating usability. Methods handbook. Trondheim, Norwegian University of Science and Technology.

Hansen, G. K., et al. (2005). Case study: Nord-Trøndelag University College, Nylåna, Røstad, Norway. CIB Task Group 51 Usability of workplaces. Trondheim, SINTEF and NTNU

Hansen, G. K. and W. Knudsen (2006). Usability – a matter of perspective? The case of Nord Trøndelag university college. CIB W70 Changing user demands on buildings. Trondheim, Norway.

Harris, R., et al. (2003). "Design and construction of the Downland Gridshell." Building Research & Information **31**(6): 427-454.

Hauge, Å. L., et al. (2011). "User evaluations of energy efficient buildings: Literature review and further research." Advances in Building Energy Research **5**(1): 109-127.

Hendriks, C. M. and J. Grin (2007). "Contextualizing reflexive governance: The politics of Dutch transitions to sustainability." Journal of Environmental Policy & Planning **9**(3-4): 333-350.

Hicks, J. (2011). "The Facility Manager's Role." Retrieved July 5, 2014, from www.sustainablefacility.com.

Hjalager, A.-M. (1999). "Interorganizational learning systems." Human Systems Management **18**(1): 23-33.

Hobbes, T. (1651 / 1999). Leviathan, or, The matter, forme, and power of a common-wealth, ecclesiasticall and civill. Hamilton, Ont, McMaster University

Holm, I. (2006). Ideas and beliefs in architecture and industrial design: How attitudes, orientations, and underlying assumptions shape the built environment., Oslo School of Architecture and Design.

Holte byggsafe (2008). Bedre Bygg Billigere. Sluttrapport. Oslo, Byggekostnadsprogrammet: 28.

Hovde, P. J. (2004). Bærekraftig infrastruktur, grunnlag for et satsingsområde. Trondheim, NTNU, ITV.

Hovde, P. J. (2008). Project description: Knowledge base and tools for development and management of a sustainable infrastructure, NTNU.

Hunt, J. and T. Townshend (2011). Climate change: self-interest may save us. Guardian Newspaper: 25.

Håkansson, H. and M. Ingemansson (2012). "Konkurransen som hinder for innovasjon og teknisk fornyelse i byggenæringen (In English: Competition as a hindrance for innovation and technical renewal in the construction industry)." Magma 7: 52-61.

Håkansson, H. and M. Ingemansson (2013). "Industrial renewal within the construction network." Construction Management and Economics 31(1): 40-61.

IEA (2010). From demonstration projects to volume market, IEA.

IEA (2013). Transition to Sustainable Buildings -- Strategies and Opportunities to 2050.

Indraprastha, A. and M. Shinozaki (2012). "Computational models for measuring spatial quality of interior design in virtual environment. ." Building and Environment 49(1): 67-85.

International Organization for Standardization (1998). ISO 9241-11 Ergonomics of human system interaction. Switzerland, International Organization for Standardization.

International Organization for Standardization (2008). Sustainability in building construction - General principles. Switzerland, International Organization for Standardization. **ISO 15392:2008**.

Jensen, M. C. and K. J. Murphy (1990). "Performance pay and top-management incentives." Journal of Political Economy April: 225-264.

- Jensen, P. A. (2009). "Design integration of facilities management: A challenge of knowledge transfer." Architectural Engineering and Design Management **5**(3): 124-135.
- Johannessen, J.-A. and B. Olsen (2008). Positivt lederskap. Jakten på de positive kreftene. (In English: Positive leadership. Raiders of the positive forces). Bergen, Fagbokforlaget.
- Johnson, B. and L. Christensen (2004). Educational research: Quantitative, qualitative, and mixed approaches, research edition. Boston, Pearson Education Inc.
- Johnson, R. B. and A. J. Onwuegbuzie (2004). "Mixed methods research: A research paradigm whose time has come." Educational researcher **33**(7): 14-26.
- Jonassen, D. H. and W. Hung (2008). "All Problems are not equal: Implications for problem-based learning." Interdisciplinary Journal of Problem-Based Learning **2**(2).
- Jonassen, J. O. (2010). Report on integrated practice. Changing business models in BIM-driven integrated practice Seattle, WA, American Institute of Architects (AIA).
- Kadefors, A. (2004). "Trust in project relationships—inside the black box." International Journal of Project Management **22**(3): 175-182.
- Kash, D. E. and R. Rycroft (2002). "Emerging patterns of complex technological innovation." Technological Forecasting and Social Change **69**(6): 581-606.
- Kemp, R., et al. (1998). "Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management." Technology Analysis & Strategic Management **10**(2): 175-195.
- Kemp, R. and H. van Lente (2011). "The dual challenge of sustainability transitions." Environmental Innovation and Societal Transitions **1**(1): 121-124.
- Kerosuo, H., et al. (2013). Knotworking – a novel BIM-based collaboration practice in building design projects. Proceedings of the 5th International Conference on Construction Engineering and Project Management ICCEPM: 1-7.
- Klakegg, et al. (2011). Management Culture in the Norwegian Construction Industry: Why can't we learn? or can we? (not published).
- Knotten, V., et al. (2014). Integrated methodology for design management - a research project to improve design management for the AEC industry in Norway. 22nd annual conference of the international group for lean constructon - IGLC22. B. T. Kalsaas, L. Koskela and T. A. Saurin. Oslo. **3**.

Kommunal- og moderniseringsdepartementet (2011–2012). Meld. St. 28: Gode bygg for eit betre samfunn. Ein framtidretta bygningspolitikk (In English: The national policy on building). Oslo.

Krapmeier, H. (2011). Strategi for bærekraftig utvikling og klimagassreduksjon i byggsektoren i Østerrike og Vorarlbergregionen (In English: A strategy for sustainable development and greenhouse gas reduction in construction sector in Austria and the Vorarlberg region). Passivhuskonferansen 2011, Oslo, AINTEF.

Kupritz, V. W. (2002). "The relative impact of workplace design on training transfer." Human resource development quarterly, **Winter**, **13**(4): 427-447.

Kuvaas, B. (2008). Prestasjonsbasert belønning og motivasjon. (In English: Performance-based reward and motivation). Lønnsomhet gjennom menneskelige ressurser. Evidensbasert HRM. (In English: Profitability through Human Resources. Evidence based HRM). B. Kuvaas. Bergen, Fagbokforlaget.

Kvale, S. (1996). InterViews: An Introduction to Qualitative Research Interviewing, Sage.

Kvale, S. (2006). Det kvalitative forskningsintervju. (In English: The qualitative research interview). Oslo, Gyldendal norsk forlag.

Larssen, A. K. (2011). Bygg og eiendoms betydning for effektiv sykehusdrift - Buildings Impact on Hospital Effectiveness. Trondheim, Norwegian University of Science and Technology (NTNU). **PhD thesis**.

Larssen, A. K. and S. Bjørberg (2004). User need/demands (Functionality) and adaptability of buildings - a model and tool for evaluation of buildings. CIB W70 conference. Hong Kong.

Larsson, N. (2002). The integrated design process. National Workshop. Ottawa, Natural Resources Canada.

Latham, M. (1994). Constructing the team. London, HMSO.

Lave, J. and E. Wenger (2003). Situated learning: Legitimate peripheral participation, Cambridge University Press.

Lavenergiprogrammet (2007-2015). "Lavenergiprogrammet (In English: The Low Energy Programme)." Retrieved June 1, 2015, from <http://www.lavenergiprogrammet.no/om-lavenergiprogrammet/>.

Lavenergiprogrammet (2014). Strategy for the Low Energy Programme 2013 - 2015. Oslo: 19.

Lawler III, E. E. (1990). Strategic pay: Aligning organizational strategies and pay systems. San Francisco, CA, US, Jossey-Bass.

Lawson, B. (2010). "Healing architecture." Arts & Health: An International Journal for Research, Policy and Practice **2**(2): 95-108.

Leaman, A. (2000). "Usability of buildings: the Cinderella subject." Building Research and Information **28**(4): 296-300.

Leaman, A. and B. Bordass (2007). "Are users more tolerant of "green" buildings?" Building research and information **38**(6): 662-673.

Lees, T. and M. Sexton (2014). "An evolutionary innovation perspective on the selection of low and zero-carbon technologies in new housing." Building Research & Information **42**(3): 276-287.

Lehtiranta, L. (2014). "Risk perceptions and approaches in multi-organizations: A research review 2000–2012." International Journal of Project Management **32**(4): 640-653.

Leiponen, A. (2012). "The benefits of R&D and breadth in innovation strategies: a comparison of Finnish service and manufacturing firms." Industrial and Corporate Change **21**(5): 1255-1281.

Lichtenberg, S. (2000). Proactive management of uncertainty using the successive principle : a practical way to manage oppurtunities and risk, Polyteknisk Press.

Likert, R. (1961). The New Patterns Of Management. New York, McGraw-Hill

Love, P., et al. (2011). "Risk/reward compensation model for civil engineering infrastructure alliance projects." Journal of Construction Engineering and Management **137**(2): 127-136.

Lysen, E. H. (1996). The Trias Energica: solar energy strategies for developing countries. Eurosun Conference 1996.

Lützkendorf, T., et al. (2011). "Engaging financial stakeholders: opportunities for a sustainable built environment." Building Research & Information **39**(5): 483-503.

Löhnert, G., et al. (2002). "Integrated design process", a guideline for sustainable and solar-optimised building design, Task 23,. Berlin, IEA.

Mackley, C. J. and S. Milonas (2001). "Knowledge transfer and Green Building Challenge. ." Building Research & Information **29**(5): 346 - 354.



Marja Rasila, H., et al. (2009). "Workplace experience – a journey through a business park." Facilities **27**(13/14): 486-496.

Marshall, N. (2006). Understanding power in project settings. Making projects critical. D. Hodgson and S. Cicmil. Basingstoke, Palgrave Macmillan: 207-231.

Marsick, V. J. (2009). "Toward a unifying framework to support informal learning theory, research and practice." Journal of Workplace Learning **21**(4): 265-275.

McLennan, P. (2000). "Intellectual capital: future competitive advantage for facility management." Facilities **18**(3/4): 168-172.

McLeod, A. (2008). Sustainability in the construction industry. A white paper. Durham, UK, Waterstone.

Meadows, D. H., et al. (1972). The limits to growth. New York, NY, Universe Books.

Meehan, J. and D. Bryde (2011). "Sustainable procurement practice." Business Strategy and the Environment **20**(2): 94-106.

Meistad, T. and L. Obolonska (2010). Knowledge transfer within the building industries. Litterature review for ZEB NTNU, Meistad Mentoring.

Meistad, T. and L. Strand (2013). Powerhouse One - erfaringer med å utarbeide konseptet for et nullenergi-bygg. ). ZEB Project report. Trondheim, SINTEF Academic press. **11**.

Miljøverndepartementet (2013). Fra avfall til ressurs. Avfallsstrategi (In English: From waste to resource. Strategy for waste). Oslo.

Miljøverndepartementet (2014 - 15). Meld. St. 13: Ny utslippsforpliktelse for 2030 – en felles løsning med EU (In English: Climate policy for Norway). Oslo.

Mokhlesian, S. M. H. (2012). "Business model changes and green construction processes." Construction Management and Economics **30**(9): 761-775.

Moore, D. R. and A. R. J. Dainty (2001). "Intra-team boundaries as inhibitors of performance improvement in UK design and build projects: a call for change." Construction Management and Economics **19**: 559-562.

Morris, P. and J. Pinto (2004). The Wiley guide to managing projects. New Jersey, John Wiley and sons.

Mosbeck, K. (2004). Workspace. Organizational goals & physical environments. . Denmark, Karen Mosbeck.

Mumford, E. (2006). "The story of socio-technical design: reflections on its success, failures and potential." Journal of Info Systems **16**: 317-342.

Müller, L. (2014 ). From law to turnkey. Negotiating sustainability in buildings. Faculty of Humanities, Department of Interdisciplinary Studies of Culture. Trondheim, Norwegian University of Science and Technology. **Ph. D. thesis**: 187.

Naoum , S. (2003 ). "An overview into the concept of partnering " International Journal of Project Management **21**: 71-76.

Neenonen, S. (2005). The nature of the workplace for knowledge creation. Turku, Turku Polytechnic. **doctoral dissertation.**

Newsham, G. R., et al. (2009). "Do LEED-certified buildings save energy? Yes, but...." Energy and Buildings **41**(8): 897-905.

Nicol, F. and S. Roaf (2005). "Post-occupancy evaluation and field studies of thermal comfort." Building Research & Information **33**(4): 338-346.

Nicol, L. A. (2011). "The role of institutional regimes in motivating change for sustainable housing." Building Research & Information **39**(5): 459-472.

Nielsen, J. and D. A. Norman (2000). Web-site usability: Usability on the web isn't a luxury. InformationWeek.

Nijstad, B. A., et al. (2010). "The dual pathway to creativity model: Creative ideation as a function of flexibility and persistence." European Review of Social Psychology **21**(1): 34-77.

Nonaka, I. and H. Takeuchi (1995). The knowledge creating company. New York, Oxford University Press.

Nordhaug, O., et al. (2008). Ledelse for fremtiden: et humanistisk perspektiv (In English: Leadership for the future: a humanistic perspective). Oslo, Forlag1.

Nordvik, V. (2011). Evaluering av Husbankens grunnlån til oppføring. (In English: Evaluation of the Basic Mortgage offered by the Norwegian State Housing Bank). Sandvika/Oslo, Asplan Viak AS /NOVA.

Nærings- og handelsdepartementet (2008-2009). St. Meld. 7: Et nyskapende og bærekraftig Norge (In English: An Innovative and Sustainable Norway). Oslo.

O'Neill, K. J. and D. C. Gibbs (2013). "Towards a sustainable economy? Socio-technical transitions in the green building sector." Local Environment **19**(6): 572-590.

Oates, D. and K. T. Sullivan (2012). "Postoccupancy energy consumption survey of Arizona's LEED new construction population." Journal of Construction Engineering and Management **138**(6): 742-750.

OECD (1996). The knowledge based economy. Paris, Organisation for Economic Co-operation and Development (OECD).

OECD (2011). Towards green growth, Organisation for Economic Co-operation and Development (OECD).

OECD (2013 ). What have we learned from attempts to introduce green-growth policies? OECD Green Growth papers.

Olsen, H. (2002). Dansk kvalitativ interviewforskning Kvalitet eller kvaler? København, The Danish National Institute of Social Research. **Arbejdsrapport 11**: 94.

Olsson, N., et al. (2010). Who is the User? . CiB W70 International Conference in Facilities Management. "FM in the Experience Economy". São Paulo, Brazil. **Publication number 336**.

Onkila, T. J. (2009). "Corporate argumentation for acceptability: reflections of environmental values and stakeholder relations in corporate environmental statements. ." Journal of Business Ethics **87**(2): 285-298.

Orange, G., et al. (2000). The facilitation of cross organisational learning and knowledge management to foster partnering within the uk construction industry. ECIS 2000.

Osterloh, M. and B. S. Frey (2000). "Motivation, knowledge transfer, and organizational forms." Organization Science **11**(5): 538-550.

Oyedele, L. O. (2010). "Sustaining architects' and engineers' motivation in design firms." Engineering, Construction and Architectural Management **17**(2): 180-196.

Ozaki, R., et al. (2012) The coproduction of "sustainability". Negotiated practices and the prius. Science, Technology and Human values

Ozaki, R., et al. (2013) The negotiated consumption of sustainability. Social Science Research Network

- Pathirage, C., et al. (2008). "Knowledge management practices in facilities organisations: a case study." Journal of Facilities Management **6**(1): 5-22.
- Paul, R. J., et al. (2000). "Empowerment, expectations, and the psychological contract—managing the dilemmas and gaining the advantages." The journal of Socio-Economics **29**: 471-485.
- Pitt, M. and M. Tucker (2008). "Performance measurement in facilities management: driving innovation?" Property Management **26**(4): 241-254.
- Porter, M. E. (1998). "Clusters and the new economics of competition." Harvard business review **76**(6): 77-90.
- Porter, M. E. and C. v. d. Linde (1995). "Toward a new conception of the environment-competitiveness relationship." Journal of Economic Perspectives **9**(4): 97-118.
- Preiser, W. F. E. and U. Schramm (2002). "Intelligent office building performance evaluation." Facilities **20**(7/8): 279-287.
- Pruitt, D. G. (1971). "Choice shifts in group discussion: An introductory review." Journal of Personality and Social Psychology **20**(3, Dec): 339-360.
- Pryke, S. D. (2004). "Analysing construction project coalitions: exploring the application of social network analysis." Construction Management and Economics **22**(8): 787-797.
- Pryke, S. D. (2005). "Towards a social network theory of project governance." Construction Management and Economics **23**(9): 927-939.
- Rahman, M. and M. Kumaraswamy (2004). "Potential for Implementing Relational Contracting and Joint Risk Management." Journal of Management in Engineering **20**(4): 178-189.
- Rasila, H., et al. (2010). "Dimensions of usability assessment in built environments." Journal of Facilities Management **8**(2): 143-153.
- Regjeringen.no (2008-2014). "Framtidens byer (In English: Cities of the future)." Retrieved 1 June, 2015, from <https://www.regjeringen.no/no/tema/kommuner-og-regioner/by--og-stedsutvikling/framtidensbyer/id547992/>.
- Regjeringen.no (2011). "Framtidens byer (In English: Cities of the future)." Retrieved 1 June, 2015, from <https://www.regjeringen.no/en/topics/municipalities-and-regions/by--og-stedsutvikling/framtidensbyer/cities-of-the-future/id548028/>.

- Reve, T. and A. Sasson (2012). Et Kunnskapsbasert Norge (In Norwegian). Oslo, Universitetsforlaget.
- Robson, C. (2011). Real World Research, John Wiley and sons.
- Roethlisberger, F. J. (1977). The elusive phenomenon: An autobiographical account of my work in the field of organizational behaviour at the Harvard Business School. Boston, Harvard University Press.
- Rogers, E. M. (1962 / 2003). Diffusion of innovations. New York, NY: Free Press.
- Roloff, J. (2008 ). "Learning from multi-stakeholder networks: issue-focussed stakeholder management." Journal of Business Ethics **82**(1): 233-250.
- Rose, P. and J. Kim (2011). "Self-monitoring, opinion leadership and opinion seeking: A sociomotivational approach." Current Psychology **30**(3): 203-214.
- Rose, T. and K. Manley (2010). "Client recommendations for financial incentives on construction projects." Engineering, Construction and Architectural Management **17**(3): 252-267.
- Rotmans, J. and R. Kemp (2008). "Detour ahead: a response to Shove and Walker about the perilous road of transition management." Environment and planning **4**: 1006-1014.
- Rousseau, J. (2002). The social contract: And, the first and second discourses, Yale University Press.
- Russell, A. D., et al. (2006). "Project innovation - a function of procurement mode?" Canadian Journal of Civil Engineering **33**(12): 1519-1537.
- Ryan, R. M. and E. L. Deci (2000). "Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being " American Psychologist **55**(1): 68-78.
- Salter, A. and D. Gann (2003). "Sources of ideas for innovation in engineering design." Research Policy **32**(8): 1309-1324.
- Sartori, I. and A. G. Hestnes (2007). "Energy use in the life cycle of conventional and low-energy buildings: A review article." Energy and Buildings **39**(3): 249-257.
- Saumure, K. and L. M. Given (2008). Data Saturation. The SAGE Encyclopedia of Qualitative Research Methods. L. M. Given, SAGE: 196-197.
- Savitz, A. W. and K. Weber (2006). The Triple Bottom Line: How today's best-run companies are achieving economic, social and environmental success -- and how you can too, Jossey-Bass.

Schot, J. and F. W. Geels (2008). "Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy." Technology Analysis & Strategic Management **20**(5): 537-554.

Schot, J. and A. Rip (1996). "The past and future of constructive technology assessment." Technological Forecasting and Social Change **54**: 251-268.

Schumpeter, J. A. (1943). Capitalism, socialism, and democracy, Routledge.

Schwandt, T. A. (2015). The Sage dictionary of qualitative inquiry, Sage Publications.

Scofield, J. H. (2009). "Do LEED-certified buildings save energy? Not really...." Energy and Buildings **41**(12): 1386-1390.

Scott, W. R. (2001). Institutions and organizations. Thousand Oaks: CA, Sage.

Scott, W. R. (2004). Institutional theory: Contributing to a theoretical research program Great minds in management: The process of theory development. K. G. Smith and M. A. Hitt. Oxford UK, Oxford University Press.

Shelbourn, M., et al. (2007). "Planning and implementation of effective collaboration in construction projects." Construction Innovation **7**(4): 357-377.

Shove, E. (2012). "The shadowy side of innovation: unmaking and sustainability." Technology Analysis & Strategic Management **24**(4): 363-375.

Shove, E. and G. Walker (2007). "Caution! Transition ahead: politics, practice, and sustainable transition management." Environment and planning **39**: 763-770.

Smith, A. (2007). "Translating sustainabilities between green niches and socio-technical regimes." Technology Analysis & Strategic Management **19**(4): 427-450.

Sorrell, S. (2009). "Jevons' Paradox revisited: The evidence for backfire from improved energy efficiency." Energy Policy **37**(4): 1456-1469.

Spurkeland, J. (2009). Relasjonsledelse. Oslo, Universitetsforlaget.

Stake, R. E. (1995). The art of case study research, Sage.

Standard Norge (2013). "Rapport om BIM, OPS og samspill (In English: Report on BIM, PPP and partnering)." Retrieved December, 2014, from <https://www.standard.no/nyheter/nyhetsarkiv/kontrakter-og-blanketter/2013/rapport-om-bim-ops-og-samspill/>.

Steele, J. and M. Murray (2004). "Creating, supporting and sustaining a culture of innovation." Engineering, Construction and Architectural Management **11**(5): 316-322.

Støre-Valen, M., et al. (2014). "Buildings' impact on effective hospital services: The means of the property management role in Norwegian hospitals." Journal of Health Organization and Management **28**(3): 386-404.

Sydow, J., et al. (2009). "Organizational path dependence: Opening the black box." Academy of Management Review **34**(4): 689-709.

Szulanski, G. (2002). Sticky knowledge: Barriers to knowing in the firm, Sage publications.

The Global Commission on the Economy and Climate (2014). Better Growth, Better Climate. The New Climate Economy Report.

Thomsen, J., et al. (2013). "The interaction between building and users in passive and zero-energy housing and offices: The role of interfaces, knowledge and user commitment." Smart and Sustainable Built Environment **2**(1): 43-59.

Thomsen, J., et al. (2011). User evaluations of energy efficient buildings. The interplay of buildings and users in seven European case studies. ZEB Project report. Trondheim, Norway, SINTEF Academic Press. **1 - 2011**.

Trist, E. and K. Bamforth (1951). "Some social and psychological consequences of the longwall method of coal getting." Human Relations **4**: 3-38.

Turner, C. and M. Frankel (2008). Energy performance of leed® for new construction buildings. Vancouver, New Buildings Institute (NBI) and U.S. Green Building Council (USGBC),.

Ulseth, P. O. and K. P. Sanila (2013). Bygg21 – Datagrunnlag for bransjestrategier, Faveo.

UN (1987). Our common future. Report of the World Commission on Environment and Development, United Nations.

UN (1997). "Kyoto Protocol to the United Nations framework convention on climate change." United Nations Framework Convention on Climate Change (FCCC). Retrieved May, 2015, from <http://unfccc.int>.

UNEP (2008). Common carbon metric for measuring energy use & reporting greenhouse gas emissions from building operations. Sustainable Buildings & Climate Initiative (SBCI): 26.

UNEP (2009). Buildings and climate change - summary for decision-makers. Sustainable Building and Climate Initiative. Paris, UNEP: 62.

Valen, M., et al. (2010). Barriers and bridges in construction processes. IPMA conference 2010.

Valen, M. S. and N. O. E. Olsson (2012). "Are we heading towards mature facilities management in Norwegian municipalities?" Journal of Facilities Management **10**(4): 287-300.

Van den Dobbelsteen, A. A. J. F. (2004). The Sustainable Office. An exploration of the potential for factor 20 environmental improvement of office accommodation. Architecture. Copie Sjop, Delft, Delft University of Technology: 520.

van Marrewijk, A., et al. (2014). "Changing collaborative practices through cultural interventions." Building Research & Information **42**(3): 330-342.

Victor, B. and A. C. Boynton (1998). Invented here: Maximising your organisation's internal growth and profitability. Boston, Harvard Business School Press.

von Hippel, E. (1994). "'Sticky information" and the locus of problem solving: Implications for innovation." Management Science **40**(4): 429-439.

von Zedtwitz, M. and O. Gassmann (2002). "Market versus technology drive in R&D internationalization: four different patterns of managing research and development." Research Policy **31**(4): 569-588.

Walker, W. (2000). "Entrapment in large technology systems: institutional commitment and power relations." Research Policy **29**: 833-846.

Warren-Myers, G. (2012). "The value of sustainability in real estate: a review from a valuation perspective." Journal of Property Investment & Finance **30**(2): 115-144.

Weick, K. E. and F. Westley (1996). Organizational learning: Affirming an oxymoron. Handbook of organizational studies. S. R. Clegg, C. Hardy and W. R. Nord. London, Sage Publications: 440-.

Weiss, J. (2008). Business ethics: A stakeholder and issues management approach, Cengage Learning.

Wenger, E. (1999). Communities of practice. Learning, meaning and identity. Cambridge, Cambridge University Press.



West, J. and S. Gallagher (2006). "Challenges of open innovation: the paradox of firm investment in open-source software." R&d Management **36**(3): 319-331.

Whyte, J. and M. Sexton (2011). "Motivations for innovation in the built environment: new directions for research." Building Research & Information **39**(5): 473-482.

Winter, M., et al. (2006). "Directions for future research in project management." International Journal of Project Management **24**(8): 638-649.

Woerdman, E. (2004). "Path-dependent climate policy: the history and future of emissions trading in Europe." European Environment **14**(5): 261-275.

Yin, R. K. (2009). Case study research: Design and methods, Sage Publications.

Young, M. (2001). "Contextualising a new approach to learning: Some comments on Yrjö Engeström's theory of expansive learning." Journal of Education and Work **14**(1): 157-161.



SECTION II

PAPERS



Paper no 1

Meistad, T. and Støre Valen, M. (2012):

**“Adding value and sustainability by involving facility managers in design phase. A preliminary study of Norwegian pilot projects of energy efficient buildings”,**

*CIB conference “Delivering Value to the Community”, Cape Town 22nd - 25th January 2012*



# **ADDING VALUE AND SUSTAINABILITY BY INVOLVING FACILITY MANAGERS IN DESIGN PHASE. A PRELIMINARY STUDY OF NORWEGIAN PILOT PROJECTS OF ENERGY EFFICIENT BUILDINGS.**

**Torill Meistad<sup>1</sup> and Marit Støre Valen<sup>2</sup>**

<sup>1</sup> *Phd student, Dep. of Civil Engineering and Transport. [www.ntnu.no/bat](http://www.ntnu.no/bat), Norwegian University of Science and Technology (NTNU)*

<sup>2</sup> *Associate Professor (Dr ing.), Dep. of Civil Engineering and Transport. [www.ntnu.no/bat](http://www.ntnu.no/bat), Norwegian University of Science and Technology (NTNU)*

Improving long term value and sustainability in built assets are among the challenges facing the construction industry. Integrating facility management in early planning of new construction projects has the potential of adding value to the result. This is a preliminary project exploring the issue for further studies as part of a doctoral thesis. The research material is interviews with informants from three case studies in Norway. Two of the cases are especially ambitious regarding energy efficiency. The material is explored and analyzed in relation to a literature review. We found involvement of facility managers in the design process have a positive effect on the energy performance of the building. Early involvement and system integration are among the identified key success factors. Finally the paper explores the knowledge management approach regarding this issue.

Keywords: involvement, environment, energy use, organizational learning.

## **INTRODUCTION**

One of the challenges facing the construction industry is the challenge of improving long term value and sustainability of built assets. Analysis of life cycle costs and benefits from buildings have gained new interest due to focus on energy and environment implications of manmade infrastructure. In search for potential improvements, clients are turning to facility management, to include operation and maintenance in planning of construction and rehabilitation projects.

### **Value of FM knowledge**

Gradually more investors and clients plead the importance of incorporating knowledge on maintenance and operation in early design. Building projects often have a clear distinction between the project phase (design and construction) and the user phase (management, operation and maintenance). Over the life cycle of the facility expenses for operation and maintenance may far exceed the initial costs. Decisions made at an early stage in the project strongly affect the operation of the building and the life cycle costs. Incorporating knowledge on maintenance and operation at an early stage will therefore make a difference on the long run (Dahl et al, 2005). Analysis of money

---

<sup>1</sup> [torill.meistad@ntnu.no](mailto:torill.meistad@ntnu.no)

## Design involvement

flows indicates that even small efforts to improve operation conditions have implications for the total result (Due, 2011).

### **Value of early involvement**

There are a variety of suggestions on how knowledge on operation, cleaning and maintenance can be taken into consideration at an early stage in construction projects. In Norway the discussion has been fuelled by reports of nationwide insufficient maintenance on public infrastructures (RIF, 2009).

The growing interests for green building have led to methods evaluate the impact of design features in the perspective of the life cycle of a facility. Energy modelling and Life cycle cost (LCC) analysis are among the methods (Dahl et al, 2005).

### **Knowledge management**

Facility managers are about to become recognized as key competence holders. Their expertise is gaining new interest for the purpose of green construction and maintenance. However there is still some way to go for this knowledge to be recognised. A study reveals that knowledge and specialization is high among FM personnel. However there is a lack of formal training opportunities (Damgaard & Erichsen, 2009)

In a knowledge management perspective FM knowledge is recognized as being at infant stage of development. It still needs greater internal and external coherence to many organizations; it has few secure methods of its own to underpin good practice and is insufficiently supported by an adequate knowledge base (Baharum & Pitt, 2009). It is expected that knowledge management within FM will develop following the FM maturity stages; recognition of importance, formulation of strategy, implementation of techniques, and evaluation of performance (Baharum & Pitt, 2009)

### **Structure of the paper**

This paper presents a preliminary study exploring value and methods for including facility management in design planning. The purpose is to develop fruitful research questions for a doctoral study on how the construction industry learn and develop towards a more sustainable practice.

Our hypothesis is that project owners experience positive effects of FM involvement to the design and performance of the buildings. Our research question is how do FM involvements improve the results, especially energy efficiency.

The paper presents findings from interviews with key informants from pilot projects. The material is analyzed in relation to international literature

The final section is a discussion summing up findings on how FM involvement affects energy and environment issues in construction projects. We also add the organizational learning perspective as a potential theoretical approach to explore for further studies on this subject.



## **MATERIAL AND METHODS**

Three construction projects<sup>2</sup> are included in the material (see table 1).

Project 1 is an office buildings in an industrial development site in Trondheim located close to the technical university and a major traffic route to the town centre. This is the third step in the development plan at the site by the same owner over a ten years period.

Project 2 is localized in central Trondheim and includes an historical building. The owner has high ambitions for innovative solutions on heating and ventilation.

Project 3 is localized in one of the new suburbs in Trondheim. The project is initiated by an ambitious local athlete club, who organize most of the activities using the facility. It became a prestige project for local politicians, and the national sports confederation that is among the funders.

All project owners have separate FM departments. The facility management department were represented in the project planning teams on Project 1 and 2, but not in Project 3.

---

<sup>2</sup> Here we focus on the characteristics of the projects without identifying them individually. This is due to confidentiality to our informants.

## Design involvement

*Table 1: Construction projects*

	Project 1	Project 2	Project 3
Owner	Investment and real estate company	Regional bank	Municipality
Purpose of facility	Offices and meeting facilities for tenants. "The green building"	Offices, conference facilities for bank head quarter. Offices and shopping space for tenants.	Athlete sports hall
Total cost	235 mil NOK	550 mil NOK	64 mil NOK
Energy consumption	Total net energy consumption: 114 kWh/m <sup>2</sup> pr year. Including: Heating and ventilation 9 Cooling 8 Lighting 25 Technical equipment 34 Total imported energy: 94 kWh/m <sup>2</sup> pr year	Total net energy consumption: 89 kWh/m <sup>2</sup> pr year. Including: Heating 6 Cooling 8 Ventilation 4 Technical equipment 57	(Numbers not available)
Energy improvements	Area efficiency Automation Extra insulation Energy saving equipment Thermic mass Re-using heat Passive solar heating	Low leaking shell Thermic mass Re-using heat	Extra insulation Low window areas Low leaking shell Low volume
Sustainability improvements	Balanced ventilation Diffusion open construction Humidity regulating materials Low emitting materials Facilities for pedestrians and bikers	Balanced ventilation Building integrated ventilation Humidity regulating materials "Clean house" construction process Reusing desposing materials	Flexible interior solutions Deposit of polluted ground masses
Comments	Pilot project supported by ENOVA <sup>3</sup> . New construction	Partly new, partly rehabilitation	The first specialized sports facility of its kind in the country. New construction.

<sup>3</sup> A Norwegian public advisory and supportive agency promoting environmentally friendly restructuring of energy consumption and energy generation. Give financial and consultancy support.

Our informants include partly representatives for facility management and partly representatives for the main construction company (see table 2). FM informants were part of the planning team for project 1 and 2. For all projects they are in charge for daily operation and energy measuring. Informants from the construction companies were respectively project manager and design managers of the construction projects.

*Table 2: Informants*

	FM representatives	Construction company representatives
Project 1	1 informant	2 informants
Project 2	1 informant	2 informants
Project 3	2 informants	2 informants

The interviews were partly performed face to face and partly on telephone. Construction company representatives were interviewed together for each project while FM representatives were interviewed individually. Interviews were performed following an interview guide covering the main issues of the study and lasted for 30-60 minutes each. Data were collected partly January 2011 and partly September-October 2011.

The interview guide includes the following variables:

- \* Organization of design phase
- \* Role of involved FM representative
- \* Means to reach energy ambitions
- \* Experiences and recommendations

Other additional material that has been studied is written project documents, presentations and reports, guided tours and oral presentations of the projects. This includes facts on energy, environmental and performance ambitions, construction concepts, materials and energy solutions, and also measured energy performance.

## **FINDINGS**

Here we present findings from the interviews. At this explorative stage of the study, we focus on the spectre of criteria our informants are concerned about. Here we present the types of arguments in use, first from the group of FM representatives, and then from the group of construction company representatives.

Some arguments are shared among the informants while others vary among projects and informants. Possible reasons for this will be explored in the discussion section.

### **Facility management representatives**

#### *Purpose and priorities of the projects*

The overall purpose for project owners and the FM representatives can be summarized as quality. This includes functionality, comfort and flexibility for the users of the buildings. Good indoor environment has first priority for the two office buildings. Similarly good performance facilities are crucial for the sports facility. This has implications for choice of materials, design plan, light, ventilation and heating/cooling. The challenging part of the projects has been to find solutions integrating all these elements. One of the elements is energy efficiency. In all projects the ambition was to set a new standard regarding energy efficiency. Another element is choosing materials with a long service life, low operation costs and also with low emissions.

All projects are using architectural elements to signal harmony with the surroundings. It'll be wood on facades and interior walls, zinc and copper that will change colour due to surface oxidation, and windows that allow all rooms to have visible contact with natural light and the outdoor view.

Finally, the economical aspect has set the limits for quality ambitions and alternative solutions. The three projects illustrate in practice the triple bottom line principle for sustainability (Savitz & Weber, 2006), by balancing environmental considerations, responsibility to the society and healthy long term economy for the facilities.

One of the consequences is the focus on space efficiency in the projects<sup>4</sup>. The owners have considered how indoor space can be used for multi-purposes, such as removable sport facilities and stages in the sports hall. Space for offices and shops can easily be prepared for new tenants. Parking space is reduced in favour of space for outdoor sports activities, parking for bicycles and easy entrance to public transport. This is solutions that reduce environmental footprint, meets new standards of urban planning and have positive effect for the project budget.

#### *The design process*

The FM informants of the pilot projects reports that they have been involved in the design process and have been able to influence the decision making to a high degree. Due to the energy efficiency ambitions the operation departments in these projects have had a key role in the project leading teams, and their competence has been crucial in discussions on construction concept. All three projects had ambitions for passive house or low energy house standard. As a part of the design process there were performed calculations and analysis regarding energy efficiency for alternative concepts. In one case there were performed an additional analysis on greenhouse gas

---

<sup>4</sup> Examples of conceptual solutions that are chosen due to energy and environmental improvements: a) A high degree of office landscapes. Free seating means better use of space for businesses where employees work part time out of the building. b) Multipurpose rooms where walls, furniture and other equipment easily can be changed. c) Routines to fully turn off all computers, printers and other energy users at night

emissions<sup>5</sup>, and this was conclusive in the question on rehabilitation of existing facilities or not.

After completion all FM informants have been actively involved in monitoring and adjusting operations of the facility. It is a shared experience that the first year of operation of a new building always needs an introduction period.

For all the cases the client put extra effort into design phase. This was done partly by establishing multi professional teams of engineers and architects to work out alternative design concepts. Partly by including technical researchers, testing in laboratories and visiting other projects in other regions and countries. Consensus on concept and design plan is reported to be crucial for navigating through practical problems and dilemmas as they occurred during the construction phase.

#### *Key success factors*

For the moment<sup>6</sup> all projects have been in operation for one year or more. Energy measurement reports indicate that all three buildings have succeeded regarding their energy ambitions. The informants were asked to reflect on the reasons for this success, and eventually on intentions that were not reached.

Ambitious and thorough project works have been performed by all parties. In case of the two pilot projects our informants emphasize the importance of the “hands on” attitude from owners in innovative projects.

Integrated concept is another key success factor. The key question in all decision making have been: How to fulfil the main purpose of the facility with a satisfying level of quality and with high energy efficiency.

Also education of the users and the operation personnel is among the success criteria. Tenants and each single employee have been educated on the energy and environmental visions, how the building facilities operates and implications for day to day use.

Throughout the process the primary users have been informed about the plans, and later there were user questionnaires and energy performance statistics. In one case the project management involved “ambassadors” among the employees to present their plans and get feedback. Our informants are convinced such communication have put energy and performance of the new facility on the agenda among the users, with a positive effect for energy consumption.

Monitoring and analyzing energy performance is vital to learn and adjust. There are a number of metering points for the individual purposes and sections of the buildings. Based upon day by day (and partly hour by hour) registrations there have been adjustments to improve performance. Operation personnel are adjusting the systems due to planned activities weather forecasts. Systems for central operation control have been calibrated. Standard computers have been replaced by low energy computers, even for tenant companies. Employees are educated to turn off all machinery instead of using stand by modus.

---

<sup>5</sup> Therefore there was performed an energy analysis, considering the two alternatives at all stages in the life cycle, and including both materials, operation, development and maintenance for a period of 60 years (Rønning & Vold, 2008)

<sup>6</sup> During the period of interviews, fall 2011

## Design involvement

There also seems to be an element of competition regarding energy efficiency. This is an underlying subject in all interviews. Facility managers are eager to find energy leaks and waste, improve routines and performance, to continually optimize the results. Owners of pilot projects proudly present the energy results for customers and the public.

### **Construction company representatives**

Our informants representing the construction companies all got involved at a stage when the overall plans were set for the building.

All our informants emphasize that their company has a positive attitude to challenges. They are attracted to ambitious projects where they have to look for new solutions to fulfil the specifications and develop their own competence, whether it concerns energy and environmental purposes or engineering and architectural issues. Some illustrating examples: How to build a concrete construction combining structural and temperature buffering qualities? What central operation control system will ensure recycling of heat and healthy ventilation under varying activities under changing weather conditions? Handling of waste and use of energy at the construction site were among the challenging specifications in the two pilot projects. The construction companies are proud to report close to 100 per cent recycling or reuse of waste materials and a low level of sickness absence during the construction period. An additional effect of the Clean Construction Site initiative is that the contractors experienced more efficient work at the site, due to better overview and better logistics. Sub-contractors reported better economic results which is an additional motivation to continue the initiative in future projects.

### **Literature review**

This review covers published studies on involving FM in the design phase of a construction project. While some of the studies focus on how to involve FM personnel in the process, others focus on the effects for environmental sustainability for the facility.

There are three types of issues that the literature is covering. The issues are dealing with a) status of FM knowledge, b) structures for construction projects, c) communication among involved actors.

Studies on FM knowledge are concerned with the lack of status and formal competence. In general the care takers and cleaning personnel do not have a high status in the facilities where they are working. These functions are often outsourced. The specific FM knowledge is the understanding of the relationship between the performance of the physical resources and their impact on the end-users. This type of knowledge can be difficult to access since it is often tacit and experimental in nature (McLennan, 2000). This might explain the lack of awareness among project owners of including this knowledge resource (Larssen, 2011).

Construction projects are complicated and fragmented processes. The many actors involved at different stages are found to hinder effective interaction between parties involved (Valen, Klakegg, & Hustad, 2010). Among the potential solutions suggested by scholars are project models including operation and long term perspective. Design-

Build-Operate-Maintain (DBOM)<sup>7</sup> delivery system and other partnership models are expected to bring critical operations and maintenance knowledge into design (Dahl et al, 2005, Damgaard & Erichsen, 2009).

Ineffective communication and collaboration is found to be among the barriers for quality and efficiency in the construction industry. This is a challenge due to the number of actors with partly varying priorities. Shared objectives, openness and clear responsibilities/roles are suggested as possible improvements (Valen et al, 2010). Within project management there is increasing interest for the relational aspects of professional team processes. Teamwork based upon trust and shared understandings are particularly important to be able to exploit tacit knowledge, such as FM experience (Damgaard & Erichsen, 2009).

## **DISCUSSION**

### **Experienced relevance of FM involvement**

The study presented in this paper is in an explorative stage. The purpose is to explore if and how involvement of facility managers in design affects the final construction, especially regarding environmental issues.

First of all, our material indicates that early involvement is crucial to reach ambitions for energy and environmental issues. To implement these issues professionals with operation and management knowledge have to be part of the initial concept considerations. In this concern our preliminary study is supported by previous research on the issue.

However, our material also indicates that energy and environment has to be kept high on the agenda also during later stages in a construction project. Especially this is crucial in situations of conflicting goals. The owner of Project 2 seems to be aware of this challenge, and insisted on consensus in the project team in all decisions. Doing in consent have similar effects as partnership contracts when it comes to sharing goals for all actors involved in construction projects (Bresnen & Marchall, 2000).

Secondly, the experience from our case studies is that involvement of FM personnel has had positive effects on the results. FM representatives have provided practical experience to the design teams for the two pilot projects.

However, good energy performance results in all three projects indicate that involving facility managers is not the only element that matters. Also tools such as energy calculations and Life Cycle Analysis have added facts to the decision making process, favouring environmental friendly alternatives. In all cases specialized advisory engineers were involved at all phases. This indicates that in addition to FM personnel there are other sources to operation and energy performance knowledge. There is reason to believe that all these sources have provided insight that have convinced the owner and the design team that the visions were possible to reach.

Thirdly, involvement of FM expertise has had positive effects for the construction project in general. Among the added values is the project economy. In all cases the

---

<sup>7</sup> In this system the owner develops a conceptual plan (eventually involving architect and engineers) for a project, then there are solicited bids from contractors on design, build, operations and maintenance of the completed project.

## Design involvement

interest for energy performance is part of a strategy for improving life cycle economy of built assets. For instance reuse of heating and cooling energy which contribute positively both to environmental footprint and operation economy. Another added value is positive effects for indoor environment, due to low emission materials and noiseless ventilation<sup>8</sup>. The crucial question however is the long term performance of the constructions regarding the purpose they were built for. This might be possible to explore in a future study.

Finally, involvement of facility managers is no guarantee for all environment issues to be taken care of. For instance energy use in manufacturing of building materials is not a focus in these projects. All in all, involving FM personnel at an early stage have had a positive effect for energy efficiency in the facilities. This is partly because their skilled competence influenced decisions in the design phase. And partly because involved FM personnel have developed good insight in the construction that is useful for operating the building in the use phase. As a bonus effect FM personnel express interest in the challenge of continual improvements. In facilities like this, with ambitious energy plans and expectations as role models for future constructions, this might be of major importance.

### **Findings related to literature review**

FM knowledge and especially the lack of formal competence are emphasized in previous studies. The FM informants in our case studies all have a high level of formal competence. They have relevant education at university level, and more than ten years of experience from construction processes. Our impression is that they have been trusted allied of the clients. This implies increased status for FM considerations and has been important for energy and environmental goals, and thereby bridges one of the barriers highlighted in previous studies.

Early involvement and extensive team work is reported in our case studies. Especially in innovative projects, where risks are higher than in ordinary projects, collaboration at an early stage is crucial to reveal and deal with conflicting purposes and solutions. Also previous studies have identified lack of shared understandings of aims and objectives as a barrier for development and improvements within the construction industry (Valen et al, 2010).

The involvement process has been given a lot of time and resources in these projects. Professionals with different specialties have exchanged ideas and arguments in a process that has led to a high degree of shared understanding of the main purposes of the project. In addition the process has been innovative and resulted in constructions that entirely fulfil multi purposes. This has been possible without organizing formal partnerships or altering other structures. Traditional procurement models have been used and given good results, contradictory to experiences in other studies. A possible explanation for this is the clients ability to specify the project in advance of the engineering phase, including specifications for energy, operation and environment.

Both informant groups are concerned about how to organize a good design process. All cases report adjustments on the way, either bringing in supplementary members or exchanging persons. There is a shared opinion among our informants that a good team

---

<sup>8</sup> Low pressure under floor ventilation (UFV)



makes a huge difference. In two projects the client is reusing the core team and develops the concept from one project to the next. Previous studies have enlightened how the project based nature of the construction activity is a barrier for taking high performance teams further (Cheng, 2009) (Haapalainen, 2008). Experiences in our case studies are highly interesting to explore further in relation to these previous studies.

### **Findings in an organizational learning perspective**

The explorative case studies presented in this paper indicates that involving experienced FM personnel is of high value in projects with high ambitions regarding environment effects and energy efficiency. In further studies we will explore whether or not this knowledge makes a difference in other construction projects and in the practice of the organizations that make up the construction industry: Do construction companies, consultants and architects change practice? What about the clients? And what are the main drivers for change? For this purpose we like to focus on the organizational and industrial level of knowledge management. Especially how FM knowledge and early participation in pilot projects affect practice in the industry in general.

Organizational learning is an area within organizational theory studying the way organizations learn and adapt. Models and theories within this tradition might be fruitful for further studies on impacts of FM involvement. In this final section we present some potentially fruitful theoretical contributions and illustrate how our preliminary findings might be analyzed further.

a) The four stage model of organizational learning presented by (Nonaka & Yakeuchi, 1995) represents an approach differing from traditional ideas of organizational efficiency. The essence of the model is a) the dynamics of tacit knowledge becoming explicit and vice versa, and b) the dynamics between knowledge at the individual level and at the organizational level. Nonaka presents organizational learning as a continual process, a spiral path from socialization to externalization, combination, internalization, new socialization and so on<sup>9</sup>.

In our cases the FM representatives proudly share their insight, and thereby their knowledge is being socialized into a broader group of professionals. Via analytical skills operators are able to externalize their tacit knowledge into explicit engineering knowledge. In the operation stage they combine their constructional insight with skilled experience to continually prepare the building for optimal performance. In our projects all employees have been involved in the high performance ambitions via energy performance reports and feedback routines. This internalization of performance knowledge to end-users has contributed to results.

b) Nonaka & Yakeuchi also indicated that there are certain preconditions for knowledge developing organizations. Of special interest is "redundance" – overlapping information and activities among the actors. This precondition implies insight in the knowledge of the other actors (Nonaka & Yakeuchi, 1995). This is

---

<sup>9</sup> Socialization – sharing tacit knowledge to others. Externalization - transforming tacit knowledge into explicit knowledge that is codified, systematic and formal. Combination – dissemination of codified knowledge, developing it further. Internalization – when employees internalize an organisation's formal rules and procedures.

## Design involvement

found to be of special importance in innovative processes, as is the case for the two pilot projects in our study. Our informants emphasize the extra efforts made to create dedicated design teams, such as sharing offices, negotiate all solutions and create a good atmosphere for the team to perform well.

c) An alternative model of preconditions for organizational learning is Senge' model of the five key disciplines of a learning organization (Senge, 1990)<sup>10</sup>. Of special interest is the system thinking. In our case studies it is obvious that system thinking has been the key to the high performance facilities. The functions of the buildings are highly integrated, especially using, producing, distributing and storing energy. Similarly the design teams were organized to create shared visions for the projects.

## CONCLUSIONS

This preliminary study has proven our hypothesis of positive effects of FM involvement to the design and performance of the buildings.

This paper shed light on how FM involvement improves the results. Based upon three case studies we have explored involvement of facility managers in the design phase of construction projects.

Our main findings are as follows:

- a) To achieve energy efficiency in new construction projects these ambitions have to be implemented at the design stage and given priority in situations of conflicting goals.
- b) Involving the facility department in the design team has positive effect on energy performance in the operation phase. Such exchange of knowledge contributes both to the design and to the daily operation.
- c) FM involvement also has positive effects for the indoor climate and the projects life cycle economy.
- d) Involvement of entrepreneurs and sub-contractors in the ambitions for energy efficiency also have additional positive effects, increasing progress, saving production costs and gaining additional competence among all employees.

Our preliminary findings will be used as hypothesis in further studies. Partly we will explore the role of ambitious owners in pilot projects as well as engaged FM roles and construction parties. And partly we will study the relation between FM involvement and energy efficiency in construction projects in general. This preliminary study emphasise system thinking as a key to high performance facilities, and this approach will be explored further.

---

<sup>10</sup> Senge's idea is to destroy the illusion that the world (or a construction project) is created of separate, unrelated forces. When giving up this illusion we can build learning organizations where people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning how to learn together." (Senge, 1990:3)

## REFERENCES

- Baharum, M. R. and M. Pitt (2009) "Determining a conceptual framework for green FM intellectual capital." *Journal of Facilities Management* 7.4: 267-282
- Bresnen, M. and N. Marchall (2000) "Partnering in construction; A critical review of issues, problems and dilemmas." *Construction Management and Economics* 18.2: 229-237
- Cheng, M. (2009) "Research on the Knowledge Transfer in Construction Projects." IEEE 16th International Conference on industrial engineering and engineering management. IEEE. 2035-2039.
- Dahl, P, M: Pohlman, T Horman and M Paluski (2005) "Evaluating Design-Build\_Operate\_Maintain Delivery as a tool for sustainability." Proceedings of the Construction Research Congress 2005: Broadening Perspectives. San Diego, USA: ASCE.
- Damgaard, T. and P., B. Erichsen (2009) "Implementation of operation in construction". Odense: Syddansk Universitet (In Danish)
- Due, P. H. (2011) "Value adding construction process. Operation knowledge in the construction process." September 29. [www.vaerdibyg.dk](http://www.vaerdibyg.dk). (In Danish)
- Haapalainen, P. (2008) "Organisational learning in projects: case construction industry." *International journal of Technology Intelligence and Planning* 4.4: 480-491.
- Larssen, A., K. (2011) "Buildings' Impact on Hospital Effectiveness". PhD thesis no 170. Trondheim: NTNU.(in Norwegian)
- McLennan, Peter (2000) "Intellectual capital: future competitive advantage for facility management." *Facilities* 18.3/4: 168-172.
- Nonaka, I. and H. Yakeuchi (1995) *The Knowledge Creating Company*. New York: Oxford University Press.
- RIF - The Norwegian advisory engineering association (2009) "State of the Nation".
- Savitz, Andrew W. and Karl Weber (2006) "The Triple Bottom Line: How Today's Best-Run Companies Are Achieving Economic, Social and Environmental Success - and How You Can Too." Jossey-Bass.
- Senge, P. M. (1990) "The fifth discipline: The Art and Practise of the Learning Organisation." New South Wales: Random House Australia.
- Valen, M. S., O. J Klakegg and S. Hustad (2006) "Barriers and Bridges in Construction Processes." IPMA conference proceedings 2010.



Paper no 2

Meistad, T., Støre Valen , M. , Lohne, J. (2013):

**“Use of collaborative working in construction projects with high energy ambitions”**

*7th Nordic conference on construction economics and organization, “Green urbanization – implications for value creation”, 12 – 14 June 2013*



## USE OF COLLABORATIVE WORKING IN CONSTRUCTION PROJECTS WITH HIGH ENERGY AMBITIONS

**Abstract.** *Norwegian construction industry is challenged to improve energy efficiency. However changes are slow. This paper redefines the problem as organizational, and explores the use of collaborative working as a means to overcome the challenge. Three role model projects with extra high energy ambitions are being analyzed. They are all new office buildings, completed in 2009-2010 by professional property developers. The concepts include combinations of technical solutions that had not previously been used in Norway at the time of completion, and they all achieved prizewinning results. Case studies include interviews with key informants from planning stage in addition to available project descriptions. Findings are that the projects include more extensive multi-professional collaboration than traditional construction projects. Lab-tests, energy and LCA analysis are among the means being used. So are partnering contracts with contractor and green tendering contracts. The relevance of extraordinary collaboration is partly to reduce risks, partly to pool knowledge and partly to improve the results. Our findings are supported by previous studies of innovative and complex projects within various industries. In conclusion extensive collaboration among highly skilled professionals had vital importance for reaching the record beating energy performance of the buildings in the role model projects.*

KEY WORDS: energy performance, collaboration, role model projects

### 1. INTRODUCTION

#### 1.1 The problem in general

Due to concern for future resource consumption and the global climate, international political initiatives strive for energy efficiency. The EU Directive on energy implies gradually more strict regulations for energy efficiency of new and refurbished buildings. As for Norway the technical requirements will become gradually stricter, and will imply passive house level within 2020. For this purpose there are a number of initiatives to promote improvements. Among these is the public support to role model projects with outstanding ambitions regarding energy. Role model projects focus on developing and testing new solutions, and are developing knowledge and skills required for the new construction practise. Experiences are shared among practitioners throughout the industry.

Within the industry there are experiences showing that the passive house ambition can be reached with conventional materials and methods (Mirza 2006), basically by improving quality of the work. However the change of practise is slow. A challenge is that the extra investment costs may hinder realization of energy efficient buildings even if operation costs might defend the investment in the long run. All in all, high energy performance asks for development within the industry to find solutions meeting the new requirements.

#### 1.2 The problem redefined as organisational

Over the last couple of decades the construction industry has developed a backlog compared to other industries regarding quality and productivity. This issue has been addressed by

the Latham and Egan reports in UK (Latham 1994, Egan 1998) and by Byggekostnadsprogrammet in Norway (Norwegian government 2004). Among the obstacles identified in the literature for improvement are organizational characteristics of the industry; project to project co-operation (Orange, Boam and Burke 1998). Complexity due to the large number of professions involved in the production chain, project-based teams and the large number of small enterprises are found to be barriers to lean production (Egan 2002) and innovation (Valen et al 2010) in the industry. The pattern of loose couplings between the actors seems to favour short-term productivity while hampering innovation and learning (Dubois and Gadde 2001). In addition the traditional system commonly implies conflict, hostility and litigation between contractors (Bishop et al 2009).

All in all organisational barriers between the professions and enterprises involved in the planning process are found to cause under-performance in the industry. In our view the same characteristics may be a barrier to improve energy efficiency and environment sustainability in construction projects.

### **1.3 Collaborative working as a means to overcome the challenge.**

Collaborative working is an alternative model to the traditional one. The notion of collaboration covers a wide range of organisational forms. In general collaborative working methods imply models for various actors (persons or enterprises) working jointly. This can be a formalized partnership or informal co-operation. In the context of the construction industry the concept covers models that differ from the traditional serial-organized design process.

In various industries collaborative working models have proved to be useful in solving new problems. To focus on a common product or service to be created a temporary collective of disparate partners may come together. In fruitful innovative processes there are observations that the participants move from a position of simple co-ordination according to occupational scripts to full co-operation and open communication. The development process may be supported by an external facilitator and “boundary crossing laboratories” or other methods. During the process the parties learn expansively from each other. However professional divisions, ingrained practices and identification boundaries are found to be challenging for the communication (Engeström et al 1999, Bishop et al 2009).

Among the collaborative working models are various forms of partnering. Partnering may be defined as a long-term commitment between two or more parties in which shared understanding and trust develop for the benefits of improving construction (the Construction Industry Institute 1991). In general collaboration is found to be beneficial in complex construction projects. In the oil industry partnering is used as a tool for stimulating performance gains and innovation (Barlow 2000). Partnering is also found to stimulate research uptake in the construction industry (Reve, Sasson et al. 2012). Partnering contracts are becoming gradually more widely used in the Norwegian construction industry. An example is the refurbishment and additional new buildings in one of the largest Norwegian hospitals (St. Olavs hospital in Trondheim). After experiencing major challenges during building no 1 the client choose partnership contracts and more collaborative working methods for building no 2 (Trondheim Chamber and Lean Construction Norway 2012).

Research on organisational cooperation in project management is in general scarce (Morris & Pinto 2004, Winter et al 2006). This is also the case regarding the construction industry, where research focus on project management rather on strategic cooperation and long term development (Aarseth 2012).



Bishop et al (2009) has performed an empirical study of collaborative working in the construction industry. The study examines two competing systems of work organization in the British construction industry: The traditional productive system is characterized by institutionalized conflict and incentivized hostility. According to Bishop et al such a system militates against development and knowledge sharing. A competing collaborative working system is suggested by Bishop. In such systems contractors share risks, pool knowledge and work together to solve problems.

#### 1.4 Purpose

Constructing buildings with high energy performance have similarities to solving new issues or complex projects in the way that there are no pre-existing solutions to how to solve the problem. We expect that traditional productive systems are not suitable for pilot projects. Based upon previous studies we expect that collaborative working systems are being used in construction projects with goal breaking energy ambitions.

In this paper we analyse the planning process of recent Norwegian role model construction projects. The purpose is to explore the use of collaborative working models and the relevance for reaching the high ambitions.

The research questions are as follows:

- a) Identify different collaborative characteristics in planning phase of the projects.
- b) Explore how collaboration is relevant for reaching the high energy performance.

Finally the paper discusses the implications for general improvement of performance in the construction industry.

## 2 MATERIAL AND METHODS

Role model projects are defined as such because they have ambitions to reach energy and environmental performance beyond requirements in public regulations and far beyond reference buildings. Role model projects demonstrate solutions for buildings of the future regarding low energy consumption and use of renewable energy sources<sup>1</sup>. The Norwegian public enterprise which promotes sustainable energy production and consumption (ENOVA) give consultancy and financial support to role model projects. While some role model projects are individual buildings others are urban development projects. Criteria for role model projects within urban development is that they represent considerable reductions in greenhouse gas emission from transportation, materials and energy consumption compared to today's practise<sup>2</sup>. Status as role model project also implies special attention from the public due to promotion in media and news reports among architects, entrepreneurs and the construction industry in general.

Selecting role model projects for the case study is due to their strategically interest. Basically the projects are similar to other construction projects. However they are deviant due to the high energy ambitions. In our analysis role model projects are considered as "critical cases" (Flyvbjerg 2004) based on the following argument: If collaborative work models are found beneficial in construction projects with high energy ambitions, then such models can be beneficial also in other construction projects.

---

<sup>1</sup> [www.enova.no](http://www.enova.no).

<sup>2</sup> [www.Futurebuilt.no](http://www.Futurebuilt.no)

## 2.1 Case studies

This paper includes three examples of Norwegian role model projects. They are all developed by private property developers. They include mainly offices, and with one exception only for tendering businesses. The example buildings are small to medium size building projects. The projects were completed in 2009 and 2010, in a period when Energy Label system and Passive House Standard were still not fully developed in Norway. All three projects had goal breaking energy ambitions at their time and proved able to reach them. Some basic facts on the projects are presented in table 1. The projects are listed according to date of completion. Energy concepts vary, and will be commented on in the case presentations.

Table 1: Case projects, facts

Project	Location and year of completion	Calculated total net energy consumption <sup>3</sup>	Calculated delivered energy	Area
The environmental building	Trondheim, September 2009	114 kWh per m2 and year	94 kWh per m2 and year <sup>4</sup> .	16 394 m2
Sparebank1	Trondheim, October 2010	100 kWh per m2 and year	85 kWh per m2 and year.	22 000 m2
The Bellona building	Oslo, October 2010	83 kWh per m2 and year.	68 kWh per m2 and year <sup>5</sup> .	3 200 m2

## 2.2 Material

Material on the case projects includes written project presentations and reports in addition to interviews with key actors. Number and roles of informants differ from project to project, and is summarized in table 2.

Data collection focuses on the planning stage of the projects, since this is where major conceptual decisions are taken, with important implications for the energy performance.

Data are partly primary data from interviews and partly secondary data from oral and written project presentations, interviews, magazine articles and reports. Interviews were performed during 2011, recently after the projects were completed. A structured interview guide was developed for the purpose, and interviews lasted up to one hour. Interviews were combined with a guided tour in the buildings. Table 2 contains an overview of the number and roles of informant of the example projects. Written documentation is referred to in the paper text.

<sup>3</sup> Based on ISO 3031

<sup>4</sup> KLP prospect and ENOVA.no

<sup>5</sup> Aspelin Ramm and FutureBuilt (2012): LCA for the Bellona building.

Table 2: Informants

Project	Number of interviewees	Roles of informants
1. The environmental building	3	Client/property developer, entrepreneur
2. Sparebank1	3	Clients project leader, entrepreneur, technical consultant
3. The Bellona building	3	Owner/property developer and project leader, environmental organisation (lessee)

### 2.3 Analysis

The case studies are used in an explorative way. Our interest is on how a fragmented industry is able to use untraditional working models to reach goal breaking results.

Previous research on industrial collaboration emphasizes some general characteristics which can be summarized as follows:

- Simultaneous work across professional borders in early planning.
- Use of tools for improving communication
- Formal agreements on sharing risks and benefits

Firstly the paper will explore to what degree and in what forms these characteristics are present in the case projects.

Secondly the paper explores what are the arguments for using collaborative models in construction projects with high energy ambitions. We analyse what benefits that are experienced by our informants, and how they consider the relevance for the project results. Based upon existing studies referred in the introduction, there are basically three strategically arguments for extensive collaboration: Solve problem/improve results, pool knowledge, and share costs, risks and benefits.

## 3 PRESENTATION OF CASE PROJECTS

The first decade of the new millennium witnessed a flow of energy efficient pilot construction projects in Norway. The three case projects to be presented here are among these: The Environmental building, Sparebank1 headquarter and Bellona house. They are all built with high energy ambitions and for the purpose of industrial and service activities. The presentation will focus on the planning phase of the projects, the energy ambitions and elements of collaborative working models.

### 3.1 The Environmental building

The Environmental building is the third in a serial of three commercial buildings called the Techno city. The former industrial area is developed into an office area by a professional property developer.

The planning process started in the 1990ies, with a workshop on improving environmental performance. A number of concepts have been considered and valuable experience has been gained from the first building to the next.

Techno City host commercial activities related to technology and innovation. Strategy of the property owner is to apply to environmental conscious tender businesses. For this purpose “green tenant contracts” are introduced<sup>6</sup>. The ambition is to build facilities with outstanding energy efficiency and environmental qualities. The property developer had the ambition that The Environmental building should become the first role model building in the city. “Norway’s most energy efficient office building” was the slogan when the building was completed in 2009.

The building itself do not look spectacular, due to compact construction. However a red “cherry” or sun at the entrance is a signal of energy. Partly standing out of the wall the red ball is drawing the attention of people passing by, and at the same time has the function as an auditorium (see figure 1). The energy performance is reached mainly by passive energy saving measurements. This includes a building with a compact body with a green garden in the middle of the building and a high degree of heat generation, including regenerating heat from cooling of computer rooms.

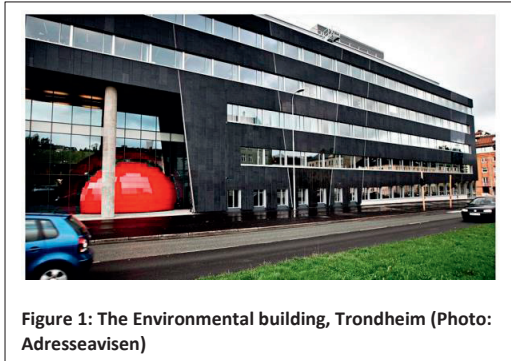


Figure 1: The Environmental building, Trondheim (Photo: Adresseavisen)

The planning phase of the Techno City differs from traditional construction projects by involving researchers to present optional energy solutions and to verify their performance. Scientists specialising on indoor environment, natural light, materials, ventilation and temperature regulation has added supplementary knowledge to the traditional planning team. In planning each of the buildings national and international scientists contributed to calculate and lab test solutions that were not currently in use in existing Norwegian office buildings.

In designing the Environmental building the client drew upon experience from the first two buildings, using the same personnel in the planning team. Also some of the contract partners have previously been involved in Techno City. In operation stage the property owner co-operate with future leasing companies and facility management personnel. After completion performance of the building is monitored, partly by continual and detailed energy measuring, and partly by user satisfaction questionnaires. These measurements are used in improving the management systems for lightning, heating and ventilation.

The property owner reports that collaboration with researchers and leasing companies has been crucial to develop office buildings for energy conscious lessees. During the process environmental sustainability has become part of the company’s profile.

### 3.2 Sparebank1 headquarters, Trondheim

The headquarters of the regional bank was considered for renovation or replacement. To upkeep status as an attractive financial partner for the construction industry and others, the bank wanted to state an example for others regarding business properties for the future. The built facilities should reflect the long term perspective of real estate values, and therefore be of high quality, have a long life time and still be down to earth. The construction project was part of a process to reorganize the banking activity. This included more collaboration across the units and

<sup>6</sup> <http://www.miljobygget.no/>

to trim the bank to improve the ability to respond to changes. The new facilities should reflect the strategical values of flexibility, environment, efficiency and technology. The architectural competition invited for «...a building for the future, both for the bank, for the employees and for Trondheim as a city»<sup>7</sup>. The winning application suggested a basic principle including energy efficiency, indoor environment and urban environment elements (see figure 2).

The project includes two interconnected buildings in the central city. One is more than a hundred years old and the other is less than forty. The considerations regarding energy performance and environmental implications were more extensive than for traditional refurbishment projects. Energy analysis and Life cycle assessment (LCA) analysis concluded that replacement of the 1970 office building is the most environmental sustainable alternative (Rønning and Vold 2008, 2009).

The buildings are partly used for the bank activities and partly for leasing shops and offices.

The original 1882 bank building is upgraded to a high energy efficiency standard and restored with historic design, for the purposes of representation, a museum and a restaurant. The new building consists of six interconnected bodies with high performance insulation, sun shading, ventilation and heat recovery systems. Energy consumption is reduced to one sixth of the former situation<sup>8</sup>, and also indoor climate and area flexibility is improved considerably. Among the innovative solutions is Under Floor Ventilation (UFV) that was being used for the first time in Norway. Combined with the thermal buffering qualities of exposed concrete, the system implies very low energy requirements for ventilation and heating.

The owner insisted on close co-operation between all parties involved in early planning. Therefore the consultant engineers, architect and the construction entrepreneur shared project office over a period of six months. According to the partnering contract<sup>9</sup> they worked together to find the optimal solutions, materials and technologies to reach the ambitions for the project. Researchers were involved to calculate and lab test heat buffering capacities. Employees were involved during planning and first year of operation to improve indoor climate and awareness of daily energy consumptions.

After completion the project has been honoured with Trondheim municipality's Energy Award. Also a local banking office has been built based upon the concepts developed for the Sparebank1 headquarters.

### 3.3. The Bellona building, Oslo

The project is the first in a row transforming a former manufacturing industry area into an urban township with offices, hotel, restaurants and apartments. Originally the market strategy was to focus on culture based industries, including education, music, food and arts. Due to demands



Figure 2: The Sparebank1 headquarters (Photo: Agriff)

<sup>7</sup> <http://www.arkitektur.no/?nid=178913&tid=158202>

<sup>8</sup> 585 kWh per m<sup>2</sup> and year

<sup>9</sup> NS 3431 . Replaced by NS 8407 in 2011.

from potential leasing businesses the property developer adjusted the strategy to include environmental aspects. An environmental organization was among the future lessees, and wanted to focus especially on environmental qualities of the building. Initiative from this organisation resulted in a close co-operation with the property developer.

The vision was to build the most energy-efficient buildings as possible within the commercial framework, and with energy label A in mind. During the process, the ambitions extended to the building's overall environmental impact, focusing on, among other LCA analysis of materials<sup>10</sup>. Early in the process there was multi-disciplinary collaboration to meet the requirements, with a focus on energy design and energy calculations. An external, independent energy advisor has followed the project from the drawing board to execution. The environmental organisation has contributed with environmental and engineering expertise throughout planning, and also in adjustments related to indoor climate after completing of construction.

Among the experiences are that the high energy performance is the result of calculations on all aspects of the building performance, and focusing on energy in all decisions. The passive energy saving measures are the most important, especially airtightness, high insulation values, efficiency of energy recovery system, thermal effects of exposed concrete ceiling and a system of sensors controlling heating and lighting in the building. The building fulfills passive house standards, even if they were not available at the time of planning. In addition the building produce energy from solar collectors and is connected to a local energy central drawing energy (heating and cooling) from heating wells at the Vulkan area.

Completed by the end of 2010, The Bellona building became the country's most energy efficient office building. The building kept the record for two years before another building managed to beat the record. The building is also the first completed within the national initiative Future Built<sup>11</sup>. The building was awarded the City prize 2012<sup>12</sup> (see figure 3).

The property developer has further developed the solutions from this building to the other buildings at the property. All buildings at the property are connected to a shared energy and heating central, with a network of heat collectors at the buildings and ground heating pumps at the property.

The non-governmental organization has since been active in public discussions and political hearings on how to improve environmental performance in the building sector, based upon their experience with the new building.



Figure 2: The Bellona building (photo: Aftenposten)

## 4 FINDINGS

### 4.1 Collaborative characteristics

All three role model projects are found to use more extensive collaboration than for traditional construction projects. Forms and degree varies among the case projects. Characteristics of collaborative working in each case project is summarised in table 3.

<sup>10</sup> <http://www.arkitektur.no/?nid=205920&filter=keyfigures&pid1=151851>

<sup>11</sup> It was also entered into partnership with Future Built in autumn 2009, which committed the project to follow FutureBuilt's quality of requirements to reduce greenhouse gas emissions from energy, transport and materials.

<sup>12</sup> <http://www.aspelinramm.no/artikkel.aspx?id=39>

Table 3: Collaborative characteristics in case projects

Project	Simultaneous work across professional boarders	Tools for improving communication	Formal agreements on sharing risks and benefits
The Environmental building	<ul style="list-style-type: none"> <li>Experienced project manager and technical professionals employed at property developer</li> <li>Workshops with scientists and international experts.</li> <li>Involving experienced facility management personnel</li> </ul>	<ul style="list-style-type: none"> <li>Learning from previous building stages</li> <li>Monitoring and adjusting operation of the building</li> </ul>	<ul style="list-style-type: none"> <li>Green tendering contracts</li> </ul>
Sparebank1	<ul style="list-style-type: none"> <li>Six months of simultaneous work in multi-professional team during concept phase</li> <li>Involving employees</li> <li>Involving facility management</li> <li>Involving scientists and external expertise</li> </ul>	<ul style="list-style-type: none"> <li>Visiting international reference projects</li> <li>Lab testing of technical solutions</li> <li>Simulation models</li> <li>Continual metering, evaluation and following up actual energy consumption</li> <li>External energy and LCA calculations.</li> </ul>	<ul style="list-style-type: none"> <li>Partnering contract with contractor, architect and consultants during concept phase.</li> <li>Engaged external controller, one on construction and one on technical solutions</li> </ul>
The Bellona building	<ul style="list-style-type: none"> <li>Establishing a multi-professional team at an early stage</li> <li>Kick-off meeting with sub-contractors and suppliers</li> </ul>	<ul style="list-style-type: none"> <li>Using the new public Greenhouse gas emission calculator<sup>13</sup> for LCA analyses</li> <li>Developing document package for environmental documentation</li> <li>Monitoring and adjusting operational systems</li> </ul>	<ul style="list-style-type: none"> <li>Green tendering contracts with leasing enterprises</li> <li>Partnering contract with contractor</li> <li>Engaged external controller on environment and energy issues.</li> </ul>

As for simultaneous work in multi-professional teams, this has been crucial in all case projects. Sparebank1 is the most extreme, where all consultants physically shared office during a six months period during concept development. In the Sparebank1 project employees have been involved. Facility management personnel were involved both in the Sparebank1 project and the Environmental building. There have been various forms of workshops, however without external facilitators and experimental workshop methods as suggested in studies referred to in the introduction of this paper.

All projects are using tools for communication and documentation. Lab tests and visits at reference projects abroad were done during planning of the Sparebank1 headquarters. Similarly

<sup>13</sup> [www.klimagassregnskap.no](http://www.klimagassregnskap.no)

this was done before building stage 1 and 2 of the Techno City, prior to The Environmental building. Energy and greenhouse gas emission analysis were performed for Sparebank1 and the Bellona building. The Bellona building project was the only one developing a tool for environmental documentation for sub-contractors. All three projects are monitoring actual energy performance during operation and adjust operation and practice to improve the results.

All case projects have formalized the collaboration. Partnering contract during concept development is used for Sparebank1 and the Bellona Building. Green tendering contracts are used for leasing partners in The Environmental Building and in the Bellona Building. Such contracts are long term based and formalize shared responsibility between property owner and lessee respectively for building performance and user performance, implying a generally higher level of rent combined with lower energy costs.

External expertise is engaged in all the case projects, partly to give input during planning stage, and partly as independent evaluators during the process.

#### **4.2 Relevance of collaboration for energy performance**

Informants involved in all three case projects have experienced benefits from the extensive collaboration. Arguments from the role model projects are reflecting the rationales for collaboration that is found in previous studies (Bishop et al 2009): sharing risks, pool knowledge and solve problems.

Share and reduce risks are the purpose of partnering contracts with contractors, green tendering contracts and external consultants evaluating the process. Such tools formalize the collaboration and include incentives to reach the results agreed upon. In addition the tendering contract implies sharing long term benefits from the high quality facilities.

Pooling knowledge is done by establishing the multi-professional teams at an early stage. These teams define the preconditions and framework for the project. The case studies include a broader and more extensive teamwork than traditionally, including external expertise on energy and environment and even key role leasing enterprises. Kick-off meeting with sub-contractors and suppliers are examples of extraordinary means to pool and share knowledge and understanding for the high energy ambitions in the case projects.

To solve the task or even improve results we find that extraordinary measurements are used in the case projects. External energy and greenhouse gas emission analysis are among these. Recently developed tools for LCA calculations were used for this purpose. Developing a system for contractors to collect environmental documentation from sub-contractors and suppliers are among the means to improve problem solving in the case projects. Also Lab tests and visits to reference projects abroad are among the means being used in the case projects.

All in all informants in the case projects report that extra time and extra costs are used during the planning phase compared to traditional construction projects. Extra resources and means are used to present and consider alternative solutions. However our informants also report that the thorough problem solving process has resulted in a shared understanding of the task which is not necessarily the case in traditional planning processes. This in effect has saved time during design and construction work and resulted in high quality work and good performance of the building.



## 5 DISCUSSION

Our material reveals that grade and form of collaboration differs according to the conditions. However extensive collaboration during planning seems to be a preferred strategy in projects where the energy ambitions are far beyond previous experience of property developer. This finding is supported by previous studies on organizational co-operation in innovative or complex projects (Larssen 2011).

All case projects have been through a phase of scepticism related to the high energy ambitions. During early planning there were major concerns regarding extra costs and lack of experience compared to potential benefits. The ability to convince the rest of the team at this critical phase has been of vital importance for the further process. Willingness to spend extra resources during concept stage is a common characteristic among the three role model projects. This finding implies that there may be other property developers in other projects during the same period that may have had to give up on their energy ambitions at this critical stage.

An unexpected observation during our case studies is that the high energy ambitions were not part of the original plan for the projects, but came as a result of a process. As for Sparebank1 it was suggested as part of the winning architectural concept. As for the Bellona Building the future tenderer was insisting. The Techno City included environmental aspects and modern technology from the beginning, but energy ambitions became specific due to the tendering contract with the national agency for sustainable energy (ENOVA). Our findings are in accordance with previous studies where collaborating teams, for the purpose of creating complex products and improve efficiency, have re-conceptualised the objective itself. This is found within the construction industry (Bishop 2009) as well as other sectors (Engström 1999).

All three case projects are part of step by step learning processes. Bellona and Sparebank1 were pilot projects for the property developers, while The Environmental building draws experience from previous buildings of the Techno City. Our material indicate that the thorough process of the initial projects establish professional teams which can perform further projects without extensive collaborative work methods. This is due to the relation building effect of collaborative development projects (Aarseth 2012) and the learning effect from when a partnership can build on experiences from one project to another (Engström 2004). Our findings are in accordance to the strategic value of collaboration that has previously been emphasized for the construction industry (Egen 1998, Norwegian Government 2004).

## 6 CONCLUSION

The main conclusion from our findings is that collaborative working processes carried out in an adequate manner significantly contribute to reach outstanding energy ambitions. This implies that collaborative working also may contribute to improve performance in the construction industry in general. Relation building and learning effects contribute to strategic value of collaboration.

An additional conclusion is that collaborative working is not sufficient to improve performance. Our findings imply that there has to be skilful and enthusiastic stakeholders involved that are able property to convinced the client about market potential and long term economy to go for the high energy ambitions. In our cases the status as role model projects by ENOVA and FutureBuilt has been encouraging, and so has the energy awards.

However our research is limited to a set of Norwegian case projects. Further studies should be performed before our conclusions can be transferred to the industry in general.

There is a need for further studies on how experiences from role model projects affect the construction industry in general. One issue is whether solutions for high energy performance are implemented into daily practise for future building projects. Another is if experiences from collaborative working is transforming practise in the industry.

## REFERENCES

- Aarseth, W (2012) *An empirical study of organizational cooperation in large traditional and global projects execution*. Phd thesis, Trondheim: University of science and technology.
- Barlow, J. (2000). Innovation and learning in complex offshore construction projects. *Research Policy*, Volume 29 ( Issues 7-8), 973-989.
- Bishop, D., A. Felstead, A. Fuller and N. Jewson (2009): "Constructing learning: adversarial and collaborative working in the British construction industry", *Journal of Education and Work*, 22, 4, pp 243-260.
- Construction Industry Institute (1991): *Partnering Toolkit*. CII.
- Dubois, A., & Gadde, L.-E. (2001). "The Construction Industry as a Loosely Coupled System - Implications for productivity and innovativity". *The 17th IMP Conference*, 9th-11th September 2001. Oslo, Norway.
- Egan, J (1998): *Rethinking construction Report of the Construction Task Force*, London: HMSO.
- Egen, J. (2002). *Accelerating Change: Consultation Paper by Strategic Forum for Construction*, London: HMSO.
- Engeström, Y. (2004 ) "New forms of learning in co-configuration work". *Journal of workplace learning*, vol 6, no 1/ 2, pp 11-21.
- Engström, Y, R. Engström and T Vahaaho (1999): "When the center does not hold: the importance of knotworking", in Chaiklin, S., Hedegaard, M. and Jensen, U.J. (Eds), *Activity Theory and Social Practice*, Aarhus University Press, Aarhus.
- Flyvbjerg, B. (2004): "Five misunderstandings about case-study research". *Sosiologisk tidsskrift*, no 02.
- Larsen, A. K (2011): *Facility management within the Specialist Health Care Service* (Norwegian: bygg og eiendoms betydning for effektiv sykehusdrift), PhD theses, Trondheim: University of science and technology.
- Latham (1994) *Constructing the Team*, London: HMSO
- Mirza, S. (2006): "Durability and sustainability of infrastructure – a state-of-the-art report." *Canadian Journal of Civil Engineering*, Vol. 33, pp 639-649.
- Morris, P & Pinto, J. (2004): "The Wiley guide to managing projects". John Wiley and sons, New Jersey.
- Orange G., Boam J. and Burke A., (1998) "A Networked System to Facilitate Organisational Learning within the Construction Industry", *NETIES 98*, Leeds Metropolitan University.
- Norwegian Government (2004) *White paper no 23(2003-04): The housing policy* (In Norwegian: Om boligpolitikken). Report from working group on construction costs. Norwegian ministry of local government and regional development.
- Reve, T. and Sasson, A. (2012). (In Norwegian) *Et kunnskapsbasert Norge*. Oslo, Universitetsforlaget.
- Rønning, A. and M. Vold (2008): (In Norwegian) *Miljøvurdering av nytt hovedkontor for SpareBank1 SMN. Sammenligning av to alternative løsninger*. Østfoldforskning AS
- Rønning, A. and M. Vold (2009): *Refurbishment or Replacement of Buildings – What is Best for*

- the Climate? *NOR LCA conference*, Aalborg.
- Trondheim Chamber and Lean Construction Norway (2012) *Efficient construction – What does it take?* Seminar in Trondheim, November 22.
- Valen, M. S., Klakegg, O. J. and Hustad, S. (2010): “Barriers and bridges in construction processes”. *IPMA World Congress 2010*.
- Winter, M., Smith, C., Morris, P., Cicmil, S. (2006) “Directions for future research in project management” *International Journal of Project Management*. Vol. 24, issue 8, pp. 638-649.



Paper no 3

Meistad, T. (2013):

**“Partnering for the development of an energy-positive building. Case study of Powerhouse #1”,**

*7th Nordic conference on construction economics and organization, “Green urbanization – implications for value creation”, 12 – 14 June 2013*



## **PARTNERING FOR THE DEVELOPMENT OF AN ENERGY-POSITIVE BUILDING. CASE STUDY OF POWERHOUSE #1**

**Abstract.** *Powerhouse #1 is planned to become the first and northernmost energy-positive office building. An alliance of companies within the Norwegian construction industry has been established to reach this ambition. Partnering has been suggested as a means to improve performance in general within the construction industry. Studies reveal that the industry is yet to yield the positive effects that have occurred in other industries. Strategic alliances such as Powerhouse are an exception within Norwegian construction industry. The paper analyses the case of Powerhouse #1 regarding collaborative working and experienced effects to the energy performance of the project. The material consists of interviews with participants in workshops during concept phase of the project, in addition to written and oral presentations. Our findings indicate that Powerhouse are aiming to combine long-term and project business objectives. Industrial Energy Design methodology has resulted in an energy concept for a building with outstanding energy performance. During the process shared understanding and respect has developed between the participants. If the project is able to realize the ambition on commercial conditions it will represent a turning point regarding energy efficient construction.*

**KEYWORDS:** energy-positive building, partnering, construction industry, collaboration

### **1 INTRODUCTION**

There is a global challenge to reduce energy consumption in man built environments, and the construction industry is expected to improve energy efficiency. However there is a concern over general under-performance in the industry and analyses indicate that improvements are slow. In this situation there are a few construction projects with outstanding aspirations regarding energy performance. In Norway for the time being Powerhouse #1 is the most extreme, with ambitions to be a net energy producer.

#### **1.1 The project background**

In 2009 the Norwegian non-governmental organization ZERO hosted a national conference on reduction of greenhouse gas emissions. The conference was addressing challenges and opportunities for the construction industry and gathered representatives from leading companies within the value chain in addition to politicians, regulation authorities and universities. ZERO especially challenged the industry on how to build energy-producing buildings in the near future. More than one of the speakers argued that this ambition is possible to reach in Norway within the near future. One of the participating companies, Hydro, suggested to establish an alliance to explore how such a building can become reality, and from this stage invited partners to join in. This was the starting point for the Powerhouse alliance.

Industrial partners establishing an alliance for a construction project is an exception to the traditionally fragmented practise within the industry. The Powerhouse #1 is a project of special interest due to the combination of business collaboration and high energy ambitions.

## 1.2 Literature background

The work method of Powerhouse #1 differs from the traditional process within the industry. Usually work tasks are performed separately by each specialist. Since the tradition of serial working within the value chain is identified as a major hindrance for improvement of environmental performance within the construction industry (Egan 2002, Bishop 2009, Norwegian Government 2004), the working method of Powerhouse is of strategically interest for improving performance within the industry in general.

The Construction Industry Institute's definition of partnership can be said to cover the main aspects of industrial collaboration in general, namely to best achieve the business objectives of all parties involved (CII 1991). There are two distinct types of collaborative relations. One is the strategic, long-term commitment. The purpose is to achieve specific business objectives by maximizing the effectiveness of each participant's resources. The other is the project specific commitment, with the purpose to achieve specific project objectives.

Within the construction industry partnering and lean construction has got special attention and has been gradually developed and tested in practice. A literature review reveals a tendency to focus on project partnering (Bygballe et al 2010). The relationships are found mainly to include clients and main contractors, while sub-contractors and suppliers rarely are included (Dainty et al 2001, Miller et al 2002). These findings are among the explanations for the limited effects of collaborative work experienced so far within the construction industry (Winch 2000).

Studies also reveal that tools and techniques to design relationships are emphasized at the expense of the social aspects, such as development of shared understanding and trust for the benefit of improving construction (Bygballe et al 2010). According to Bresnen and Marchall (2002) this can be characterized as an engineering approach to relation development. Engineering processes focus on formal and systematic tools and techniques, including contracts and financial incentive systems, dispute resolution procedures and use of workshops and facilitators for teambuilding. The alternative according to Bresnen and Marchall are evolutionary processes, which focus on the dynamic, social and informal aspects of collaboration, including the acknowledgement of the complexities of relations between individuals and organizations with varying structural and cultural backgrounds.

Collaborative work forms are found to be of special interest in complex projects, in international projects and for innovative purposes (Aarseth 2012). Research and development on project management within the construction industry has led to a number of methodologies for these purposes. Of special relevance for our case study is Integrated Energy Design (IED). The method focus especially on the design process, and emphasize multi-disciplinary teams, participants skilled and motivated in energy issues, use of workshops and facilitating close cooperation between architect, engineers and relevant experts through the process (KS architects 2009). The purpose of IED is to obtain a high level of integration and synergy of systems to reach very low energy use over the whole life cycle of the building. The idea is that the best gains of performance are achieved from the beginning of the project. Therefore the design process requires a high level of general skills and of communication within the team (KS Architects 2009, Andresen 2012).

The case study presented in this paper will explore what characteristics from the literature that can be recognised in Powerhouse #1.

## 1.3 Purpose

This paper analyse the first Powerhouse project, Powerhouse #1. Focus is on the partnership and the collaborative work methods being used during the concept stage in order to reach the energy ambition.

The purpose is to explore partly what collaborative work methods that are being used. And



partly, and what implications the partnership has had for the development of the building concept.

## **2 MATERIALS AND METHODS**

This case project is selected due to its strategic interest. Compared to other construction projects the energy ambitions are outstanding. Related to case study theory the Powerhouse project can be considered a “critical case” (Flyvbjerg 2004) based on the following argument: If collaborative work models are found to benefit the result of this project, then such working models can be beneficial to improve energy performance also in other construction projects.

Data is provided partly via interviews with participating informants, and partly from written and oral presentations.

Interviews with nine representatives at the workshops were carried out on behalf of the ZEB program. Each interview was performed according to an interview guide prepared specifically for the purpose. They were performed in face to face meetings, by telephone or via Skype and lasted about one hour. Interviews were carried out during a three month period after the Design concept report were completed in June 2012.

Oral and written presentations have been given by various alliance partners during 2012. A concept report on Powerhouse #1 is published by architects (Snøhetta 2012), and has been available for this analysis. Also articles in newspapers and industrial magazines are analysed.

## **3 PRESENTATION OF THE CASE PROJECT**

### **2.1 The alliance**

The Powerhouse alliance consists of developers Entra Eiendom, construction group Skanska, architects Snøhetta, environmental group ZERO and aluminium company Hydro.

The Powerhouse alliance is part of a shared strategy to improve use of energy efficient and energy producing solutions in construction projects. The Powerhouse projects intends to renew the way of working in construction projects and also be innovative regarding technological solutions and the visual design.

During the process of developing the concept for Powerhouse #1 additional stakeholders have been involved. Among these are scientists within the Research Centre on Zero Emission Buildings (ZEB), which draws upon the expertise at the Norwegian University of Science and Technology (NTNU), SINTEF, national and international associates. Also Siemens and Multiconsult have contributed with experts on automation and photovoltaic (PV) energy production, respectively.

### **2.2 The ambition**

The Powerhouse alliance aims to prove by an example that it is possible to build energy-positive buildings in Norway. The ambition is to build Norway’s first energy-positive commercial building, Powerhouse #1. The chosen location is Trondheim, north of 62nd latitude (see figure 1), which implies that it will also be the world’s northern-most building of its kind.

The building shall be energy-positive over its total life time. By this it is meant that it has to generate more renewable energy over the operational life than it required by the manufacturing of all materials, the erection, operation and disposal of the building. Expected operational life time is set to 60 years. Produced energy is required to be of equally high quality as consumed energy. This in effect implies that the building must produce electricity, not only heat or other types of energy, at a quantity larger than its own consumption. And

production of electricity must be on the building itself.

In addition, the project shall be economically sustainable, implying to be realized at commercial conditions. Potential tenders are enterprises with a focus on energy and the natural environment.

The alliance plans to build more than one energy-positive building. Already while Powerhouse #1 is at the concept stage, the construction work of Powerhouse #2, - a refurbishment project further south in Norway - has started.

### 2.3 The concept

The building is prepared mainly for offices, approximately 750 workstations over 10 floors. In addition it will include public space on ground floor, meant for cultural activities, and parking space at the basement floor.

To reach a positive net energy production, the building combines a set of measurements: Energy efficient building shape, demand control, hybrid ventilation, optimized daylight, sea water heat exchange, local photovoltaic production of electricity and reduction in embodied energy in building materials. The building is planned according to passive house standard and to reach BREEAM category “outstanding”.

The extensive use of solar energy is the most innovative element in Powerhouse #1. To create ideal conditions for photovoltaic electricity production, the building has got a shape where the roof is made out of one surface facing south and with an ideal gradient of the slope. Instead of the traditional cubic shape of office buildings Powerhouse #1 consists of inclined planes with its volume stretched in height. An elliptical outdoor room admits daylight into the building (See figure 1 and 2). To summarize the non-conventional design Powerhouse use the slogan “Design follows environment”.

The concept for Powerhouse #1 is reflected in sustainability in a broad sense. It aims to be climate neutral in a life cycle perspective. The building will produce local and renewable energy. It also intends to be energy producing in the sense that it provides added activity and creativity for people who will be working in and visiting the facilities.



Figure 1: Powerhouse #1 concept project with integrated photovoltaic energy production (Illustration: Snøhetta / MIR)



Figure 2: Powerhouse #1 concept project at the location at Brattøra (Illustration: Hydro)

## 2.4 The work methods

The Powerhouse alliance has made extraordinary efforts for collaboration during the process of developing Powerhouse #1. This includes interdisciplinary work methods during concept stage, and also cooperation with local authorities and neighbour enterprises regarding development of the Brattøra area.

The Powerhouse #1 concept has been developed during serial workshops with a process leader (facilitator). Up to fifty persons have contributed with theories and experience, suggestions and questions in an open and multi-professional dialogue. In this early process the combination of key competence has been emphasized. To handle the complexity of the task, namely to consider all energy implications of the construction, participants as well as project leader reported that the workshops were necessary.

Collaboration with the local authorities has been according to traditional role models. There is a local zoning plan for the Brattøra area, which regulates the building plot for industrial activities and sets physical limitations for the buildings. For the time being there are on-going negotiations regarding the height of the planned Powerhouse #1 which exceeds the height restrictions.

Very low or zero energy buildings require that energy supply, thermal storage and day lighting systems, are viewed in integration with the architectural design. Cooperation between the client, architects and the various specialized engineers early in the design phases offer opportunities for large impacts on performance to the lowest cost and disruption (Andresen 2012).

## 4 FINDINGS

The case study reveals that collaborative working has been crucial for the development of Powerhouse #1. The powerhouse alliance chose to establish a multi-disciplinary team to develop the building concept, and used workshops to explore alternative solutions for the ambition of an energy-producing office building at Brattøra in Trondheim. Four main findings will be presented here.

### 4.1 Developing shared understanding

During the concept phase members of the project team have developed a shared understanding of the task. Workshop participants and the project leader report that this is unique for the chosen work method, and would not have been achieved with traditional work methods. The shared understanding has been developed through exchange of knowledge and ideas within the team. Participants report to have learned how professionals within other

disciplines reflect. The team members have improved mutual respect for the needs and expertise of other professions, implying that traditional boundaries between disciplines were demounted. The mutual understanding and respect have proven crucial for the positive outcome of the challenging concept discussions.

Workshop as a collaborative work method has been a new experience to most Norwegian participants. Especially for the engineers close collaboration with the architects has been a challenge and inspired to explore innovative concepts and new combinations of solutions.

In fact, members of the project team report how their basic idea of an office building has been challenged during the process. The energy ambition has forced the project team to handle a set of very differing comprehensions of energy. One of them is the idea of a building as a power station. Another is the idea that a building should provide creative energy to the people using them. In addition there is the vision of buildings as part of a circular flow of ecological energy.

#### **4.2 Exploring optional solutions**

The workshop model has proved valuable for presenting alternative energy solutions. The various theoretical possibilities were tested through exchange of questions and arguments among the participants at the workshops. Photovoltaic energy production was compared to wind energy and heat pumps, and a broad spectre of building designs and materials were explored regarding energy performance.

Shared understanding of the task and mutual respect for each other's expertise has also been vital for the necessary decision making. During the workshops, as alternatives were discussed and one solution stood out to give the best performance, there was a consensus decision on the chosen solution.

Participants experience that close cooperation has affected the project concept positively. The process has exposed the complexity of the project and in particular how decisions are intertwined.

#### **4.3 Intensifying energy ambitions**

One of the underlying discussions in the workshops has been on how to operationalize the ambition of "an energy-positive building". Together the team has specified to include embodied energy in the energy accounting, and to include a greenhouse gas emission account for the total life time. These two criteria are set in accordance to requirements of the ZEB researchcentre. Further there was a discussion on quality of the energy. The project team agreed that electricity is of higher quality than heat. Implication of this is that the overall energy accounting cannot be fulfilled by exporting heat and importing electricity. The team also discussed where the energy can be produced. To ensure that the building in itself is energy-positive, the team specified that production of electricity shall be on the construction.

All in all, the criteria specified by the project team have raised the energy ambitions for the project. The alliance has thereby created a definition of plus buildings, different from existing buildings in other parts of Europe, without succumbing to the temptation of reducing the ambition due to localization of the project.

#### **4.4 Early involvement of contractors**

Previously ambitious construction projects have faced the challenge of finding experienced and willing entrepreneurs and sub-contractors. Implications have been that parts of the concept were left in negotiations with the entrepreneur or that the project has incurred extra

costs due to lack of experience or materials not fulfilling the specifications.

The Powerhouse alliance already includes a construction group and a supplier of energy producing building surfaces. If these partners continue the collaboration during the next project stages, the shared understanding that has been developed during the concept stage may ensure successful completion of the project.

#### **4.5 Commercial success?**

Powerhouse #1 is to be built within commercial conditions and restrictions. This is a part of the ambition that so far has gained little attention, and is in contrast to traditional project planning. According to the project group this is done by purpose, to be able to focus on the energy ambition. The intention of the alliance is to consider the costs of alternatives in the coming design stage, and also to upkeep the energy qualities. However, this may prove to be more conflicting than at the previous project stage.

Traditionally, entrepreneurs will calculate additional costs for risk implied by new building concepts. However, after being part of the concept development an entrepreneur within the Powerhouse alliance can be expected to minimize the extra risk cost.

All in all, there is uncertainty regarding the market value for energy-positive office facilities. The prestige of being the first and northernmost building of its kind might turn out to become the conclusive aspect when the final decision has to be made with respect to actually build Powerhouse #1 at Brattøra or not.

#### **4.6 Socially acceptable?**

Environmental sustainability is the major aspect of Powerhouse #1, as illustrated in the project slogan. However, after the energy concept has been developed the next challenge is to meet the criteria of social sustainability, both regarding formal regulations and acceptance among the public in general.

The design of Powerhouse #1 is developed to optimize the production of electricity via photovoltaic systems on the roof and surface of the building. To reach the office area criteria for the project the total volume is erected to a shape that can be associated with ancient pyramids. As a result the height of the building exceeds the limitations in the regulations for the Brattøra area. This experience raises the question if traditional regulation plans take considerations for environmental innovative constructions. To find a solution for how to combine regulation criteria with innovative design is crucial for this project to be realized.

Dialogue with the public has proved more challenging than expected. The innovative design is a contrast to building traditions in Trondheim, and has triggered loud arguments in regional media. The impression is that even to people who appreciate the idea of environmental friendly constructions, the design of Powerhouse #1 is highly challenging.

The Powerhouse alliance organized a working group for community contact. However, this group has not been active so far. How the challenges of social acceptance are solved is another conclusive aspect regarding realization of Powerhouse #1.

## **5 DISCUSSION AND CONCLUSIONS**

Our analysis reveals that Powerhouse #1 to a high degree is in accordance with the definition of partnership suggested by the Construction Industry Institute (CCI 1991). First of all it is both a strategic and a project partnership. The alliance was first established for strategically purposes, and has developed from one project to the next. Secondly the results so far indicate that the partnership has succeeded in achieving both business and project objectives due to shared contributions of the partners involved. The Powerhouse #1 concept

and the refurbishment project Powerhouse #2 are both intended to break records regarding energy performance among Norwegian buildings. These characteristics make the Powerhouse alliance an exception within Norwegian construction industry today. The strategic partnership have similarities with other industries, e.g. the petroleum industry, where partnering has been crucial for stimulating performance gains and innovation (Barlow 2000). Our material gives no explanation to why the alliance partners have chosen this untraditional strategy, and further studies are needed to explore this issue.

The findings indicate that Powerhouse #1 has been able to combine an engineering approach to partnering with an evolutionary process (Bresnen and Marshall 2002). There exist a contract formalizing the alliance, stating the ambitions and conditions for when a project is considered part of the strategic alliance. Similarly for each project there are partnering contracts formalizing ambitions and financial aspects among others. Workshops and process facilitation is used in accordance to the Integrated Energy Design methodology. According to Bresnen and Marshall these methods are considered part of an engineering approach to partnership. However our informants are enthusiastic about the relational experiences that have come as results of the process. The shared understanding and mutual trust that has developed within the team is considered as valuable for the result of the concept process. However our informants report that the process has been challenging. Informants report that they have had times when they could not see the relevance or participating in discussions that were outside their own area of expertise. Consensus decisions during workshops were a new experience for the participants, and against strong traditions within all partner organizations. However, to overcome different understandings and develop a shared understanding of the complexity of the energy issue is reported to be a key success factor to conclude on a concept for the energy positive office building at Brattøra. Again Powerhouse is found to differ from the majority of partnership projects within the construction industry, which invites for further studies.

The IED methodology emphasizes to establish multi-disciplinary teams from the start of the project. While partnering theory emphasize involving the whole value chain in partnering relationships. Powerhouse #1 has managed to combine this. Partly by including a contractor, an architect, a property developer and one key supplier in the alliance. And partly by inviting external participants to participate in the workshops. According to the literature these are characteristics that might contribute to Powerhouse achieving full benefit from partnering.

The definite success criteria for a partnership among industrial enterprises is whether the business objectives are achieved. For the time being Powerhouse #1 stands on hold, while Powerhouse #2 is already in construction stage. This might indicate that the concept developed during the project #1 is considered as a business success worth using in the refurbishment project, project #2. Documenting the commercial success will be the final test for Powerhouse. Making the Powerhouse projects into reality, and prove economic and environmental sustainability might be the turning point for the Norwegian construction industry, both regarding energy performance and partnering.

## **6 CONCLUSIONS**

The concept project of Powerhouse #1 is an illustrative example on the relevance for collaboration in constructions with high energy ambitions. Energy effects of several aspects and functions of the building have been considered, with special focus on mutual effects. The principles of Integrated Energy Design have been put into practice.

The alliance has produced a goal breaking concept project. Collaboration between resourceful and ambitious companies has proved to be powerful in this regard.

Workshops have proved to be a creative and efficient work method to solve the challenges

of complex integrated design. Over a series of workshops, and with support from specialist working groups, the multi-professional team has developed a mutual understanding and consensus on the final concept project for Powerhouse #1.

So far the method of integrated energy design has been used within the alliance and the project team. To bring the project further, local authorities and the public in general, will also have to be involved. Innovative design relies on co-operation in a broad sense.

## REFERENCES

- Aarseth, W (2012) *An empirical study of organizational cooperation in large traditional and global projects execution*. PhD thesis, Trondheim: University of science and technology.
- Andresen, I. (2012): Integrated Energy Design IED – for Zero Emission Buildings. PowerPoint presentation, Trondheim, ZEB/NTNU. Retrieved from <http://www.zeb.no> (Last accessed 22.11.2012).
- Barlow, J. (2000). “Innovation and learning in complex offshore construction projects”. *Research Policy*, 29 (7-8), 973-989.
- Bishop, D., A. Felstead, A. Fuller and N. Jewson (2009): “Constructing learning: adversarial and collaborative working in the British construction industry”, *Journal of Education and Work*, 22, 4, pp 243-260.
- Bresnen, M. and Marshall, N. (2002): “The engineering or evaluation of co-operation? A tale of two partnering projects”. *International Journal of Project Management*, 20 (7), 497-505.
- Bygballe, L., E., Jahre, M. And Swärd, A. (2010): “Partnering relationships in construction: A literature review”. *Journal of Purchasing and Supply Management*, 16 (2010) 239–253.
- CII (1991): *Partnering Toolkit*. Construction Industry Institute.
- Dainty, A.R. J., Briscoe, G. H., Miller, S. J. (2001): “Subcontractor perspectives on supply chain alliances.” *Construction Management and Economics*, 19, 841-848.
- Egan, J. (2002). *Accelerating Change*: Consultation Paper by Strategic Forum for Construction, London: HMSO.
- Flyvbjerg, Bent (2004): “Five misunderstandings about case-study research”. *Sociologisk tidsskrift*, no 02.
- KS architects (2009): Integrated energy design IED. Retrieved from <http://www.intendesign.com/> (Last accessed 22.11.2012).
- Miller, C. J. M., Packham, G. A., Thomas, B. C. (2002): “Harmonization between main contractors and subcontractors: a prerequisite for lean construction?” *Journal of Construction Research*, 3 (1), 67-82.
- Norwegian Government (2004) White paper no 23(2003-04): *The housing policy* (In Norwegian: Om boligpolitikken). Report from working group on construction costs. Norwegian ministry of local government and regional development.
- Powerhouse (2012). *The Powerhouse Alliance*. Retrieved from <http://www.powerhouse.no/english> (Last accessed 22.11.2012).
- Snøhetta (2012): *Powerhouse # 1, Brattørkaia 17A Trondheim. Concept project* (in Norwegian: Skisseprosjekt).





Paper no 4

Torill Meistad, Marit Støre Valen and Ole Jonny Klakegg (2013):

**“Three stories describing the impact of research on the development of Norwegian Construction industry”.**

CIB World Building Congress 2013, Brisbane



## Three stories describing the impact of research on the development of Norwegian Construction industry

Torill Meistad<sup>1</sup>, Marit Støre Valen<sup>2</sup>, Ole Jonny Klakegg<sup>3</sup>

### Abstract

Increasing focus on energy and climate performance is challenging the construction industry. At the same time globalization of the economy is a driving force for improving competitive advantages. Involving research and developing new technology are among the strategies to meet these challenges. This paper presents three role model projects with goal-breaking performances. The history of these projects illustrates how R&D is involved in the ongoing processes of change and improvements within the construction industry. The cases includes Vennesla library illustrating innovative use of wood, Powerhouse #1 illustrating innovative energy solutions, and Brøset neighborhood illustrating plans for ambitious sustainable urban living. Using an innovation system approach we focus on the institutional framework supporting the development processes. Four elements are found to be of special importance in the development history of the three case projects: a) collaboration via research centers with industry partners, b) support from funding institutions combining financial and expertise support, c) industrial development programs triggering competition, and d) a tradition for government / industry collaboration in policy development. Professional networks are crucial for R&D processes, both regional, national and internationally. Finally the paper discusses whether the findings are specific for a Norwegian or Nordic context. Our findings support previous studies in that the Nordic countries have developed a variety of the knowledge based economy strategy that emphasize learning, knowledge transfer and collaboration in R&D processes.

**Keywords:** Low energy use, Wood, Construction process, Innovation, R&D involvement.

---

<sup>1</sup> PhD student, Department of Civil and Transport Engineering, Norwegian University of Science and Technology, N-7491 Trondheim, Norway, [torill.meistad@ntnu.no](mailto:torill.meistad@ntnu.no)

<sup>2</sup> Associate Professor, Department of Civil and Transport Engineering, Norwegian University of Science and Technology, N-7491 Trondheim, Norway, [marit.valen@ntnu.no](mailto:marit.valen@ntnu.no)

<sup>3</sup> Professor, Department of Civil and Transport Engineering, Norwegian University of Science and Technology, N-7491 Trondheim, Norway, [ole.jonny.klakegg@ntnu.no](mailto:ole.jonny.klakegg@ntnu.no)

## **1. Introduction**

### **1.1 Background**

Increasing focus on climate performance in buildings and demands for higher energy efficiency are drivers for a changing construction industry in Norway. Industry partners, researchers and public enterprises cooperate to reach higher performance levels involving new technology and new collaboration methods. The last couple of decades represent a period of high activity level within the industry, challenges from a global market and also new technological opportunities.

The Norwegian construction industry is the third largest industries in Norway regarding occupation and turnover. However, the relative share invested in research and development (R&D), is low compared to other industries (Espelin and Reve 2007). In the increasingly more knowledge-based economy collaboration between industry and researchers is crucial to upkeep Norwegian and European competitiveness (European Commission 2007).

In this paper we present three role model projects in order to explore how the impacts of R&D are bringing the construction industry forward.

We are especially interested in exchange and uptake of knowledge during the development process.

### **1.2 Theoretical approach**

For this purpose we apply a system approach to R&D in industrial development and innovation. This theoretical perspective acknowledges that progress is carried out through a network of various actors underpinned by an institutional framework (Asheim and Coenen 2005). The innovation system involves the various actors in the value chain of the construction industry. The framework includes institutions and measures constituting the current research and innovation policy. In Norway this framework includes universities and research institutes, centres for research-based innovation, funding for research and industrial innovation, and various development programs (Norwegian Ministry of knowledge 2008-2009). This policy model is in accordance with theories describing the dynamics of innovation as a Triple Helix of university – industry – government relations (Etzkowitz and Leydesdorff 2000).

The system perspective is also useful to enlighten how the production system interacts with and responds to changes in its surroundings (Luhmann 1996). Of special relevance in this paper is how the construction industry responds to incentives for improving environmental performance.

### 1.3 Research questions

Purpose of this paper is to enlighten how R&D ideas are translated into industry outcomes. The analysis will address the question of what institutional framework are involved in successful R&D processes.

The case presentations will focus on what actors and networks that are involved, what research contributions role model projects draws upon, and what challenges triggered the industrial innovations.

Finally the paper discusses the relevance of the Norwegian (or Nordic) context for R&D uptake in the construction industry.

## 2. Material and methods

The case projects are selected among recent and on-going projects with goal breaking ambitions and results.

The material on which we base our analysis is partly published in project reports and partly in form of news and reports published at various industrial magazine's and web pages. The Brøset and Powerhouse cases also include interviews with the project partners.

### 2.1 Case presentations

*Vennesla* library illustrate the development of using wood as a design and construction material. *Powerhouse #1* is a concept project for a building design optimized for sun energy production in Nordic climate and *The Brøset district* is planned to become a sustainable neighborhood that motivates for a extremely low climate gas emission life style.

#### 2.1.1 Case 1: Vennesla library – wood as a design and construction material

Wood has a long tradition as construction material in Norway and is considered environmental friendly and a natural building material among Norwegians<sup>4</sup>. Back in the Viking age wood was a natural building. As experts of their time the Vikings used the huge forest resources to build Long houses of timber logs and Long ships of oak. The tradition of building houses with timber logs lasted until the beginning of the 19th century before steel and other materials as concrete took over as construction materials.

Its use has a long tradition, including mountain villages of log houses, urban neighbour houses that is internationally recognized on the UNESCO World Heritage list as Bryggene i Bergen (Hansatic wharfs houses) the wooden mining city of Røros and the stave churches. In general Nordic people like the idea of being surrounded with healthy and natural materials in a modern community with increasing focus on technology.

---

<sup>4</sup> 94 per cent (Norsk Monitor 2005)

In the 90'ties there was an upswing of using wood as a construction material as new technology made it possible to develop new products that could handle larger span and larger dimension and stronger wooden beams of glulam and massive wood elements. This story tells the impact of the R&D investment between research organizations and actual stakeholders on wood as a construction material.



**Figure 1: Vennesla library and culture centre (Photo: Moelven)**

Vennesla library is a project exploring the characteristics of wood as construction material both from engineering and an architectonic point of view. Figure 1 show the wooden ribs that not only are carrying the load of the building, but also integrate the interior in a spectacular way. The architect<sup>5</sup> company Helen & Hard has specialized on wood constructions combining environment ambitions and outstanding design, and has become internationally recognized also for the Norwegian pavilion at Expo Shanghai (2010) and the Pulpit Rock Mountain Lodge (Preikestolen, 2008). Vennesla library has been awarded a number of prizes

for innovative architecture and use of wood as construction material.

The Vennesla library illustrates a history where new design, technology and research are combined with a traditional material and cultural recognition. Vennesla library represents a continuation of development of wood constructions in Norway and the Nordic countries, and draws upon a number of R&D inputs, among others on load-carrying capacity in various shapes of massive wood.

Development of glulam came as a result of an industrial network around the Moelven timber mill in the Hedmark region. Existing practical knowledge on wood were combined with research at the Norwegian Wood Technology Institute<sup>6</sup> resulting in innovative glue techniques. The leap into this new product were triggered by a national political initiative to invite the national construction industry to promote Norwegian culture and values in the new facilities to be built for the Olympic Games at Lillehammer (1992) and the new Oslo airport (1994). The crucial challenge of fire protection was solved via collaboration with a chemical industry partner within the same region.

### **2.1.2 Case 2: Brøset - Development of urban green living**

In general, settlements in Norwegian cities are densely built. In these times of urban growth there is a challenge to develop environmental sustainable neighbourhoods in urban areas. This example presents the plans for Brøset in Trondheim and show how experiences and research contributions is included in the front end phase.

---

<sup>6</sup> [www.treteknisk.no](http://www.treteknisk.no)

Traditional urban settlement and industrial buildings in the 1000 years history of Trondheim are built on wood. Major parts of the central city still have the characteristics from this tradition. Recently the Trondheim municipality has decided that wood will be a preferred material for new public buildings. This came as a result of major R&D impacts. Among these are new experiences on the potentials of multi-storey buildings in wood, and new knowledge on greenhouse gas emission qualities of wood and forestry as alternative to other construction materials.

Trondheim municipality presented the plans for the first environmental friendly neighbourhood in 2003. The plan for Rosenborg Park included ambitions for reducing energy consumption to 50 %, improving waste handling and recycling, reducing the number of private cars and including landscape architecture as part of the plan for 500 new dwellings. The project was one of six projects in a national initiative for urban environmental pioneering, supported by the Norwegian Housing Bank, Enova and SINTEF Building and Infrastructure as a research partner. There was also international comparative research on the initiative<sup>7</sup>. The project succeeded in improving environmental performance, and provided valuable experience for further urban development. However, the fact that a very high number of dwellings were accepted to be built in this area got a lot of negative attention in the media.



**Figure 2: The area planned for the new Brøset neighbourhood. Experimental garden and outdoor shed with information (Photo: Trondheim municipality)**

When the Ministry of environment initiated the development program *Cities of the future* in 2008, Trondheim applied as partner, and introduced the plans for a new carbon neutral neighbourhood, Brøset. Cities of the future is an initiative to meet the national ambitions for improved environmental sustainability, and is a cooperation between Norwegian municipalities and the State. The program will provide valuable know-how for future urban planning. Especially there will be intensified exchange of experience among the three municipalities aiming to develop similar green urban livelihoods; Kristiansand, Bærum and Trondheim.

The ambition for Brøset is to be a carbon neutral neighbourhood, using little energy and "healthy" materials and being a socially sustainable living environment. There are ambitious plans for reducing traffic and energy use and at the same time uphold living comforts.<sup>8</sup>

---

<sup>7</sup> The international research initiative included participation from 14 countries in Europa (Husbanken, 2003).

<sup>8</sup> <http://www.regjeringen.no/en/sub/framtidsbyer/the-participating-cities-/trondheim/a-new-city-of-the-future.html?id=548223>

The Brøset project has accomplished an architectural competition with four parallel contributors. This material is used to develop a zoning plan in 2012. All throughout the process citizens of Trondheim have been invited to participate at open workshops of the architectural competition and then through the public hearing of the zoning plan. The hearing in itself is experimental, as citizens were invited to visit the area throughout the summer 2012, and to meet planners in an outdoor shed close to the experimental garden (see figure 2) where people could rent a bed to grow vegetables and useful plants. In addition the plans received a lot of attention in media.

The Norwegian University of Science and Technology (NTNU) and the research institute SINTEF follow the process (Gansmo et al 2011). The research team includes a broad span of disciplines in order to match the many aspects of the planned neighbourhood, in particular designing settlements that enable people to lower their total "carbon footprint". Preliminary calculations on carbon neutral living arrangements are among the inputs.

Throughout the process there is built a special relation with the city Freiburg in Breisgau in Germany<sup>9</sup>. This Green City Freiburg has approximately the same number of inhabitants and similar goals for environment friendly living, housing and transport. In contrast to Trondheim, however, Freiburg has nearly thirty years of experience, being a result of strong local engagement in the Green Alternative Movement since the 1980ies. Inspired by Freiburg a *Climate Centre* will be located at Brøset, for the purpose of demonstration and documentation for the industry during the development, and for inhabitants and visitors.

In this case we find that planners and politicians are the primary partners in R&D activities. Due to the global challenge of improve climate performance, national policy has provided financial support for local initiatives, and institutional support via research programs and international exchange of knowledge. R&D uptake is most active in relations between the public representatives, local community planners, universities and expertise within the Housing bank and Enova. Municipalities are exchanging experiences while at the same time competing about the most innovative green project. Meanwhile the construction industry is expectant and awaits convincing market opportunities.

### **2.1.3 Case 3: Powerhouse #1 – development of energy efficient and energy producing commercial buildings**

The Powerhouse alliance was established in 2010 by a property and developing company, an entrepreneur, an architect, an aluminium producing company and an environmental organization.

The alliance wants to demonstrate that it is possible to build energy-positive buildings not only in warm climates, but also in colder climates such as that in Norway. The first project, Powerhouse #1, is planned as a new office building for business tenders. The intended location is at the city harbour of Trondheim. The project includes energy saving

---

<sup>9</sup> [http://www.fwtm.freiburg.de/servlet/PB/show/1199617\\_l2/GreenCity.pdf](http://www.fwtm.freiburg.de/servlet/PB/show/1199617_l2/GreenCity.pdf)



measurements, integrated ventilation, heating/cooling solutions, and electricity production integrated in the building's construction (see figure 3). The ambition is to develop Norway's first – and the world's northernmost – energy-positive office building.

While Powerhouse #1 is still in the concept phase the Powerhouse alliance is now designing its first rehabilitation project. New façade solutions, new technology for energy production and control systems are among the planned measurements. The ambition is to transform the existing building from the 1980ies into net energy producing buildings – “plus buildings”.



**Figure 3: Powerhouse #1 at Brattøra port, Trondheim (Photo: [www.powerhouse.no](http://www.powerhouse.no))**

The Powerhouse Alliance<sup>10</sup> draws upon experience from the various partners. The environmental organization Zero took the initiative by challenging the Norwegian construction industry to increase the investments of research for renewable energy. Among those responding is the aluminium company Hydro. Hydro has during its more than hundred year's history been active in research and development activities. The current priorities are building systems and façade solutions with integrated energy production. The property and developer company Entra joined the alliance due to its environmental friendly business concept<sup>11</sup>. Entra contributes with experience from a major energy efficient rehabilitation project and later the completion of Norway's largest office building with passive house standard<sup>12</sup>. Similarly the construction company Skanska and the architects Snøhetta joined the alliance with international experience and high ambitions regarding energy efficiency and environment performance.

---

<sup>10</sup> <http://powerhouse.no/en/>

<sup>11</sup> <http://www.entra.no/en/>

<sup>12</sup> Papirbredden II, Drammen. Completed 2012. Low carbon concrete and geothermal energy wells.

The Research Centre for Zero Emission Building (ZEB)<sup>13</sup> is part of a national program for environmental friendly energy research, involving NTNU, SINTEF and a group of industry partners and international research partners. ZEB has become an associated partner in the Powerhouse #1 project. ZEB is responsible for the challenge of calculating embodied energy in the building material<sup>14</sup> and comparing various alternatives.

The story of Powerhouse exemplifies the behaviour of industrial actors seeing a potential market for innovative solutions. Similar to the Vennesla story, a group of individual enterprises saw an opportunity to collaborate due to supplementary expertise. The alliance draws partly on internal R&D capacity and partly on the newly established ZEB centre. Both include relations to international R&D networks. Special in this case is that a non-governmental organization triggered the initiative, that R&D investments are basically financed by the industrial partners, and that the ambition is to prove that the innovative building concept can be realized on a commercial basis (as a business rental building).

### 3. Findings

The institutional framework for R&D in Norwegian construction industry has some characteristics that are illustrated by the three case stories in this paper.

Firstly it is the funding institutions. The national housing bank (Husbanken) has a long tradition to be a financial instrument to implement national policy regarding housing in Norway. As for environmental and energy ambitions, Husbanken share this role with the more recently founded institution Enova. They both provide support from highly qualified experts. They also honor initiatives with goal-breaking results status as Role model projects. The three case stories illustrate how R&D activity in the construction industry is encouraged by an institutional framework that combines promotion with expertise and financial support. This finding is supported by previous studies revealing that R&D uptake in a market dependent industry depends on the potential economic value of new knowledge (Saviotti 1998, Schartinger et al 2002).

Secondly there are the centres for research-based innovation. Examples illustrated by the cases are The wooden centre, TreSenteret at the technical university NTNU and the Zero Emission Building research centre (ZEB). They both have industry and research partners and operate on long term conditions. Previous studies have explored how research centres operate as a source for learning for their industrial supplier companies (Bozeman 2000), and the three case stories illustrates this mechanism.

Thirdly there are the development programs. The case stories illustrate how ambitious clients and visionary politicians have succeeded to trigger the industry with programs such as Cities of the Future, Future Built and Norwegian Wood. Award-winning buildings and Role

---

<sup>13</sup> <http://www.zeb.no/index.php/about-zeb>

<sup>14</sup> Embodied energy covers energy consumed in obtaining, processing and transporting the building materials for the construction, maintenance during operation life span and final disposal of the materials.

model projects receive a lot of publicity and interest from the market. Previous studies have revealed the dynamic of regional innovative systems (Cooke & Leydesdorff 2006, Asheim & Coenen 2005), and how competition can be a driving force in innovation processes.

Fourthly there is the tradition for government/ industry collaboration. Involvement of industrial actors has proved to be a key to success in development processes. Organizations within the construction industry are involved in formulating new building regulations, and only research-based knowledge is considered legitimate to underlie new regulations. Such involvement contributes to implement R&D investments into practice, and is in accordance to recent theories including the element of democracy into innovation systems of the twenty-first-century (Carayannis & Campbell 2012).

#### **4. Discussion and conclusion**

The institutional framework identified in this paper may have some characteristics that are specific for the Norwegian or Nordic countries. Variations in the political economy between the Nordic countries and others may provide an explanation for the specific institutional framework for R&D based innovation. In “coordinated market economies” the state and its government plays an active regulative role in the construction market and are also active in supporting R&D activities together with industrial bodies. In such economies strategic interactions between firms and public actors are important for innovation and environmental improvements, compared to liberal market economies. There are discussions among scholars what implications this has for translating R&D into industry outcomes. According to Hall and Soskice’s theory (2001) actors within the Nordic countries have a strong developed knowledge absorptive capacity. The focus is on incremental innovation while the capacity for creating radical innovations is weaker than for liberal market economies. Empirical studies however have not proved this distinction, and rather suggest to focus on the productivity of R&D processes independent of economic and political systems (Akkermans et al 2007)

Norway and other Nordic countries have applied a variety of the knowledge based economy strategy that might be characterised as “learning economy” (Asheim and Coenen 2005). In a learning economy innovation is understood as an interactive process which is socially and territorially embedded and culturally and institutionally contextualized (Lundvall 1992). The learning perspective implies a dynamic notion of innovation, drawing the attention to knowledge transfer and collaboration in R&D processes. The three case stories presented enlighten how innovation and development progress step by step and who are the driving actors.

The three case stories illustrate some mechanisms and processes of the innovative development within the Norwegian construction industry. The system approach has revealed the relevance of networks and roles of various actors involved. The examples indicate that “the learning economy” has proved as a striking institutional framework for translating R&D into environmental ambitious projects.

In addition to national collaboration also international exchange of R&D is most relevant. Norway has great advantages from learning from European countries<sup>15</sup> regarding the use of wood, energy efficiency and green urban living. Similarly Norwegian experiences are conveyed to other countries. The Moelven glue laminated wood has been developed further and the production of massive wood element is now transferred to the Holtz 100 massive wood technology. Research and product development performed by Hydro for a European market is about to become recognized in Hydro's home country. The Scandinavian Architecture is internationally recognized due to several status projects done by architects with international education and background. They are among the driving forces for new and green urban settlements in Norway.

R&D investment impacts should be considered at a long time-frame. Research investments on massive wood has a long history in Norway. Research on energy efficiency has a shorter history than wood. However existing research institutes and universities are mobilized by extensive research programs during the last few years. Green urban living, on the other hand, is a new research area, and so far there exist no research investments dedicated for this purpose.

## References

Akkermans, D., C. Castaldi and B. Los (2007) *Do "Liberal Market Economies" really innovate more radically than "Coordinated Market Economies"?* Hall & Soskice reconsidered. DIME Working paper 2007.06, DIME (Dynamics of Institutions and Markets in Europe) Working Package 31. University of Groningen.

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

Bozeman, B., (2000) "Technology transfer and public policy: a review of research and theory." *Research Policy* **29** (4–5), 627–655.

Carayannis, E. G. and D. F. L. Campbell (2012) *Mode 3 Knowledge Production in Quadruple Helix Innovation Systems*, SpringerBriefs in Business 7.

Cooke, P. and L. Leydesdorff (2006): Regional development in the knowledge-based economy. The construction of advantage. *Journal of Technology Transfer*, **31** (1), 5-15.

Etzkowitz, H and L. Leydesdorff (2000) "The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university – industry – government relations." *Research Policy* **29**, 109-123.

---

<sup>15</sup> <http://www.regjeringen.no/en/dep/lmd/whats-new/Speeches-and-articles/speeches-and-articles-by-the-minister/speeches-and-articles-/2012/speech-at-a-seminar-on-wood-and-wood-den.html?id=670145#>

Espelien, Anne og Reve, Torger (2007): *Hva skal vi leve av i fremtiden? En verdiskapende bygg-, anlegg og eiendomsnæring.* (In Norwegian), Research Report nr. 5 – 2007, Handelshøyskolen BI., Senter for byggenæringen, BI, Oslo.

European Commission (2007): *Improving knowledge transfer between research institutions and industry across Europe: embracing open innovation.* EUR 22836 EN, COM(2007)182.

Gansmo, H. J., Larssæther, S. & Thomsen, J. (2011) *Brøset – Towards a carbon neutral housing settlement in Trondheim, Norway (2009-2012)*, NTNU and Sintef report, 23.09.2011, Trondheim (available online <http://brozed.wordpress.com/research/evaluating-parallell-opdraget/>) [accessed on 15/11/2012].

Hall, P., Soskice, D., (2001) *Varieties of Capitalism: The Institutional Foundations of Comparative Advantage.* Oxford University Press, Oxford

Husbanken (2003): *Husbankhus halverer energibehovet – 6 prosjekter, 600 boliger,* (In Norwegian), Report, Trondheim.

Luhmann, N. (1996) *Social systems.* Stanford University Press, Palo Alto, California.

Lundvall, B.-A. (Ed.), (1992) *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning.* Pinter, London.

Norwegian Ministry of knowledge (2008-2009) *White paper on research policy.*

OECD (2000) *Science, Technology and Industry Outlook 2000.* Innovation Networks.

Saviotti, P.P., (1998) "On the dynamics of appropriability of tacit and codified knowledge". *Research Policy* **26**, 843–856.

Schartinger, D., Rammer, C., Fischer, M.M., Fröhlich, J., (2002) "Knowledge interactions between universities and industry in Austria: sectorial patterns and determinants", *Research Policy* **31**, 303–328

Szulanski, G. (1996). "Exploring internal stickiness: Impediments to the transfer of best practice within the firm." *Strategic Management Journal*. **17** (Winter special Issue): 27-43.



Paper no 5

Meistad, T. (2014):

**“How Energy Efficient Office Buildings Challenge and Contribute to Usability”,**

*Smart and Sustainable Built Environment* Volume 3, Issue 2

Is not included due to copyright





Paper no 6

Meistad, T. (2015):

**“Developing energy efficient buildings – beating the organizational challenge”,**

*Engineering Construction and Architectural Management*

*Submitted March 2014.*





**Developing energy efficient buildings – beating the organizational challenge**

Journal:	<i>Engineering, Construction and Architectural Management</i>
Manuscript ID:	ECAM-03-2014-0040
Manuscript Type:	Original Article
Keywords:	Partnership, Organization and methods, Buildings, Case Studies, Integration, Innovation
Abstract:	

SCHOLARONE™  
Manuscripts

Review

## Developing energy efficient buildings – beating the organizational challenge

### Structured Abstract:

**Purpose** – Purpose is to explore what organizational means are effective to reach outstanding energy performance in construction projects. Focus is on management throughout the process; the means and the experienced effects.

**Design/methodology/approach** - The approach is to learn from experiences in building projects that are honored as role model projects for their outstanding energy performance. Analysis is based upon five case projects. They are all office buildings located in Norway. Data is based upon interviews with representatives of clients, architects, consultants, project managers, constructors and tenant organizations.

**Findings** - Organizational means differing from conventional projects have been important to reach the energy goals of the projects. This includes both structural and social/cultural elements, such as early involvement of parties from all stages, creating arenas with an atmosphere for involvement, and following up on the energy goals throughout all stages into occupation and operation of the building.

**Research limitations/implications** - The material is limited to five case projects, all on Norwegian office buildings. Supported by previous studies the findings are relevant for other innovative construction projects.

**Originality/value** - The findings are supplementing previous studies of energy efficient buildings, by exploring the relevance of organizational development to reach high energy efficiency.

### Key words:

Energy efficiency, office buildings, construction project, organization, process, involvement, partnering, integrated process

## 1. Introduction

Worldwide there is a growing interest for developing energy efficient buildings. Every year constructions are completed that are beating previous buildings. In Norway a program honoring projects with outstanding energy efficiency<sup>1</sup> has contributed to this development. New role model projects are added to the list every year, and each project is pushing the limits further.

Development of technology, materials and design has been crucial to reach improved energy performance, and receive a lot of attention in literature and among practitioners. Less attention has been given to organization and management of the projects. For the purpose of this article we re-define the challenge of energy efficiency in buildings as organizational.

The relevance of organization is partly due to experiences that there is a distance between calculated energy levels of the building designs and actual measured energy consumption of the buildings in operation. Studies have revealed that one explanation is malfunction of the building, due to lack of considering mutual energy effects of the various aspects of the design (Newsham *et al.*, 2009, Scofield, 2009). Another explanation is that facility managers and daily users of the buildings may not be sharing knowledge and goals with developers or owners of the buildings (Leaman and Bordass, 2007, Baird, 2010).

The relevance of organization is also due to experiences that the level of investments in innovation and development in general is low within the construction industry (Reve and Sasson, 2012). Studies indicate that characteristics of the industry system are among the obstacles for changes. Compared to other industries the construction industry is characterized by one of-a-kind projects, a complex production chain with a high number of actors and professions being involved, and project teams being established and re-established with new participants for each project (Gadde and Dubois, 2010). Among the implications is a focus on short term cost efficiency, poor conditions for transfer of new knowledge (Rygshaug and Sørensen, 2009), and mistrust and hostility among the actors (Bishop, 2009). In addition the market based competition and the procurement system is found to advocate against co-operation for innovative changes in the construction industry (Håkansson and Ingemansson, 2013).

Conventional practice for organizing construction projects have been questioned regarding their effect on improvements in general and energy performance in particular. Therefore it is of interest to study projects with goal breaking ambitions to explore how they are dealing with structural and cultural characteristics of conventional project management.

Special for the role model projects is that they have ambitions to reach outstanding performance and therefore are innovative in all aspects of the projects. Prize winning projects have beaten the challenges, not only regarding solutions for design and construction but also for organization and management of the process. *Purpose of this study is to explore how they have organized the process to achieve this goal.*

---

<sup>1</sup> The Norwegian Energy Fund ([www.enova.no](http://www.enova.no))

## 2. Literature review

The challenge of fragmentation and under-performance of construction industry have received political attention, triggering a series of public and private initiatives with a shared ambition to improve collaboration. The following literature explores theories and experiences within two major approaches, namely partnering and integrated processes.

### 2.1 Partnering

The idea of partnering was introduced in UK in the 1990ies (Latham, 1994, Egan, 1998). Partnering may be defined as a long-term commitment between two or more parties, developing shared trust and understanding for the benefit of improving construction (The Construction Industry Institute 1991). There are project-based partnerships, focusing on specific project objectives. And there are strategic partnerships between enterprises with a long-term purpose. Partnering contracts provides joint objectives and encourage the contract parties to work together to solve problems. Partnering contracts include financial incentive systems rewarding the parties equally for success and penalizing for failure. The intention of partnering contracts is to focus on continuous improvements rather than simply meeting the minimum needs of the legal contract (Bennett and Telford, 1998).

In general collaboration is found to be beneficial in complex construction projects (Berker and Bharathi, 2012, Arge and Hjelmbrække, 2012). Within the oil industry partnering is used as a tool for stimulating performance gains and innovation (Barlow, 2000). Partnering is also found to stimulate research uptake in the construction industry (Reve and Sasson, 2012). However, research on organizational cooperation in project management is in general scarce (Morris and Pinto, 2004, Winter *et al.*, 2006). This is also the case for construction industry, where research focus on project management rather than on strategic cooperation and long term development (Aarseth, 2012).

Literature on experiences on partnering reveals that tools and techniques to design relationships are emphasized at the expense of the social aspects, such as shared understanding and trust (Bresnen and Marchall, 2000, Bygballe *et al.*, 2010). Another finding is that within construction industry project partnering has got the most attention. Among these is the increasing number of Public private partnering projects. Strategic partnering has got little attention, while this is common for example within the offshore industry. The effects of partnering are found to be limited compared to the high expectations. Among the explanations for this is the long history of competition which has created a culture of hostility and mistrust within the industry (Bishop, 2009). Studies of fruitful innovation processes have revealed how the participants move from a simple co-ordination according to occupational scripts to co-operation and open communication (Engström *et al.*, 1999). However social and informal aspects of relational development have got little attention in practical experience with partnering (Bresnen and Marchall, 2000).

### 2.2 Integrating

Integrated design processes (IDP) was introduced in manufacturing industry during the 1980ies, to speed up development of new complex products. Later it has been introduced into the construction industry, and has received special attention for the purpose of designing sustainable buildings. The

## Engineering, Construction and Architectural Management

integrated approach is an alternative to the conventional sequential design process, which is experienced to generate sub-optimal buildings at a higher cost (Larsson, 2002, Löhnert *et al.*, 2002).

The basic principle of IDP is early involvement of actors from all stages of a building's life cycle, from design and construction to operation and use. For the purpose of such a "frontloaded" process there is established a multi-professional and collaborative team. The conventional sequential process is replaced by iterative processes with feedback loops. The team represents continuity throughout the whole project as an alternative to the conventional process where members of the project team are being replaced at each stage. The whole team is involved in decision making instead of problems being distributed among people that work and develop solutions in isolation. Role of design and project manager is to facilitate and support the team rather than the more conventional controller (Guren, 2013). Guidelines for IDP has been developed for Canadian, American and German context among others (Busby Perkins+Will and Stantec consulting, 2007).

A special variety, Integrated Energy Design (IED) is developed for the purpose to optimize energy performance. Early stages of design is important to explore synergy effects for energy, therefore the "frontloaded" organization of IDP is relevant (Andresen and Flakstad, 2009).

Experiences with integrated processes in construction have revealed some challenges. Among these is the risk that the team may not perform well together, due to each member representing different organizations, professional cultures, and may partly have different goals (Moore and Dainty, 2001). While project teams in manufacturing industry usually have experience from a serial of projects, the lack of existing well performing teams is a challenge within construction industry (Forgues and Koskela, 2009).

In literature on innovations there is suggested that to establish teams where the members represents culturally diverse backgrounds bring fresh ideas and new approaches to the problem. The challenge is that they also introduce different understandings and expectations regarding team dynamics and integration. There is also suggest that with increasing complexity the importance of management of relations is increasing (Aarseth, 2012, Morris and Pinto, 2004).

Analysis of the case projects will explore whether suggestions from previous studies corresponds to experiences in the Norwegian role model projects.

### 3. Methods and materials

The study is based upon analysis of five construction projects.

#### 3.1 Selection of cases

The case projects are selected due to their outstanding energy efficiency (Norske arkitekters landsforbund, 2003-). The buildings have all been honored as national prize winners at their time of completion. According to Flyvbjerg (Flyvbjerg, 2004) the case projects can be considered as strategic cases due to their goal breaking results and status as role model projects.



## Engineering, Construction and Architectural Management

Four of the projects were completed in the period from 2009 to 2012 while the fifth project is at concept stage at the time of analysis. All buildings are mainly office buildings. Four of the are developed for the purpose of tenant enterprises and organizations while one building is occupied by the owning enterprise. The size of the buildings ranges from 3000 to 16 000 m<sup>2</sup> floor area. Facts about the case projects are summarized in table 1.

<TABLE 1>

### **3.2 Methodology**

Information is collected via interviews with representatives for the property developers, participants during concept and design phase, and with representatives for main contractors. See table no 2. Informants were selected to include a variety in parties involved in the value chain, with special focus on concept and design phase. The owner and the main contractor are represented by the project managers.

<TABLE 2>

Interviews were performed partly face to face and partly by phone or Skype. Interviews were done in a period from June to August 2013 and lasted from 25 to 90 minutes. With two exceptions informant were interviewed individually. Interviews were based on a semi-structured guide, and included questions on ambitions and expectations for the project, working methods and organization for the purpose to reach the energy ambitions, and lessons learned from the projects.

The analysis is based upon qualitative data. Data on working methods and organization is based upon what the individual informants consider as extraordinary compared to conventional construction projects. Also the effects for the energy goals are the subjective experiences of the informants.

### **3.3 Presentation of case projects**

Presentations focus on the goals, participation at various stages, unconventional organization, and experienced effects regarding energy performance.

#### **Case 1 – The Techno park**

The Techno Park consists of three buildings, built one at a time.

When planning first started in the 90ies, there was special attention on environmental performance. Series of workshops involved consultants with experience from energy efficient building concepts that were currently not in use in Norwegian buildings. Further researchers contributed to present, calculate and lab test various alternatives. Property developer have Experienced personnel on energy and indoor environment. Facility managers and some of the future tenants have been involved during planning.

## Engineering, Construction and Architectural Management

The buildings were developed to apply to environmental conscious tenants. "Green leasing contracts" is introduced for this purpose. The case building is the third at the plant, and was developed with the ambition to be the most energy efficient building in the country at the time.

Ambition/Strategy of the property developer is to be a market leader with high quality and energy efficient facilities. The broad collaboration is experienced to be crucial to reach this goal. So has the strategy of drawing on experiences from building to building, testing and evaluating alternative solutions and designs.

### Case 2 – The Bank

At the time when The Bank were considering renovation or replacement of their headquarters there was made a strategic decision to state an example for future business properties by demonstrating solutions with high quality for both indoor and external environment.

Owner's project manager insisted on close co-operation between all parties during design phase. Therefore all consultants, architect and main contractor shared project office over a period of months. According to the turnkey contract they co-operated to find optimal design and solutions. Energy analysis and Life Cycle Assessment analysis were added to conventional planning. New technical solutions were introduced after intensive calculations and lab tests. Employee representatives were involved during planning and during post occupancy evaluations and adjustments in first year of operation. (A regional bank office has later been built based on the same concept as the new headquarters.)

The bank has experienced high user satisfaction, improved productivity and has been honored for the energy concept. Broad and intensive collaboration were crucial for reaching the ambitions.

### Case 3 – The Culture Center

The case building was the first in a row transforming a former manufacturing industry area into facilities for culture based enterprises, including music, food, art and education. One of the future tenants is an environmental organization, and persuaded the property developer to make environmental qualities a central quality of the concept.

There was a multi-disciplinary collaboration on how to reach the ambition, energy label A, and practical solutions to reduce the environmental footprint. An external energy consultant has followed the project from the drawing board to execution. The solutions from the first building have been developed further in the following building stages at the plant. The building has proved that the high energy performance can be reached by using well known technology, by calculating all aspects of building performance and focusing on energy in all decisions.

For two years the case building was the most energy efficient office building in the country. Partnering with the environmental organization has been decisive for setting the high energy ambitions, and focusing on the shared vision crucial for reaching the goal.

### Case 4 – The Innovation Park

The case building is number two in a plant developing to facilitate knowledge based enterprises, education and research. The recent business strategy of the property developing/owning company focus

## Engineering, Construction and Architectural Management

on environmental friendly buildings, and goal for the project was to become the first Norwegian office building according to passive house standard.

To draw on experiences from other parties there was established a broad team during concept phase. (The regional urban development program contributed with expertise on energy and urban planning). An environmental consultant was engaged from the start to develop an environmental quality program, to follow up throughout detail planning, procurement and construction. Close following up from client and environmental consultant is experienced as a major success criterion for the result.

### **Case 5 – The Energy Plus Building**

This is a building concept developed to become the first net energy producing office building in the country. An alliance has been established to prove by an example that it is possible to build energy positive buildings and to compete in the market. The alliance includes a property developing company, an architect office, a construction group, a producer of energy producing construction materials and an organization working for the natural environment.

The alliance intends to renew the way of working in construction projects and also to be innovative regarding technological solutions and visual design. The concept project has been developed through a series of workshop with a dedicated process facilitator. For the time being the alliance is about to complete a refurbishment project based upon the energy plus concept that has been developed.

## **4. Findings**

So, what are the organizational means that make a difference compared to conventional building projects? Here we present experiences from the five case projects. Some of the means are shared by all projects, while some have been used only in individual projects. Purpose is partly to illustrate the variety in organizational efforts, and partly to explore what effects have been experienced.

### **4.1 Broad and early collaboration**

All projects are characterized by broad teams from the start of the project; in concept phase. In addition to architects this includes specialists on energy and environment: consultant engineers, scientists and experienced facility managers. Future tenant organizations, urban development programs, contractor and potential suppliers of special technology have also been involved in some of the projects (see table 3).

<TABLE 3>

The broad involvement has in all cases been organized in one or more workshops. The workshop methodology was especially elaborated in case of the Energy Plus Building, with a series of four workshops within a period of two months. 50 persons were attending at the most. In this case a dedicated facilitator has been engaged to ensure an open and trustful atmosphere, secure progress and results from the process.

## Engineering, Construction and Architectural Management

The property developers and owners decided to use early and broad involvement to explore opportunities, expectations, ideas and alternatives, and also to draw on existing experience. The main purpose was to be creative and brainstorm on potential solutions to reach the high ambitions. There are four major effects experienced by the owners of the case projects. The following statements illustrate the experiences.

- Set energy targets: "A survey revealed that environmental friendly facilities were important for the potential tenants. Energy goals were not part of our original concept" (... Cultural park)
- Testing optional solutions: "All parties coming together at this early point make it possible to show what is possible." Broad participation during concept stage has revealed potentials that otherwise may not been considered. (Manager of property developer, Innovation Park)
- Learning effects/sharing knowledge: Clients emphasize on involving experienced people. "In this way we ensure not to repeat others' mistakes." (Manager of property developer, Innovation Park)
- Time efficiency: Broad and extensive collaboration in concept stage ("frontloading") implies investing extra resources in early planning compared to conventional organization. Clients and property developers have experienced that projects were developed further during concept stage than in other projects. Since more decisions had been made the following stages are developed more quickly than normally is the case. "The project can be developed further more quickly due to a high number of solutions have been developed during concept stage than normal." (Energy Plus Building).

### ***4.2 Dedicated person to follow up on energy***

The property developers/clients emphasize the importance of a dedicated person responsible for the energy and environmental targets through all stages of the project. The energy consultant is representing the client, and is partly a planner and partly a controller. contributing with the overall energy and environmental calculations, evaluating the work, following-up and reporting progress according to energy and environmental goals agreed upon It is considered crucial that this role is independent from other roles in the project, and that the role follows the project throughout the whole process.

This role has been employed either by contracting a specialized consultant for this purpose (The innovation Park, The bank), using experienced personnel already employed at the property developer (The Techno Park), or by one of the partners in the project (The Culture Park).

To ensure continuity is challenging in turnkey contracts. Since all personnel might be exchanged there is a risk that the shared understanding that has been developed during concept stage gets lost in the hands of new actors. In these cases the clients have separate contracts with energy and environmental consultant, running from day one of the project. "This is a partnering project based upon a turnkey contract. This implies that the main contractor had the possibility to contract other consultants. However we () contracted the environmental consultant" (project manager, Innovation Park). "An external and independent energy and environment consultant were contracted to follow the whole process. This person is also responsible for evaluating optional solutions and giving input to

## Engineering, Construction and Architectural Management

improvements" (owner's representative, Cultural center). In one case project (The Innovation Park) there were designated people among team leaders at construction site to be responsible for the energy aspects of activities at construction site and to follow up on suppliers. Those responsible for procurement of the sub-contractors were also responsible for considering energy and environmental performance of the products being provided.

An energy and environmental plan has proved to be a good tool for the dedicated energy consultant. The plan translates the overall project goals into means and measurements at all stages and among all parties involved in the project. The close following up includes weekly meetings, documenting performance and honoring results. "The environmental follow-up form became a crucial document" (Innovation Park). The extensive energy and environmental requirements was a new experience for the main contractor, the sub-contractors and the suppliers. However, experienced effects are that it upkeeps focus and status for the energy and environmental goals. All parties experience benefits relevant for their own job, such as saving costs or time, or gaining credit in the market for acquired competence on energy and environment.

### **4.3 Ambitious clients**

The courage of ambitious clients is emphasized as a success criterion by our informants. "The project manager had the courage to step into unfamiliar terrain, to put on pressure for ambitious targets, and to use unconventional methods to reach the goals" (HR manager, The bank). Alternative methods for project management are among the unconventional methods being used by these demanding clients.

For other participants in the projects it has been of special importance to experience proofs of this courage. The dedicated energy consultant and following up on an environmental plan is one such proof. Inviting participants at all stages of the process to present ideas for improvement is another proof. An even stronger proof is to leave problem solving and decisions in situations with conflicting goals to the project team. "In situations of conflicting goals the project team turned to me to make a decision as in conventional projects. In this case the team had to co-operate to find the best solution" (project manager, The Bank building).

Among the experienced effects is that energy and environmental ambitions have been added or increased compared to the client's initial goal for the project. This has been the case in the projects where environmental organizations were involved in concept and design stage (The Culture Center and The Energy Plus Building), and also where the local government and urban development program were involved (The Innovation Park). As the potentials in design, technology and the market were explored, ambitious partners and ambitious future tenants have been influencing the owners by pushing for higher ambitions.

Leaving decisions to the project team also imply a risk that energy ambitions may be reduced. Our informants report on a number of situations where unconventional solutions have been met by skepticism by the team. Ambitious clients have proved courage by inviting to discuss the ideas. The most promising has also been subject to thorough calculations, lab tests and visits at demonstration projects.

## Engineering, Construction and Architectural Management

The owners and property developers of the case projects emphasize knowledge building regarding energy performance. All case buildings are part of serials of buildings being developed over time. This can be interpreted as if the approach for ambitious clients is to learn step by step. Knowledge and concepts from one building is being re-used and adjusted in the next.

### ***4.4 Formal organizing***

The formal arrangements of the case projects are basically in accordance with conventional practice. Partnering contracts were used between the client and the contractors in three out of four completed building projects. This type of contract is about to become dominating in Norwegian construction industry. Only one of the clients has chosen to sign a turnkey contract with the contractor.

Characteristic for the case projects is that the content of the formal contracts are highlighting the energy ambitions more than in conventional projects. Partnering contracts were chosen since they include incentives for both parties to put in extra efforts to succeed. This has been experienced to work according to the intentions.

The turnkey contract used in one of the case projects were supplemented with the client contracting an energy consultant to follow up all the way to the building were completed, according to the energy and environmental plan.

The Energy Plus Building is an exception among the case projects regarding formal collaboration. Contracts between the partners implies that the main contractor and one key supplier is pre-selected for erecting the building as soon as it is ready to proceed further from concept stage. The alliance partners have already completed a refurbishment project based on the concept.

Formally the arrangements with the tenant organizations are basically according to conventional practice. However there are exceptions relevant for energy performance. One exception is that in all buildings there arrangements for close following-up on performance of the buildings after completion in all the buildings. This includes meetings and negotiations with the user organizations, and continual measurement of energy consumption for various purposes in the buildings. The other exception is Green leasing contracts, which are being used in two of the case buildings (The Techno City and the Culture Center). Both arrangements is experienced to contribute to education of the users, feedback from users to property developers and facility managers, and to gradually improve actual energy performance of the new buildings.

### ***4.5 Involvement throughout the process***

In addition to the broad involvement during concept stage, involvement in later stages has been more extensive in the case projects than in conventional projects.

Close collaboration during design stage contrasts to conventional construction projects. The most extreme were the Bank building, where architects and the various consulting engineers were sharing office during a working period of six months to optimize energy performance and the other goals for the project. Collaborating on problem solving and the team being responsible for decision making has been a new situation/experience for the participants. "There was a challenge to make the actors to become

## Engineering, Construction and Architectural Management

players at the same team and to agree on the conclusions. All participants had to get to know each other and to work together" (The Bank). Similar processes have been necessary to convince contractors and sub-contractors of the realism in the low energy solutions. "The parties of the partnering contract were or became positive to the environmental goals." (project manager, The Innovation Park).

Further, the craftsmen at building site have been educated in the principles of low energy or passive house buildings, and are trained in the new practice. Also the users of the buildings,- employees of the tenant organizations, have been introduced to how the buildings are operated and how design and technology contribute to energy performance. Kick-off meeting with sub-contractors and suppliers has proved to increase understanding and co-operation on reaching the goals of the energy and environmental plan (The Culture Center).

Involving people in all parties of the value chain is emphasized by our informants. The approach is to present the energy goals, and open up for ideas of improvements. During planning and construction of the Bank building "ambassadors" among the bank employees have been communicating suggestions and challenges between employees and project owner. At construction site constructors and sub-constructors have been challenging their employees on energy saving practice, measuring energy consumption and rewarded employees for improvements (The bank building and the Innovation Park).

Involvement throughout the process has resulted in win/win effects; Owners and property developers have got buildings with better energy performance than otherwise would have been the case. Contractors and sub-contractors save energy costs. Occupants of the buildings get knowledge and awareness about energy in their daily work, which will affect energy performance of the building during future operation of the buildings. All parties learn. For instance, contractors that have developed new systems to build and document according to energy and environmental criteria are now able to meet the requests of environmentally conscious clients. "We can demonstrate that we have systems to handle environmental goals and requirements." (Innovation Park) Similarly, involving the craftsmen to find solutions have been educational for the suppliers. (Project manager, The bank).

### **4.6 Social relations**

Our informants emphasize the value of developing a team spirit with shared goal among all participants. The major experience is that extensive working together over a period of time made people knowing and trusting each other. The atmosphere of trust has been crucial for convincing the participants that it is possible to reach the high goals when collaborating. Parties that initially were negative have changed their mind. One example is the consultant on heating and ventilation in design team in the Bank building project. Due to lack of experience the consultant was negative to under floor ventilation at the beginning. However a laboratory demonstration convinced the consultant and the rest of the team. Another example is the main contractor that initially was negative to the high environmental goals, and later took initiatives to reach the goals. "The contractor created good practice and attitude which gave good results." (Innovation Park).

Clients with an inviting and challenging attitude have given all participants a shared ownership to the goals and the project. "The whole team participated in negotiating energy and environmental criteria

## Engineering, Construction and Architectural Management

and goals for the project. "My experience is that this way of working creates a sense of ownership to the environmental goals among all involved" (Project manager, The Innovation Park). "The idea of partnering is to create a shared ownership to the solutions. Not for the client to make the decisions alone. In this we succeeded" (The bank).

Close co-operation during concept stage have resulted in the three main effects that has been suggested in literature on partnering, namely to pool knowledge, share risks and work together to solve problems (Bishop, 2009). This includes testing of optional solutions: "All parties coming together at this early point make it possible to show what is possible." (Energy plus building). Barriers between professions have been reduced: "I learned a lot about how others are thinking and acting. I understand what they want and what they need. This is due to the workshops." (consultant, Energy Plus building). All informants participating at the workshops experience that they have developed a shared understanding of the project. All have contributed to exploring the task, and all have been challenging each other. Through the process participants got to trust each other. There have been disagreements during the process, arguments have been tested, and the group agrees on the solutions that have been chosen.

### 5. Discussion

The five case projects are representing a historical development regarding energy efficient office buildings in Norway. Calculated energy performance has improved from building to building (see table 1) parallel to the development of gradually more strict technical regulations, Energy Label system and Passive house standard for non-residential buildings, BREEAM and LEED certification systems. Also the market for "green" office buildings has increased. There is a parallel chronology regarding organizational means focusing on collaboration and integration whereas the recent projects are frontloaded to a higher degree than the earlier of the case projects. This might indicate that extensive early collaboration is considered crucial to develop projects with outstanding performance, similar to experiences from other complex projects (Barlow, 2000). However this may also be a result of new relevant planning tools being available, such as handbooks for integrated design, the guide for integrated energy design, software for computing energy and environment performance. In addition more experienced people have become available for owners and property developers.

The projects have in common the extraordinary means being used to create multi-professional teams during planning stages and to involve all parties in the projects. This is in accordance with previous studies which suggest increasing collaboration and frontloading of the planning process (Andresen and Flakstad, 2009) to explore the synergy effects of design, technology and the users regarding energy, and to motivate all parties to focus on potentials for improvements (Bennett and Telford, 1998). The Energy Plus Building is the most extreme regarding broad and extensive collaboration during concept stage, while The Bank Building is the most extreme during design stage. These two projects, and also the Techno Park building were the ones involving scientists and also performed computer modelling and laboratory tests on the suggested solutions. This indicates that there was a lack of experience with the suggested solutions, and that risks were considered as high (Bishop, 2009) .

As for formal agreements, the most extreme is the alliance developing the concept for the Energy Plus Building. This is the only example of a strategic partnership, established to involve partners from various



## Engineering, Construction and Architectural Management

parts of the production chain in a serial of construction projects based upon the concept of buildings as self-sufficient energy producers. Partnering contracts for the other case projects are established on a project basis. At first sight it looks as if the rest of the case projects are operating on a short-term perspective, similar to conventional projects. However the reality is that all projects are part of a serial of projects where experiences from one building is implemented and concept adjusted in the next building.

All projects have been focusing on the informal aspects of collaboration, adding organizational means that create new social settings for developing the collaborative atmosphere. Workshops and use of big office has proved effective. The facilitator of serial workshops and the dedicated person following-up across all stages of construction have been adding to the creation of new social contracts among the involved participants. It was a new experience for the participants when clients left decisions to the design team and when constructors opened up for suggestions from suppliers and craftsmen at the construction site. The experienced effects are in accordance with studies of innovation where team members move from simple co-operation to full co-operation on the task to be solved (Engström *et al.*, 1999). To challenge conventional practice has obviously been risky for the project owners, due to the strong cultural traditions within the industry. However, all informants are aware that bridging the cultural borders have been crucial for exploring the synergy effects of integrated processes and partnering contracts. Comparison of the case projects indicates that the projects with the highest ambitions have been the most challenging to social conventions of the industry. The findings are in compliance with previous studies regarding the relevance of cultural barriers for innovation and improvement (Gadde and Dubois, 2010, Bishop, 2009), and of relation building to bridge these barriers (Aarseth, 2012, Bresnen and Marchall, 2000).

The study presented here is limited to five case projects. However support from literature indicates that the findings may be transferable to other innovative construction projects.

### 6. Conclusion

Three major conclusions are revealed from analysis of the role model projects on energy efficiency.

The first conclusion is that broad and early involvement has been crucial to succeed in reaching outstanding energy performance. This is partly by combining resources and sharing knowledge during planning, and partly by developing ownership and involvement by participants at all stages of the project, including occupants and facility managers. Informants emphasize to create arenas and an atmosphere for sharing understanding and trust to bridge organizational borders of conventional sequential construction processes. Workshops and "big office" have proved to be successful organizational means during planning stages, while training of craftsmen and kick-off meetings with suppliers are among the extraordinary means during construction stage.

The second conclusion is that close following-up on the energy ambitions has been crucial during all stages of the project. Ambitious owners experience the importance of contracting a dedicated person specialized on energy performance during all stages of the project. This role is supplementary to partnering contracts and turnkey contracts. Specific energy plans has proved to be an useful tool for

## Engineering, Construction and Architectural Management

following up during construction. Up keeping the dialogue with operators and users during first year of occupation has proved useful to get feedback on actual performance.

The third conclusion is that a combination of structural and informal means has proven successful to bridge the barriers in conventional organization of construction projects. The basic ideas of partnering and principles of integrating processes have been implemented in the case projects. Sharing resources, risks and benefits is experienced to be the key to create buildings with extraordinary qualities by. For this purpose establishing social contracts have proved to be equally important as formal contracts.

### References

- Aarseth, W. (2012), "An empirical study of organizational cooperation in large traditional and global project execution", *Faculty of Engineering Science and Technology*, Trondheim, Norway, Norwegian University of Science and Technology p. 360.
- Andresen, I. and Flakstad, A. G. (2009), "Integrated Energy design IED. A guide to integrated energy design.", *Integrated Energy Design in Public Buildings*, intendesign.com, [EcoArchWiki.net](http://EcoArchWiki.net).
- Arge, K. and Hjelmbrække, H. (2012), "Value enhancing processes in building and real estate", *Joint CIB W070, W092, & TG72 International Conference on Facility Management, Procurement Systems and Public Private Partnership*, Cape Town, South Africa.
- Baird, G. (2010), *Sustainable Buildings in Practice: What the Users Think*, Routledge.
- Barlow, J. (2000), "Innovation and learning in complex offshore construction projects", *Research Policy*, Vol. 29 No. 7-8, pp. 973-989.
- Bennett, J. and Telford, T. (1998), *The Seven Pillars of Partnering: A Guide to Second Generation Partnering*, Thomas Telford Publishing.
- Berker, T. and Bharathi, K. (2012), "Energy and buildings research: challenges from the new production of knowledge", *Building Research & Information* Vol. 40 No. 4, pp. 473-480.
- Bishop, D. (2009), "Construction learning:adveriarial and collaborative working in the British construction industry", *Journal of Education and Work*, pp. 243-260.
- Bresnen, M. and Marchall, N. (2000), "Partnering in construction; A critical review of issues, problems and dilemmas.", *Construction Management and Economics*, Vol. 18 No. 2, pp. 229-237.
- Busby Perkins+Will and Stantec consulting (2007), "Roadmap for the Integrated Design Process", BC Green Building Roundtable.
- Bygballe, L. E., Jahre, M. and Sward, A. (2010), "Partnering relationships in construction: A literature review", *Journal of Purchasing & Supply Management*, Vol. 16, pp. 239-253.
- Egan, J. (1998), "Rethinking Construction", UK, The construction task force.
- Engström, Y., Engström, R. and Vahaaho, T. (1999), "When the center does not hold: the importance of knotworking", in Chaiklin, S., Hedegaard, M. and Jensen, U. J. (Eds.) *Activity theory and social practice*, Aarhus university Press, Aarhus.
- Flyvbjerg, B. (2004), "Five Misunderstandings About Case-Study Research", *Sosiologisk tidsskrift* Vol. 2, pp. 118-142.
- Forgues, D. and Koskela, L. (2009), "The influence of a collaborative procurement approach using integrated design in construction on project team performance", *International Journal of Managing Projects in Business*, Vol. 2 No. 3.
- Gadde, K.-E. and Dubois, A. (2010), "Partnering in the construction industry - problems and opportunities", *Journal of Purchasing and Supply Management*, No. 16, pp. 254-263.

## Engineering, Construction and Architectural Management

- Guren, E. F. (2013), "Håndtering av usikkerhet i tidligfase av bygg- og anleggsprosjekt (Eng: Managing Uncertainty in the Early Phase of Construction Projects)", Trondheim, Norway, Norges teknisk-naturvitenskapelige universitet (NTNU), Fakultet for ingeniørvitenskap og teknologi, Institutt for bygg, anlegg og transport.
- Håkansson, H. and Ingemansson, M. (2013), "Industrial renewal within the construction network", *Construction Management and Economics*, Vol. 31 No. 1, pp. 40-61.
- Larsson, N. (2002), "The integrated design process", *National Workshop*, Ottawa, Natural Resources Canada.
- Latham, M. (1994), "Constructing the Team", London, HMSO.
- Leaman, A. and Bordass, B. (2007), "Are users more tolerant of "green" buildings?", *Building research and information*, Vol. 38 No. 6, pp. 662-673.
- Löhnert, G., Dalkowski, A. and Sutter, W. (2002), ""Integrated design process", A Guideline for Sustainable and Solar-Optimised Building Design, Task 23," Berlin, IEA.
- Moore, D. R. and Dainty, A. R. J. (2001), "Intra-team boundaries as inhibitors of performance improvement in UK design and build projects: a call for change", *Construction Management and Economics*, Vol. 19, pp. 559-62.
- Morris, P. and Pinto, J. (2004), *The Wiley guide to managing projects*, John Wiley and sons, New Jersey.
- Newsham, G. R., Mancini, S. and Birt, B. J. (2009), "Do LEED-certified buildings save energy? Yes, but...", *Energy and Buildings*, Vol. 41 No. 8, pp. 897-905.
- Norske arkitekters landsforbund (2003-), "Ecobox", Norske arkitekters landsforbund (In English: National Association of Norwegian Architects), <http://www.arkitektur.no/om-ecobox> (last accessed 10 March 2014).
- Reve, T. and Sasson, A. (2012), *Et Kunnskapsbasert Norge (In Norwegian)*, Universitetsforlaget, Oslo.
- Ryghaug, M. and Sørensen, K. H. (2009), "How energy efficiency fails in the building industry", *Energy Policy*, Vol. 37 No. 3, pp. 984-991.
- Scofield, J. H. (2009), "Do LEED-certified buildings save energy? Not really...", *Energy and Buildings*, Vol. 41 No. 12, pp. 1386-1390.
- Winter, M., Smith, C., Morris, P. and Cicmil, S. (2006), "Directions for future research in project management", *International Journal of Project Management*, Vol. 24 No. 8, pp. 638-649.

## Engineering, Construction and Architectural Management

Table 1: Facts about the case projects

Project	Year of completion	Net energy, consumption/ delivered <sup>1</sup>	Contract
Techno park, building no 3	September 2009	114/94 kWh per m <sup>2</sup> and year	Partnering contract
The bank, head quarter building	October 2010	100/85 kWh per m <sup>2</sup> and year	Partnering contract
Culture center, building no 1	October 2010	83/68 kWh per m <sup>2</sup> and year	Partnering contract
Innovation park, building no 2	August 2012	70/58 kWh per m <sup>2</sup> and year	Turnkey contract
The energy plus building	(at concept stage)		

---

<sup>1</sup> According to ISO 13790 Energy performance of buildings

## Engineering, Construction and Architectural Management

Table 1: Data sources

Project	Informants
Techno park, building no 3	Representative of property developer 2 representatives of main contractor
The bank, head quarter building	Manager of property owning company Manager of organizational development project
Culture center, building no 1	Representative of property developer Architect External energy consultant Representative of tenant organisation
Innovation park, building no 2	Manager of construction project Manager of property owning company Manager of strategic development project Representatives of tenants Facility manager
The energy plus building	9 participants in workshops, including project manager and facilitator

## Engineering, Construction and Architectural Management

Table 1 Stakeholders involved in early planning

Stakeholder	Techno Park	The bank	Culture Center	Innovation park	Energy Plus building
Client/developer	X	X	X	X	X
Architect	X	X	X	X	X
Project manager	X	X	X	X	
Consulting engineers	X	X	X	X	X
Environmental consultant				X	
Constructor				X	X
Sub-contractors			X	X	
suppliers			X	X	X
User organization / tenant		x	x	X	
FM				X	
Scientists	x				x
Public incentive program				X	
Local government				x	



Paper no 7

Meistad, Støre Valen, Brattås and Gissing (2012)

**“LCC as a decision tool for strategic development of the public building portfolio. A Norwegian study.”**

IALCCE 2012 conference, Vienna, Austria, October 3-6.





## LCC as a decision tool for strategic development of the public building portfolio. A Norwegian study

T. Meistad & M. S. Valen

*Norwegian university of Science and Technology, Department of Civil and Transport Engineering, Trondheim, Norway*

H. Brattas & H. Gissinger

*Ramboll, Trondheim, Norway*

### EXTENDED ABSTRACT

The paper explores the status of use of LCC and whole life costing methods in Norwegian municipalities today. The material is a questionnaire to leaders of municipal boards and chief municipal executives, and also interviews with senior managers in some municipal FM organization units. The study includes questions on the status for use of LCC today, interest and knowledge for operation and maintenance costs among the decision making politicians, and the value of extensive use of LCC in improvement processes.

Experience with and use of LCC in Norwegian municipalities today varies partly according to the size of the municipalities. In accordance to previous studies our material indicates that larger municipalities have the most expertise and practice in LCC-based planning.

Methods in use for existing portfolio varies, and includes historical accounting and use of national key performance indicators. Also benchmarking for best practice among similar municipalities and computer assisted FM systems are in use. For improvement and optimizing work cleaning and energy get more attention than maintenance.

The value of LCC depends partly on the usability for optimizing processes and partly on the ability to communicate to the political decision makers the long term implications of alternative priorities.

Norwegian municipalities manage a building portfolio which represents a considerable share of the national capital assets. Attention has been drawn to a maintenance backlog and the long term consequences of reduced technical quality of existing building portfolio. During the last decade there have been initiatives to improve knowledge of life-cycle cost considerations.

### REFERENCE

Brattas, H. & H. K. Gissinger 2011. Questionnaire. Political ownership to building portfolio management (In Norwegian) Ramboll: 24

# LCC as a decision tool for strategic development of the public building portfolio. A Norwegian study

T. Meistad & M. S. Valen

*Norwegian university of Science and Technology, Department of Civil and Transport Engineering, Trondheim, Norway*

H. Brattas & H. Gissingner

*Ramboll, Trondheim, Norway*

**ABSTRACT:** The paper explores the status of use of LCC and whole life costing methods in Norwegian municipalities today. The material is a questionnaire to leaders of municipal boards and chief municipal executives, and also interviews with senior managers in some municipal FM organization units. The study concludes that a variety of LCC methods are in use, including use of historical data and key performance indicators. Benchmarking is used for improvement purposes. The value of LCC depends partly on the usability for optimizing processes and partly on the ability to communicate to the political decision makers the long term implications of alternative priorities.

## 1 INTRODUCTION

Norwegian municipalities spend 6 to 16 % of their yearly budget on facility management (SSB 2010). If adding investments, the built facilities represent 15-20 % of their economic resources.

The national policy during the last decade has implications for building ownership in Norwegian municipalities. To provide kindergarten for all children and improve quality of elderly care homes, investment level has been high. In the same period the population has increased (by 1 % the last decade) and there is mobility for centralization. As a consequence the existing portfolio of schools and other service buildings are not meeting today's standards and future needs, and municipality boards have to consider refurbishment or new buildings.

The high attention to investments seems to have made maintenance of existing building portfolio suffer. Surveys have revealed a backlog of maintenance (PwC 2008; RIF 2010), implying decrease of quality and value of the total public building portfolio. However, building portfolio management lately has gained increased priority within local public administrations and increased attention among the politicians (Brattås 2011).

### 1.1 *LCC as tool and politicians as decision makers*

The Norwegian law on public procurements (see EU regulations) says that LCC analysis should be among the criteria taken into consideration. Also environ-

mental implications should be considered when making decisions about public procurements and investments. Gradually LCC analysis is now becoming part of practice in Norwegian municipalities.

This paper seeks to find what may be the status of LCC and other methods for whole life cost (WLC) calculation in Norwegian municipalities today, and how LCC calculation may or may not contribute to optimize the overall cost level per capita connected to municipality building portfolio.

It is important to remember that a LCC is a calculation tool, which will not directly impact on LCC performance without going through a decision. To find the status and the effects of using LCC tools we have to focus on the decision makers. The respondents in this paper are the top management (majors and city managers) for the questionnaire and senior managers in the FM departments for the interviews.

### 1.2 *What is LCC in Norwegian public building portfolio management*

According to ISO 15686-5:2008 Life-cycle cost include costs for construction, operation, maintenance and end-of-life. However the definition in the Norwegian Standard NS3454 differs a little from the ISO standard. In the Norwegian version non-construction costs are included, such as administration, strategic property management and finance (Jensen 2001). This is also the case for municipalities and other public building portfolio managers.

Regarding management of existing building portfolio, the focus is on overall optimizing processes rather than individual decisions. From previous studies (Bjorberg 2007; Valen 2011) we expect that municipal building portfolio management units mainly have experience with LCC calculations from construction projects.

Among the overall life-cycle costs related to a building, operation costs amount by far to the largest share. According to this a hypothesis is that cleaning and energy have first priority in processes for quality and efficiency improvements in Norwegian municipalities. This implies that other means than LCC calculations may be in use in portfolio management today.

### 1.3 Objectives for public building portfolio management (ownership)

Overview and control of the building portfolio is vital for daily activities and ongoing development of the local community. Without control maintenance and investments will be ad hoc, depending on surprising damages, official rules from inspections etc. which are costly and annoying (Horjen 2011).

To upkeep the quality level of the building portfolio is good long term economy. Also customer /user satisfaction and attitude towards the local municipality is influenced by the quality of the buildings (Horjen 2011). Basically portfolio management principles are the same for private and public owners, and also include the following objectives (Cooper 2000):

- To properly allocate scarce resources
- To yield the right balance of investments and management of existing facilities
- To forge the link between project selection and overall strategy, and achieve a stronger focus
- To communicate priorities within the organization
- To provide greater objectivity in project selection

On this background we expect the informants of our survey to consider all these objectives for building portfolio in their own municipality. The question is how they enlighten the multiple aspects and compare alternative solutions/strategies.

### 1.4 The role of politicians

Local politicians elected for the municipal board have at least three roles regarding the municipal building portfolio. The municipal board is represent-

ing the inhabitants as owners of the public buildings, and responsible for administrating the ownership. The municipal board also provides services for the inhabitants, and the teaching, care, sport and cultural activities etc are depending on the facilities. In addition the municipal board is employer for the local public employees. The quality of building portfolio management is crucial for all these roles.

Local public ownership is of political importance for a number of reasons. In addition to providing public services to the inhabitants, the built infrastructure serve as means for community and industrial development and for the general reputation of the municipality (Horjen 2011).

On this background we expect politicians to represent an overall perspective in relation to the facility management (FM) department of the municipality administration. As responsible owners politicians in the municipal board are expected to provide targets and the necessary resources for the FM department, and to follow-up performance and long term development.

### 1.5 Relevance of municipality size and organization model

Floor area per inhabitant (per capita) is often used to compare performance of municipalities. The higher floor area per capita the higher is the cost level of building portfolio management. Therefore the long term cost level is depending on how the total building area relates to the number of inhabitants in each municipality (Horjen 2011). In Norway the level varies among municipalities from less than 5 up to 20 m<sup>2</sup> per capita (SSB 2010). The average for municipalities with less than 5 000 inhabitants is twice the area of municipalities larger than 20 000 inhabitants. This reflects less flexibility in use of area in the smaller municipalities. It is also a consequence of scarce population and demographic change in Norwegian communities (Bjorberg 2009).

National benchmarking proves that in general the service cost level for the smaller municipalities is higher than for the larger ones. This is partly compensated through redistribution of tax money between the communities. However economical compensation, there is still the challenge of competence and capacity for management of the building portfolio in small administrations. Due to increased demands of service quality and number of public regulations (including regulations on health and security for users and employees, energy and environment regulations, procurement regulations etc.), the demands for competence, strategies, tools and capacity is increasing. National and international research has enlightened positive effects from organizing larger

portfolio units. Examples are the relatively recent reorganization of building portfolio management at state level (Statsbygg and Forsvarsbygg). The merged organizations have improve performance and costs, and proved able to compete for recruiting key personnel. One study suggest inter municipal co-operation regarding building portfolio management (Rohn 2011). The argument is that even the 30 % that score “best performance” among Norwegian municipalities today are not considered robust enough to deal with future challenges (Rohn 2011).

There are three main models for management of local public buildings (BE 2011):

- A. Building portfolio management within each service (school, elderly home etc)
- B. Building portfolio management as one department of the municipal administration
- C. Public enterprise owned by the municipality

On this background we expect that in our material that the status for building portfolio management, the knowledge and the use of LCC considerations will be higher for the largest municipalities.

We also expect that knowledge and use of LCC varies according to management model for the building portfolio.

## 2 MATERIALS AND METHODS

### 2.1 Methods and informants

The material covers FM managers and leading politicians in Norwegian municipalities. It is a combination of a web-based questionnaire to nearly every 4th of the municipalities, and interviews with some sample municipalities.

The web-based questionnaire were sent to 100 out of 430 municipality administrations, including 5-6 from each Norwegian county, both small and larger municipalities. The questionnaire was sent to two representatives in each municipality, the top political leader (mayor) and the top administrative leader (chief municipal executive). 21 % reply (42 out of 200). Inquiries on participating in the survey were made February 1th 2011, and reminders sent March 1th and 9th.

The survey includes questions and statements on the situation for facility management in the respective municipalities, including tools for long term maintenance planning, economical resources, political priority of these means and barriers for further improvements. Some of the questions are repeated from a similar survey performed in 2004. This gives the opportunity for comparing answers and enlightens change over time.

In addition to the survey, semi structured interviews with senior manager in the FM organizations in 9 municipalities has been performed. These interviews focused mainly on the calculation tool and how the different tools is used to support decision making in connection with the municipality building portfolios in refurbishment project, day to day building operation and new building projects. In addition there are questions regarding the relation between politicians as decision makers and the portfolio management unit as responsible for planning, maintenance and daily operation. Interviews were performed by phone during January 2012, and lasted from 30 to 60 minutes each.

### 2.2 Characteristics of municipalities

The municipalities in our material represent the variety among Norwegian municipalities. 75 per cent of the Norwegian municipalities have a population up to 10 000. This is the case for 50 per cent of the municipals represented in our material (see Table 1). This implies that the larger minority of municipalities is somewhat over represented in our material.

Table 1. Characteristics of case municipalities

Case municipality	a	b	c	d	e	f	g	h	i
Population (1000)	4	6	6	6	10	16	18	26	165
New construction projects last 5 years	2	0	4	4	3	4	3	7	55
Refurbishment projects last 5 years	6	4	2	1	0	0	4	5	7

As for investments in new buildings and refurbishment the activity level varies a lot, from full investment stop in one case to investment boom in others (see Table 1).

Table 2. Management model for building portfolio

	Case municipalities (n=9)	Questionnaire (per cent)
A. Building portfolio management within each service	1	12 %
B. Building portfolio management as one department of the municipal administration		80 %
B1: Split between unit	4	

for operation and management and unit for investments and refurbishments		
B2: United functions	4	
C. Public enterprise owned by the municipality	1	8 %

As for model for management of the building portfolio 90 per cent of all municipalities in our material have a shared unit for all service buildings (see B and C in Table 2). The units are reporting to the chief municipal executive or the executive board. While half of the case municipalities have one unit for operation and management and another for investments and refurbishment, the rest have a shared unit for all these functions.

### 3 RESULTS

#### 3.1 Status of building portfolio management in Norwegian municipalities

Status of maintenance and operation have improved since the 2004 white paper focused on municipal building portfolio management. Our material indicates that focus has increased and standard have improved. (see Table 3.) However the opinion is that investments in new facilities still have a higher priority in the municipality board.

Table 3. Statements on maintenance, investments and costs

Statement	Questionnaire (per cent)
Planned maintenance decrease costs in the long run	90
Increased focus have given stronger priority to facility management	52
Standard of facilities have improved the last five years	60
Investment in new facilities have higher priority than working capital for maintenance	70

#### 3.2 Status of LCC in building portfolio management

Our material indicates that the use of LCC calculations in Norwegian municipalities is at an early stage. As for considering refurbishment and for comparing alternative new building designs it is partly being used. However, for the purpose of optimizing facility management costs for the existing

municipal building portfolio, such methods are hardly in use today (see Table 4).

Table 4. Status for practice of LCC today in case municipalities

Statement	Number of municipalities where this is the case today (n=9)
Use LCC today for optimizing FM in existing building portfolio	1
Experience from using LCC in considering refurbishment or new building	2
Experience from using LCC in comparing alternative designs for new building	2

For those using LCC analyses, the calculations are performed by external advisory engineers or contractors as part of procurement. No one of our case municipalities use their own personnel to perform such calculations.

There is more LCC experience from investment projects than from operation and maintenance planning. Still LCC is not widely used in decisions on building projects. Other factors, such as demands from an increasing population, the overall technical condition of existing building, or new localizations are often the basic argument for investment decisions.

For the purpose of cost planning of maintenance of existing buildings, a variety of methods and practices are in use. Most common is using local historical data or key performance indicators to find an expected yearly cost level for the building portfolio (a in Table 5). Some have computer assisted FM systems (about half of case municipalities, d in Table 3), however our informants report that the level of use varies. Others use benchmarking for best practice (b in Table 5), by participating in municipal networks focusing of quality and cost improvements. Some municipalities have status reports on each building (f in Table 5). Some have additional long term plans for major maintenance work for the whole portfolio, customer survey and external evaluations have been performed (e, g and j in Table 5), however this is the exception. Planning and improvement of cleaning and energy use (h and i in Table 5) have a higher priority than on maintenance.

Table 5. Status for practice of LCC today in case municipalities

Methods in use for optimizing maintenance and operation in existing buildings	Interviews Frequency (n=9)	Questionnaire (per cent)
a) LCC, including key performance indicators and own historical cost numbers (per m2)	4	64 %
b) Benchmarking networks	4	60 %
c) Reports from caretakers and inspectors	1	-
d) Computer assisted FM systems	5	-
e) 4 year period maintenance plans	1	-
f) Status report for each building*	1	33 %
g) Customer surveys	1	-
h) Cleaning planning	6	-
i) Energy accounting**	4	60 %
j) External evaluation of building portfolio management	2	-

\*) survey of technical condition

\*\*) including use of follow-up tools in Energy labeling schemes.

Among our interview cases are municipalities without plans or long term budgets. In these municipalities the building management units experience low priority on the budgets and a severe backlog on maintenance.

### 3.3 Contributions of long term calculations to building portfolio management

All interview informants have knowledge of the basic principles for life-cycle cost analysis. They see the potentials for improving the long run economy of operation and maintenance. They are also aware

that such analysis improves communication with the political decision makers (the municipal board) and the head administration of the municipality. This finding is in accordance to findings in a German survey, showing that the perceived importance of LCC for decisions is much higher than the frequency of actual calculations being performed (Peltzer 2006).

Historical numbers, national key performance indicators and benchmarking networks are examples of methods in use in building portfolio management planning. Experiences in these municipalities illustrate how long term planning contributes to optimize the overall cost level per capita connected to municipality building portfolio:

- The methods contribute to communicate to the municipal board (eventually the enterprise board for the municipal enterprise) implications of existing policy for facility maintenance. Historical experience numbers and/or national average numbers also contribute to communicate the implications of new building projects. The main implications communicated are as follows:

- o effects of high/low area efficiency of the building portfolio
- o the need for personnel (teachers, health personnel and others) depending on usability and quality of buildings in use
- o energy efficiency of alternative materials, heating solutions and operation control systems

- The methods contribute to focus on quality, efficiency and potential improvements. FM administration experience increased interest from the local politicians. FM personnel and clients are involved in improvement initiatives. Politicians follow up more frequently and dialogue with the FM unit improves.

## 4 DISCUSSION

#### 4.1 *How do LCC make a difference?*

When LCC has been used in major refurbishment project, it is only in situations “when in doubt”. With other words, LCC matters within a limited part of the overall consideration of priorities in a local community. Firstly, the municipal board has to decide which to prioritize; “the children or the grandmothers”. Next, the administration is aware that daily cleaning and operation, including energy, are the dominating part of the total LCC costs. This leaves for discussion the strategic choices of standards and the related cost levels.

The question to our interview informants is if and how LCC a make a difference. The challenge consists of two parts (Bjorberg 2009). One is to optimize operation and maintenance efficiency in the long run. The other part is to document the relation between budget level and quality level, and to communicate this between the operational level of the organization and the strategic decision making level.

Informants in our material illustrate there have to be a balance between the two purposes: “If LCC can improve communication then such methods are useful”. There seems to be a positive relation been increased documentation of historical development and long term implications, and interest for building portfolio management in the municipal boards. Budget effects may however vary, due to overall conditions. Two positive examples are worth mentioning. One is when an external evaluation documented high efficiency within FM compared to other municipal sectors and resulted in budgets for recruiting extra personnel (case municipality D). Another example is a recent signed energy performance contract (EPC), based on a budget where after few years the energy cost savings have paid for the investments and future saved costs can be redistributed to other operation and maintenance purposes (case municipal B).

#### 4.2 *Relevance of municipality size*

Other reasons for limited use of LCC methods are also worth exploring based upon our hypothesis and available material.

Size of the municipality partly matters. While practice varies among small and medium size municipalities, the one larger city in our material have by far the most thorough planning and evaluating system for building portfolio management. This might be related to the large portfolio and the large investment level recently. Competence on LCC methods is high, and in general “we are expected to be professional”. Our findings support our hypothesis, and also support the suggestion of considering increased co-operation between municipalities on management

(Rohn 2011), long term planning and benchmarking for improved practice.

#### 4.3 *Relevance of organization model*

Organizing of the overall municipal building portfolio management partly matters. Reorganizing to common building portfolio management units in most municipalities a decade ago have proved positive, and our informants report of continually ongoing improvement processes. Today some municipalities have one organizational unit covering the whole life of the building portfolio, from construction to operation and maintenance, while others have two separated units. The main reason for the split model is to separate the client role in procurement and design processes from the FM role. However our informants report that this might be a barrier for LCC (rather whole life cost) planning and for implementing FM experience in investment decisions.

## 5 CONCLUSION

Our material implies that even if building portfolio management and facility management has relatively high priority in Norwegian municipalities, LCC is hardly in use for long term planning of existing portfolio. LCC is partly being used for procurement and refurbishment projects. As for management of existing building portfolio historical numbers of actual cost values, national key performance indicators and benchmarking is being used today.

The contribution of long term cost planning tools is to relate FM cost level to the suitability of the existing municipal building portfolio. Primarily such methods enlighten the relevance of area efficiency, energy efficiency and personnel needs to the overall cost level. The ability to communicate these issues for decision makers, both politicians and administration, has highest priority in choosing tools for this purpose.

The usefulness of LCC in improvement processes is emphasized in our study. Independent of methods and level of planning “good building portfolio management” basically presuppose a long term overview that can be used to document the situation and work for improvements. Computer assisted FM systems are contributing in this process. However our informants remind us about the importance of dialogue with clients and personnel. This since organizing of the working process is a dominant part of the total LCC cost. It also affects efficiency for teaching, care taking and other activities in the buildings, and job satisfaction and eventually work related sickness leave for all personnel. The overall challenge is to



further upgrade the interest regarding operation and maintenance among both personnel and politicians. In this perspective LCC is an important tool both for process optimizing and communication.

## REFERENCES

- BE 2011. Municipal building portfolio management (In Norwegian: Byggtknisk institutt: 65
- Bjorberg, S. 2007. Life cycle cost (LCC) in Norway – experience and state of art. MM conference.
- Bjorberg, S 2009. Public buildings - from decay to model of excellence. MM conference Rome.
- Brattas, H. & H. K. Gissinger 2011. Questionnaire. Political ownership to building portfolio management (In Norwegian) Ramboll: 24
- Cooper, R. G., Scott J. Edgett & Elko J. Kleinschmidt 2000. *New Problems, New Solutions: Making Portfolio Management More Effective*. Research Technology Management (Industrial Research Institute, Inc.) 43(4).
- Horjen, F. 2011. Good municipal building portfolio management (In Norwegian). BE - Statens byggtkniske etat.
- Jensen, P. A. 2001. Handbook in Facilities Management (In Danish) Taastrup, Danish Facilities Management Association.
- Peltzer, A. 2006. *Lebenszykluskosten con Immobilien – Einfluss von Lage*. Gestalt und Umwelt, Müller, Köln
- PwC, 2008. Maintenance in the municipalities (In Norwegian) Multiconsult & PwC.
- RIF 2010. State of the nation.
- Rohn, H. 2011. Report on ownership and organizing of building portfolio management in municipalities. (In Norwegian). Reinertsen
- SSB 2010. KOSTRA 2010, Statistics Norway
- Valen, M. S., N. Olsson, S. Bjorberg and H. K. Gissinger 2011. Maintenance of buildings (in Norwegian), Tapir akademisk forlag

## APPENDIXES

- A. INTERVIEW GUIDE, FM in design and plan phase – adding sustainability and long term value – learning and changing, 2011 (In Norwegian)
- B. INTERVIEW GUIDE, Bruk av LCC I norske kommuner, 2012 (In Norwegian)
- C. INTERVIEW GUIDE, Powerhouse One, 2012 (English version)
- D. INTERVIEW GUIDE, forbildeprosjekter (2013) (In Norwegian)
- E. CONSENT AGREEMENT, Interviews for Building Bridges/Zero Emission Buildings (English version)
- F. CONSENT AGREEMENT , Erklæring om samtykke til å delta i datainnsamling. Intervjuer for studien «Læringseffekter fra forbildeprosjekter» (In English: Consent agreement regarding interviews, «Learning effects from role model projects»)

## INTERVJUGUIDE -

### FM in design and plan phase – adding sustainability and long term value – learning and changing

Bygg/case:

Intervjuobjekt:

Tid og sted:

#### A) Erfaringer fra plan- og byggeprosessen

Målsettinger for bygget/prosjektet	
Om valg av anbudskonkurranse	
Suksesskriterer	
Er det gjort en evaluering av byggeprosessen?	
Hvilke vurderinger er gjort for bygget på lang sikt?	

#### B) Del om FM i planarbeidet

<b>Om integrering av FM i planprosessen</b>	
Hvem tok initiativet til å integrere drift/vedlikehold i planarbeidet for byggeprosjektet? I hvilken grad var det intergrert?	
Hvordan vil du beskrive prosessen i forhold til å involvere FM enhet i tidlig fase/prosjekteringsfase? Var den vellykket? På hvilken måte?	
Hva var viktige motiver? Miljøprofil? Bevisst valg hos byggherre? Betydningen av tidligere erfaringer?	
Hvordan foregikk samarbeidet? Hvem har FM enheten forholdt seg til?	
Hvilke effekter ser dere av å inkludere FM tidlig? Betydning for miljø, energi, arbeidsforhold for brukerne, økonomisk, annet.	
Utfordringer underveis?	
Er det noe å lære for andre byggherrer?	

Hvordan markedsfører dere bedriften ut mot kundene? Hva er bedriftens fortrinn i forhold til kunden?	
Har dere miljø/energibevisste kunder i prosjektet? Hvilken rolle har de evt. hatt i prosessen?	

C) Del om erfaringer fra første driftsår

<b>Om erfaringer etter at bygget ble tatt i bruk</b>	
Hvor fungerer samarbeidet mellom driftsavdeling og leietakerne/brukerne til daglig? (Praksisfellesskap)  Har det vært endringsbehov?	
Hvor nært er samarbeidet med byggets eier til daglig?	
Hvordan systematiserer informasjonsflyten mellom med leietaker/brukerne for å bruke bygget på beste måte?	
Hvordan kommuniserer bruker sine behov for driftsoppgaver til forvalter?  Hvordan systematiserer drifts og vedlikeholdsoppgavene?  I hvilken grad kan bruker påvirke utviklingen av bygget og melde inn endringsbehov?	
I hvilken grad handler driftsfunksjonen om planlegging og langsiktig planmessig vedlikehold vs "brannslukking"?  Hvor stort er vedlikeholdsbudsjetter pr år?	
Hva slags statistikk og rapporter gis tilbake til eier og bruker om driften av bygget?  Blir det gjennomført noen benchmarking m/gitte nøkkeltall mot tilsvarende andre energibygger i ?	

## INTERVJUGUIDE OM BRUK AV LCC I NORSKE KOMMUNER

### Bidrag til IALCCE konferanse, oktober 2012

Torill Meistad, 2012 – 12 – 11

### **Innledning**

Bygningers levetid/funksjonstid påvirkes av drift og vedlikehold gjennom livsløpet. Og beslutninger under planleggingen av nybygg får betydning for kostnader til renhold, vedlikehold og utvikling etter at det tas i bruk.

Det er utfordrende å vurdere og prioritere oppgaver opp mot hverandre, og finne en optimal balanse. Det er siden 2000 lovpålagt å ta hensyn til livssyklus kostnader ved offentlige anskaffelser.

Vi gjør nå en undersøkelse for å samle erfaringer med livssyklusvurderinger i noen utvalgte norske kommuner. Dette gir oss et bilde av praksis i kommunal eiendomsforvaltning idag. Arbeidet skal presenteres på internasjonal konferanse i høst.

### **Guide for telefonintervju**

#### Spm 1:

- a) Har kommunen erfaring med vurdering av livssyklus kostnader for eksisterende bygningsmasse?
- b) I tilfelle nei, bruker dere andre verktøy (som f.eks Benchmarking, balansert målstyring Lean eller annen metodikk for å optimalisere bygningsdrift og renhold?
- c) I tilfelle ja, hvilke framgangsmåter brukes (styringsverktøy)?
- d) I tilfelle ja, hvilken betydning har dette for hvordan renhold og vedlikehold legges opp?

#### Spm 2:

- a) Hvordan agerer politikerne i forhold til beslutninger om nyanskaffelser?
- b) Er de opptatt av kostnader i driftsfasen ved beslutninger om nybygg/rehabilitering?
- c) Hvordan fungerer LCC-analyser som beslutningsverktøy for politikerne?
- d) Hva er viktigst for politikerne når de skal fatte beslutninger om eiendomsforvaltningen?

#### Spm 3:

- a) Kan du gi en grov oversikt over gjennomførte byggeprosjekt i din kommune siste 5 år
- b) Hvor mange av disse var nybygg?
- c) Hvor mange av disse er gjennomført som rehabilitering?
- d) Hvor mange av disse sakene var det spørsmål om enten nybygg eller rehabilitering?

#### Spm 4:

- a) Ble det utført egne LCC-analyser?
- b) Hvordan har kommunen gått fram for å belyse kostnader over livsløpet for de aktuelle alternativene?
- c) I tilfelle ja, hvilken betydning hadde dette for beslutningene?

Spm 5:

- a) Hvilke målsettinger har kommunen for drift av eiendomsmassen?
- b) Hvordan blir målene fulgt opp? Sanksjoner?
- c) Arbeides det med forbedringsprosesser? Hvordan?
- d) Er målsettingene politisk forankret?
- e) Er politikerne opptatt av kostnader til drift og vedlikehold i eksisterende bygningsmasse?

## Interview guide Powerhouse #1

### Purpose of interviews:

The research Centre for Zero Emission Building (ZEB) in Norway, is currently collecting experiences from the Powerhouse #1 project workshops.

The interview material will be summarized in a paper for internal use among ZEB partners for the purpose to share experiences and lessons learned from the process so far. In addition the material may be used in future research on zero emission in the built environment. All data will be depersonalized.

The interview will be done by phone or Skype and will last for an hour. With your permission the interview will be taped.

1. Your personal background
  - a. Demographic information
    - i. age
    - ii. current occupation
    - iii. educational background
    - iv. previous jobs
  
  - b. Your role in the Powerhouse #1 project
    - i. How you got involved
    - ii. Your expectations in advance of project involvement
    - iii. Who are covering expenses for your contribution?
    - iv. How much have you been involved?
    - v. How and how much will you be involved in the future?
    - vi. How important is the project for you personally?
    - vii. Would you prefer to be less/more involved in the future?
    - viii. What are your benefits from succeeding with the project?

2. Context of the project
  - a. What other projects of your knowledge can be compared to Powerhouse #1?
  - b. What makes Powerhouse #1 special?
  - c. Are there other projects that you would consider as more important? Why is that?
  
3. Your experiences with the project
  - a. Have you had any surprises so far?
  - b. The present and the future for the project:
    - i. From your perspective what is the background for the project?
    - ii. What do you know about what will happen further on?
    - iii. In your opinion, what are the preconditions to succeed?
    - iv. What role would you like to have in realization of the project?
  - c. Involvement of your employee (Hydro BS)
    - i. What do you know about your employee's involvement in the project?
    - ii. In your opinion, should your employee be more or less involved? How?
  
  - d. About aims of the project
    - i. What are the targets? And where do they originate from?
    - ii. In your opinion, should the targets be adjusted? Why is that?
    - iii. What challenges regarding the environmental targets have you met during the project so far? How have you overcome the challenges?
    - iv. Have there been any conflicts or dilemmas? How have they been dealt with?
  - e. Co-operation
    - i. How have partners involved in the project been co-operating?
    - ii. Do you experience interest and willingness for co-operation, development and improvements?
  
4. Learning effects
  - a. What are your lessons learned from involvement in the project?
  - b. How have you been learning?
  - c. Are there knowledge missing among the participants? What is most important in your opinion?
  - d. Is there any knowledge missing that in your opinion will be crucial in the future?
  - e. Is there actors/personell that should be involved in future work? Who and why?
  - f. Is there any knowledge that so far has proven not to be useful?
  - g. Are you an active member in other networks or co-operation projects?
  - h. How will you be using your experiences in future projects?
  
5. Finally, are there anything else you would like to comment on?



## INTERVJUGUIDE FORBILDEPROSJEKTER

### 1. Om energi- og miljømålene i prosjektet

- a. Hva var bakgrunnen for disse målene?
- b. Hvem tok initiativet?
- c. Hvem har vært pådriver underveis?
- d. Har det blitt endringer i målene? Hvorfor?
- e. (Hvis bygget er i drift allerede:) Hva vet du om målene er oppnådd?

### 2. Om samarbeid mellom aktørene i planfasen av byggeprosjektet

- a. Hvilke aktører var involvert fra starten?
- b. Hvordan ble planleggingsarbeidet organisert?
  - i. Ble det gjort særlige tiltak for å nå energi/miljømålene? Evt hva?
  - ii. Skiller arbeidsformen seg fra tradisjonelle byggeprosjekter, evt hvordan?
- c. Var det endringer i samarbeidet underveis?
- d. Har det vært utfordringer? Hva?
- e. Ble følgende brukt? **Ja/nei**
  - i. Arbeidet i tverrfaglige team over tid
  - ii. Workshops
  - iii. Innvolving av driftspersonell
  - iv. Innvolving av ansatte og brukere
  - v. Samspillkontrakt med entreprenør
  - vi. Samspill/partnerkontrakt med andre aktører? Evt hvem?
  - vii. Grønne leiekontrakter
  - viii. Målinger og justeringer etter innflytting/i drift. Evt. hva er erfaringene?
  - ix. Samlet inn EPDer for bygningsmaterialer
  - x. Satt opp klimagassregnskap
  - xi. Ekstern miljøkonsulent
  - xii. BIM. Evt kunne BIM lettet arbeidet med energi/miljømålene?
  - xiii. Andre tiltak for bedre kommunikasjon
- f. Hvordan har samarbeidet hatt effekt på energi- og miljøresultatene?

### 3. Om læringseffekter

- a. Hvilke erfaringer fra tidligere prosjekter ble brukt i arbeidet med høye energi/miljømål i dette prosjektet?

- i. Hvilke prosjekter
- ii. Hvilke aktører
- b. Evt læring fra tidligere byggetrinn?
- c. Hvilke tidligere erfaringer med tett samarbeid/integrert prosjektering ble brukt?
- d. Hvilke erfaringer ble høstet i løpet av dette prosjektet?
- e. Har du brukt det du lærte i senere prosjekter?
- f. Hvordan er læringen spredt til kolleger i din virksomhet?
- g. Er noen av erfaringene blitt en del av ordinær praksis i din virksomhet?
- h. Hvilke smitteeffekter har prosjektet hatt som forbilde for byggenæringen?

*Har du noe å tilføye til slutt?*

## CONSENT AGREEMENT

### Interviews for Building Bridges/Zero Emission Buildings

#### Purpose

The main objective of the Research centre for Zero Emission Buildings (ZEB) is to develop competitive products and solutions. Building Bridges is an initiative to collect and disseminate experiences from pilot projects initiated by ZEB partner companies. Powerhouse #1 is among these projects.

Interviews will be used for a memorandum summarizing lessons learned from the Powerhouse #1 project at this stage. The memorandum will be used within the ZEB partners. Depersonalized data may also be used in relevant research by the ZEB centre and by the two phd students undertaking the interviews, Torill Meistad and Lillian Strand.

Torill Meistad is Phd student at Department of Transport and Civil Engineering at the Norwegian University for Science and Technology (NTNU). Her research topic is on increasing sustainability in Norwegian construction industry and focus on diffusion effects of pilot projects.

Lillian Strand is PhD student at Department of Architectural Design, History and Technology at NTNU. Her research topic is on value chains within the construction industry and use of local resources, especially on wood as construction material in urban constructions.

#### Data security

All data will be treated confidentially. Informants have the opportunity to read and correct notes from the interview. Phonograms will be stored until the research work is completed, by the end of 2013. Data will only be available for the two phd students and ZEB professor Thomas Berker.

Contribution in interviews is optional. Informants may at any time withdraw without stating any reasons, and may ask for notes and phonograms to be deleted.

#### Contact information

Further informateion can be provided by the following:

PhD cand. Torill Meistad, NTNU: [torill.meistad@ntnu.no](mailto:torill.meistad@ntnu.no), ph +47 95972035

PhD cand. Lillian Strand, NTNU: [lillian.strand@ntnu.no](mailto:lillian.strand@ntnu.no), ph +47 91685967

Project manager Prof. Dr. Thomas Berker, Zero Emission Building (NTNU/ZEB):

[thomas.berker@ntnu.no](mailto:thomas.berker@ntnu.no), ph +47 92434811

#### Concent agreement

I have received written and oral information about the project "Building Bridges – PowerHouse1», and am willing to contribute in the study as described .

\_\_\_\_\_  
Name

\_\_\_\_\_  
Date

\_\_\_\_\_  
Phone no and email adress

## ***ERKLÆRING OM SAMTYKKE TIL Å DELTA I DATAINNSAMLING*** ***Intervjuer for studien «Læringseffekter fra forbildeprosjekter»***

### ***Formål***

Formål med denne undersøkelsen er å studere læringseffekten av forbildeprosjekter med høye energi- og miljømålsettinger. Tre tema står i fokus:

- a) Organisering og samarbeid i tidlig planleggingsfase
- b) Erfaringer med brukskvaliteten for de virksomhetene som bruker byggene.
- c) Læring og spredning av erfaringer til byggenæringen.

Studien omfatter ca ti forbildeprosjekter med støtte fra Enova, Husbanken, Framtidens byer og/eller FutureBuilt fra de siste fem år.

For hvert prosjekt intervjues minst en representant fra byggherre, arkitekt, rådgivere og entreprenør. Dessuten representanter for virksomheter med daglig tilhold i bygget. Intervjuene følger en spørsmålsguide som brukes til alle prosjektene.

### ***Bruk av intervjumaterialet***

Notater fra intervjuene vil bli skrevet ut og legges til grunn for en analyse. Resultatene vil bli publisert på konferanser og i internasjonale tidsskrifter. Det er også aktuelt å publisere i norske fagtidsskrifter.

Når materialet publiseres ønsker jeg å kunne referere til navn på hvert enkelt bygg/prosjekt. Imidlertid vil informantene være anonyme. Analysen vil omhandle de ulike rollene i prosjektene, ikke enkeltpersoner eller virksomheter i de enkelte prosjektene. Det er ikke planlagt å bruke sitater. Hvis det skulle bli aktuelt, vil jeg på forhånd be om tillatelse fra informanten.



Torill Meistad er PhD stipendiat ved Institutt for bygg, anlegg og transport ved NTNU. Hennes doktorgradsarbeid, «Økt bærekraftighet i byggeprosjekter. En studie av innovasjon, samarbeid og læring i norsk byggenæring», tar utgangspunkt i forbildeprosjekter med høye energimål for å studere utviklingen mot økt miljømessig bærekraft/levedyktighet i norsk byggenæring. Arbeidet avsluttes ved utgangen av 2013.

Jeg ønsker å ha en god dialog med virksomhetene i forbildeprosjektene og med dere som stiller opp for intervju. Derfor vil jeg gjerne dele mine analyser med de som er interessert, og tar gjerne imot tilbakemeldinger!

### *Kontaktpersoner*

Ytterligere informasjon om prosjektet kan fås ved henvendelse til:

PhD-stipendiat Torill Meistad, Institutt for bygg, anlegg og transport, NTNU, [torill.meistad@ntnu.no](mailto:torill.meistad@ntnu.no), tlf 73594795/ 95972035

Veileder Marit Støre Valen, instituttleder ved Institutt for bygg, anlegg og transport, NTNU, [Marit.valen@ntnu.no](mailto:Marit.valen@ntnu.no), tlf 73594644 / 91897967

Veileder Prof. Dr. Thomas Berker, Zero Emission Building (NTNU/ZEB): [thomas.berker@ntnu.no](mailto:thomas.berker@ntnu.no), tlf 92434811

### *Avtale om samtykke*

**Vennligst kryss av:**

Jeg har fått skriftlig og muntlig informasjon om prosjektet, og jeg er villig til å bidra i undersøkelsen slik det er beskrevet ovenfor. Jeg kan når som helst trekke meg og be om at notater slettes, uten at dette må begrunnes.

Jeg ønsker å få tilsendt notater fra intervjuene, for å kunne lese igjennom og rette opp eventuelle feil.

Jeg vil gjerne få tilsendt utkast til analyser og rapporter fra studien.

\_\_\_\_\_  
Navn

\_\_\_\_\_  
Dato

\_\_\_\_\_  
Telefon og epost

