SUSTAINABLE OFFICE RENOVATION

Integrated design processes in Norwegian practice

TU Delft
Delft University of Technology

Master thesis
building engineering
by Daan Boonstra
# COLOPHON

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<td><strong>Cover photo</strong></td>
<td>From left to right: Lysaker Park (photo made by the author, June 2013), impression of Powerhouse Kjørbo (Hegli, 2012), Fredrik Selmers vei 4 (photo made by the author, June 2013)</td>
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SUSTAINABLE OFFICE RENOVATION

Integrated design processes in Norwegian practice
This report is the result of a master research project in the master programme building engineering at Delft University of Technology. Design and construction processes of several office renovation projects are analysed to research the best way to organize a design process with ambitious sustainability goals. Interviews are performed with actors around five projects in Norway and the Netherlands. Of these five projects, three Norwegian projects are analysed in detail.

All actors that potentially influence the sustainability goals are interviewed, including the client, tenant, architect, contractor and sustainability consultant. I hope the final result is an inspiring read for all building professionals, interested in sustainability or not. I sincerely hope that it can find practical application rather than being ‘only’ an academic result. Therefore a guideline with short and practical advice is developed, which can be found in Appendix D.

I would like to thank my supervisors Andy van den Dobbelsteen, Roel Schipper and Jules Verlaan for their time and feedback in the final phases and their confidence in the subject in the earliest phases. Also thanks to Pål Kjetil Eian for providing me with office space and lots of free coffee at Norconsult Sandvika.

I would like to thank all interviewed actors for their time and insights in the construction practice. I do not know if it is the Norwegian culture, but I think the willingness to participate in this research (without posing any confidentiality requirements) was overwhelming and makes the final result more valuable. Anton Koomen, Arne Forland Larsen, Arne Rønning, Camilla Dalen Moneta, Egil Kongsvold, Einar Borve, Eli Mathiesen Delp, Elisabeth Meyer, Frank Foleide, Fredrik Dachli, Fritjof Salvesen, Inger Stole, Jaap van Dijk, Jan Knoop, Johan Korff, John Mak, Katharina Bramslev, Maarten Dansen, Morten Steinkjer, Per Jørgensen, Petter Schach, Philip van de Velde, Sverre Tiltnes, Thomas Aasen, Torjus Myrulsaker, Ulf Eitrik Larsen, Ulla Hahn, Unn Hofstad, and Yngvar Christiansen: Thank you!

Finally, I would like to thank my friends and family who, willingly or unwillingly, listened to my first ideas, figments and visions about the organization of sustainable design processes with all implications of sustainability around it. Denise, Sander and Janne who conducted a research at the same time should be thanked. Often it did not feel that you were working in Delft while I was in Oslo. Also Sophie should be gratefully thanked. And finally, my father who was ready for discussions and feedback at short notice until the final delivery.

During the course of this research I induced around 1200 kg CO₂, including a return flight Oslo - Amsterdam, several train trips to Trondheim, and daily computer usage. On the other hand, emissions were saved by regularly cycling to work (positive side effect: a better condition). I decided to compensate this CO₂ impact via the Fair Climate Fund. Another environmental gimmick added to this report is that it is printed on FSC approved paper.

Of course, compensating CO₂ does not literally improve the situation. It does not change my emissions in the past or future. However, I believe that if everyone starts doing something small with environmental issues, the world can change quite rapidly. I hope you will enjoy reading this report and become inspired and learn from the practical experiences in the Norwegian (and Dutch) construction practice.

Daan Boonstra
Roosendaal, 27 September 2013
SUMMARY

Sustainability is a hot topic, both in the construction industry and on the global agenda. This research focuses on the organization of the design process by conducting a case study research on Norwegian office renovation projects.

Introduction

Sustainability can fight three major global trends: climate change, depletion of fossil fuels and a scarcity of clean resources. Policies seem to favour sustainability. Besides, a profitable business case can be built on sustainability because economic feasible solutions are available, and several benefits are attached to sustainability. On the other hand, several barriers inhibit sustainable solutions, which are extensively described in literature and practical reports. Less is known about the way sustainability knowledge is applied in practice. Therefore, this research is focussed on the organization of the design process.

Research set up

The main research question, “How can a design process be organized in order to involve sustainable solutions in office refurbishment projects?” is researched by means of a literature review and subsequent case study research. In total 25 interviews are conducted. The case study data is complemented with available information from the internet.

Theoretical approach: integrated design process (IDP)

The literature review focused on sustainability as design parameter, the refurbishment task and the organization of the design process led to the conclusion that sustainability requires an integrated design approach. Contradictory parameters have to be optimized, such as daylight and energy. As Figure 0.2 shows, costs increase over time while the impact on performance decreases. Therefore, an integrated design process as presented in Figure 0.3 should be used.
Case study research

The researched projects are presented in Figure 0.4. Three ambitious sustainable office renovation projects in Norway are analysed, while two projects (one in the Netherlands, one in Norway) serve as a reference.

The cases show that sustainability goals are developing over time. The oldest project, Lysaker Park, aimed for Norwegian energy label B, while subsequent projects aimed for a passive house renovation and ‘energy producing’. The pilot case studies confirm this finding. The goal of Nesøyveien 4-6 is to achieve the Norwegian low energy standard, because it is experienced as the minimum level a building should achieve to be in line with societal requirements. The Monarch provided evidence for a shift in investment direction by investors.

Conclusions

The cases show that an integrated design process is a prerequisite to apply sustainability. An integrated design process is characterized by three prerequisites: early actor involvement, goal setting and quality assurance, and knowledge transfer and evaluation.

The outcome of the research suggests that improvements can be made especially in the role of the contractor and tenant, as well as in knowledge transfer between phases and post occupancy evaluation. These recommendations are displayed in Figure 0.5

Finally, it is concluded that the research projects have crossed the gap as is displayed in Figure 0.1. Many actors recalled that sustainable construction is becoming more mainstream. Committed clients are able to overcome barriers inhibiting sustainable solutions. However, a reputation gain in corporate social responsibility (CSR) is the most important reason to get involved in the project. Other benefits, such as improved indoor comfort and lower energy use are experienced more as a bonus than as a driving force at the project start up. This has implications for the adoption of sustainability, as not all actors are interested in CSR of buildings.

Further research

Two types of recommendations for further research can be given: new research themes and research related themes. New research themes are waste recycling, design for disassembly, difference in theoretical and real energy use and finding the best strategy for a façade replacement or upgrade. Research related themes are the combination of IDP theory with existing project and process management literature, case study research on less ambitious projects as well as further social research on the role of the contractor and the role of the tenant in office renovation projects.
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ABBREVIATIONS

BIM building information modelling (software)
BMS building management system (technical system)
BRE Building Research Establishment (organization)
BREEAM Building Research Establishment Environmental Assessment Method (assessment method)
CHP combined heating and power (technical term)
COP coefficient of performance (technical term)
CSR corporate social responsibility (management term)
D&B design and build (contract form)
DBB design bid build (contract form)
DBFMO design build finance maintenance operate (contract form)
DBG C Dutch Green Building Council (organization)
DHW domestic hot water (technical term)
EEA European Economic Area
EEP Energy efficiency plan (legislation)
EIFS exterior insulation and finishing system (technical term)
EMS energy management system (technical term)
EU European Union (organization)
FSC Forestship Steward Council (assessment method)
GHG greenhouse gas emissions (emission term)
GWP global warming potential (emission term)
HSE health safety and environment
HVAC heating ventilation and air-conditioning
IDP integrated design process
IEA International Energy Agency (organization)
IEA SHC International Energy Agency solar heating and cooling program (organization)
IPCC Intergovernmental Panel on Climate Change (organization)
LCA life cycle analysis
LCC life cycle costing
LEED Leadership in Energy and Environmental Design (assessment method)
MaTRID Market transformation of integrated design (research program)
Net ZEB net zero energy building
NGBC Norwegian Green Building Council (organization)
NVE Norges vassdrags- og energidirektorat (Norwegian water resources and energy department) (organization)
ODP ozone depletion potential (emission term)
PHPP Passive House Planning Package (software)
PV photovoltaic (technical term)
SBS sick building syndrome (emission term)
TDP traditional design process
TPA transfer of physical assets
VOC volatile organic compound (emission term)
WGB C World Green Building Council (organization)
ZEB zero energy building
1.1 INTRODUCTION TO CHAPTER 1

This chapter provides an introduction to the master thesis research. Figure 1.1 provides a graphical overview of this chapter’s structure.

In the next section a background analysis is given, describing the need for sustainability in the building sector. Based on global trends, international policies and market trends the question is raised why not every construction project is sustainable. This question is explored in section three by describing barriers inhibiting sustainability in the following section.

Based on the barriers, the main objective is developed and discussed in section four. Here also the boundary conditions will be described. Subsequently the objective is translated into the main research question, which will be described in section five, together with the applied methodology. Afterwards, the report structure is presented in section six.

The chapter ends with a description of the academic, practical and political relevance of this research.

Figure 1.1
Structure of Chapter 1 - Introduction
1.2 BACKGROUND: THE NEED FOR SUSTAINABILITY

In this section the need for sustainability in the building industry is described. First trends that favour sustainability are discussed, after which the definition of sustainability is given. Subsequently policies and market trends towards sustainability will be presented. The section ends with the question why not every project is sustainable.

1.2.1 WHY DISCUSS SUSTAINABILITY?

Sustainability is a hot topic in the building sector, as well as on the global political agenda. There are three major trends that favour sustainability: climate change, depletion of fossil fuels and scarcity of clean resources.

1. Climate change: There is scientific consensus that global warming is happening and for a large part caused by human behaviour (e.g. Strengers et al., 2013; IPCC, 2007; Powell, 2012).

2. Depletion of fossil fuels: The amount of fossil fuels is limited, and abundant use of fossil fuels leads to environmental issues because of the CO₂-emissions involved (e.g. IEA, 2013; Shell International, 2008).

3. Scarcity of clean resources: Other materials than fossil fuels are also limited (e.g. Eijdens, 2012). The emissions from the production of building materials become more important. There is a much discussion on recycling, reuse, and the creation of a circular economy.

These trends are presented graphically in Figure 1.2. Sustainability can fight these three major trends, as well as provide energy security and combat the current economic crisis (Mclecknik, 2013; IEA, 2007).

1.2.2 WHAT IS SUSTAINABILITY?

Sustainability is described as the solution for the three major trends that cause the global climate, economy and social world to change. But what is sustainability? Sustainability is a concept that derives in many forms and is a heavily debated term (Guy & Farmer, 2001). The most used definition is the Brundtland-definition of sustainable development:

**Brundtland definition:** “Sustainable development is to ensure that we meet the needs of the present without compromising the ability of future generations to meet their own needs.” (WCED, 1987)

Sustainability is thus achieved when present needs are obtained without compromising the needs of future generations.
Several subsequent reports show the developments in the definition of sustainability. The first report was ‘Limits to Growth’ from the Club of Rome in 1972. In 1987 the WCED published a report ‘Our Common Future’, and finally in 1992 at the RIO1992 conference the people-planet-profit framework was defined (Goethe Institut, 2008). In a follow up conference, Johannesburg 2002, profit was changed to prosperity to take welfare into account (UN, 2002). The main conclusions of the three reports are summarized in Table 1.1. The people-planet-profit (PPP) framework is shown in Figure 1.3.

In conclusion, the Brundtland definition, together with the PPP-framework can be defined as the definition of sustainability. However, several building related issues have to be addressed in more detail. Duijvesteijn (2002) added a fourth parameter to the framework, ‘project’, to take the relationships of the three elements into account as well as aspects such as spatial quality. However, it is still not directly known how a sustainable building looks like when taking care of people, planet, and profit/prosperity. Also other questions have to be addressed such as: what does sustainability mean for architecture and construction principles? Moreover, which technological issues have to be considered?

### 1.2.3 POLICIES TOWARDS SUSTAINABILITY

The need for sustainability is foreseeable in (inter)national policies. In 1997 the Kyoto Protocol was the first international agreement to lower greenhouse gas emissions. In 2012 an amendment was made with new commitments (UN, 2013). The European Union (EU) has adopted long-term policies as well as short-term focussed legislation. Countries within the EU have implemented these policies and legislation into their national policies, as well as adopted their own approaches towards sustainability.

On the long-term, the EU Roadmap 2050 sets the framework towards a ‘competitive low carbon economy’, which can be achieved with an emission reduction of 80% to 95% by
2050 compared to 1990, while ensuring energy security and competitiveness (European Commission, 2011a). On a shorter term the Energy Roadmap 2020 sets the 20-20-20 targets as compared to values in 1990 (European Commission, 2010a):

- Increase the share of renewable energy to 20%)
- Make 20% improvement in energy efficiency
- Reduce greenhouse gases (GHG) with 20%

The Energy Roadmap 2020 is translated into legislation such as the Energy Efficiency Plan (EEP) and the recast of the European Performance of Buildings Directive (EPBD Recast). The EEP tries to accelerate the refurbishment rate of public buildings (European Commission, 2011b), while the EPBD Recast includes that every new building from 2020 on should be ‘nearly zero energy’ (European Commission, 2010b).

The European framework also leads to changing policies and legislation in individual countries. Norway, member of the European Economic Area (EEA), has for example published an expected stepwise tightening of the energy requirements in the building code (Lavenergiutvalget, 2009). The expected tightening is shown in Figure 1.4.

It can thus be concluded that several policies are tuned towards more sustainability in buildings. The policies are mostly focussed on energy use and energy efficiency.

### 1.2.4 COSTS AND BENEFITS

Besides governmental interventions there are also private initiatives to promote sustainability. In literature several benefits of sustainability are suggested and evaluated, most of the time by comparing ‘green’-labelled buildings with their ‘non-green’ counterpart (e.g. Fuerst & McAllister, 2011a; 2011b; Eicholtz et al., 2010).

Benefits of sustainability can be divided into soft benefits and financial benefits. Soft benefits found in literature are the improvement of indoor climate and image benefits. Financial benefits found in the literature are lower operating costs, higher asset value and risk mitigation. These benefits are summarized in Table 1.2, and are described in detail on the next page.

**Table 1.2**

Sustainability benefits found in literature

<table>
<thead>
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<th>Category</th>
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<td>Soft benefits</td>
<td>Improved indoor climate</td>
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<td>Image benefit in corporate social responsibility</td>
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<tr>
<td>Financial benefits</td>
<td>Lower operating costs (e.g. reduced energy costs, reduced maintenance costs)</td>
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<tr>
<td></td>
<td>Higher asset value</td>
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<tr>
<td></td>
<td>Risk mitigation (e.g. higher rent, reduced vacancy risk, and reduced physical risk)</td>
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The soft benefits found in literature are an improved indoor climate and image benefits. Green certified buildings usually have an improved indoor climate (Miller et al., 2009). Improvements in indoor climate lead to 10-15% improved productivity and 2.5% less sick-leave (Leijten, 2002). Improvements in indoor climate can thus be the sole reason to invest in sustainability, as the costs of business are much higher than the technical improvement costs (Guertler et al., 2005). Furthermore, users of green buildings tend to be more ‘forgiving’ than users in non-green buildings, which means users in green buildings offset negative features of the building with positive ones, which is not the case in conventional buildings (Gou et al., 2013). With respect to the image benefits, green buildings can contribute to an improved corporate social responsibility (CSR) for the building owner and tenant, leading for example to the attraction of key personnel (Eichholtz et al., 2010).

The financial benefits found in literature can be divided into lower operating costs, higher asset values and risk mitigation. First, reduced energy and water use, together with lower long-term operations and maintenance costs lower the total operating costs for the building (WGBC, 2013). Secondly, the soft benefits together with the lower operating costs can lead to higher rent premiums, higher sales prices and lower vacancy rates, summarized as higher asset value. (Fuerst & McAllister, 2011a; 2011b; Eichholtz et al., 2010). These findings are also confirmed for renovation projects. (Kok et al., 2012). However, it should be noted that price effects are hard to measure because other effects, such as location and type of tenant, tend to dominate the price setting of buildings (Fuerst & McAllister, 2011b). Finally, in markets where sustainability is more common, ‘non-green’ buildings receive a rent penalty (WGBC, 2013). Other risks that can be reduced by taking care of sustainability are: physical risks (e.g. extreme weather events), market risks (e.g. changing preferences of tenants) and technology risks (e.g. other maintenance regime needed) (WGBC, 2013).
Besides the mentioned benefits, cost aspects also seem to favour sustainability. Figure 1.5 provides an overview of the societal costs per reduced megaton CO2-equivalent (MtCO2e) per year, which shows that 75% of the researched technologies provide net economic benefits. Especially replacement of lighting, appliances and refurbishing the current building stock are profitable strategies (McKinsey, 2009). The results did not change significantly when the effect of the economic crisis from 2008 was included (McKinsey, 2010). Recent research on the Dutch energy market showed the same trend: at least 20% of the final energy use can be saved by applying economic profitable and currently available measures (CE Delft, 2013).

It should be noted that these researches took a societal perspective. With a private investment perspective different aspects play a role. Investment costs can, for example, be more important than life cycle costs. However, when sustainability is integrated in the budget and not viewed as added scope, green buildings do not necessarily have to cost more than their conventional counterparts (Matthiessen & Morris, 2004; 2007). The World Green Building Council reports additional costs in the range of -0,4% to 12,5% dependent on the additional features in the building program (WGBC, 2013).

To conclude; there are soft benefits as well as financial benefits to integrate sustainability in a building project. Combined with the already available economic feasible sustainable solutions, it is thus possible to make a successful business case out of a ‘green’ building compared to a ‘non-green’ building.

1.2.5 WHY IS NOT EVERY PROJECT SUSTAINABLE?

Summarizing this section, sustainability can fight three major global trends: climate change, depletion of fossil fuels and a scarcity of clean resources. Furthermore, sustainability can provide energy security and help fighting the current economic crisis. Sustainability is defined as the state in which present needs are obtained without compromising the needs of future generations. Social, economical and environmental needs should be taken into account.

Policies seem to favour sustainability, and it is expected that legislation will become more stringent over time. Sustainability can be beneficial from a private perspective. Economic solutions are available, and it is possible to create a successful business case out of sustainable construction compared to conventional construction.

The question that comes into mind is: why is not every project, new-built or renovation, sustainable? What are barriers inhibiting to be more ambitious with respect to sustainability in building projects compared to current building codes?
1.3 PROBLEM: BARRIERS FOR SUSTAINABLE CONSTRUCTION

The previous section provided an overview of sustainability and its costs and benefits. The question why not every project is constructed sustainable is raised. This section will describe barriers inhibiting sustainability from being implemented.

1.3.1 BARRIERS FOR SUSTAINABILITY

Already in 1994, Jaffe & Stavins wrote a theoretical paper about the energy efficiency paradox, investigating factors that inhibit energy efficiency measures (Jaffe & Stavins, 1994). Their analysis can also be applied to sustainable measures in general. Jaffe & Stavins (1994) distinguish two types of failures: market failures and non-market failures. The following subsection is based on their analysis, and complemented with other literature findings. A third category with failures described by others is added to the analysis as ‘other failures’

Market failures inhibiting sustainable solutions are information problems, principal-agent problems and unobserved costs. First of all, information problems occur because it is costly to learn about new technologies. The building sector is large and fragmented into several small- and medium-sized companies, together with some large actors. Small companies lack the budget and time to invest in research and development (Ryghaug & Sørensen, 2010). Another constraint in learning about new technologies is the building sector which operates mostly in project work, making it harder to transfer knowledge between projects (Koch, 2004). Secondly, participants in economic exchange can have different goals or incentives, leading to suboptimal solutions. This is called a principal-agent problem, which is sometimes called the landlord-tenant or split-incentive problem. An example is the landlord who has to invest in energy reduction, while the tenant will reap

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<th>Table 1.3</th>
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<tr>
<td><strong>Market failures</strong> (Jaffe &amp; Stavins, 1994)</td>
<td>Information problems</td>
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<td>Principal-agent problems</td>
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<td>Unobserved costs</td>
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<tr>
<td><strong>Non-market failures</strong> (Jaffe &amp; Stavins, 1994)</td>
<td>Private information problems</td>
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<td></td>
<td>High discount rates</td>
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<td>Heterogeneity of potential adopters</td>
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<td><strong>Other failures</strong></td>
<td>Lack of urgency</td>
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<td></td>
<td>Incomplete market for sustainability</td>
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<td>Access to capital</td>
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the benefits from a reduced energy bill (IEA, 2007). Another example can be a contractor who does not face the operating costs of a building, optimizing their design decisions on the basis of upfront capital costs (McKinsey, 2009). Thirdly, unobserved costs can form a barrier as the price of goods does not include all external costs, such as the environmental costs. For example, in the Netherlands coal is the cheapest fuel while it has the highest CO₂-emissions (CE Delft, 2013).

Non-market failures inhibiting sustainable solutions are private information problems, high discount rates and heterogeneity among potential adopters. First, private information problems occur where firms have to find out how the technology affects their own business and learn about suppliers. Firms sometimes do not know which possibilities there are available, or they do not know how to apply the knowledge in their business field; an unknown-known problem (CE Delft, 2013). Secondly, high discount rates form a problem for sustainability. Building costs are analysed relative to the current building code. The building code thereby sets the minimum standard, as well as the maximum at the same time (Nässen et al., 2008). There is uncertainty about future payback time and energy prices. Furthermore, the perception of additional costs for sustainability is higher than the real additional costs (WGBC, 2013). Therefore, sustainability is often accounted with a higher discount rate. The final non-market failure is heterogeneity among potential adopters. Although a technology can be profitable on average, it can be that the specific technology is not profitable for a certain firm or individual.

Other factors found in the literature but not directly addressed by Jaffe & Savins (1994) are a lack of urgency, incomplete markets for energy efficiency and the access to capital. First, there is a lack of urgency because energy use comprises only a small percentage of the total costs of business (Guertler et al., 2005). Secondly, energy efficiency and sustainability are not a product by themselves, which is called an incomplete market. An energy efficient retrofit should, for example, be coupled to other retrofitting and maintenance measures before it is considered as beneficial (IEA, 2007). The final limitation is access to capital. It is not always possible to quantify all benefits of sustainability. Furthermore, investments in energy efficiency are often of small scale and other factors, such as the location of a project, safety and aesthetics, can outweigh investments in energy efficiency (IEA, 2007). For example, the connection between indoor comfort and an improved productivity is not always made, and when it is made it is hard to quantify the benefits. Jones Lang LaSalle indicates that the biggest hurdle is not financing, but convincing owners and investors that the expenditures are worth the costs (JLL, 2012).
In conclusion there are several barriers inhibiting sustainability. Market-related problems are information problems, principal agent problems, and unobserved costs. Non-market related problems are private information problems, high discount rates, and heterogeneity among potential adopters. Other factors that inhibit sustainability are: a lack of urgency, an incomplete market for sustainability and a lack of access to capital.

1.3.2 HOW CAN PROJECTS BE ORGANIZED TO OVERCOME THE BARRIERS?

As indicated in the previous subsection, there are several barriers that inhibit sustainability from being widespread implemented. Although economic feasible solutions exist and a lot of research shows possible solutions, sustainability is not always applied in a design process. Most barriers are touched upon during the design process and relate to unknown-known problems, as well as market adoption problems.

Unknown-known problems are organizational problems where solutions are known within the greater organization or in society, but not at the right time and place in a project team that is in need of a specific solution (Hombergen, 2011). This concept is shown in Figure 1.6 and relates to for example the private information problem described earlier. The project team can simply lack the knowledge or expertise to look into sustainable solutions. The question thus becomes how this can be overcome. How can you unlock the known solutions and knowledge within the project team, so that the right persons are involved at the right time? Furthermore, it turns not only into a question how to find the knowledge, but also how to apply it, and how to transfer the knowledge from first ideas, to the design, construction and operation phases.

A complicating factor is the knowledge gap between theory and practice. A lot of literature on sustainable solutions, barriers and opportunities exists. However, this knowledge is not always applied. Moore (2006) states that there is a gap in the adaptation of innovative solutions between early adopters and mainstream actors, as indicated in Figure 1.7. Furthermore, mainstream actors only accept and trust evidence from other mainstream actors (Moore, 2006). It can be argued that researchers are among the early adopters, while the market is among the mainstream actors.

The unknown-known problems and the barriers described earlier can possibly be solved by re-organizing the design process. The question thus becomes: how should a design process be organized?
1.4 OBJECTIVE AND RESTRICTIONS

In the previous section the question how to overcome barriers in the organization of a design process is raised. This section describes the objective and the boundary conditions that apply for this research.

1.4.1 OBJECTIVE
The organization of the design and construction process is an interesting research theme. Economic profitable sustainable solutions are available, and sustainability provides several benefits. It is possible to create a profitable business case with sustainable solutions.

On the other hand, several barriers inhibit sustainable solutions. These sustainable solutions, barriers and opportunities are extensively described in literature and practical reports. However, less is known about the way this knowledge is applied in practice. Therefore the objective of this research is defined as follows:

**Objective:** “Provide evidence from practice on the organization of a design process in order to overcome barriers to implement sustainable solutions in buildings”

1.4.2 RESTRICTIONS
This research applies four restrictions as every research is limited in scope. The restrictions are related to the building typology, project type, geography and the type of sustainable solutions researched, and are given in Table 1.4. The restrictions will be described in more detail below.

The first restriction is the building typology, which is limited to office buildings. According to McKinsey (2009), commercial buildings account for 38 percent of the building sector. Kok et al. (2011) found that large projects and large companies are more likely to adopt sustainable innovations than smaller ones, because there is more budget, time and competence available. Therefore, it can be assumed that the uptake of sustainability in the commercial sector is larger as compared to other sectors.

<table>
<thead>
<tr>
<th>Table 1.4</th>
<th>Restrictions in this research</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Restriction</strong></td>
<td><strong>Description</strong></td>
</tr>
<tr>
<td>Building typology</td>
<td>Offices</td>
</tr>
<tr>
<td>Project type</td>
<td>Post-war renovation</td>
</tr>
<tr>
<td>Geography</td>
<td>Norway</td>
</tr>
<tr>
<td>Sustainable solutions</td>
<td>BREEAM and energy use</td>
</tr>
</tbody>
</table>
The second restriction, the type of projects, led to the limitation to research only renovation projects. Due to the earlier described EU policies and targets, renovation as research subject is gaining momentum. A large part of the office stock exceeds the age of 30 years (Ebbert, 2010). These buildings have to be upgraded because of changes in technical, functional and economical requirements. Often a renovation provides a more sustainable alternative compared to demolition and rebuilt, especially in terms of material use (e.g. Thomsen & Flier, 2010). However, this decision can only be made on a project-by-project basis. Therefore, this research assumes that the decision to renovate (vs. demolition) is already taken. Only post-war renovation projects are to be researched.

The third restriction is the geographical boundary to Norway. Norwegians have a relatively high income and a sound property market, which means the diffusion of sustainable solutions is high (Kok et al., 2011). Furthermore, Norway has the most stringent building codes in Europe (Schild et al., 2010). Research in the homogeneous Nordic countries can be used as a test case, after which successful innovations can be further diffused into the rest of Europe and the world (IEA, 2013). Paradoxically, Norway owes its economic prosperity to the oil sector. While the country itself is responsible for 44 MtCO₂-emissions per year (or 8,8 MtCO₂ per person), Norwegian oil induces 300 MtCO₂-emissions abroad (Fæhn et al., 2013). However, this complex political dilemma is outside the scope of this research, and will thus not be considered any further.

The final restriction concerns which sustainable solutions to assess. Only economic feasible solutions will be researched. In the context of the previous three boundary conditions this implies that the focus will be primarily on ‘energy use’ and the broad environmental rating scheme BREEAM. Although a project-by-project analysis should determine the feasibility of these sustainability issues, BREEAM and ‘energy use’ can be assumed to be the most relevant issues in the current market conditions. Therefore this will form the starting point for the analysis of sustainability as design parameter in practice.
1.5 MAIN RESEARCH QUESTION AND METHODOLOGY

The previous section defined the main objective. Several boundary conditions were given to limit the research objective. This section provides an overview the main research question, the taken perspective and the applied methodology.

1.5.1 MAIN RESEARCH QUESTION

The introduction led to the question why not every project is sustainable. The subsequent analysis led to the main objective to find evidence from practice on how to organize the design process to implement sustainable solutions.

Schweber & Leiringer (2012) analysed current trends in construction research focussed on ‘energy use’ and the treatment of ‘non-technical’ factors. Their main conclusion was that while organizational, social and behavioural issues are acknowledged as important research areas for the implementation of sustainable construction practices, these issues are relatively unexplored (Schweber & Leiringer, 2012). This supports the need for organizational research. The main objective, together with the restrictions, can be translated into the main research question:

**Main research question:** “How can a design process be organized to involve sustainable solutions in office refurbishment projects?”

1.5.2 THREE PERSPECTIVES AND QUESTIONS

The main research question can be approached from three different perspectives: sustainability as design parameter, the refurbishment task, and design process management. These three perspectives all provide barriers and opportunities for the design process, where non-technical barriers are of main interest for this research. The three different perspectives to approach a sustainable project in practice are shown graphically in Figure 1.8.

The three perspectives will be explored by answering three sub research questions:

1. **Sustainability as a design parameter:** what are the barriers and opportunities with respect to economic available sustainable solutions?
2. **Refurbishment task:** what are the barriers and opportunities when refurbishing post war offices?
3. **Management of the design process:** what are the barriers and opportunities in the design process itself?
The first perspective, sustainability as design parameter, focusses on the technical side of sustainable solutions in building projects. Sustainable economic solutions will be researched, as well as problems and opportunities that will arise when a design team tries to implement these solutions.

The second perspective, the refurbishment task, analyses the extra difficulties in a refurbishment process as compared to a new-built project. On the other hand, the perspective sheds light over the opportunities of refurbishment projects.

The third perspective focusses on the organization of the design process. The organization of the design process also brings in own barriers and opportunities. Central to this perspective is the integrated design approach, optimizing the total building instead of subsystems (e.g. Löhnert et al., 2003).

### 1.5.3 APPROACH AND METHODOLOGY

Each perspective leads to a sub conclusion on barriers and opportunities in theory. Subsequently the barriers and opportunities in practice will be researched by means of case study research. From these cases lessons can be learned. Combined with the literature findings the research questions can then be answered.

The three perspectives will first be analysed by means of a literature review. Furthermore, seven interviews will be conducted in the Netherlands and Norway to gain knowledge from practice, prepare the author on the case studies, and check the conclusions. These interviews will be used to guide the literature review towards practical relevant themes.

Subsequently, the practical part of this research will be based on case study research. The case study research is conducted as described in Yin (2009). Two pilot case studies are performed, after which three cases are analysed more in detail. The most important actors around each project are interviewed. Sometimes the actor performed the same role in several projects. In total 18 interviews are conducted. More information on the exact case study approach and structure can be found after the literature review in Chapter 5 - Case study approach.

This research uses an interpretive approach. There is a lack of interpretive research in building and energy research (Schweber & Leiring, 2012). Interpretive research assumes that the natural scientific method (positivist approach) is not able to explain social reality (Lee, 1991). The design process is determined by the social background of the different actors involved. Therefore, the design process can only be understood by analysing it in its context. The difference between a positivist research set-up and the interpretive approach is shown in Table 1.5.

<table>
<thead>
<tr>
<th>Goal</th>
<th>Positive</th>
<th>Interpretive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Find patterns in the relations between variables</td>
<td>Describe the meaning of the relations between the variables</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>Positive</th>
<th>Interpretive</th>
</tr>
</thead>
<tbody>
<tr>
<td>The world can be described by theories and models (natural scientific method)</td>
<td>Same physical entity can have different (social) meaning for different human beings (including the researcher)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value of findings</th>
<th>Objective</th>
<th>Interpreted by researcher</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rules of formal logic</td>
<td>- Analyse subject in its context</td>
<td></td>
</tr>
<tr>
<td>Falsifiability</td>
<td>- Analysis of total system instead of parts</td>
<td></td>
</tr>
<tr>
<td>Logical consistency</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Relative explanatory power</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
1.6 REPORT STRUCTURE

The previous section described the main research question and the approach and methodology. This section provides an overview of the corresponding report structure. The report structure is shown in Figure 1.9.

The report starts with the findings from the literature review in three subsequent chapters: sustainability as a design parameter, refurbishing the current office stock and design process guidelines. Each chapter ends with barriers and opportunities to involve sustainability in a design process.

Chapter five describes the case study methodology in detail and provides two pilot case studies. Subsequently, three projects with ambitious sustainability goals are analysed in the three following chapters.

The report ends by combining theory and practice in chapter nine and finally by summarizing this discussion into general conclusions and recommendations in chapter ten.

Figure 1.9
Schematic overview of the report structure
1.7 RELEVANCE

The previous sections provided an overview of the research set-up. The background and problem analysis provided already an indication of the relevance of this research. This section will recapture and summarize the relevance of the research, divided into political, practical and academic relevance.

First, the political relevance will be described. The current rate of renovation lies between 1,0 and 1,5% of the building stock, and the European Commission tries to accelerate this to 3% for public buildings (European Commission, 2011b). This research can help speeding this renovation rate, as information on the organization of the design process will become available. Furthermore, with more sustainable renovation projects also other political goals, such as the 2020-targets can be achieved. Research by EcoFys has shown that a deep renovation scenario will stimulate the economy by creating jobs and at the same time help meeting the EU targets (Boermans et al., 2010).

Secondly, this research has practical relevance. The last decade a lot of knowledge, innovative products, and environmental labelling schemes have become available. Although the first design process models are based on experience from practice (e.g. Löhnert, 2003), it is not known how integrated sustainable design theory is applied nowadays. Are projects shifting towards integrated design? Currently two international research programmes, MaTRID and IEA TASK 47, are working on the question how a project should be organized to involve sustainable solutions in renovation projects. This provides evidence that this research has a practical relevance. Table 1.6 shows the two research programmes and their aim.

Finally, this research has academic relevance. There are few publications on integrated sustainable design and the design process. The most cited articles show that there is no confined definition of integrated design processes (Brunsgaard, 2009). Furthermore, as described earlier, there is a lack of organizational research on energy use and buildings (Schwebers & Leiringer, 2012). However, there is an enormous amount of literature on barriers and opportunities of sustainability. This research takes the current work as a starting point and focusses on how to implement sustainability. Instead of finding more barriers and opportunities in theory the research provides evidence how to overcome the barriers. Because of the interpretive approach taken in this research it is most likely that this research provides directions for further research themes.

<table>
<thead>
<tr>
<th>Table 1.6</th>
<th>Two international research programmes with the same aim, showing the practical relevance of this research.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MaTRID</strong></td>
<td></td>
</tr>
<tr>
<td>Name</td>
<td>Market TRansformation of Integrated Design</td>
</tr>
<tr>
<td>Aim</td>
<td>Support the implementation of Nearly Zero Energy Buildings by 2020</td>
</tr>
<tr>
<td>Years</td>
<td>2012-2014</td>
</tr>
<tr>
<td>More info</td>
<td><a href="http://www.integrateddesign.eu">www.integrateddesign.eu</a></td>
</tr>
<tr>
<td><strong>IEA TASK 47</strong></td>
<td></td>
</tr>
<tr>
<td>Name</td>
<td>Solar Renovation of Non-Residential Buildings</td>
</tr>
<tr>
<td>Aim</td>
<td>Develop a knowledge base how to renovate non-residential buildings towards Net-Zero Energy</td>
</tr>
<tr>
<td>Years</td>
<td>2011-2014</td>
</tr>
<tr>
<td>More info</td>
<td>task47.iea-shc.org/</td>
</tr>
</tbody>
</table>
PART 1

sustainable office renovation in theory
PART 1 | Sustainable of office renovation in theory
CHAPTER 2
SUSTAINABILITY AS DESIGN PARAMETER
2.1 INTRODUCTION TO CHAPTER 2

This chapter discusses the technical details of sustainability as a design parameter. Three subjects are described: design strategies, energy efficiency and the environmental assessment method BREEAM. The position of this chapter in the total research structure is shown in Figure 2.1. The chapter is based on a literature review on barriers and opportunities when using sustainability as a design parameter.

The first section describes the practical application of the Brundlandt-definition and the people-planet-profit framework. Design strategies, as well as the broadness and plurality of sustainability are presented.

The second section discusses relevant definitions on energy use and building codes. The Norwegian energy labelling scheme is described. Furthermore, the section provides an overview of the passive house concept and its application in a Norwegian climate. The section ends with an outlook on net zero energy buildings.

The third section describes a broader environmental assessment method: BREEAM-NOR. This method rates the environmental performance on the basis of nine categories. Design implications and critiques on the method are discussed.

Every section ends with barriers and opportunities that are found by analysing literature on sustainability as a design parameter. The chapter ends with a summary of all barriers and opportunities. The structure of this chapter is given in Figure 2.2.
2.2 APPROACH AND STRATEGY FOR SUSTAINABILITY

In Chapter 1 - Introduction, the broadness of sustainability is briefly described by stating the Brundtland-definition and the people-planet-profit-framework. First, the concept of sustainability is further explored. Subsequently, there will be a focus on design strategies that can be used to structure technological design issues with a focus on sustainability.

2.2.1 DESIGN APPROACHES

There is an ongoing debate on what sustainability comprises and how to deal with sustainability in buildings. Guy and Farmer (2001) state that this debate is often sidestepped by assuming that buildings are technological configurations and that a sustainable building just has a different configuration that has to be found. Instead of looking for this optimal configuration, a relative approach should be taken. The concept of sustainability is then only used as a means to raise awareness for different issues that can be considered. Sustainability, in their view, is pluralistic and defined by the social context of time and place (Guy & Farmer, 2001).

Guy and Farmer (2001) explore the plurality of sustainability by defining six design approaches, each based on different ideas and concepts, leading to different solutions towards a sustainable future. The six design approaches are described in Table 2.1. In practice, buildings can be designed with several design strategies in mind, or without any of the design strategies (Guy and Farmer, 2001).

<table>
<thead>
<tr>
<th>Design strategy</th>
<th>Approach to a sustainable future</th>
<th>Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eco-technic</td>
<td>- Concern about global topics</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Modern technology provides answers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- High-tech design (e.g. double skin façade)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Planet</td>
</tr>
<tr>
<td>Eco-centric</td>
<td>- Limits are set by nature</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Precautionary approach towards the planet</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Planet</td>
</tr>
<tr>
<td>Eco-aesthetics</td>
<td>- Sustainability as a social metaphor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Aesthetics as identification between nature and humans</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>People</td>
</tr>
<tr>
<td>Eco-cultural</td>
<td>- Environmental and cultural values most important</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Counteracting modernism and globalism</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Design based on vernacular approaches.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>People</td>
</tr>
<tr>
<td>Eco-medical</td>
<td>- Individual health of human being most important</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Design with focus on the quality of water, air and urban space.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Application of natural materials, light and ventilation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>People</td>
</tr>
<tr>
<td>Eco-social</td>
<td>- Focus on decentralized and democratic communities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Technology should be low tech</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Design with participatory design processes or self-build concepts with renewable and local materials.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>People</td>
</tr>
</tbody>
</table>
Building sustainably is an ongoing process with different actors having different interests and different struggles. This is also observed in more recent debates on the promotion of sustainable buildings (Guy, 2005). Yet, all design strategies somehow implement the people-planet-profit framework as described in Section 1.2 - The need for sustainability.

2.2.2 DESIGN STRATEGIES

According to research by the International Energy Agency Solar Heating and Cooling (IEA SHC) program, there is a consensus view that sustainable buildings require a high performance standard over the total life-cycle in specific areas, as described in Table 2.2 (Löhnert et al., 2003). Several design strategies are developed to guide a design process towards these goals, such as the Trias Energetica, Kyoto Pyramid and the New Stepped Strategy. Most of these design strategies focus on energy use.

The Trias Energetica was developed by Lysen (1996) as an integral design strategy to implement solar and renewable energy in buildings. The strategy is shown in Figure 2.3 and consists of three steps. The first step is to reduce the energy demand, for example by applying energy reducing measures as insulation, air tightness and heat recovery. Secondly, increase the use of sustainable resources, for example by the application of wind, solar and biomass. The rest of the energy demand should be covered by fossil fuels in the cleanest possible way, for example by using highly-efficient boilers.

The strategy is widespread applied in the Netherlands. In practice the method is applied in two ways. The first approach leads to buildings designed with a fairly good insulation level (step 1), together with energy-efficient installations (step 3). The second approach focusses on an extremely well insulated envelope (step 1) which renders step 3 obsolete (Andresen et al., 2008). The Trias Energetica can thus be interpreted in different ways by focusing on either the application of clean fossil fuels or by reducing the energy demand.

Dokka & Rødsjø (2005) extended the Trias Energetica, by inventing the Kyoto Pyramid. Their strategy is especially useful in designing highly energy-efficient buildings, such as passive houses. The method is shown in Figure 2.4 and consists of five steps.

Another strategy, based on the work of the Trias Energetica is the New Stepped Strategy, developed by Dobbelsteen (2008). This strategy, inspired on the cradle-to-cradle philosophy, is shown in Figure 2.5 and includes the following four steps:

1. Reduce demand,
2. Reuse and recycle internally (less input is needed)
3. Supply resulting demand sustainably (A), and finally let waste be food (B)

---

Table 2.2

<table>
<thead>
<tr>
<th>Goal</th>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimal</td>
<td>Non-renewable resource consumption</td>
</tr>
<tr>
<td>Minimal</td>
<td>Atmospheric emissions</td>
</tr>
<tr>
<td>Minimal</td>
<td>Liquid effluents and waste</td>
</tr>
<tr>
<td>Minimal</td>
<td>Negative impact on ecosystem</td>
</tr>
<tr>
<td>Maximal</td>
<td>Indoor climate quality</td>
</tr>
</tbody>
</table>

---

Figure 2.3

Three steps of the Trias Energetica (after Lysen, 1996)

1. Reduce energy demand
2. Increase use of renewable resources
3. Use fossil fuels as clean as possible

---

Figure 2.4

Five steps of the Kyoto Pyramid (after Dokka & Rødsjø, 2005)

1. Select energy source
2. Ensure efficient electricity use
3. Optimise solar heat gains
4. Show and control consumption
5. Reduce heat loss
This method improves the Trias Energetica in several ways. First, it does not foster the use of fossil fuels, if applied correctly the resulting in- and output in step three is sustainable. Secondly it can be applied on other flows than energy. Finally, The New Stepped Strategy can also be applied in a larger context, for example analysing a whole neighbourhood (Tillie et al., 2009)

The plurality of sustainability can thus be seen in the different design strategies. All design strategies aim at reducing the energy demand, but use different focus points, leading to different solutions. The New Stepped Strategy can also be used for other flows and can be applied in a larger context.

Extra information about the design strategies is provided in Appendix A.2.

### 2.2.3 CONCLUSIONS

In this section the broadness of sustainability is described. The Brundtland-definition and people-planet-profit framework of sustainability are translated into more specific building design approaches as described by Guy & Farmer (2001). Secondly, several design strategies are explored. From this analysis barriers and opportunities can be derived.

First, the six design approaches provide the opportunity to gain new insights as several viewpoints can be taken. The design approaches also show that sustainability can facilitate different architectural designs. Sustainability thus does not have to be seen as a limitation. On the other hand, the design approaches can cause confusion. It can perhaps be difficult to guide a design towards sustainable solutions if so many approaches are possible.

To provide more structure to the design process, several strategies can be used. Although the strategies do not set explicit goals, they can be used to guide the design and form the overall vision of a project. However, also here the plurality of design strategies can be confusing. An example is the Trias Energetica that can be interpreted in several ways.

Barriers and opportunities found in this section are summarized in Table 2.3. The remainder of this chapter will cover energy-efficient building design and BREEAM.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Barriers</th>
<th>Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design approaches</td>
<td>Different design approaches can cause confusion</td>
<td>Sustainability may facilitate many designs (design approaches provide new insights)</td>
</tr>
<tr>
<td>Design strategies</td>
<td></td>
<td>Design strategies can guide the design (form the overall vision of a project)</td>
</tr>
</tbody>
</table>
After describing sustainable design strategies, this section focuses on energy-efficient design. First, the basic principles from energy use in buildings are given. Then the principles of a passive house and its Norwegian application. The section ends with an outlook on net zero energy buildings.

2.3.1 ENERGY USE IN BUILDINGS

The calculation methodology plays an important role in energy-efficient design, because different calculation methodologies can be applied. Most important differences in building codes across European countries are the energy definition, reference areas and volumes, efficiency assumptions and building-related issues taken into account. (Schild et al., 2010). Four energy definitions and their relation are given in Figure 2.6. More information is provided in Appendix A.3.

Most building codes start by calculating the heat losses [4]. This is also done in the Norwegian building code. Every new building has to comply with a predefined set of measures, or the net energy demand [3] should be below a certain value. Furthermore, the building code provides several minimum requirements for building components (TEK10, 2010). The EPBD Recast requires all European countries to steer on primary energy demand [1] (European Commission, 2010b).

The combination of the net energy demand with strict minimum requirements provides a strong incentive towards compact architecture and a good insulated building. It appears that the Norwegian building code has the tightest building component requirements in Europe (Schild et al., 2010).

Figure 2.6
Four energy calculation definitions (based on Feist et al, 2005; Norsk Standard, 2011; Haase, 2012)
An important barrier described in Chapter 1 is that the building code acts as a norm instead of a minimum requirement (Nässen et al., 2008). However, with the voluntary passive house standard and an intermediate low-energy standard the goal is set. The Norwegian government supports energy-efficient buildings with subsidies (ENOVA, 2013).

An often discussed barrier with respect to energy efficiency is the rebound effect. It is found that users in energy-efficient buildings consume more energy than expected by the energy label calculation (rebound effect), while users in old buildings use less energy than calculated (prebound effect) (Sunnikablan & Galvin, 2012). This limits the gains from investing in energy efficiency, as shown in Figure 2.7. Although the rebound effect is a barrier, the total effect is small and should therefore not be an excuse to withhold investment in sustainability at all (Gillingham et al., 2013).

2.3.2 NORWEGIAN ENERGY LABEL

According to the EPBD Recast all countries in the European zone should implement an energy labelling scheme (European Commission, 2010b). The Norwegian scheme came into use in 2010 for offices. The following paragraph is based on information about energy labels that can be found on the website energimerking.no (NVE, 2013).

The Norwegian labelling scheme provides information about the amount of energy used by means of a mark (A-G) and the percentage of non-renewable energy used for heating by means of a colour, as is shown in Figure 2.8. However, the difference between the mark and the colour can be difficult to understand by laymen. In practice most focus and communication is on the mark. The average office building has an energy mark E and a delivered energy 260 kWh/m²a.

Two main colour groups can be distinguished. Offices which apply electrical heating (red), because Norway has relatively cheap electricity and offices that apply district heating (light green), which can be explained by the focus of the Norwegian government to provide district heating to new buildings. It is possible to obtain a red label A or green label G.

Although the total amount of certificates is rising to a total of 15,000 in May 2013, a recent survey by the NVE showed that 64% of the office stock rented out or sold in 2012 did not show an energy certificate at the transfer. This trend is also shown in Figure 2.9, which shows the amount of new certificates per quarter since 2010.

To conclude, the energy labelling scheme provides an incentive to raise awareness about energy use in buildings, however, in practice the energy label is not always used or understood. More information can be found in Appendix A.3.
2.3.3 ORIGINAL PASSIVE HOUSE CONCEPT

It is possible to obtain a lower energy use than required in the current building code. The passive house concept is defined as buildings that have a comfortable indoor climate in summer and winter, with only a simple heating system (Feist et al., 2005).

By applying the passive house concept, the primary energy demand for heating can be reduced by 80%, and the total primary energy consumption can be reduced by 50%, while at the same time indoor comfort will be improved (Schnieders & Hermelink, 2006). Although the term passive house indicates that the concept is applicable to residential buildings, the principles can be applied to a wide range of constructions. Examples of passive house certified schools, sport venues, offices, factories and other commercial buildings exist (PHI, 2013).

A passive house requires super-insulation, heat recovery and passive solar gains. Furthermore, electrical efficient equipment is a prerequisite. In this way the heat losses, and thus the heating demand, are reduced. The remaining total energy demand is so low that it can be fulfilled with energy sources like solar thermal, solar PV or other renewable energy sources (Schnieders & Hermelink, 2006). This approach complies with the Kyoto Pyramid described in Section 2.2.2 - Design strategies, and is shown in Figure 2.10. Recent European research has provided an overview of solutions that are generally applied in passive houses (Strom et al., 2005). Mlecknick (2013) re-grouped the found solutions into six energy-saving principles, which are easier to communicate to companies and clients than specific solutions. These principles are shown in Figure 2.11.

In Central European climates it is possible to obtain a passive house certificate from the Passive House Institute (PHI) in Darmstadt, Germany. The heat balance should be calculated with the Passive House Planning Package (PHPP) and the outcome should comply with criteria, as given in Table 2.4.

### Table 2.4
Minimum requirements for passive house certification at the passive house institute (PHI, 2012a; 2012b).

<table>
<thead>
<tr>
<th>Certification criteria</th>
<th>New</th>
<th>Renov.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific heating demand ((Q_h)) ([\text{kWh/(m}^2\text{a})])</td>
<td>15</td>
<td>25(*)</td>
</tr>
<tr>
<td>Specific useful cooling demand ([\text{kWh/(m}^2\text{a})])</td>
<td>15</td>
<td>-</td>
</tr>
<tr>
<td>Total specific primary energy demand ([\text{kWh/(m}^2\text{a})])</td>
<td>120</td>
<td>120 + ((Q_h - 15) * 1,2)</td>
</tr>
<tr>
<td>Pressure test result at 50 Pa pressure difference ((n_{50})) ([\text{h}^{-1}])</td>
<td>0,6</td>
<td>1,0</td>
</tr>
</tbody>
</table>

(*) = Criteria can also be fulfilled with consequent use of Passive House Certified Components (PHI, 2012b)
Many of the required components, such as triple-glazing, good insulated wall systems and highly efficient heat recovery are available, also in Nordic countries (Blomsterberg, 2011). Furthermore, the concept as a whole has proven to be economical feasible (Schnieders & Hermelink, 2006; Audenaert et al., 2008). In practice many parameters determine the feasibility, such as the required payback time and energy price scenarios. Audenaert et al. (2008) conclude therefore that a passive house is feasible, but a low energy house can be a more safe investment.

### 2.3.4 Norwegian Passive House Concept

The first developments of the passive house concept took place in a Central European climate. However, in the cold Norwegian context different climatic boundary conditions apply (Dokka & Andresen, 2006). Furthermore, building traditions are different across countries (Schild et al., 2010).

The Northpass research project focussed on the application of the passive house concept in a Nordic climate. Three important restrictions were found: the difficulty to obtain net heat gains in a Nordic climate, a lack of building tradition for summer comfort and the harsh winter conditions (Northpass, 2012). In conclusion, the original passive house requirement of 15 kWh/m²a for the heating demand is harder to obtain in a Nordic climate.

Dokka & Andresen (2006) reached the same conclusion, and proposed to alter the passive house requirements to allow a slightly higher heating and cooling demand. This line of reasoning is followed by the current Norwegian passive house standard, which is introduced as a voluntary standard in 2012 (Norsk Standard, 2012). More information is provided in Appendix A.2

The Norwegian passive house standard defines two levels of energy use: passive house and low-energy. The calculation methodology is similar to the building code. Since the introduction of the passive house standard there is an increased interest in the passive house concept (Rønold, 2013). However, some building professionals regard the passive house concept as inflexible. Small design changes between design, construction and operation can have large consequences. For example, if users have a different ventilation behaviour than expected, the energy consumption will go up (Schnieders & Hermelink, 2006).

A comparison of the Norwegian passive house standard and the original European guidelines for passive houses can be found in Appendix A.3.
2.3.5 TOWARDS (NET) ZERO ENERGY

The next step in energy efficiency is the construction of net zero energy buildings (net ZEBs). According to the Recast EPBD, all new buildings shall be ‘nearly zero energy’ by 2020 (European Commission, 2010b). When a building has a low energy standard, for example a passive house, it is a small extra step to offset the energy use with the production of renewable energy.

The concept of a net zero energy building is generally understood as a building that is highly energy-efficient, able to compensate for its demand by generating energy from renewable energy sources, and connected to a grid system (Sartori et al., 2012). This concept is shown in Figure 2.12.

The main barrier with respect to net zero energy buildings is the lack of a common definition. It is up to design teams to come up with a definition, which can be commercially biased (Sartori et al., 2012). This can lead to the paradox that energy consuming buildings can achieve a ZEB balance easier than energy-efficient buildings (Sartori et al., 2011). Although, in practice Net ZEB buildings are built much more energy-efficient than conventional buildings (Musall et al., 2010).

2.3.6 CONCLUSIONS

In the previous subsections technical details on energy-efficient building are given, by describing energy use, the passive house standard and the definition of net zero energy buildings in a Norwegian context.

From this analysis barriers and opportunities implementing energy efficiency, or ‘energy use’-issues in a design process. A summary of barriers and opportunities is given in Table 2.5.

As sustainable construction comprises more than just ‘energy use’, the next section will be devoted to BREEAM-NOR.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Barriers</th>
<th>Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy use and labelling</td>
<td>- Building code is norm rather than minimum</td>
<td>- ENOVA subsidies available for energy-efficient constructions</td>
</tr>
<tr>
<td>Passive house concept</td>
<td>- Energy efficiency requires extra skills at construction site (e.g. airtightness)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Energy efficiency requires new design skills (e.g. focus on summer comfort)</td>
<td>- Economic solutions exist (e.g. insulation, windows, air tightness)</td>
</tr>
<tr>
<td></td>
<td>- Perceived inflexibility of the passive house concept</td>
<td>- National passive house standard provides guidance</td>
</tr>
<tr>
<td>Net zero energy</td>
<td>- No commonly accepted definition for net ZEBs (bias possible, not necessarily energy-efficient)</td>
<td>- Increase renewable share at grid and offset the emissions from material use with net ZEB</td>
</tr>
</tbody>
</table>

Figure 2.12 Graphical representation of the concept of a net zero energy building (after Sartori et al., 2012)
In the previous section the principles of building energy-efficient are explained. However, sustainable design can comprise more than energy use. Water use, social security and recycling are just some examples of issues that also can be considered in sustainable construction. In this section an environmental assessment scheme will be described that takes into account a broad range of issues: BREEAM-NOR.

First the background of certification schemes will be explained. Secondly, BREEAM and its application in the design process will be described. The section ends with barriers and opportunities using BREEAM.

### 2.4.1 CERTIFICATION SCHEMES

There are several environmental performance methods and tools developed in different countries, of which the UK-originated BREEAM, developed in 1990, was the first one. Table 2.6 provides an overview of several methods and tools with their country of origin (Cole, 2005).

The main advantage of a certification scheme is that it quantifies the ‘green performance’ of a building. This is interesting for investors and building owners because it is then possible to put a monetary value on sustainability. As described in Chapter 1, research has shown that owners of certified buildings can ask a higher rent, obtain a higher real estate value and ask higher selling prices.

Besides, certification schemes can assist a design team finding improvement areas to lower the environmental impact of a building (Ng et al., 2012). It will become easier to discuss sustainability with the design team, building professionals, as well as with other stakeholders (Cole, 2005). As an example, BREEAM-NOR uses a checklist approach, which makes it easy to discuss alternative solutions.

### 2.4.2 BREEAM-NOR

BREEAM is an abbreviation for Building Research Establishment Environmental Assessment Method and is developed by the BRE, an English research institute. BREEAM is a checklist for environmental performance, based on a specific set of guidelines and rules. Currently there are country-specific versions for the UK, Netherlands, Spain and Norway, while Sweden and Germany are in the process of developing a country-specific version (BRE, 2012).
BREEAM-NOR is the Norwegian adaptation of BREEAM, developed by the Norwegian Green Building Council (NGBC, 2012), and will be analysed in more detail. Other certification methods are not often applied in Norway and are therefore outside the scope of this research.

The BREEAM rating system works with two certificates: an interim design certificate, and a final certificate. BREEAM has five certification levels: pass, good, very good, excellent and outstanding (NGBC, 2012), which is shown in Figure 2.13. Targets in BREEAM go beyond the minimum practices required by legislation. Targets are set as sustainable best practice solutions found in the market. The requirements in BREEAM become more stringent depending on the required level of certification. Thereby BREEAM provides, like all voluntary certification schemes, a market pull towards more stringent environmental laws (NGBC, 2012). This idea is shown schematic in Figure 2.14.

The final certification level in BREEAM is defined by the amount of collected credits in nine different categories. For each credit specific documentation is required to prove that the credit is obtained. Technical descriptions on how to fulfil the credit demands and the required documentation are given in the official BREEAM manual (NGBC, 2012). A summary of the issues that are assessed with BREEAM is given in Figure 2.15.

Appendix A.4 provides extra information on BREEAM, such as the calculation method and further reading.
2.4.3 BREEAM IN THE DESIGN PROCESS

In practice, a project aiming for a certificate should be considered as BREEAM-steered (Norconsult, 2012). Since the documentation requirements are so stringent it is advised to take BREEAM with its considerations, credits, solutions and documentation requirements already into account from the initiative phase (Cinquemani & Prior, 2010). The advised process of certification is shown in Figure 2.17.

Many credits in BREEAM are time or expert dependent. An example is the management credit MAN13. Credits are given when a security expert is consulted before the detailed design phase. Early consideration of credits can reduce additional costs and increase the benefits (Cinquemani & Prior, 2010). There are process models developed for BREEAM, which can be used to manage the certification process (e.g. DGBK, 2012; Cinquemani & Prior, 2010; Norconsult, 2012).

From the moment the project team decides to pursue a certificate, credits should be prioritized. Research by Target Zero concludes with a flowchart with guidance on the steps to develop a cost-effective route to a BREEAM target rating (Target Zero, 2012). This flowchart is shown in Figure 2.16.

One of the most important steps in the flow chart is the analysis of BREEAM experience in the design team. An example of the influence of the design team on the certification costs is shown by research on the first eight BREEAM projects certified in the Netherlands. It was found that three quarters of the budget assigned for the BREEAM certification process was spent on research and documentation (Korbee, 2011). These costs are part of the learning curve, which can be reduced with more experience.

2.4.4 CONCLUSIONS

As a method is never perfect, BREEAM can be criticized. Three themes can be distinguished related to the documentation requirements, goal setting, and the treatment of certain themes. These three themes will be discussed in more detail now. Some critiques are based on research on LEED, a US-originated certification system based on the same principles as BREEAM (Ng et al., 2013).

First the documentation requirements will be described. The main advantage of an environmental assessment method is that the environmental performance of a building is rated objectively. BREEAM takes a holistic view on the environmental performance of buildings. On the other hand, the detailed level of information required can form a barrier, compared to a conventional project (Denzer & Hedges, 2011).

Secondly, the goal setting of BREEAM is discussed. BREEAM gives definition to certain issues of a sustainable
building, and at the same time obscures others (Schweber, 2013). Thus BREEAM locks-in certain solutions. Denzer & Hedges (2011) state that practices and solutions are rewarded, but not the basic principles behind sustainability, which can be interpreted as a lack of vision. It should be recognized that a design comprises more than certification. The certification tool should be used as a means, not as an end goal in itself (Lewis, 2012). However, when BREEAM is used deliberately, it can be used to fuel the discussion of environmental design in the project, defend design decisions and stimulate product innovation (Schweber, 2013).

Finally, there is critique on specific credit content in BREEAM. Three critiques can be distinguished: a lack of social sustainability, the existence of ‘easy-credits’, and the technical content in some credits. First, a lack of social sustainability exists, because the credits focus thus more on environmental issues than on social sustainability (Schweber, 2013). Secondly, some credits add more sustainability to a project than others. Less environmental concerned project teams may choose the cheapest and less environmentally concerned credits (Parr & Zaretsky, 2011). Thirdly, there is critique on the technical content of some of the credits. For example, the disposal phase is not directly taken into account. Furthermore, BREEAM mainly focusses on emissions from operational energy (Ng et al., 2013). However, as a market-driven certification tool, BREEAM is updated in regularly intervals (NGBC, 2013). It can be assumed that the update process can handle parts of the critique. For example, in the Netherlands a BREEAM demolition scheme is developed to take the disposal phase into account (DGBC, 2013). The closed cycle is shown in Figure 2.18.

To conclude, the most important barrier is the documentation requirements. An opportunity is BREEAM becoming a means to facilitate sustainable design decisions, as well as the fact that sustainability becomes measurable with BREEAM as a holistic rating system. This is recalled in Table 2.7.

The next section provides a summary of this chapter and analyses a solutions to overcome the barriers and implement the opportunities: integrated architecture and integrated management.

<table>
<thead>
<tr>
<th>Barriers</th>
<th>Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Documentation requirements</td>
<td>Measurable rating system with holistic view on environmental performance</td>
</tr>
<tr>
<td></td>
<td>BREEAM is means to facilitate sustainable design decisions</td>
</tr>
</tbody>
</table>

Figure 2.18
A closed cycle can be obtained when BREEAM-NL new built, in use and demolition are used in subsequent phases (based on DGBC, 2013)
In this chapter design strategies and approaches, energy efficiency and BREEAM-NOR were described. This section provides a summary of the findings and concludes with the necessity of integrated architecture.

### 2.5.1 CHAPTER SUMMARY

The chapter started by presenting several design approaches to reach sustainable futures, dependent on the chosen approach. The subsequent design strategies can form the overall vision of a building project. However, they do not provide concrete technical solutions for every project.

Subsequently, energy efficiency was explored as one of the most important topics when discussing sustainability. Several European and Norwegian policies are tuned towards more energy-efficient buildings. Afterwards BREEAM-NOR is discussed. This environmental assessment method comprises more topics than energy, and can thus form the basis to discuss sustainability on a broader scale.

Barriers and opportunities for all three themes are found and summarized per theme in Table 2.8.

### Table 2.8

Barriers and opportunities using sustainability as a design parameter

<table>
<thead>
<tr>
<th>Theme</th>
<th>Barriers</th>
<th>Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design approaches and strategies (Section 2.2)</td>
<td>- Different design approaches an confuse</td>
<td>- Sustainability may facilitate many designs (design approaches provide new insights)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Design strategies can guide the design (form the overall vision of a project)</td>
</tr>
<tr>
<td>Energy efficiency (Section 2.3)</td>
<td>- Building code is norm rather than minimum</td>
<td>- ENOVA subsidies available for energy-efficient constructions</td>
</tr>
<tr>
<td></td>
<td>- Energy efficiency requires extra skills at construction site (e.g. airtightness)</td>
<td>- Economic solutions exist for a passive house concept</td>
</tr>
<tr>
<td></td>
<td>- Energy efficiency requires new design skills (e.g. focus on summer comfort)</td>
<td>- National passive house standard provides guidance</td>
</tr>
<tr>
<td></td>
<td>- Perceived inflexibility of the passive house concept</td>
<td>- Increase renewable share at grid and offset the emissions from material use with net ZEB</td>
</tr>
<tr>
<td></td>
<td>- No commonly accepted definition for net ZEBs (bias possible, not necessarily energy-efficient)</td>
<td></td>
</tr>
<tr>
<td>BREEAM-NOR (Section 2.4)</td>
<td>- BREEAM documentation requirements are stringent</td>
<td>- BREEAM is a measurable rating system with holistic view on environmental performance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- BREEAM is means to facilitate sustainable design decisions</td>
</tr>
</tbody>
</table>
2.5.2 INTEGRATED ARCHITECTURE

The previous sections have provided an understanding of barriers and opportunities for sustainability as design parameter. This subsection describes a solution to overcome the barriers. Two prerequisites, knowledge and goal setting, lead to the real design task: creating integrated architecture.

As can be concluded from the previous sections, many barriers have to deal with a lack of knowledge or skills. Therefore, the first step in overcoming barriers and implementing opportunities is creating a common knowledge base. For example, the perceived inflexibility and required extra skills for a passive house can be overcome when more experience is gained with passive houses. An assumption is that the project team sees the benefits of gaining more knowledge. If they do not see this benefit in the first place, there is also no need to gain more knowledge, and the barriers will stay in place. Some benefits of building sustainably are discussed in Chapter 1.

When the project team has gained a common knowledge base, goals can be set. For example, confusion about energy use can be taken away by presenting the Sankey-diagram (Figure 2.6 on page 36). Goal setting is important because it provides the basis to work towards the same objective. For example, when the design team has obtained the knowledge about energy use according to the Sankey-diagram, it should be decided which parameter to optimise: primary energy, delivered energy or net energy. If the goal is undefined, then there can still occur miscommunication.

Gaining knowledge and setting goals are thus important and form the two prerequisites for the real design task, which is to create an integrated architecture. In practice many parameters that should be optimised can work contradictory. For example, energy consumption can be easily reduced by reducing the air change rate in the ventilation system. However, this can have negative effects on the indoor comfort. On the other hand, if only indoor comfort is optimised, energy use can be high. To make it more complicated, sustainable design also includes for example waste management, water flows, and material use. To create an integrated architecture all parameters of the program should be coupled to the people-planet-profit framework, and optimised holistically. Contradictory parameters to consider when designing a sustainable building are show in Figure 2.19 and Figure 2.20. Integrated architecture can only be obtained when the two prerequisites of a common knowledge base and goal setting are in place.

This first chapter analysed sustainability as a design parameter. The next chapter will be devoted to barriers and opportunities that come from the refurbishment task. Subsequently Chapter 4 will describe the organization of the design process to implement all these findings.
CHAPTER 3

REFURBISHING THE CURRENT OFFICE STOCK
3.1 REFURBISHMENT TASK

Little is known about the existing building stock and its technical possibilities. Buildings are either refurbished extensively, or demolished while they are still structurally in good shape, which leads to costly planning and advanced refurbishment concepts (Ebbert, 2010).

In this introduction the influence of refurbishment on the design processes will be given, after which the chapter structure will be described. The position of this chapter in the research framework is given in Figure 3.1.

3.1.1 REFURBISHMENT DESIGN PROCESS

In principal a design process for new-built constructions and renovation projects is the same. The main difference is in the limitations that are set by the existing building. This is shown in Figure 3.2. A simplified design process is shown, and the restrictions following from the refurbishment task are shown in light blue.

The program is mostly informed by the wishes of the user for the new building (step 1A). However, an existing building provides some restrictions compared to a completely new construction. Therefore a building assessment has to be undertaken (step 1B). This building assessment provides more information about the values in the existing building that can guide the design, and provides first indications of technical limitations. The building assessment then informs the program (step 2A). Subsequently, a more detailed analysis will be done on the existing façade (step 2B) to come up with a refurbishment strategy (step 3). This refurbishment strategy,
Figure 3.3 Refurbishment cycles (after Brand, 1994)

Together with the program, is then translated into a concept design (step 4 and step 5). The rest of the design process does not differ from a ‘normal’ design process, resulting in several evaluations and re-designs, ending in a refurbished building.

As can be seen in Figure 3.3, buildings can be divided into several layers, each having its own value and required refurbishment rate (Brand, 1994). Especially the skin and service layer, consisting of the façade and installations, have an influence on indoor comfort, energy use, daylight capabilities and other sustainability issues. Therefore, this chapter shall focus mainly on façade refurbishment. In practice also the other layers, especially space and stuff, are subject to change during a refurbishment process.

3.1.2 STRUCTURE OF THIS CHAPTER

This chapter describes barriers and opportunities in a design process following from the refurbishing task. Therefore the three elements forming the refurbishment tasks will subsequently be described in this chapter (light blue part in Figure 3.2 on the previous page).

First, methods and tools for a building assessment will be described, as well as the parameters that influence the building assessment most. Second, most common façade typologies are given. Third, the refurbishment strategy will be described. The chapter ends with barriers and opportunities renovating the existing building stock. The chapter structure is given schematically in Figure 3.4.

Section 3.2, 3.3 and 3.4 are mainly based on research by Ebbert (2010) on refurbishment strategies for the technical improvement of office façades in Western Europe and complemented with for example literature on office concepts and installations.

Figure 3.4 Schematic overview of this chapter

3.1 Chapter introduction
3.2 Refurbishment potential
3.3 Building typology
3.4 Refurbishment strategies
3.5 Barriers and opportunities for refurbishment

Appendix B Market share of facade typologies
3.2 REFURBISHMENT POTENTIAL

This section provides an introduction to the building assessment of existing buildings, as well as an overview of four main factors that have to be assessed in a refurbishment process: architectural design, building construction, technical installations and economic aspects.

3.2.1 METHODS AND TOOLS

Building assessment can be divided into two interrelated parts: assessing the existing situation, and assessing the potential. The potential refers to the possibility of the existing building to obtain the desired situation after renovation. If the existing situation has a certain quality, this will lead to a certain potential. An example is a building with a large building depth. When much daylight is required, extensive measures have to be taken. Thus, the daylight potential is low.

Tools and methods used in the refurbishment process should be able to assess the existing situation and later compare different concepts on its potential. In principle methods as BREEAM-NOR can be used. Where BREEAM-NOR is too extensive in the preliminary phases, also other tools can be used such as SPeAR or the Wheel of Potentials, providing a valuation based on self-selected indicators (Ebbert, 2010). An example of SPeAR is shown in Figure 3.5. In the end, the selection of a tool depends on the preferences and experiences of the design team.

Often, an assessment of the existing situation is neglected, which can lead to extra costs and even a complete redesign in the middle of the planning, for example when it turns out that the load bearing capacity is too low for the proposed solutions (Geier et al., 2012). This emphasizes the need for a complete assessment method in the earliest design stage.

3.2.2 FOUR ASSESSMENT FACTORS

Ebbert (2010) described several factors that should be assessed in a renovation project: architectural design, building construction, technical installations and economic aspects. Every factor has multiple aspects and subsequent restrictions, which are given in Table 3.1. In this subsection the most important restrictions are described per factor.

Aspects that inform the architecture and function of the refurbished building can be divided into the surrounding environment, the existing architecture, and the interior quality. First, the most important restriction by the surroundings is posed by the legal zoning regulation plan, because changing
legal documents can be a time-consuming process. Secondly, every building has an existing architecture and history. There are three strategies available to deal with the architecture: preservation, dialogue and desire for change.

The building construction is informing the program in three ways: the quality of the load bearing structure, building physics and comfort, and hazardous materials. Most important is the capacity and quality of the load bearing structure, because this determines the amount of material that can be added to the building. Furthermore, possible hazardous materials can be present. Authorized experts should be consulted in case hazardous materials are found in the existing building.

In the refurbishment task it is essential to analyse the existing technical installations and come up with proposals for a new installation concept that is integrated in the total building

<table>
<thead>
<tr>
<th>Table 3.1</th>
<th>Building aspects that inform the program design phase (Ebbert, 2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Factor</strong></td>
<td><strong>Aspects</strong></td>
</tr>
<tr>
<td>Architecture and function</td>
<td>Existing architecture</td>
</tr>
<tr>
<td></td>
<td>Urban surrounding</td>
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<td></td>
<td></td>
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<tr>
<td></td>
<td>Interior quality</td>
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<td></td>
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<tr>
<td>Building construction</td>
<td>Load bearing construction</td>
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<td></td>
<td>Building physics and comfort</td>
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<td></td>
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<tr>
<td>Hazardous materials</td>
<td></td>
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<tr>
<td>Technical installations</td>
<td>Heating and cooling concept</td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ventilation concept</td>
</tr>
<tr>
<td>Electrical installation</td>
<td></td>
</tr>
<tr>
<td>Installation distribution</td>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Economic aspects</td>
<td>Construction costs</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Operational costs</td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Building process</td>
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<td></td>
<td></td>
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<tr>
<td></td>
<td>Life cycle performance</td>
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<td></td>
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</tr>
</tbody>
</table>
concept. Factors that restrict the refurbishment strategy from an installation point of view are: the heating and cooling concept, the ventilation concept, the electric installations, and the distribution of installations in the building together with user control possibilities.

Finally, a refurbishment project has demands regarding economic aspects. The same aspects as in a new-built project play a role: construction costs, operational costs, building process costs, and life cycle performance. A renovation project can be more expensive than a new-built project because of technical restrictions. On the other hand, the refurbishment project can also provide cost savings. Reusing the load bearing construction can for example save a large part of the construction costs. Furthermore, a renovation project provides the opportunity to lower the operational costs, because the energy demand can be lowered. An existing building site poses restrictions on the construction processes and subsequent costs. Inner city locations restrict the space for storing goods and require a more advanced building planning. Building activities can also be restricted if the building is in use during construction. Prefabricated elements can reduce the time used on-site (Geier et al., 2012).

3.2.3 CONCLUSIONS

To conclude, this section provided an overview of aspects that inform the program design (step 1B in Figure 3.2 on page 48). From this analysis barriers and opportunities can be derived that are summarized in Table 3.2.

Each factor, as given in Table 3.1, should be analysed by determining the existing situation and the potential. It depends on the specific knowledge and preferences of the design team which methods and tools are used. In practice a thorough assessment of the existing building is often neglected. The assessment can be used to determine the qualities in the building, and find cost-saving opportunities.

The next section describes different typologies that can be found when performing a building assessment on a post war office building based on the four parameters as presented in this section.

<table>
<thead>
<tr>
<th>Barriers</th>
<th>Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building assessment is often neglected</td>
<td>Smart solutions can lead to cost savings compared to new building, and existing qualities can be optimised</td>
</tr>
</tbody>
</table>
### 3.3 BUILDING TYPOLOGIES

Possible building typologies will now be described based on the parameters found in the previous section (see Table 3.1 on page 51). First architecture and function will be described in two subsequent paragraphs. Secondly, two paragraphs are devoted to the building construction. Thirdly, building installations are discussed. The chapter ends with a summary. Economic aspects are not dealt with in this section.

#### 3.3.1 POST WAR OFFICE DEVELOPMENT

The history and architectural development in post war offices can be distinguished into three phases: reconstruction, economic prosperity and a current phase (Ebbert, 2010). The findings of Ebbert (2010) are described below and summarized in Table 3.3.

In the first phase after the second World War, the focus was on reconstructing the city centres and residential areas. Urban design was focussed on the separation of functions. Architectural styles in this phase were rationalism and modernism. Rationalism is characterized by a fast and cost-optimised building process.

The second phase is dominated by economic prosperity. Increasing car use made urban locations more accessible. Building activity moved outside the city centre. Architectural styles moved to brutalism and structuralism. Brutalism is characterized by visible structural materials and functional design related to the structure. Structuralism uses the structure of the building to provide a framework for flexible use.

The current phase is characterized by an upcoming environmental consciousness. Several oil crises influenced architectural development and there is a desire for spatial quality. Main architectural styles are ‘high-tech’ architecture and post modernism.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Reconstruction</th>
<th>Economic prosperity</th>
<th>Current phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>From - to (years)</td>
<td>1950 - 1965</td>
<td>1965 - 1980</td>
<td>&gt; 1980</td>
</tr>
<tr>
<td>Historical background</td>
<td>- Clean up city centres</td>
<td>- Increasing motorization</td>
<td>- Upcoming environmental consciousnes</td>
</tr>
<tr>
<td>- Separation of functions</td>
<td>- Offices moved to outskirts</td>
<td>- Spatial quality</td>
<td></td>
</tr>
<tr>
<td>Architecture</td>
<td>- Rationalism</td>
<td>- New Brutalism</td>
<td>- High-Tech</td>
</tr>
<tr>
<td>- Modernism</td>
<td>- Structuralism</td>
<td>- Postmodernism</td>
<td></td>
</tr>
</tbody>
</table>

Refurbishing the current office stock | 53
3.3.2 OFFICE CONCEPT

The second aspect of architecture and function is the internal organization of the building. The office concept determines the amount of space required and thus influences the environmental impact of the building (Dobbelsteen, 2004). Several concepts will be described based on Dobbelsteen (2004): cellular offices, open-plan offices, and the combi-office. These developments are shown in Figure 3.6.

Cellular offices became mainstream from 1900 until the period of reconstruction (Ebbert, 2010). The offices consist of a personal room for each employee with a corridor in between. These offices provide privacy and an individual adjustable indoor climate. Sometimes more than one person works in the cellular office, making it a small group office.

In 1920 the first open-plan offices were developed in the US. The lack of daylight regulations and almost unlimited access to cheap fossil fuels led to artificially lighted buildings with deep building depths. In Europe these kind of buildings often have more overhead windows. A new kind of open-plan office was developed at the end of the 1950s in Germany. This type of concept is an open-plan office, but more randomly organized. Instead of rationality the analysis of work patterns was the dominant parameter. These buildings were fully air-conditioned, providing a homogeneous climate.

In 1980 the combi-office was introduced in Sweden. Cellular offices were placed alongside a central zone that includes equipment such as photocopiers. This office type combines the advantages of the open plan office and the cellular office, but requires more space.

The environmental impact of the typologies is thus mainly determined by the required space (Dobbelsteen, 2004). Not discussed here is the influence of the place of the building and the use of the workplace (see for a detailed analysis Dobbelsteen, 2004). Especially the place of the building and its position in the organization is not likely to change during a renovation project. The use of the workplace tells something about the amount of people working in the same room, and is almost directly related to the type of office described earlier.

It should be noted that the type of office is related to the organizational structure of the tenant of the building. It is also dependent on the future tenant if the office concept should change after the renovation project.

To conclude, the office concept influences the environmental impact of the building. First of all because it influences the required space. Secondly, the office concept sets requirements on the building construction and installations, which will be described in the next paragraphs.
3.3.3 LOAD BEARING STRUCTURE

The load bearing structure contains a lot of embodied energy in the form of steel and concrete (Baker, 2009). Therefore, it is often chosen to reuse the load bearing structure in a renovation project. Besides, it saves time and money to reuse the existing structure.

The status of the load bearing structure depends on many parameters, such as the year of construction, the used materials and the original design loads. This means the extra load bearing capacity can be either high or low. The load bearing capacity determines the feasibility of several refurbishment strategies. For example, when a low extra capacity is available it might be impossible to hang a new curtain wall on to the building. It is therefore advisable to conduct a building assessment (Geier et al., 2012).

Ebbert (2010) assessed façade refurbishment strategies and took account for typical load bearing structures as well, which will be described in the next paragraph.

3.3.4 FAÇADE TYPOLOGIES

According to Ebbert (2010), the post-war architecture has delivered a wide variety of office façade typologies. All existing façade constructions can be sorted into 22 main types that determine possible refurbishment strategies. The typology is based on three parameters:

1. Position of the thermal layer,
2. Structural form
3. Amount of layers.

A fourth parameter that can be considered is material use. Although the facing material determines the aesthetics and influences the durability of the facade because it is often the wind barrier, Ebbert (2010) argues that the same materials can be applied on all different typologies, and thus creates a too detailed approach. Furthermore, the facing material is of less importance than the quality and build-up of the three earlier described parameters when considering refurbishment strategies in terms of available options, time and costs.

Combining the three parameters to feasible options leads to 22 different typologies. Subsequently, Ebbert (2010) has performed a spot check analysis in Germany, the Netherlands and the United Kingdom. The result of this spot check is a list with market shares, which is recaptured in Appendix B. It is assumed that a representative overview of possibilities in the Norwegian office stock is given by focusing on typologies from that represent a market share over 5% in Western Europe.

The built-up, qualities and problems of the most common façade typologies are given in Figure 3.7.
3.3.5 INSTALLATIONS

Installations have an impact on the environmental impact which can be of the same amount as the façade typology. Typically installations have a lower service life and are changed accordingly (Baker, 2009). In this paragraph typical issues for installations will be described based on Baker (2009).

The first assessment can be made of the heating and ventilation systems. The efficiency and age of, for example, the central boiler determines if it can be reused or not. Other important aspects are the heat distribution system and heat emitters. The state of the distribution system is determined by zoning, which relates to the office concept, as well as by the state of ductwork and the diameter of the existing ducts. Small diameters mean high velocities and thus high fan power. Furthermore, the position, size and type of heat emitters should be assessed.

Another large part of the installation system is the lighting system. The required lighting level is determined by the task that should be fulfilled, which is provided by a combination of daylight and artificial lighting. In general lighting levels tend to be higher than necessary. Also user equipment should be analysed.

The final part of the installation systems is the type of control. When parts of the building are not used or used for different purposes automatic or manual control can lower the energy demand. Examples of control systems are occupancy detectors, daylight detectors, and energy management systems.

3.3.6 CONCLUSIONS

This section has described the different typologies that influence the refurbishment strategy based on the parameters described in Section 3.2 - Refurbishment potential.

With respect to architecture and function, three architectural phases can be distinguished after the Second World War: reconstruction, economic prosperity and a current phase. Each phase is characterized by different architectural styles. Also office concepts differ over time. Three concepts are described: cellular office, open-plan office and combi-office, which all influence the environmental impact of the building in a different way.

The load bearing capacity, determined by parameters such as year of construction, material use and design loads, influences the refurbishment strategy. Therefore a building assessment is advisable. Subsequently, the built-up, qualities and problems of the most common façade typologies are given, as well as common installation types.

As the different typologies are described, the next section will be devoted to the refurbishment strategy and thus describe how to deal with the different typologies.
3.4 REFURBISHMENT STRATEGIES

When the typologies and existing state of the building is known, a refurbishment strategy should be made. In this section first the intervention level is described. Subsequently, the strategies for the three of the four main factors are described: architecture and function, installations, and façade strategy. Economic aspects are not described in this section.

3.4.1 INTERVENTION LEVEL

First of all the intervention level is discussed, which is determined by the wish of the design team to either restore, upgrade or change the existing building qualities and values.

Restoration strategies set the original building qualities and values central, for example when a monument is to be renovated. Upgrade strategies are used to upgrade the building’s quality, for instance when it does not fulfil current functional and economical demands. In the final strategy, change, also an upgrade is required, but the existing building’s value is not important. In practice strategies can overlap.

Ebbert (2010) has summarized a list of definitions on renovation and refurbishment. The results of this summary are placed on the intervention level scale in Figure 3.8. This research focuses mainly on the upgrade strategies. The words refurbishment and renovation are used interchangeably.

3.4.2 ARCHITECTURE AND FUNCTION

A decision should be made on how to deal with the existing building. In principle three options are available: preservation, dialogue and desire for change (Ebbert, 2010). Furthermore, the new office concept influences the design.

Firstly, preservation is required for monuments or when zoning regulations do not provide room for change in the outer appearance of building. This can reduce the possibility of an outside upgrade. Secondly, dialogue implies that the renovation design should respond to the existing situation. Thirdly, desire for change offers the most radical possibilities for the design. The effect of the renovation should be visible.

Besides the architectural strategy, also the office concept should be taken into account. A renovation project can be used to trigger an organizational change at the same time. For example by changing the office concept from cellular office to an open plan office. This should be taken into account as it determines the required space and the way the building is used.
3.4.3 FAÇADE STRATEGY

When the architectural strategy and office concept are known, the façade strategy should be made. In principal, five main refurbishment strategies to update a façade can be distinguished: façade replacement, extra exterior layer, upgrade exterior layer, upgrade interior layer, extra interior layer. The five strategies are presented in Figure 3.9.

In strategy A, façade replacement, the building is deconstructed to its loadbearing structure and subsequently the façade is rebuilt. The building should be empty during construction. The architectural appearance can be changed. Limitations are formed by the current load bearing capacity and connections. Besides, a lot of material is removed and replaced by the new façade.

With strategy B, an extra secondary layer is added to the building envelope. The existing layer is kept intact and usually still forms the primary thermal layer, limiting the possibilities to upgrade towards energy concepts such as passive houses or net zero energy construction. This refurbishment strategy can be applied while the building is in use. However, the feasibility is strongly dependent on the existing technical situation.

Strategy C imposes an exterior upgrade. This strategy requires enough load bearing capacity in the existing situation. This strategy often changes the architectural appearance. However, this is design dependent. For example, an Exterior Insulation and Finishing System (EIFS) is a lightweight method to improve the amount of thermal insulation, using a limited amount of material. An example is shown in Figure 3.10. Disadvantages are an unclear end-of-life scenarios and limited architectural options for the choice of cladding.

When the architectural appearance is not allowed to change, it is possible to upgrade the interior layers (Strategy D). However, future renovation possibilities are limited and comfort levels can be difficult to realize, because interior insulation blocks the thermal mass of the façade. Furthermore, there is a risk of frost-damage of ducts that perforate the insulation layer. Other disadvantages are labour intensive work, thermal bridge problems and a loss of usable space.

The final strategy is the addition of an extra interior layer (Strategy E), which is comparable with strategy D. This solution solves much of the thermal bridge problems. Limits are set by the existing building height and loadbearing capacity.

Not all refurbishment strategies are applicable to all façade typologies. Most important is the quality of the existing façade. If the façade is in good condition, other strategies can be chosen than when insulation levels and airtightness values are below the required standard. Furthermore,
technical risks are associated with the refurbishment, such as thermal bridges, fire safety and comfort issues. The load bearing capacity and structural connections (the existing grid) form limitations in almost every refurbishment strategy. Finally, it is likely that a building requires a new upgrade after a certain lifetime. Future renovation works should be taken into account as much as possible. Ebbert (2010) provides a detailed analysis on how the five strategies can be applied on the different façade typologies described in Section 3.3.

### 3.4.4 INSTALLATIONS

The façade and installations in a building are closely related, as both influence indoor comfort, energy use, daylight and other sustainability issues. The new installation concept should thus be integrated in the total building concept.

Insufficient ventilation and contaminations from building materials or other sources can cause the Sick-Building Syndrome (SBS): users in a building get health problems, such as irritation of nose and eyes and concentration problems. When the refurbished building will be more airtight there is higher chance for SBS when the ventilation concept does not take account for the extra ventilation need (Vrijders et al., 2011). Therefore, the ventilation concept has to be considered holistic with other parameters, such as required energy use.

### 3.4.5 CONCLUSIONS

In this section refurbishment strategies are described. From this analysis barriers and opportunities can be distinguished, which are summarized in Table 3.4.

The most important barrier is the status of the existing architecture, which determines much of the possibilities. On the other hand, several design strategies can be chosen depending on the status of the architecture: desire for change, dialogue or preservation. The technical condition in combination with the required performance determine the size of the refurbishment task, as an opportunity all design strategies lead to an up-to-date façade. A limitation in almost all strategies is the lack of future renovation possibilities.

The next section provides a summary of the complete chapter.

<table>
<thead>
<tr>
<th>Table 3.4</th>
<th>Barriers and opportunities for the five refurbishment strategies.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Barriers</strong></td>
<td><strong>Opportunities</strong></td>
</tr>
<tr>
<td>Status of existing architecture can be limited (three strategies possible: preservation, dialogue, change)</td>
<td>Up-to-date façade can be obtained</td>
</tr>
<tr>
<td>Limited future renovation possibilities</td>
<td></td>
</tr>
</tbody>
</table>
In this chapter the refurbishment task is discussed. First a section was devoted to the refurbishment potential of a building, after which several façade typologies were described in more detail. Subsequently refurbishment strategies were discussed. This final section sums up the barriers and opportunities to involve sustainable solutions in a design from a refurbishment perspective. The barriers and opportunities are summarized in Table 3.5.

Most important in a refurbishment process is to realize that the existing building poses more restrictions to the design as compared to a new building. A thorough assessment of the existing situation is therefore one of the most important prerequisites in refurbishment projects. Nevertheless, a building assessment is often neglected in the early design stages. When a building assessment is done it provides the opportunity to optimise qualities in the building, and it helps determining the true wishes and requirements of the client and tenant.

The refurbishment strategy is mostly depended on the façade typology. Each façade typology has different qualities and restrictions. The most important restrictions are formed by the status of the existing architecture and the condition of the existing façade. The design team has to make a decision on how to deal with the architecture and come up with solutions to bring the façade up to date. In some refurbishment strategies, the upgrade locks future renovation possibilities. It is not always taken into account that the building might be in need of a refurbishment again in 25 or 30 years.

Table 3.5 provides a summary of all barriers and opportunities in a design process from a refurbishment perspective.

Now sustainability as a design parameter is analysed as well as the refurbishment process. The next chapter will be devoted to the design process.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Barriers</th>
<th>Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refurbishment potential (Section 3.2)</td>
<td>- Building assessment is often neglected</td>
<td>- Smart solutions can lead to cost savings compared to new building, and existing qualities can be optimised</td>
</tr>
<tr>
<td>Refurbishment strategy (Section 3.4)</td>
<td>- Status of existing architecture can be limited (three strategies possible)</td>
<td>- Up-to-date façade can be obtained</td>
</tr>
<tr>
<td></td>
<td>- Limited future renovation possibilities</td>
<td></td>
</tr>
</tbody>
</table>
CHAPTER 4
INTEGRATED DESIGN PROCESS GUIDELINES
4.1 WHAT IS INTEGRATED DESIGN?

The previous chapters described barriers and opportunities for sustainability as a design parameter (Chapter 2) as well as for the refurbishment task (Chapter 3). This chapter will describe the integrated design process as a theoretical approach to overcome the previously described barriers and opportunities. The position of this chapter in the total research structure is given in Figure 4.1.

4.1.1 SETTING THE VOCABULARY

Integrated design is seen as a necessity to increase the building’s quality at lower costs and create sustainable buildings. Integrated design optimises the building as a whole, as opposite to optimizing subsystems (Löhner et al., 2003).

In principal it is possible to distinguish several meanings of integrated design: integrated architecture, integrated management, and integrated tools and contracts. Their relationship is shown in Figure 4.2 and will be explained now in more detail.

First, integrated architecture refers to the technical integration of systems, such as the optimization of window orientation to fulfil both heating and cooling requirements, as a daylight strategy. This is a prerequisite to obtain sustainable buildings, for example passive houses or BREEAM-certified offices. The need for integrated architecture is described in Chapter 2 - Sustainability as a design parameter,

Secondly, integrated management refers to the integration of several actors in a design process. Often it is necessary to integrate different professions to reach the integrated architecture as described before. For example the integration of daylight, heating and cooling requires cooperation between an architect, façade engineer, installation engineer and possibly a sustainability consultant.

Finally, integrated tools are sometimes referred to when discussing integrated design methods (e.g. Andresen et al., 2008). Integrated tools can be interpreted as the design strategies as described shortly in Section 2.2, while they can also be interpreted as for example the use of building information models (BIM). Although important in collaboration forms, the specific use of integrated tools will not be dealt with in this master thesis. A final way to interpret integrated design is as integrated contracts, such as design & build. It is assumed that tools and contracts are supporting integrated management.
Table 4.1
There are five major research programmes in IDP both with the European Union and the IEA as responsible body

<table>
<thead>
<tr>
<th>Years</th>
<th>Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997 - 2001</td>
<td>IEA SHC Task 23</td>
</tr>
<tr>
<td>2007 - 2009</td>
<td>IEE INTEND</td>
</tr>
<tr>
<td>2009 - 2012</td>
<td>IEA SHC Task 41, Subtask C</td>
</tr>
<tr>
<td>2011 - ongoing</td>
<td>IEA SHC Task 47</td>
</tr>
<tr>
<td>2012 - ongoing</td>
<td>IEE MaTRID</td>
</tr>
</tbody>
</table>

In this research the main objective is to provide practical evidence for the organization of the design process. Therefore, the focus when discussing integrated design is on integrated management.

In the rest of this chapter integrated management will be referred to as the integrated design process (IDP). There are several research programmes focussed on integrated design and its applications in practice, as is shown in Table 4.1. Apart from these research programmes there is not much literature available. The available literature describes several ways of approaching integrated design (Brunsgaard, 2009). The different approaches, together with the findings from the international research programmes will form the basis for the theoretical description of IDP.

4.1.2 CHAPTER STRUCTURE

This chapter starts by describing the traditional actors and economy in a building project. Subsequently the traditional linear design process will be described. In this section also innovative contract forms will be discussed. Afterwards, the integrated design process is presented as solution to create integrate architecture.

The chapter ends with barriers and opportunities of the design process, based on the literature findings in this chapter. The complete chapter structure is shown in Figure 4.3. Appendix A.5 recaptures terms often used in this chapter such as the phases of a design process and the actors involved.

Figure 4.3
Structure of Chapter 4 - Integrated design process guidelines
4.2 ACTORS AND ECONOMY IN A BUILDING PROJECT

Before describing the traditional and the integrated design process it is necessary to provide some information on the actors involved in a building project. Furthermore, the standard way of value creation in the building sector is described.

4.2.1 THREE GROUPS OF ACTORS

There are several actors involved in a construction process, who together are responsible for a supply and demand side of the building, as will be discussed in the next paragraph. Every project is unique in its nature (Ridder & Noppen, 2009). Besides, the project organization and actors involved can be different in each project. The following paragraphs should therefore be interpreted only as a general description. The actors can be divided into three groups: builders, designers and clients, which are shown in Figure 4.4

The first group, the builders, are the actors actually delivering the construction. They represent the supply side of a construction work, and are often led by the main contractor. The main contractor relies on subcontractors, suppliers and manufacturers.

The second group are designers. The design is often led by the architect, who delivers architectural knowledge and is responsible for the total building design, including functional requirements. The architect is assisted by engineers and other advisors who deliver specific expert knowledge, such as knowledge on construction and fire safety. It depends on the

![Figure 4.4: Three groups of actors in a design process can be distinguished: builders, clients and designers](image-url)
knowledge of the architect how much assistance is needed in fields as sustainability, daylight and building physics.

The third group is the demand side of the project, represented by the client of the project. The client sets the main requirements on the design and invests money in the project. The client can be the owner of the building or a project developer. The client side can also include an investor, who speculates with buildings and/or the future tenant of the project.

### 4.2.2 ECONOMY OF A BUILDING PROJECT

All actors in the building process have the objective to make a profit, which leads to the economy of a building project as is shown in Figure 4.5. The economy of a building project differs from a normal economic transaction (e.g. to buy a product in a store), because more actors are involved. Furthermore, the product is undefined at the beginning of the process (Ridder & Noppen, 2009). When a design process starts there is usually a list of requirements, but it is not yet known how the final product, the finished building, will look like.

An important implication that can be derived from the economy of a building project are goal conflicts between actors. For example, an investor tries to optimise revenues, the contractor minimises costs and the designers try to maximise the perceived value, which can become a conflict. This is called a split-incentive. The overview as given in Figure 4.5 is a simplification of reality. Actors can extend their influence both to the supply and demand side. A current trend is, for example, the integration of contractors into the design work, which will be described in the Section 4.3.3.

### 4.2.3 CONCLUSIONS

In this section three actor groups are described: clients, builders and designers. The economy of a building project is described, and it is shown that goal conflicts can occur. In the next section the traditional design process will be analysed in more detail.

---

**Figure 4.5**

Economy of a building project (based on Ridder & Noppen, 2009)
4.3 TRADITIONAL LINEAR DESIGN PROCESS

In the previous section three groups of actors are described: clients, builders and designers. The actors, trying to make a profit out of their business, lead to a certain economy of the building project. This section analyses the traditional design process (TDP).

4.3.1 LINEAR DESIGN ORDER

The traditional design process tries to translate the requirements from the demand side into a concept design. This concept design is then translated into specifications for the supply side. The traditional design process is linear (Löhnert et al., 2003). The description of the traditional design process as given by Löhnert et al. (2003) is shown in Figure 4.6 and will now be described in more detail.

The architect and client define the program by setting the project definition, and requirements. After the program phase, the goals for the project are defined in terms of the budget and available time. The architect translates the program into an architectural concept based on several creative design loops. The next phase is the detailed design, where engineers suggest systems and installations to transform the architectural concept into a detailed design. Subsequently the construction documents are prepared. A contractor constructs according to these construction documents and delivers the building to a user or owner. At this point the project goals and objectives are checked with reality, although the project has reached a point of no return and it is not possible to make adjustments.

4.3.2 SUBOPTIMAL PERFORMANCE

Buildings constructed with a traditional design process lead to suboptimal buildings with high operational costs and a
low environmental performance (Löhnert et al., 2003). This is caused by two reasons:

1. Lack of optimization possibilities
2. Limited innovation possibilities

First of all, basic choices are taken in the concept design phase. In the detailed design phase engineers can only optimise subsystems instead of proposing solutions from a systems perspective. For example, the amount and position of windows is determined by the architect in the concept design, which sets limitations on the lighting strategy that has to be determined by the engineer in the detailed design phase. The same holds for material choices and other sustainability aspects. An optimization to create integrated architecture as described in Chapter 2 is not possible.

The second reason for suboptimal performance is the limited use of knowledge of all involved actors. First, budget and time constraints limit the possibilities for innovation within a project and limit the knowledge transfer to future projects (Koch, 2004). Secondly, the building sector is fragmented among many actors which all deliver a small part of the project work (Nederveen et al., 2010; Hojem & Lagesen, 2011). All actors have limited knowledge about the total building work. Furthermore, the actors work in a subsequent order on the project. As a consequence, actors that are involved in later phases have a limited ability to change the design, while actors in the beginning phase of the project hardly learn from failures that occur later in the project. The knowledge of the different actors can thus not be combined into an optimal design.

### 4.3.3 CONTRACT INNOVATION

Traditionally the design is prepared by the architect and finalized by the engineers, after which a contractor bids on the construction documents and starts the construction phase. This process has a contract form called design-bid-build. The last years contract innovations have taken place integrating the contractor in more design phases (Ridder & Noppen, 2009). The type of contract can influence the level and quality of construction integration, as well as the allocation of responsibilities (Löhnert et al., 2003).

There are two ways of contract integration: forward and backward integration. With forward integration the contractor is more involved in phases before the actual construction. Backward integration is integration of phases after the construction phase. In this case the contractor becomes responsible for operation and maintenance (Ridder & Noppen, 2009). Often used contract forms are given in Table 4.2. A detailed analysis of all integrated contract forms can be found in Ridder & Noppen (2009).

<table>
<thead>
<tr>
<th>Table 4.2</th>
<th>Contract forms (Ridder &amp; Noppen, 2009)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abbreviation</td>
<td>Acronym</td>
</tr>
<tr>
<td>B</td>
<td>(Design-Bid)- Build</td>
</tr>
<tr>
<td>DB</td>
<td>Design &amp; build</td>
</tr>
<tr>
<td>DBO</td>
<td>Design, build &amp; operate</td>
</tr>
<tr>
<td>DBFM</td>
<td>Design, build, finance &amp; maintain</td>
</tr>
<tr>
<td>DBFMO</td>
<td>Design, building, finance, maintain &amp; operate</td>
</tr>
</tbody>
</table>
Integration of the contractor leads to innovation because knowledge from construction methods can be implemented earlier in the design (forward integration). Furthermore, the contractor has more design responsibilities and can thus be motivated to stick to the design. With backward integration, the contractor has an incentive to optimise the design for the operation phase. Forward and backward integration are shown visually in Figure 4.7.

Integrated contracts provide incentives to stimulate innovation and knowledge transfer in the supply chain and thus solves the second problem of TDP. Especially the transfer of ‘contractor knowledge’ into the detailed design phase is stimulated. However, the first problem, a lack of optimization possibilities, is not necessarily solved. Most of the time the contractor comes in after the concept phase, when important sustainability decisions are already made. Furthermore, it is not necessarily the case that the contractor has more competence in sustainability issues than the design team. A risk of design and build contracts is the contractor cutting design time in favour of construction time and lower investment costs (Hagen & Jørgensen, 2012). It can be concluded that the integrated contracts shift responsibility towards the contractor, but the design process itself is not necessarily changed. In practice the same gaps between phases can occur, especially when the contractor works with different departments for design, construction, and operation.

4.3.4 CONCLUSIONS

In this section the traditional design process is described as linear design process. The subsequent phases lead to a suboptimal design because the lack of system optimization and limited knowledge transfer.

Integrated contracts are a recent innovation, providing a contractor with more responsibility in the design and/or operation phase, and stimulate knowledge transfer. However, the system optimization, that is necessary to create integrated architecture, is not specifically addressed by contract integration alone. The next section will therefore discuss the integrated design process as opposite to the linear design process.
4.4 INTEGRATED DESIGN PROCESS

In the previous section the traditional design process (TDP) is described. TDP has two problems, limited optimization possibilities and limited knowledge transfer. The latter problem can be solved with integrated contracts. This section describes the integrated design process (IDP) as solution to the limited optimization possibilities of TDP.

Based on existing research on IDP (Löhnert et al., 2003; Jørgensen, 2010), and complemented with findings from relevant research papers, IDP will be described.

4.4.1 OPTIMIZATION ON BUILDING LEVEL

There are technical solutions available for sustainable office renovation (see Chapter 2 and Chapter 3). However, an important problem is an unknown-known problem, where it is not known in a project team that specific knowledge is available (see Chapter 1). An extra difficulty is to create an integrated architecture, where several contradictory parameters have to be optimised on the total building level.

How can project teams make sure that they have the required knowledge available at the right time and optimise the building from a systems perspective? When the quality has to be raised without impact on costs or time available, it is better to integrate the right solutions and specify correct goals from the beginning on. This principle is shown in Figure 4.8.

The integrated design process is shown in Figure 4.9 and can be distinguished from the traditional process in three ways:

1. Early actor involvement
2. Goal setting and quality assurance
3. Knowledge transfer and evaluation
Jørgensen (2010) summarized the earlier work by Löhnert et al. (2003) in nine steps which are given in Table 4.3. The three differences with TDP are also given in this table.

The next subsections will describe the three differences in more detail: early actor involvement, goal setting & quality assurance, and knowledge transfer & evaluation.

### 4.4.2 EARLY ACTOR INVOLVEMENT

While in the traditional process often only the architect and the client are involved in the first phases, an integrated design process requires all actors to be involved from day one. More actors involved means a higher probability that the required knowledge is available. However, it also sets extra requirements on communication and management, and changes the design task, especially in the concept phase. These three topics will now be described in more detail: the set-up of a multidisciplinary design team, communication requirements, and a different design task.

As all actors become involved in the beginning of the design process, the project team changes towards a multidisciplinary design team. Examples of the set-up of such a team in the concept and detailed design phase are given in Figure 4.10. Although the majority of researchers agrees on the importance of early actor involvement, it is not always necessary to involve everyone (Kanters & Horvat, 2012). An example given by Kanters & Horvat (2012) is a small building project, where the architect can take the role of several consultants at

<table>
<thead>
<tr>
<th>#</th>
<th>Content of the step</th>
<th>Difference with TDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>- Select multidisciplinary design team from day one</td>
<td>Early actor involvement</td>
</tr>
<tr>
<td></td>
<td>- Members should have knowledge on sustainability issues</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Be motivated for close cooperation and openness</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>- Analyse boundary conditions of the project</td>
<td>Goal setting &amp; quality assurance</td>
</tr>
<tr>
<td></td>
<td>- Analyse clients’ needs and demands</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Formulate a set of specific goals for the project</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>- Make a quality assurance program</td>
<td>Goal setting &amp; quality assurance</td>
</tr>
<tr>
<td></td>
<td>- Make a quality control plan</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>- Arrange a kick-off workshop to create a common understanding of the design task</td>
<td>Early actor involvement</td>
</tr>
<tr>
<td>5</td>
<td>- Facilitate close cooperation between architect, engineers, and relevant experts</td>
<td>Early actor involvement</td>
</tr>
<tr>
<td></td>
<td>(co-localisation or workshops during concept design phase)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>- Update the Quality Control Plan</td>
<td>Goal setting &amp; quality assurance</td>
</tr>
<tr>
<td></td>
<td>- Document sustainability performance during the process</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>- Make contracts that encourage integrated design and construction</td>
<td>Knowledge transfer &amp; evaluation</td>
</tr>
<tr>
<td>8</td>
<td>- Motivate and educate construction workers</td>
<td>Knowledge transfer &amp; evaluation</td>
</tr>
<tr>
<td></td>
<td>- Apply appropriate quality tests</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>- Make a user manual for operation and maintenance of the building</td>
<td>Knowledge transfer &amp; evaluation</td>
</tr>
</tbody>
</table>

Figure 4.10 Typical design team set-up in the concept and detailed phase (after Jørgensen, 2010)
the same time. However, consultants that come in the project later do not feel commited to the project. Moreover, the role of the contractor is underexposed in current literature on IDP. Although all actors should be involved from the beginning, no IDP process model includes the contractor in the concept design. This can be explained by an implicit assumption that if the design is good and sustainable, the constructed building will also reach that quality. However, in practice there is a risk that the design and constructed building differ on details.

General disadvantages of a multidisciplinary design team are the extra management and communication tasks. There is a risk that all involved experts defend their own territory instead of optimise the total building (Kanters & Horvat, 2012). A multidisciplinary project can only work if the team members are open for cooperation. Engineers and architects tend to have different communication requirements (Trebilcock, 2009). In an IDP the engineer has to be open for the development of concepts and alternatives and accept more uncertainty, which is mainly caused by the uncertain nature of the beginning phase of a design. On the other hand, the architect has to accept more technical restraints.

As is shown in Figure 4.11, IDP has a different work load distribution. Design time, budget and risks are shifted towards the earlier design stage. Furthermore, in the early design stage not only architecture, but also the environmental impact and sustainability issues will be discussed. The planning phase, with a proper analysis of the boundary conditions becomes more important. The boundary conditions include the building assessment as described in Chapter 3.

4.4.3 GOAL SETTING & QUALITY ASSURANCE

The second main difference between IDP and TPD is the goal setting and quality assurance over the complete life cycle. Where in TDP goals are set in terms of budget and time after the first ideas, an IDP process starts generating ideas based on goals for budget, time and sustainability. Three topics will be described in more detail: client commitment, rooting of the goals, and quality assurance over the total life time.

First of all, the client should be more active in defining goals and keep committed throughout the process. Clear goals set a target to measure progress and make it easier to discuss alternatives. Secondly, it is important that the goals are defined on the basis of budget, time and sustainability, which all three should have the same level of priority and be discussed in every meeting. Contract forms can be adjusted to show the importance of the goals, for example by providing a bonus when a certain goal is achieved. Thirdly, the goals should cover the complete life cycle, from design, to construction, operation and demolition. Finally, the goals should be checked by quality assurance between subsequent phases.
4.4.4 KNOWLEDGE TRANSFER & EVALUATION

As can be seen in Figure 4.9 on page 69, it is assumed that every building design phase makes a design loop. In each phase several alternatives are developed and evaluated based on the goals and quality assurance plan, after which the next design phases will be executed. A major assumption is that there is an optimal knowledge transfer between subsequent phases.

Current IDP literature gives three solutions to optimise the knowledge transfer: by using a multidisciplinary design team as described earlier, by motivating and educating construction works, and by creating a user manual. Current IDP models focus mainly on the concept design phase, which explains why knowledge transfer in later phases is not worked out in detail. For example, it is questionable if a user manual is enough to facilitate a smooth operation after the construction phase. A possible solution for more knowledge transfer in subsequent phases is not only early actor involvement, but also longer actor involvement.

Furthermore, current IDP models do not include current trends, such as the circular economy, directly. Closing circles can be integrated in the design goals, but in theory the complete buildings life cycle can be seen as a total design loop, as is shown in Figure 4.12. Important questions such as how to deal with the end-of-life solutions, are currently not explicitly addressed in IDP models.

4.4.5 CONCLUSIONS

In summary, IDP differs from TDP in three ways: early actor involvement, goal setting and quality assurance, and design loops and knowledge transfer. All three differences are described in literature, but have some specific limitations.

First, early actor involvement leads to a multidisciplinary design team, with extra communication requirements and a shift in time of the design task. Although IDP literature states that all actors should be involved from day one, no IDP model mentions the contractor’s role. Secondly, goal setting and quality assurance can be achieved by client commitment, priority for budget, time and sustainability goals, and by quality assurance over the total life time. Finally, alternatives are developed in every design phase and knowledge is transferred between phases. However, these aspects are mainly worked out for the concept design phases. Concepts such as the circular economy are not directly integrated in the IDP model.

Furthermore, a practical design process is often not as smooth as described in the previous sections. The practical application can be dependent on the type of client, building and design team (Kanters & Horvat, 2012). The next two sections will be devoted to examples from practice.
This chapter was devoted to the organization of the design process. First, the vocabulary of a design process was defined. Secondly the traditional and integrated design process were described. Finally two examples from office renovation in practice were given. This section sums up the chapter and ends with a conclusion on the barriers and opportunities to involve sustainable solutions in a renovation project from an organizational perspective.

The meaning of integrated design is split into integrated architecture, integrated tools & contracts, and the integrated design process. Integrated architecture refers to the total building optimization necessary to involve sustainability in a design, as described in the conclusion of Chapter 2 - sustainability as design parameter. Integrated tools are not discussed in detail, although some strategies are provided earlier in Section 2.2 - approach and strategy for sustainability.

Subsequently, three groups of actors involved in most design processes are described: clients (setting requirements), designers (translating the requirements into specifications), and buildings (construct according to specifications). The economy of a building project is shortly discussed, and it is shown that goal conflicts can occur.

It is argued that the traditional design process is a linear process leading to suboptimal solutions, because of a lack of optimization possibilities, and limited room for innovation and knowledge transfer. Integrated contracts, such as design & build, can solve the latter barrier. In these innovative contract forms the contractor has more responsibilities and knowledge transfer is stimulated. However, the integrated contracts do not necessarily address the required systems optimization.

The integrated design process can be a theoretical solution for the first problem, a lack of optimization possibilities. IDP provides system optimization from a total buildings perspective. Integrated design differs from traditional design in three ways: early actor involvement, goal setting & quality assurance, and knowledge transfer & evaluation.

Current literature on IDP focuses mostly on the early design phases, because that is the place where decisions can be made without a large influence on the final construction costs. The role of the contractor is underexposed in the literature. The application of IDP in the later detailed design and
construction phases is also open for interpretation. This can be considered as an important barrier for the application of IPD.

Table 4.4 provides an overview of the most important barriers and opportunities to involve sustainability in the design process from an organizational perspective.

In Part 1 sustainable office renovation in theory is described leading to barriers and opportunities from three perspectives: sustainability as design parameter, refurbishment process, and the organization of the design process. In the following part 2 five projects from Norwegian and Dutch practice will be analysed from the same perspectives. Two projects are analysed as pilot case, while three projects are analysed in depth. In Part 3 theory and practice will be combined. Part 2 will start in the next chapter by describing the approach of the case studies.

<table>
<thead>
<tr>
<th>Barriers</th>
<th>Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDP requires a shift of time and budget in comparison with TDP (early actor involvement)</td>
<td>Integrated design process provides system optimization possibilities (not possible with TDP)</td>
</tr>
<tr>
<td>Ambitious goal should be set by committed actors (goal setting &amp; quality assurance)</td>
<td>Integrated contracts provide knowledge transfer and a more important role for the contractor</td>
</tr>
<tr>
<td>Knowledge should be transferred from phase to phase and evaluations should be performed in every phase, including construction and operation phases (knowledge transfer &amp; evaluation)</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.4
Barriers and opportunities to involve sustainability in the design process from an organizational perspective.
PART 2

sustainable office renovation in practice
CHAPTER 5
CASE STUDY APPROACH
5.1 INTRODUCTION INTO CASE STUDY APPROACH

In Part 1 the question how to organize a design process to involve sustainable solutions was researched from a theoretical perspective. In Part 2 evidence from practice will be analysed and related to the theoretical findings.

This chapter provides more information on the case study approach. In Figure 5.1 the structure of this chapter is displayed. This first section explains the reason to use case study research and provides a short theoretical introduction.

5.1.1 WHY CASE STUDY RESEARCH?

This research aims to describe non-technical factors that affect the implementation of sustainable solutions in design processes. As stated in Chapter 1, organizational, social and behavioural issues are relatively unexplored (Schweber & Leiringer, 2012). A case study approach enables to make in-depth descriptions of the design process, and explore these soft factors. Leading to ‘lessons learned’ about the application of sustainable solutions in practice.

5.1.2 THEORY OF CASE STUDY RESEARCH

Case study research tries to explain a decision or set of decisions: why they were taken, how they where implemented and with what results, which complies with the interpretive approach and main objective as described in Chapter 1. According to Yin (2009), case study research is the method of choice when the main research question is a ‘how’ or ‘why’ question, when there is little control over the events of interest, and when the events are contemporary in a real-life context.

If well-planned, case study research can achieve accuracy, generality and describe complexity, of which accuracy should never be compromised (Woodside, 2010). Case study research has three main limitations, which are: risk of biased views, lack of a systematic approach, and sometimes lack of generalizability of the findings (Yin, 2009).

A case study research should have checks to construct validity, create internal validity, create external validity and reliability. Furthermore, each selected case should be critical as it either confirms, challenges or extends existing theory (Yin, 2009).

The above described method, goals, risks and checks are summarized in Table 5.1. In the next sections the application of this methodology will be described.
5.2 CASE STUDY STRUCTURE

Case study research aims to learn from practice, by interviewing relevant actors around several office renovation projects in Norway. This section describes how the methodology is applied in practice. First the relationship of the case study structure and the total research structure is presented. Subsequently validation is described by discussing the data collection protocol.

5.2.1 RELATION TO RESEARCH STRUCTURE

The cases are related to the previous literature review and total research structure as shown in Figure 5.2. Each case study consists of five sections.

The first section provides a general introduction to the project. The second section analyses sustainability as design parameter, which relates to Chapter 2. The third section addresses the refurbishment task, and relates to Chapter 3. In this section also the applied solutions to achieve the sustainability goals will be presented. The fourth section is devoted to the organization of the design process, following the same structure as Chapter 4.

Each case ends with several lessons learned. These overall lessons learned will form the basis for the conclusions and recommendations in Chapter 9 and Chapter 10.

In conclusion, each case study chapter will use the following structure:

1. Case description (describes the context)
   - General description of the project
   - Actors involved in the project
2. Sustainability as design parameter (relates to Chapter 2)
   - Sustainability goals
   - Initiative for sustainability
   - Construction budget
   - Barriers & opportunities
3. Refurbishment process (relates to Chapter 3)
   - Refurbishment potential
   - Refurbishment strategy
   - Barriers and opportunities
4. Organization of the design process (relates to Chapter 4)
   - Early actor involvement
   - Goal setting and quality assurance
   - Loops and knowledge transfer
   - Barriers and opportunities
5. Lessons learned (conclusions)
5.2.2 DATA COLLECTION (VALIDITY)

Data collection mainly deals with the construction of validity and the creation of internal validity as specified by Yin (2009), which will now be described in more detail.

Validation is constructed by using multiple sources of reference and by letting key informants review the draft version. The key actors around a case were contacted for a 45 to 90 minutes interview. Key actors included the client/owner, tenant, project manager, contractor, architect, energy consultant, and environmental consultant. The interview data was complemented with magazine articles, internal project documentation, and presentations. A draft of each respective chapter was send to the interviewed actors for feedback.

Internal validity is obtained by relating the case studies to the theoretical findings of Part 1. Moreover, the interviewed actors were asked specifically to give feedback on how they valued the conclusions. Internal validity is obtained if all actors agree with the conclusions, because then it can be assumed that the conclusions are logically derived.

5.2.3 DATA PROCESSING (RELIABILITY)

Data processing mainly deals with reliability and external validity, as specified by Yin (2009). These aspects will now be described in more detail.

Reliability ensures no bias occurs during the research. Several protocols are developed during the course of this research. First of all the cases are structured the same. Secondly, the interviews were performed according to a special format which can be found in Appendix C. The interviews were semi-structured. This means a conversation found place following the interview format with room for discussion and other questions in between. The intention of the interview format was followed, rather than strict posing questions and getting answers. The interviews were recorded by the author and can be made available on request.

External validity follows from the internal validity arguments. Because the case studies are analysed following existing literature, it is also possible to relate the conclusions and lessons learned back to improve the theoretical findings. Especially integrated design process theory is used to create external validity.

In the next section the selection of cases will be discussed.
5.3 DESCRIPTION OF THE CASES

The previous sections discussed the methodology and its application. The final section discusses the selection of cases and provides a short description for each case.

5.3.1 SELECTION OF CASES

According to Yin (2009), a selected case can be a critical case that either confirms, challenges or extends existing theory. It is possible to select an extreme or unique case, a representative case, a revelatory case or a longitudinal case. At the same time each case is vulnerable of not displaying the information for what it was chosen for (Yin, 2009).

During the research two pilot cases studies will be conducted, providing a reference line. One pilot case is revelatory in its nature, providing new insights to complement the theory. The other pilot case is representative, as it provides an overview of current renovation practice.

Subsequently, three cases will be researched in more detail. These cases form the main data of this research, and can be interpreted as extreme but representative. The cases represent trends in the building market, from awareness about energy issues, passive house standard to energy producing buildings. On the other hand, all cases have specific sustainability features, which can be considered as exemplary performance, especially in the period the projects were designed, planned and build.

For each case the most important decision-makers with respect to sustainable solutions are interviewed. Appendix C provides an overview of the interviewed persons and their respective role per case.

5.3.2 DESCRIPTION OF CASES

This subsection provides more information on the two pilot projects, and subsequently on the three detailed cases: Lysaker Park, Fredrik Selmers vei 4, and Powerhouse Kjørbo.

The Monarch pilot case is the first pilot project. The project aimed for a BREEAM ‘excellent’ certificate. The BREEAM requirement was important, because otherwise the investor did not want to invest in the project. This is a revelatory case, as it provides more practical insight into the benefits of sustainable solutions. The Nesoyveien 4-6 case can be seen as a typical case, because the energy and other sustainability goals are set on a market level. The two pilot cases are covered in Section 5.4 and Section 5.5.
The first detailed case study is devoted to Lysaker Park. The project had goals set in a quality program and aimed for Norwegian energy label B. The project was completed in December 2009. The case is covered in Chapter 6.

The second case is Fredrik Selmers vei 4. The project shall obtain the passive house standard and a BREEAM ‘very good’ certificate. The project should be completed in October 2013. This case can be found in Chapter 7.

The third case study project is Powerhouse Kjørbo. The Powerhouse alliance is a partnership which aims to show the possibilities to construct energy producing buildings. The project should be completed in February 2014, and is examined in detail in Chapter 8.

Figure 5.3 provides a summary of the three projects. Throughout the remainder chapters the owner and developer will be called client, since in all three cases this actor comes from the same company. The next sections are devoted to the pilot case studies.
In the previous chapters refurbishment strategies, as well as sustainable design are described. In this section a practical example of sustainable office renovation in the Netherlands will be given to illustrate the previous described design approaches and considerations. This practical example also provide a further understanding of barriers and opportunities in a design process.

This project is chosen from the nominee list for non-residential renovation projects from the Gulden Feniks 2013. The Gulden Feniks is a yearly price for the best renovation project. Sustainability is one of the criteria to get awarded (NRP, 2013).

The Monarch I will be described in detail, based on an interview with the project developer and several sources with project information found in magazines and on the internet.

First the case will be described. Subsequently the project organization will be given. Then barriers and opportunities in the design process will be given. The section ends with lessons learned.

5.4.1 CASE DESCRIPTION

The Monarch I (Monarch) is the first building of a larger development in the Beatrixkwartier, the Hague. The building is a renovated and extended office building of the 1960s (Monarch, 2013). An impression of the finished office is given in Figure 5.4.

The Beatrixkwartier is a development location in The Hague. The location is shown in Figure 5.5. By means of a public-private partnership (PPS), office space, apartment blocks, a hotel, and parking space will be developed. The Monarch I is one of the realized projects in the Beatrixkwartier. The redevelopments of the Beatrixkwartier started already in 1999 with a master plan by J. Busquets. Several architectural designs were made within the master plan. However, budget issues as well as the economic crises led to a constant change of plans.

The final designs for the Monarch I and II were chosen because of lower investment costs and the possibility to realize the projects in several phases. The contractor agreement for The Monarch I was signed in November 2010, and an investor was found in December 2010. The construction was finished in February 2012.
The project comprises a realisation of 19,500 m² floor area. The sustainability goal was to obtain a BREEAM-NL Excellent certificate. This certificate was a prerequisite for the investor. If there was no BREEAM certificate, the project would not have been realized. The costs of the sustainability demands where integrated in the total budget costs. Table 5.2 provides a summary of the project.

5.4.2 ORGANIZATION OF THE PROJECT

The project was led by Provast, a project developer. They were chair of the weekly design meeting and facilitated a contract with the tenant, investor and constructor. An overview of the project participants and their relationship is given in Figure 5.6.

The main interest of a project developer is to make a profit out of a project. The investor, Union Investment Group, is a German based company. They were interested in this project if the sustainability was assured by a certification scheme. BREEAM is an international recognized environmental assessment scheme, and was therefore used in this project. Provast did not have knowledge about BREEAM before this project. Therefore, Provast went to a BREEAM introduction seminar and asked C2N to come up with a cost and risk analysis. After a quick scan, it was found that the efforts to obtain a BREEAM certificate were overseeable, so the project started.

According to the project developer, the preferred design process is a traditional process, with a tender on the basis of the final design. There are two assumptions behind this thought: consultants in the design phase should not make mistakes, and the market has to be transparent in the tender.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>The Hague, NL</td>
</tr>
<tr>
<td>Floor area</td>
<td>19,500 m²</td>
</tr>
<tr>
<td>Sustainability goal</td>
<td>BREEAM-NL Excellent</td>
</tr>
<tr>
<td>Sustainability budget</td>
<td>Integrated in total costs</td>
</tr>
<tr>
<td>Construction phase</td>
<td>Completed (February 2012)</td>
</tr>
</tbody>
</table>

Table 5.2 Summary of case project the Monarch

![Figure 5.6 Organization of the design and construction process for the Monarch I (in red the interviewed actor)](image-url)
Reasons to follow a different process and contract form are: complexity of the project, time pressure, risk policy, wanted level of influence and juridical reasons. In the Monarch a design & build (D&B) contract was used because the tenant had to move in within 12 months, and the first time of using BREEAM was perceived as a higher risk. BAM was selected as a contractor after the concept design, but before the detailed design was finished.

During the design process Provast assured that the risks for BREEAM were taken care of by the actors that could influence the risk. For example, the tenant was responsible for credits to show a time schedule with public transport connections.

When asked for the amount of integrated design in this project, the project developer pointed to the fact that there was one contract between the developer and the contractor, as well as one contract between the developer and the tenant. This would imply that all issues had to be solved integrated. As said, the contractor had a D&B contract. The tenant had a rental contract, while the contract with the investor was a Transfer of Physical Assets (TPA).

The project was monitored with weekly design meetings, while there were monthly meetings with the boards of the investor, tenant, and contractor.

The role of the architect was to guard the aesthetics, while the sustainability issues were taken care of by other consultants, as well as by the basic experience from the project developer. In the design brief for example, starting points were given such as a limitation of the amount of glazing and the use of exterior solar shading. The final architectural concept is shown in Figure 5.7.

### 5.4.3 BARRIERS AND OPPORTUNITIES IN PRACTICE

The project experienced several barriers and opportunities in the design process, leading to the final design. The design will now be described with the corresponding barriers and opportunities, which are summarized in Table 5.3.

<table>
<thead>
<tr>
<th>Barriers</th>
<th>Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unexpected technical issues</td>
<td>Save money and time by reusing casco</td>
</tr>
<tr>
<td>BREEAM did not value all sustainability issues</td>
<td>Good location, high BREEAM score relatively easy</td>
</tr>
<tr>
<td>Functional requirements (height and space)</td>
<td>New façade construction</td>
</tr>
</tbody>
</table>

Table 5.3
Barriers and opportunities experienced during the Monarch project
As described in section 3.2 - refurbishment potential, in a renovation project a building assessment has to be made, informing the program design. In the Monarch a certain amount of asbestos was reported. Nevertheless, during the construction it was found that the amount of asbestos was even higher than expected. It was decided that all asbestos should be removed. It can be argued that removing all asbestos is a sustainable measure, although this was not a requirement in BREEAM, nor is it required by the current legislation. In total this led to a rise of construction cost.

The project developer appreciates the objective measurement method of BREEAM. However, sometimes the method can be off-balance, as with the asbestos example. In the eyes of the project developer, the most important parameter in sustainability (and project development in general) is the location. The Monarch is developed on a location near public transport and living areas. It can therefore be expected that there will always be a demand for office locations in this area, as opposed to a sustainable office outside the city centre.

The high BREEAM-NL Excellent score was obtained relatively easy by balancing costs and performance. The focus was mainly on a reduction of the energy performance, by applying insulation and heat pumps. Other solutions, such as bird cabinets and water saving toilets were also applied. By focussing on the organization of the construction process, 100% of the management score was obtained (BAM, 2012). However, the balance also caused a low score of 15% for material use (DGBC, 2012b).

An opportunity formed by the renovation task itself is material saving. The reuse of the structural frame in the Monarch led to a cost- and time saving compared to a new construction (Wind, 2012). The major refurbishment task in the building was to gain usable space and deal with the restricted height. The project developer wanted to create floors of at least 1000 m², also to assure future tenancy. To reach these goals, the north-eastern façade was extended with 7,5m (Allin, 2012). Furthermore, the building was stripped to its casco and a new façade was built 760 mm outside of the existing floor connection. This new façade includes all the installations, so the free height of 3,2m can be left intact, and the usable space is increased (Wind, 2012). This can be classified as sub-strategy A1: replacement with a curtain wall, as described in Section 3.4 - Refurbishment strategies.

A detail and impression of the façade can be seen in Figure 5.8.

5.4.4 LESSEONS LEARNED
After analysing the Monarch case, the organization of the design process, and experienced barriers and opportunities, it is possible to find some lessons learned. These lessons
learned will form the basic input when answering the main research question later in Chapter 9. From the Monarch case, six lessons can be learned, summarized in Table 5.4.

The first lesson is that IDP can be interpreted in several ways. When asked for integrated design, the project developer interpreted this as contract forms, while literature often defines integrated design as the integration of architecture and engineering (e.g. Löhner et al., 2003). The plurality in meanings with respect to design and integrated design terms between different actors is also mentioned by Brunsgaard (2009). The vocabulary used in this research is described earlier in Section 4.1.1 - what is integrated design?

The second lesson is that several contract forms are possible to obtain integrated architecture. The project developer in the Monarch project states that he wants to use a tender process to develop buildings. There are reasons to use a different contract form, but sustainability is not one of them. This preliminary conclusion is also found in a larger EU research program on sustainable renovation of residential buildings (Geier et al., 2012).

The third lesson learned from the project is that sustainability competence can be brought in by several actors, and not necessarily the architect. In this project the architect was unaware of the design consequences of BREEAM. The BREEAM knowledge was brought in by consultants and by basic knowledge of the project developer, who went on an introduction course to gain competence.

The fourth lesson is the observation that sustainability (mostly in the form of a BREEAM certificate) is gaining importance. This project was not realized if there was no BREEAM certification involved. This shows that the goal of BREEAM, to provide a market pull, is obtained (see Section 2.4 - designing for BREEAM). On the other hand, the Monarch project also shows that there are other sustainability aspects that are not covered directly in BREEAM, such as the asbestos example.

The final lesson is the importance of benefits and a project realization within the budget. The project developer stresses the benefits that should be gained from investing in sustainability. In the end every actor in the project wants to create a (financial) benefit. At this moment sustainability, certified with BREEAM, is indicated as a good return on investment (Simons, 2012). The project developer stresses during the interview the importance of the total budget. As soon as sustainability is seen as something extra it will not work. These statements from practice correspond with research performed by Davis Langdon (Matthiessen & Morris, 2004; 2007).
The second pilot case study is Nesøyveien 4-6. Three existing buildings will be connected with an atrium and renovated towards the low energy standard. The construction phase is almost started. The building owner wants to create a future-oriented and modern building, for which the Norwegian low energy standard is a prerequisite. An impression of the renovated building is displayed in Figure 5.9.

Nesøyveien 4-6 will be described in detail, based on an interview with the project manager (fulfilling the role of client, owner and future tenant), as well as the architects. Several sources with project information from the internet complement the interviews.

First the case will be described. Subsequently sustainability as design parameter, the refurbishment process and the organization of the design process will be discussed. The section ends with lessons learned.

### 5.5.1 CASE DESCRIPTION

Varner Gruppen, one of the largest clothing companies in Norway, has decided to move to a new headquarters. The current building at Bergerveien is 8,000 m² and has space for around 350 employees. The company is growing so fast that they decided to develop a new headquarters at Nesøyveien 4-6 of around 15,000 m², which offers place to maximum 600 employees. The expected completion is in November 2015 (Helland, 2013). The location of the new building is shown in Figure 5.10.

The new headquarters at Nesøyveien will be a renovation project of three old buildings from the 1980s, that will be connected with an atrium. At this moment Varner Gruppen tries to sell their old headquarters (Revfem, 2011a). The project manager told that Varner desires to sell the building as soon as possible. It is also an option to redevelop the old headquarters into housing (Revfem, 2012).

The project is managed by Varner, which means Varner fulfills the role of client, owner and future tenant. Varner has a building department, which works with indoor (re)design of clothing shops. This department has provided the project manager for this project. The project manager is assisted by the architects and several specialised consultants. The project organization is presented in Figure 5.11.
At this moment the project is in a tendering phase to find a main contractor under a design and build contract. The project started in 2011 when Varner bought Nesøyveien 4-6. Subsequently an architectural competition led to the current renovation proposal. In total the design team has thus worked around two years on the project at the time of writing. A time-line can be found in Figure 5.12.

5.5.2 SUSTAINABILITY AS DESIGN PARAMETER

The corporate social responsibility (CSR) program of the client focuses on issues mainly outside the building sector. For example, goals are set to reduce chemicals in clothing and improve the working places in third world countries (Varner, 2013). With respect to the headquarters, the client has expressed the wish to be environmentally leading, but not ‘Miljøfyrtårn’-certified. The ‘Miljøfyrtårn’-certificate is a Norwegian environmental certificate focused on headquarters (Miljøfyrtårn, 2013).

The only concrete goal set for the renovation project is that it should obtain the Norwegian low energy standard. In practice energy label B will be obtained, while at the same time the minimum requirements for indoor climate are ensured.

After consideration it was decided to not use BREEAM in this project. First, the project manager highlighted that the client owns the building and does not wish to sell it, which renders the need to value the sustainability of the building obsolete. Second, the project manager recalled that the CSR resources are devoted to clothing related issues; CSR in a building is of less importance for the client. Third, the project manager highlighted the high investment costs associated with BREEAM, which would be 20% higher.

5.5.3 REFURBISHMENT PROCESS

The project manager mentioned that the passive house standard would be technical not feasible because of thermal bridge problems. While a façade replacement would solve this problem, this was economically not feasible. Therefore, the goal was set on the low energy standard.

The existing building site consists of three separate buildings, which will be connected with an atrium. The existing buildings will be insulated from the inside. Furthermore, the windows will be replaced by triple-glazing. The interior and existing installations will be replaced with a new indoor concept and a new system, including decentralized heat recovery ventilation. The outdoor appearance will be changed, as can be seen by comparing the existing situation (see Figure 5.13) with the new design (see Figure 5.9).
5.5.4 ORGANIZATION OF DESIGN PROCESS

In general the project can be regarded as a typical case. The most important incentive is to find the economically most feasible solutions. At this moment the concept design is finished, with detailed requirements set on themes such as ventilation, lighting and insulation levels. The project is in the process of finding a main contractor, who will construct the building under a design & build contract.

Measurement and verification will become the responsibility of the main contractor. The design team has not set specific evaluation requirements. The project manager expects that the detailed design specified after two years project time the will lead to the desired quality in the building.

5.5.5 LESSONS LEARNED

From this typical case three lessons can be learned: the budget limitation to develop several alternatives, the focus of BREEAM on certification, and the life-time considerations of façade replacement, which are summarized in Table 5.5.

The first lesson is that budget can be a limitation to develop several alternatives. To reduce costs sometimes decisions have to be taken fast. It is not possible to develop several alternatives to the same level of detail. In this project the passive house standard was rejected as technically and economically not feasible in a quite early stage. No complete design alternative of the passive house standard including a detailed cost analysis was made.

The same holds for the choice to not use BREEAM in this project. The extra costs for documentation are perceived too high. Although this project could have used BREEAM as a guiding tool, it was perceived mainly as an extra consultancy cost. This relates to the second lesson learned: BREEAM is too much focussed on certification, instead of providing assistance in design choices on environmental issues. Certification can be a benefit when the owner wants to rent out the building or sell it to an investor because the certificate provides an objective proof of evidence. It provides the buyer or tenant with trust. For an owner that occupies his own building this benefit is low or absent.

The final lesson is that the façade strategy leads to a debate including several factors. In this project low investment costs led to the decision to upgrade the existing façade instead of replacing it. However, factors such as the embodied energy (in this project inside insulation is added, windows are replaced and the outdoor appearance is changed), operational energy (with a façade replacement, using more embodied energy, a lower energy label could be achieved) and the lifetime of the façade could also play a role in the decision making process.

<table>
<thead>
<tr>
<th>#</th>
<th>Lesson learned Nesøyveien 4-6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Budget can be a limitation to develop several alternatives</td>
</tr>
<tr>
<td>2</td>
<td>BREEAM is focussed on certification, which is a benefit to sell or lease the building. For an owner-occupied building the benefit of certification is low</td>
</tr>
<tr>
<td>3</td>
<td>Façade strategy leads to a debate about what is most sustainable (lifetime, operational energy use, embodied energy, investment costs)</td>
</tr>
</tbody>
</table>
6.1 CASE DESCRIPTION

The first case that will be described in detail is Lysaker Park. This building, completed in December 2009, was one of the first renovation projects achieving the Norwegian energy label B, and was also used as demonstration project in the EU INTEND research. The project won the Cityprisen 2010 (Jensen, 2010).

The client, tenant, contractor, architect, project manager, energy consultant and environmental consultant are interviewed for this project. Details of the interviewed actors can be found in Appendix C.

The chapter is built up as described in Chapter 5 - Methodology. The structure of the chapter is recaptured in Figure 6.1. This first section starts with a general description of Lysaker Park. Subsequently, the main actors involved will be described.

6.1.1 GENERAL DESCRIPTION

Storebrand ASA, a Norwegian insurance company, was originally located at Aker Brygge, the most expensive real estate location in Oslo. At the same time it was known that the existing tenant at Lysaker Park would move out in 2007. Storebrand ASA decided to relocate to Lysaker Park. The location of Lysaker Park is shown in Figure 6.2.

Storebrand had three reasons to renovate Lysaker Park: first, the organization needed more space. Secondly, the space should be optimised for new working procedures, such as open landscape offices. Finally, the company wanted to save money by relocating to Lysaker Park, and by realizing energy savings (Storebrand, 2013).

The internal real estate department (Storebrand Eiendom) was responsible for the renovation project. The aim of the renovation project was to create a pleasant work environment. Moreover, top management decided that the project should satisfy high quality standards in health, safety and environment (HSE) since Storebrand ASA has a sustainable company profile (Storebrand, 2013).

The renovated building is shown in Figure 6.3 on the next page. The project includes the provision of 1,600 open office landscape working places, 160 quiet rooms and 130 meeting places. The renovated building comprises 55,000 m² including the parking garage, while the rentable area is around 38,000 m² (Storebrand, 2013).
Figure 6.3
Impressions of the Lysaker Park building ("After renovation", "Before renovation", as well as the plan are taken from Storebrand (2013), all other photos made by the author during a site visit)
6.1.2 ACTORS INVOLVED

A time-line of the project is presented in Table 6.1. The project began in 2005, because it was known that the contract with the existing tenant, Kværner, would be ending in 2007. In 2006 the first ideas and sketches were made how to renovate the building. In 2006, Kværner decided not to extent their contract and move to another building. As described, Storebrand decided to renovate the building for their own organization.

In this case study, the design process is studied from 2007, with the revised concept design as starting point. Although a concept design was made in 2007, the architects at that time and Storebrand decided not to translate this concept design into a construction. By the end of 2007 a new design team was put together with Link Signatur as architects. The completion deadline did not change when the design team changed.

Although owned by the same mother company, Storebrand ASA, the financial inspection requires a strict division between the client (Storebrand Eiendom) and the tenant (Storebrand Livsforsikring). Because the time pressure and delay caused by the change of architects, an ‘owner-steered-contractor’ model was used. The construction work was divided over more than 40 small contracts. For this case study one of the subcontractors, AF Gruppen, is interviewed. AF Gruppen won a small contract for concrete works (worth 5 million NOK). Afterwards, AF Gruppen was assigned with more work, ending up with contracts worth 200 million NOK, including building site logistics.

In Figure 6.4 the project organization from 2007 until completion is given.

<table>
<thead>
<tr>
<th>Date</th>
<th>Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>Idea</td>
</tr>
<tr>
<td>2006</td>
<td>Program design</td>
</tr>
<tr>
<td>2007</td>
<td>Concept design</td>
</tr>
<tr>
<td>End 2007</td>
<td>Revised concept design</td>
</tr>
<tr>
<td>Begin 2008</td>
<td>Start demolition, detailed design</td>
</tr>
<tr>
<td>Mid 2008</td>
<td>Start construction, detailed design</td>
</tr>
<tr>
<td>Dec 2009</td>
<td>Construction completed</td>
</tr>
</tbody>
</table>
6.2 SUSTAINABILITY AS DESIGN PARAMETER

In this section a description of sustainability as a design parameter will be presented. First, the sustainability goals, as set in the quality program, are given. Subsequently, the initiators of these goals are discussed. Next, a paragraph is devoted to the construction budget. The section ends with a conclusion on the barriers and opportunities of the project organization from a sustainability perspective.

6.2.1 SUSTAINABILITY GOALS

As described in the previous section, it was decided that the renovated building should satisfy high quality standards in health, safety and environment. In the interviews it was acknowledged by the tenant, client, and the project manager that this would require more competence. Furthermore, all three actors were aware of the difficulties of obtaining an integrated architecture. Especially the contradiction between comfort and energy use was highlighted during the interviews.

To set clear sustainability goals, the environmental consultant made a quality program based on five principles: comfort, environment, robustness, universal access, and aesthetics. The environmental goals specified a maximum amount of delivered energy of 125 kWh/m², or Norwegian energy label B. Furthermore, all materials should be environmental friendly (Bramslev, 2009). The quality program is shown in Table 6.2.

The requirement for energy label B was set in a dialogue between the client, environmental consultant and project manager. At the start of project, the client demanded only energy label C. The energy goal was thus raised during the project. According to the tenant and the client it was not an option to achieve a label A at that time. The project manager pointed to the fact that even nowadays label A is hard to achieve, because of the required quality of the construction, high construction costs, and a large failure probability.

6.2.2 INITIATIVE FOR SUSTAINABILITY

The initiative to involve sustainability in the project was mostly client-driven. As an insurance company, Storebrand has one of the largest real estate departments of Norway. Storebrand ASA has a sustainable business profile. Storebrand wanted to show their competence and vision on sustainable real estate, also in their own headquarters (Storebrand, 2007).

Especially the project manager pointed out the importance of the top management in Storebrand ASA. The top management
was responsible for overall corporate social responsibility guidelines, and wanted to extend this to Lysaker Park. An example of the importance of the top management is the addition of robustness in the quality program. Robustness was brought in by the CEO of Storebrand at that time, not by the consultants. According to the environmental consultant most sustainability projects are client-driven, because clients understand that tenants will demand only sustainable buildings in the near future.

6.2.3 CONSTRUCTION BUDGET

The project was constructed within time and budget constraints. However, several interviewees highlighted a budget increase over the project time. The first budget was set on 200 million NOK, which was later adjusted to subsequently 500 and 700 million NOK. All interviewees agreed that the first budget was not in line with the final achieved quality.

The budget and rent were determined within formal processes and negotiation between the client, tenant and project manager. These processes were mainly based on the required rate of return, the expected quality and the market rent. The client mentioned these formal processes being easier than in conventional projects, because in the end Storebrand ASA was both client and tenant. However, according to the project manager, it took some time to find the responsible persons in the top management, and get the budget and expectations in line. In the end the realized project was approved both by the client and the tenant in terms of budget and delivered quality.

6.2.4 BARRIERS AND OPPORTUNITIES

From the analysis of sustainability as design parameter it is possible to find barriers and opportunities, which are summarized in Table 6.3.

First of all, the theoretical barrier of perceived inflexibility (see Chapter 2) is mentioned during the interviews. As opportunity, the interviewees refer to the use of the quality program, as well as appointing competent professionals in the project team. The budget was first not in line with the expectations. Because the goals were anchored in the top management, the expectation problem could be solved.

Next, the refurbishment process will be described.

<table>
<thead>
<tr>
<th>Barriers</th>
<th>Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived inflexibility of label B and label A</td>
<td>Quality program provides holistic sustainability view</td>
</tr>
<tr>
<td>Budget not in line with expectations (start phase)</td>
<td>Goals anchored in top management/committed client</td>
</tr>
<tr>
<td>Lack of competence/knowledge</td>
<td>Appoint competent professionals</td>
</tr>
</tbody>
</table>

Table 6.3
Barriers and opportunities for Lysaker Park from a sustainability perspective
6.3 REFURBISHMENT PROCESS

In this section the refurbishment process and the technical solutions applied in Lysaker Park are described. First the refurbishment potential is given. Subsequently, the refurbishment strategy is discussed. The section ends with a conclusion on the barriers and opportunities of the project from a refurbishment perspective.

6.3.1 REFURBISHMENT POTENTIAL

As discussed in Chapter 3, the refurbishment potential can be assessed by four parameters: architectural design, building construction, technical installations, and economic aspects. The most important restrictions in this project were posed by the architectural design, and economic aspects.

First, the architectural restrictions will be described. The original building consisted of five separate building blocks, each build in a different period of time. The architect tried to combine the existing five buildings in a holistic, contemporary way. This strategy can be called ‘dialogue’. Furthermore, restrictions were posed by logistics and daylight conditions. In the existing building, offices were randomly placed, people had to walk though office space, and clear entrances were missing. Furthermore, daylight conditions did not meet current standards (Link Arkitektur, 2010). Finally, the nearby E18 auto way poses acoustical requirements on the façade. The existing plan of building C is shown in Figure 6.5.

Second, the economic aspects were important in this project. The client wanted to realize costs savings by reducing the energy demand. It was known that the building construction and technical installations were not up to today’s energy standard (Førland-Larsen, 2009).

6.3.2 REFURBISHMENT STRATEGY

Regarding the refurbishment possibilities for the total building, three alternatives were discussed: major renovation, minor renovation, and demolition and new-built. Alternatives were calculated with a life cycle analysis tool, providing a ranking based on CO₂-equivalent for energy use and material use. The alternatives are listed in Table 6.4.

Table 6.4

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Energy use [kWh/m²]</th>
<th>Material use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demolition + new built</td>
<td>84</td>
<td>Large</td>
</tr>
<tr>
<td>Minor renovation</td>
<td>158</td>
<td>Low</td>
</tr>
<tr>
<td>Major renovation (façade replacement)</td>
<td>104</td>
<td>Medium</td>
</tr>
</tbody>
</table>

The three alternatives were discussed for each building block. It was found that the major renovation would lead to the most sustainable result, because reusing the load bearing construction would lead to lower CO₂-emissions. Only building A should get a minor renovation, because the budget was limited and building A was a relatively new building.
During the interviews, the tenant stated that it would have been better to renovate building A as well, because now the quality is lower than in the other building blocks. The client expressed the same feelings about this subject. However, it is not planned to upgrade building A in the near future.

The renovation of the buildings included the addition of several atria to provide daylight, a better indoor climate, and the required logistics. The new plan of building C is displayed in Figure 6.6. The acoustical problem from the nearby highway E18 was solved by a double façade at the entrance. Furthermore, solar thermal panels are added at building B. However, all actors highlighted that these solar panels were a gimmick feature at that time, to provide a green image. The panels provide only a small percentage of domestic hot water heating. The energy measures included a reduction of the cooling load by means of exterior shading. The chosen Colt system is semi-transparent and tracks the position of the sun.

Another important measure was a change in the specifications of the tenant. By accepting some hours with temperatures above 26 degrees in summer, it was easier to achieve the energy goals within budget. Furthermore, the tenant was required to change their computer specifications (leading to lower internal loads and lower energy use). All measures are summed up in Table 6.5.

### 6.3.3 BARRIERS AND OPPORTUNITIES

From the analysis of the refurbishment process, it is possible to find some barriers and opportunities, which are summarized in Table 6.6.

The most important barriers from the refurbishment perspective were posed by the architectural design and the budget. Because the building was stripped and an atrium was added to the building, the architects were able to deal with these restrictions. It was necessary to change the specifications of the tenant to obtain a label B without exceeding budget. However, the budget was not large enough to include building A in the renovation, or to provide more solar thermal panels.

In the next section the design process will be discussed.
In this section the organization of the design process will be described, divided into early actor involvement, goal setting and quality assurance, and design loops and knowledge transfer.

6.4.1 EARLY ACTOR INVOLVEMENT

Lysaker Park was a demonstration project in the development of the integrated design guidelines (Kanenergi et al., 2010). These guidelines are developed with special focus on the early design phases. In the Lysaker Park project the environmental consultant, energy consultant, architect, client, tenant and other relevant consultants participated in a kick off workshop. Close cooperation in the design team was facilitated by the environmental consultant (Forland-Larsen, 2009).

Because the tenant was known, the design could be developed in dialogue with the tenant. As described in the refurbishment strategy, several specifications set by the tenant had to be changed. The environmental consultant highlighted the importance of these specifications, and told time and resources were devoted to the dialogue about the specifications. However, the tenant referred to this process as an easy step. Perhaps this can be explained by the fact that a tenant is more interested in the function, aesthetics and office concept of the project and not necessarily the technical details, while an environmental consultant is specifically devoted to sustainability issues. The environmental consultant highlighted that the specifications from the tenant are important contract documents, and that the biggest barrier when changing specifications is to fight against believes.

The subcontractors were involved after the concept design. Several problems were experienced during the construction period related to a lack of time, and a lack of coordination in the construction works. The first problem is caused by the change of architects without changing the deadline. According to the interviewed subcontractor it would have been better to take more time for the revised concept design. Now, the architects were still drawing the detailed design, while the contractors had already started demolition and construction works. Sometimes a change in functional requirements led to double work and thus extra costs. Due to the lack of time, the construction work was split into around 40 contracts, so work could be carried out in parallel. However, all contracts have limitations, and the gaps between these limitations also have to be filled. In this case the gaps were solved by extra focus on the building logistics and by additional workers on-site.
6.4.2 GOAL SETTING & QUALITY ASSURANCE

All actors agreed that the quality program, made by the environmental consultant, provide clear guidance for the goal setting and quality assurance. The role of the environmental consultant as quality coordinator within the project management organization was highlighted as the driving force in the project’s success in almost every interview.

Every week a decision making meeting was scheduled, where changes were discussed based on economy, time and environment. Changes in the design were only allowed if they either raised the quality or lowered the costs. Storebrand ASA wanted to have a report of the economy, time and environment status every two months.

The environmental consultant checked all materials chosen by the architects. Most materials were approved straightaway. An example of a disapproved material was the carpet. However, because of the size of the project, the producer was able to change his product manufacturing method, receive an environmental certificate, and use the carpet in the project. The environmental consultant also checked material use during the construction phase. Moreover, the quality program made by the environmental consultant was used as an appendix for the rental contract. It can thus be concluded that the environmental consultant was indeed a key player in the organization.

6.4.3 KNOWLEDGE TRANSFER & EVALUATION

As described previously, this project was used as an example project in the development in the EU INTEND guidelines. A workshop was carried out in the start-up phase of the project, and design changes were checked in accordance with economy, time, and environmental goals. The quality program was used to develop alternatives and to check the design. In the construction and operation phase some discrepancies between IDP theory and reality started to appear.

During the construction phase decisions were only taken once, and the energy calculations were done at parallel, because of the time restrictions. This implies there is no place for large design loops in the construction phase anymore, as the IDP theory states. Moreover, as described in the previous subsection on ‘early actor involvement’, sometimes already built parts had to be reconstructed because of a change in functional requirements. The architects also said that time restriction resulted in the fact that parts were constructed as soon as they are finished. For example, the sprinkler system was built as one of the first installations, posing restrictions on other installation possibilities and the architectural design.
During the operation phase actual energy usage seemed to exceed the theoretical energy budget because of different user habits than assumed, a learning phase, and failures in delivered equipment (Førland-Larsen, 2011). A list of differences between theory and reality is presented in Table 6.7. The client mentioned during the interview that it is a long process to find all causes to drive the energy budget down. Additional changes after the construction process, such as the connection of several zones, are not always documented. Furthermore, despite the large number of measurement devices, it is not always possible to obtain the required information. Moreover, not all devices were calibrated correctly. The client would have made a different measurement and verification plan if the project was done over again. In summary, the information transfer after the construction phase could have been better, especially on technical operation details.

### 6.4.4 BARRIERS AND OPPORTUNITIES

From the analysis of the design process, it is possible to find some barriers and opportunities, which are summarized in Table 6.8.

First of all, although Lysaker Park was an example project in the INTEND research project, time pressure made it hard to apply all guidelines in the construction and operation phase. Changes after the construction phase are not documented well enough, and are not checked holistic on the consequences they have on the quality program. The project is successful, mostly because of the central role of the environmental consultant, who had the ability to steer on economy, time and quality. This was also possible because the client showed commitment, and demanded a report every two months based on those three parameters. A minor barrier was to convince the tenant to change the specifications. However, with time and resources devoted, this barrier could be overcome.

In the next section lessons learned will be discussed.
6.5 LESSONS LEARNED

This last section combines the barriers and opportunities from the previous sections into several main lessons learned. These lessons are summarized in Table 6.9 and will now be explained in more detail.

First of all, Lysaker Park has shown that a project can be steered by economy, time and environmental requirements. In the weekly decision making meeting solutions were discussed. Each solution should either raise the quality, or lower the costs.

Secondly, Lysaker Park showed the importance of a committed client. The central role of the quality program, made by the environmental consultant, was required by the client. Storebrand even added a requirement, robustness, by themselves. The client has pushed the limits of the tenant, the architects, consultants, contractors and managers. Furthermore, the client remained committed by evaluating the quality program and energy use also during operation.

Thirdly, time for the concept design is important. Due to the change of architects, a lot of valuable design time has been lost. Especially the contractor pointed towards the importance of finishing at least the functional requirements. Furthermore, when more time is taken for the design the boundary conditions of the contract are easier to fulfil. In the pre-design it is important to be aware of the construction order, because this can influence future possibilities for change.

The fourth lesson is that IDP also should have been used in the construction and operation phase. Especially the information transfer of technical design assumptions can help to operate the building as designed. Furthermore, changes should be documented with the quality program in mind, also after construction.

As fifth lesson it is found that a calibrated measurement system is necessary to monitor the real energy use. In the design phase a plan should be made, especially focussed on which detailed posts should be measured.

The final lesson is that a renovation project is a long-term investment. At Lysaker Park, already four years after completion, the client and tenant partly regret the fact that building A did not get a major renovation, which led to a difference in quality.

Table 6.9

<table>
<thead>
<tr>
<th>#</th>
<th>Lesson learned from Lysaker Park</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Steer on economy, time and environment is possible</td>
</tr>
<tr>
<td>2</td>
<td>Committed client is important</td>
</tr>
<tr>
<td>3</td>
<td>Take time for concept design and include the contractor</td>
</tr>
<tr>
<td>4</td>
<td>IDP should have been carried through in the construction and operation phase (document changes)</td>
</tr>
<tr>
<td>5</td>
<td>A good measurement and verification plan including a calibrated measurement system is necessary to monitor the real energy use</td>
</tr>
<tr>
<td>6</td>
<td>Be aware that renovation is a long-term investment</td>
</tr>
</tbody>
</table>
CHAPTER 7
FREDRIK SELMERS VEI 4
7.1 CASE DESCRIPTION

The second case study project is Fredrik Selmers vei 4 (FS4). The project is expected to be completed in October 2013, meeting the Norwegian passive house standard and a BREEAM ‘Very good’-level (NAL, 2013).

The tenant, façade contractor, architect, project manager, energy consultant and environmental consultant are interviewed for this project. Appendix C provides an overview of the interviewed actors by name and company. The client was not available for an interview. Because the client of FS4 and Powerhouse Kjørbo are the same, it can be assumed that the client’s role was comparable in the two projects.

The chapter is built up as described in Chapter 5 - Methodology. The structure of the chapter is recaptured in Figure 7.1. This first section starts with a general description of the FS4 project, after which the main actors will be described.

7.1.1 GENERAL DESCRIPTION

The project is a renovation of the existing National Tax Authority building (NTA, ‘Skatteetaten’ in Norwegian). The location of the project is shown in Figure 7.2. In 2009 it was known that the existing lease contract with the NTA would expire. The owner of the building, Entra Eiendom, did not want to lose this large and risk-free client, and started an internal architectural competition and a negotiation process with the tenant to convince them to sign a new lease contract.

The tenant had two major starting points for the negotiations and the architectural competition: the project should achieve minimal Norwegian energy label B, and be based on new requirements. The tenant had earlier expressed a wish to move into a new building, instead of renovating the existing one. The architect proposed a first design, which was accepted by the tenant. Major conclusions of the process included the extension of the floor area, use of recycled aluminium, a temporary relocation, and the data central in the building that should remain in use during construction (Haavik, 2013). This will be described in more detail in Section 7.3.

An impression of the renovated building is provided in Figure 7.3. The building consists of five blocks, originally separated. In the redesign the open landscape office have an orientation across the building blocks. The total area is around 35,000m². Around 6000m² is available for other tenants, although the NTA has an option to rent this extra space. The data central is placed in the basement.
Figure 7.3
Impressions of the building at Fredrik Selmersvei 4 ("façade detail" and "before renovation" by Førland-Larsen (2012), background plan by LPO Arkitekter (2012), all other photos made by the author during a site visit)
7.1.2 ACTORS INVOLVED

A time-line is displayed in Figure 7.4. The project started in 2009, when it was known that the existing lease contract with the National Tax Authority (NTA) would run out in Entra Eiendom, a state-owned real estate developer, had to come up with big changes to convince the NTA to not buy a new building (Haavik, 2013).

During the design and construction phases the sustainability goals were continually raised. The program was based on the label B requirement. After the concept design was finished, the goals were raised to passive house standard, and the project was included in the FutureBuilt program. In June 2011 the contractor documents were signed. These contractors were divided into three design & build contracts: façade, installations, and internal works (Revfem, 2011b). According to the project manager this was the economic most advantageous contract form. After signing the construction contracts, the detailed design was performed by the contractor. Although the construction had started in August 2011, in November 2011 it was decided to include the BREEAM certification system in the project.

The design team, led by the project manager, made the concept design and set the constraints. Although in Norway it is quite normal that the design team is changed after the concept design, in the FS4 project the design team remained the same from design to construction. A change of design team can free the way to fresh thinking and cheaper solutions. Although, the energy consultant highlighted that it can also become more difficult to bring the concept design further.

Figure 7.5 displays the project organization for FS4. Appendix A provides an overview of the interviewed actors.
7.2 SUSTAINABILITY AS DESIGN PARAMETER

In this section a description of sustainability as a design parameter will be presented. First, the sustainability goals are presented. Subsequently, the initiators of these goals are discussed. Next, a paragraph is devoted to the construction budget. The section ends with a conclusion on the barriers and opportunities of the project organization from a sustainability perspective.

7.2.1 SUSTAINABILITY GOALS

As shortly described in the previous section, this project was characterized by continuously raising sustainability goals. The project started with the requirement for Norwegian energy label B, which was raised to energy label A/passive house level. The project also took part in the FutureBuilt program and is going to be BREEAM certified. The project goals and their respective status are presented in Table 7.1.

FutureBuilt is a program that tries to realize 50 example projects in the Oslo region. Each project has to realize minimal 50% lower environmental impact with respect to transport, energy use and materials compared to a modelled reference building (Futurebuilt, 2013). In practice this meant that the FS4 design team had to make a climate gas calculation to optimise energy and material use.

BREEAM was brought in during the construction phase. It was simply not possible to integrate BREEAM in earlier design phases, because BREEAM-NOR was introduced in the Norwegian market in 2011 (NGBC, 2012). The project manager pointed out that environmental goals and BREEAM are not going away and will become more stringent over time. Therefore, it is better to learn the system as fast as possible. This is in line with the vision of the client (Entra, 2013b). The project aims for a ‘Very Good’ or ‘Excellent’ certificate. The final score depends on the documentation and interpretation by third party experts (Entra, 2013a)

7.2.2 INITIATIVE FOR SUSTAINABILITY

Only the first sustainability goal, energy label B, was set by the tenant. Afterwards all sustainability goals were initiated by the client. The client is eager to set ambitious sustainability goals, because the companies main strategy is to ‘become branch leader in environment’ (Entra, 2013b).

The raising of goals from label B to label A was not directly accepted by the tenant. The tenant had no previous experience with passive houses, and was sceptical about label A in the

<table>
<thead>
<tr>
<th>Table 7.1</th>
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</thead>
<tbody>
<tr>
<td>Sustainability goals in the FS4 project were replaced. Finally the passive house standard became the main target.</td>
</tr>
<tr>
<td>Goal</td>
</tr>
<tr>
<td>Energy label B</td>
</tr>
<tr>
<td>Environmental program</td>
</tr>
<tr>
<td>FutureBuilt</td>
</tr>
<tr>
<td>Passive House</td>
</tr>
<tr>
<td>BREEAM-NOR</td>
</tr>
</tbody>
</table>

Fredrik Selmers vei 4 | 107
beginning phase. The tenant was afraid that indoor comfort would be sacrificed in favour of energy savings. According to the environmental consultant this was the beginning of an extensive process, especially because the contracts were already signed. The energy consultant pointed out that a lot of calculations were made to compare the situation before and after the renovation. It turned out that indoor comfort would actually improve in the new situation. Besides, also the daylight conditions would improve. This process led to the acceptance of the tenant to change the specifications in their contracts.

### 7.2.3 CONSTRUCTION BUDGET

The described convincing process of the tenant also had influence on the construction budget. The contracts with the tenant were already signed and based on the label B requirement. It is a formal process to change contracts. Besides, it was negotiated that the tenant should not pay more rent after raising the sustainability goals.

A large part of the extra investment costs necessary to obtain the passive house standard are covered by ENOVA (ENOVA, 2013). This organization provided a subsidy covering part of the extra investment costs. In comparison to a new building cost savings were realized because of reuse of the load-bearing construction, and reuse of the basement. An overview of the costs and benefits is presented in Table 7.2.

### 7.2.4 BARRIERS AND OPPORTUNITIES

From the analysis of sustainability as design parameter it is possible to draw some conclusions, which are summarized in Table 7.3.

The main barrier in this project was the raising of goals after signing the contracts. First the tenant was sceptical about raising the goals. However, the tenant could be convinced and it was agreed to change the specifications, but without a rent increase. The extra investment costs thus had to be recovered in another way. This was done with the ENOVA subsidy and by cost saving possibilities in the renovation process. The main opportunity in this design process was the committed client, who kept demanding higher sustainability goals.

Next, the refurbishment process will be described.

### Table 7.2

<table>
<thead>
<tr>
<th>Extra costs</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extra investment costs by façade replacement</td>
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<tr>
<td>Extra investment costs for better installations</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Extra Financial benefits</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>No higher rent possible</td>
<td></td>
</tr>
<tr>
<td>ENOVA subsidy (3% of total building costs)</td>
<td></td>
</tr>
<tr>
<td>Cost savings by reusing load-bearing structure and basement</td>
<td></td>
</tr>
</tbody>
</table>

### Table 7.3

<table>
<thead>
<tr>
<th>Barriers</th>
<th>Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raising of goals after contracts were signed</td>
<td>Committed client</td>
</tr>
<tr>
<td>Scepticism at the tenant about passive house comfort</td>
<td>Tenant was known and could be convinced</td>
</tr>
<tr>
<td>Extra investment costs (no rent increase possible)</td>
<td>ENOVA subsidy and cost savings reuse</td>
</tr>
</tbody>
</table>
7.3 REFURBISHMENT PROCESS

In this section the refurbishment process and the technical solutions applied in Fredrik Selmersvei 4 are described. First the refurbishment potential is given. Subsequently, the refurbishment strategy is discussed. The section ends with a conclusion on the barriers and opportunities of the project from a refurbishment perspective.

7.3.1 REFURBISHMENT POTENTIAL

As discussed in Chapter 3, the refurbishment potential can be assessed by four parameters: architectural design, building construction, technical installations, and economic aspects. Based on these parameters the potential for FS4 will be described.

First of all, the building construction set limitations on the façade and plan. As can be seen in Figure 7.6, the existing floor plan consisted of several building blocks, connected by elevator shafts. In practice the load bearing structure has a maximum capacity. Therefore, the weight of the façade and the amount of areas that can be added is restricted. Another restriction set by the building construction was the impossibility to insulate under the basement floor. Furthermore, the building construction had low U-values and several thermal bridges problems. According to the project manager this often leads to the conclusion that energy label B is the highest possible goal.

The architectural design was restricted by a low daylight factor and the aesthetic potential. The structure of the floor plan did not promote a good daylight factor. Besides, the old brick wall was considered as not aesthetic by the tenant, who expressed a wish for a light and white architectural impression. Therefore an architectural strategy ‘desire for change’ was preferable.

7.3.2 REFURBISHMENT STRATEGY

The main strategy in this project to obtain the sustainability (and other) goals, was to extend the area between the building blocks and replace the façade. First, the extension of floor area will be described. The new floor plan is displayed in Figure 7.7. The extension adds usable floor area and helps fulfilling the energy demands, because the renovated building becomes more compact.

Another major part in the refurbishment strategy was the façade replacement. The existing brick wall was demolished and recycled. The new façade is presented in Figure 7.8.
new outdoor façade would be produced in prefabricated elements. Prefabricated elements lead to a low construction time on site, and low weather influence. The passive house competence from the supplier was used to convince the client that this solution would deliver the same performance as conventional on-site construction. The process of constructing the prefabricated elements is shown in Figure 7.9. The façade was covered with perforated aluminium, because of the weight restriction. The architect mentioned the weight restriction as an important but exciting requirement in the material choice.

According to the environmental consultant maybe less façade would have been changed if the project was done over again. However, according to the energy consultant a passive house standard can never be achieved without a façade replacement. The energy consultant told that a façade replacement is never feasible from cost savings alone. Other alternatives, especially focussed on equipment, can be much more cost-effective. In this project the façade replacement was chosen because it also opened possibilities to improve the daylight factor and architectural appearance.

Besides the façade replacement, the change of tenants specifications was an important energy measure to achieve the sustainability goals within budget (see Section 7.2.2 - Initiative for sustainability). These and other applied measures are presented in Table 7.4.

### 7.3.3 BARRIERS AND OPPORTUNITIES

From the analysis of the refurbishment process, it is possible to draw some conclusions, which are summarized in Table 7.5.

The most important architectural barrier was posed by the restricted weight available for the façade. This is solved by the use of perforated aluminium. A discussion is currently going on about the economic advantages of façade replacement. In this case the replacement also offered other qualities such as improved daylight and a fast construction time because of the prefabricated elements. An important barrier not yet discussed is the need to relocate the total office for the 2 years of construction time. On the same time, this provides freedom to the contractor. This issue will be, amongst others, described in more detail in the next section.

<table>
<thead>
<tr>
<th>Barriers</th>
<th>Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restricted weight for façade</td>
<td>Perforated aluminium façade fits in design</td>
</tr>
<tr>
<td>Façade replacement is not most economic advantageous solution</td>
<td>Replacement with prefab elements offers other qualities, e.g. daylight, fast construction time</td>
</tr>
<tr>
<td>Relocation necessary for the movement process</td>
<td>Building not occupied during construction</td>
</tr>
</tbody>
</table>

Figure 7.9
Prefabricated elements of 2,5m x 12m (including windows) are attached to the building (Entra, 2012b)

Table 4
List of applied energy measures (Entra, 2012a; 2012b)

- **Applied energy measures**
  - Window area maximal 40%
  - Low window U-value (~ 0,8 W/m²K)
  - Low façade U-value (~ 0,15 W/m²K)
  - Thermal bridge value (~ 0,03 W/m²K)
  - Airtightness (~ 0,6 h⁻¹)
  - Ventilation heat recovery (~ 86%)
  - Change user requirements (user controlled ventilation, energy-efficient equipment, low internal loads, new comfort set point)
  - Heat pump coupled to server room

Table 7.5
Barriers and opportunities for FS4 from a refurbishment perspective
7.4 ORGANIZATION OF THE DESIGN PROCESS

In this section the organization of the design process will be described, divided into early actor involvement, goal setting & quality assurance, and knowledge transfer & evaluation.

7.4.1 EARLY ACTOR INVOLVEMENT

In Fredrik Selmersvei 4 the integrated design principles are mainly introduced by the energy consultant (NAL, 2013). During the interviews the architect highlighted the new kind of design task. The architect pointed out that FS4 required to work with new types of consultant in a timely fashion on topics such as daylight, materials, and energy use. This is in line with the IDP theory which requires the set-up of a multidisciplinary design team and a different design task in the earliest phases.

It was noted by the architect and project manager that clear goals set in the earliest phases make it easier to obtain a good design for a low price. The architect told that it was a good luck that the architectural concept of extending the areas was robust enough to support the change in goals. However, some parts of the design had to be changed. For example, the façade was first designed with more glass area. The first and final façade design are displayed in Figure 7.10.

The contractor was included from the detailed design phase. The design & build contract form made the contractor responsible for the detailed design and construction. Because different contractors were assigned for the installations and façade, solutions had to be clearly specified. The contractor mentioned that sometimes decisions were not completely ‘landed’. For example, several windows had to be reordered because the size conflicted with the ceiling height.

A final important aspect in the early actor involvement was the convincing process of the tenant, as described in Section 7.2.2 - Initiative for sustainability. The tenant, project manager and client had a meeting every two weeks. The tenant valued this meetings as important, because they felt included and that the project would be more according to their requirements. The tenant intends to get involved more in future projects as well.

7.4.2 GOAL SETTING & QUALITY ASSURANCE

It is confirmed in all interviews that the client was the driving force for the sustainability goals. The project manager thought that the reason for this commitment is triggered by the experience of the client that buildings from before the years 2000 are already harder to rent out. These buildings

![Figure 7.10](image)

Top: Sketch of the first façade design (Haavik, 2013), bottom: final façade design. The design was adjusted to maximise daylight and minimise heat losses through the windows.
require a façade or installation replacement. At the same time it is known that requirements for energy and environment will become more stringent over time. Therefore, the project manager was sure that the learning experience and high goals for FS4 were a good and necessary step.

The construction quality was assured mainly by previous passive house experience of the supplier of prefabricated elements. Furthermore, the façade contractor had arranged more design meetings than normal. In practice the construction process was not so different compared with a conventional project. The contractor highlighted that they had to be more clear about the construction tasks, and trust the carpenters. A lot of other procedures, such as a kick-off workshop were already standard procedure of the contractor.

After the construction had started it was decided that the project should be BREEAM certified. During the interview the contractor highlighted the importance of BREEAM to sharpen the industry. The project manager used this project as an opportunity to learn the system. The project manager recalled that BREEAM will require some resources, both in time devoted to the documentation, as in more expensive solutions. However, a lot of procedures, such as a clean building site and waste sorting, are already standard for contractors. The other sustainability goals, such as FutureBuilt and the passive house standard, in combination with the contractor and design teams competence led to the final score of ‘Very Good’ or ‘Excellent’.

7.4.3 KNOWLEDGE TRANSFER & EVALUATION

As described in the previous paragraph, most starting points for BREEAM were already in place. All actors agreed that BREEAM did not change the design, except that more documentation and follow-up was required, as is shown in Figure 7.11. The difficulty with BREEAM was to learn the system. Most interviewed actors called BREEAM ‘a system for already known energy and environmental goals’. According to the project manager, most difficult was to get the correct documentation at the right time in place. Normally consultants deliver operation and management plans after the construction is completed, but BREEAM requires these documents earlier. Everyone has to be more proactive.

The project manager further raised questions such as how can we know that the aluminium façade contains the amount of recycled material as described? And how is the brick wall going to be recycled in this project? What happens to waste in general? The project manager experienced that suppliers are working on environmental product declarations and clients are interested in what happens with waste, but not all answers are already found.
The building had to be empty during the renovation works. Therefore, the tenant was relocated for a period of 2 years. During this relocation the tenant tried out new office concepts such as the open office landscape, which were evaluated with employee researches.

The client is responsible for follow-up during the operation phase. The tenant will only provide feedback, while the client operates the building. Despite earlier doubts on the passive house concept, the tenant now thinks that the indoor comfort will be of high quality. Moreover, the tenant is convinced that any mistakes in the building process can be fixed afterwards. One would expect the tenant to raise the energy requirements in future building projects in the rest of Norway, after the good experience with this project. However, the tenant has not decided to demand exclusively label A buildings in next project, because of experience with other projects were it was not possible to obtain this high energy standard. The tenant highlighted that it is mainly the client’s competence that determines if an energy-efficient building is feasible.

7.4.4 BARRIERS AND OPPORTUNITIES

From the analysis of the refurbishment process, it is possible to draw some conclusions, which are summarized in Table 7.6

The most important barrier was the raising of sustainability goals. Luckily, the architectural concept was robust to support this raising of goals. The competence of the multidisciplinary design team was used to further optimise the design. Another experienced barrier was the introduction of BREEAM in the construction phase. On the other hand, this gave the opportunity to learn the system straight away. The boundaries of the contractor’s contract form a barrier for the integration of the work, as can be seen in the window example. The experience of the supplier could be used to deliver the high quality. A final opportunity experienced by the tenant was the good process and high delivered quality. However, the tenant has stated that only the good process is taken as a learning process. The tenant will not demand only label A buildings from now on.

The next section summarizes the chapter with lessons learned.

<table>
<thead>
<tr>
<th>Barriers</th>
<th>Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raise of sustainability goals</td>
<td>Multidisciplinary design team, robust concept</td>
</tr>
<tr>
<td>BREEAM system must be learned</td>
<td>Learning experiences high environment goals</td>
</tr>
<tr>
<td>New challenges for building sector (e.g. waste, EPD)</td>
<td>Committed and competent client</td>
</tr>
<tr>
<td>Contract boundaries for contractor</td>
<td>Experience of supplier</td>
</tr>
<tr>
<td>Tenant does not see his responsibility</td>
<td>Good experience with project and process by the tenant</td>
</tr>
</tbody>
</table>
This last section combines the barriers and opportunities from the previous sections into several main lessons learned. These lessons are summarized in Table 7.7 and will now be explained in more detail.

First, an important lesson is the observation that the high sustainability goals indeed called for an integrated design approach. Both the architect and energy consultant confirmed the new design task. In several optimization rounds the design team has to come up with design solutions.

The second lesson that can be drawn from this project is the importance of clear goal setting in a timely fashion. During this project the goals were raised after the tenant contract was signed, and BREEAM was introduced when the construction was already started. This led to an ambiguous design task. Furthermore, changing contracts is a time-consuming and juridical process.

The third lesson is that all actors confirmed the importance of energy and environmental goals. In the future legislation will become more stringent and it is likely that more and more issues, such as waste reduction, become integrated in these goals. It can be assumed that more and more topics become part of the sustainability discussion.

It is interesting that the tenant pointed to the client as main actor that influences the possibility to achieve a label A building. The debate about façade replacement and energy efficiency from equipment shows that the tenant can play a major role in reducing energy demand. Furthermore, the tenant played a crucial role in the FS4 project, because the required change of specification. The fourth lesson is thus the importance of the tenant.

Furthermore the importance of follow-up is highlighted. Related to the development of new sustainability issues, is the question how it can be assured that the quality is guaranteed. How do we know what happens with building waste? These are all questions addressed by developments such as the circular economy. The main lesson however is that also these developments need follow-up and evaluation.

A conservative conclusion can be drawn about the ENOVA subsidy. The subsidy certainly lowers the threshold to evaluate the passive house option, but it’s influence on the total business case is hard to give.

<table>
<thead>
<tr>
<th>#</th>
<th>Lesson learned from FS4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IDP guidelines confirmed in terms of early actor involvement</td>
</tr>
<tr>
<td>2</td>
<td>Importance of clear goals set in the earliest phases</td>
</tr>
<tr>
<td>3</td>
<td>Development of new sustainability issues such as waste and non building related energy use</td>
</tr>
<tr>
<td>4</td>
<td>Importance of tenant</td>
</tr>
<tr>
<td>5</td>
<td>Importance of follow-up</td>
</tr>
<tr>
<td>6</td>
<td>ENOVA subsidy lowers the threshold to evaluate the passive house option, but it’s influence on the total business case is hard to give.</td>
</tr>
</tbody>
</table>
CHAPTER 8
POWERHOUSE KJØRBO
The third case study project is Powerhouse Kjørbo. The main goal is to generate more renewable energy over the lifetime of the building than energy used for the production of materials and energy used for operation (Powerhouse, 2013a). Other goals are a BREEAM ‘outstanding’ certificate, the FutureBuilt program, and the use of cradle to cradle products (Entra, 2013c). The project is now in its construction phase with expected completion in February 2014.

The client, tenant, main contractor, façade supplier, architect, project manager, and an energy consultant are interviewed for this project. Appendix C provides an overview of the interviewed actors by name and company.

The chapter is built up as described in Chapter 5 - Methodology. The structure of the chapter is recaptured in Figure 7.1. This first section starts with a general description of the Powerhouse project, after which the main actors will be described.

8.1.1 GENERAL DESCRIPTION

The location of the project is presented in Figure 8.2. The project consists of two building blocks on a large office park. This is shown in Figure 8.3. The park is constructed in the early 1980s, with a common canteen and parking garage. Two buildings stood empty after the tenant moved out. Because the buildings were in functional bad shape, a renovation project was started. The owner, Entra Eiendom, proposed to upgrade the buildings with the Powerhouse alliance.

Powerhouse is a partnership between several actors in the building sectors’ supply chain and includes the project developer Entra Eiendom, the construction company Skanska, Snohetta architects, the environmental organization ZERO, and aluminium supplier Hydro. The main goal of the alliance is to show the building sector possibilities to construct energy producing buildings in Norway within an economic feasible framework (Powerhouse, 2013b). The partnership is formed as an open alliance, which means that more actors can get involved, if two or more existing partners agree.

The renovated building is displayed in Figure 8.4. The two buildings have a floor area of 5,200 m2 and provide office spaces for 220 to 230 employees. Most important restriction in the project was the zoning regulation plan, which required that the architectural expression of the building as a black cube should be maintained.
Figure 8.4
8.1.2 ACTORS INVOLVED

A time-line of the project is presented in Figure 8.6. The project was limited in time. The tenant needs the building delivered in February 2014, which reduced the total design and construction time to around two years.

The actors from the Powerhouse alliance were involved from the earliest phases, including the contractor, client, and architect. The contractor was responsible for the energy concept and BREEAM consultancy, while the architects took care of the process management. The contractor worked under a design and build contract. The client, contractor and main supplier worked on the basis of open-book rules, which means the actors had full insight into each others costs and profit margins.

Although a lease contract was not directly signed, the future tenant was involved in the project from the beginning on. Asplan Viak, a consultancy company, already rented one building in Kjørbo and had the option to rent an extra building block. Asplan Viak was thus the first tenant to approach for this project. However, the Powerhouse alliance was not sure about the outcome of the project and the required construction time. Asplan Viak demanded to be involved in the project as ventilation and energy consultant, otherwise they would not be interested to start the tenancy negotiation process. Therefore it was decided that Asplan Viak was involved from the beginning on as ‘tenant’s representative consultants’. In the end of 2012 a ten years lease contract was signed for both buildings. In June 2013 Asplan Viak officially joined the powerhouse alliance.

The project organization is displayed in Figure 8.5.
8.2 SUSTAINABILITY AS DESIGN PARAMETER

This section provides a discussion on sustainability as a design parameter. First the sustainability goals will be presented. Second, the actors initiating these goals are discussed. Third, a paragraph is devoted to the construction budget. Finally the barriers and opportunities to involve sustainable solutions in the organization of the design process are summed up.

8.2.1 SUSTAINABILITY GOALS

Several goals are set and displayed in Table 8.1. The overall goal is the Powerhouse goal to become ‘energy producing’, without compromising good architecture and indoor comfort conditions (Powerhouse, 2013c). Secondly, the project aims to achieve a BREEAM ‘outstanding’ certificate, participates in the FutureBuilt program, and implements Cradle2Cradle goals. No actor mentioned how Cradle2Cradle is practically applied. Therefore it is no subject of further discussion.

The architect noted that although the 5000 m² of the project is not particularly large, every partner in the Powerhouse alliance has something to lose. The project is seen as so ambitious by all actors, that it will influence the reputation of every involved actor, which can be either positive or negative depending on the project outcome.

The overall Powerhouse goal had to be defined in detail. No standard exists today that takes account for embodied energy, operational energy and renewable energy at the same time. Details the alliance agreed upon are summarized in Table 8.2. In practice the Powerhouse goals imply that a passive house is constructed with extra focus on embodied energy. The building-related operational energy use is compensated by means of solar energy. User-equipment is excluded from the energy balance. An extensive framework of net zero energy definitions and implications is described earlier in Chapter 2.

How the solar energy will be used is not yet known in details. To obtain the yearly net zero energy balance a grid connection is required. Currently, the client negotiates with the electricity supplier about the details of the grid connection. The contractor highlighted that it is not possible to make money out of selling electricity to the grid. Therefore, as much as possible energy will be used in the Powerhouse buildings. Surpluses will probably used in the other buildings of office park Kjørbo, who are also owned by the client. Any remaining surpluses will be sold to the grid, while in times of deficit electricity has to be bought from the grid.
8.2.2 INITIATIVE FOR SUSTAINABILITY

The main initiator for the project was the client who in 2011 proposed the tenant to renovate the building together with the Powerhouse alliance. In practice, the complete alliance can be seen as the initiator of the sustainability focus. The combination of competence among actors, knowledge that energy neutrality is possible, and knowledge that building components and solutions are available led to the establishment of the Powerhouse alliance, initiated by Hydro in 2010. All actors that participate in this alliance have anchored the goals in their organizations by the top management.

8.2.3 CONSTRUCTION BUDGET

Central in the Powerhouse alliance is the objective to develop solutions within ‘commercial conditions’ (Powerhouse, 2013c). During the interviews all actors highlighted that the costs and budget-steering was not different from normal projects. The client and the contractor highlighted that while some costs are higher than usual, other costs are lower. Examples of cost savings are the simple heating system, with a low amount of radiators and pipes. Perhaps the open book between the contractor and client has played a role in the achievement of economic benefits.

Although all interviewees pointed out that profits were made, almost every actor also mentioned the pilot nature of the project. For example, the supplier mentioned that in future projects efforts can be allocated and priced in a different way. The extra investment costs are covered with an ENOVA subsidy, as well as that the tenant pays more rent in return for the energy savings (Førland-Larsen, 2013).

8.2.4 BARRIERS & OPPORTUNITIES

In summary, this section presented the Powerhouse goal. Barriers and opportunities are presented in Table 8.3.

An opportunity is the Powerhouse objective includes to built under economic conditions. Thus, this project can show the economic feasibility of sustainable projects. On the other hand, every interviewed mentioned the pilot nature of the project, which seems to contradict the commercial goal. Another barrier found is the economic feasibility of renewable energy production in Norway. An opportunity is the reputation gain for all involved parties if the project succeeds. Next, the refurbishment process will be discussed.

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### Table 8.3

<table>
<thead>
<tr>
<th>Barriers</th>
<th>Opportunities</th>
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</thead>
<tbody>
<tr>
<td>Economic feasibility of renewable energy production</td>
<td>Project realized under commercial conditions</td>
</tr>
<tr>
<td>Pilot nature mentioned by many actors</td>
<td>Reputation gain for all involved parties</td>
</tr>
</tbody>
</table>
In this section the refurbishment process is described. First, the potential of the existing building is discussed. Second, the refurbishment strategy is given. The section ends with barriers and opportunities in order to involve sustainability.

8.3.1 REFURBISHMENT POTENTIAL

As discussed in Chapter 3, the refurbishment potential can be assessed by four parameters: architectural design, building construction, technical installations, and economic aspects. The most important restriction in this project was posed by the architectural design.

In the program phase the architects came up with several façade proposals. However, the zoning legislation required the building to keep its existing appearance as black cube. The design team thus had to apply a ‘preservation’ strategy. With this restriction in mind more alternatives were generated. First sketches of the façade are displayed in Figure 8.7.

The outdoor appearance should look architecturally good, achieve a good indoor daylight factor and keep the building insulated. Especially the optimization of the last two parameters was dominant in the design process. The indoor design potential was restricted by an optimization process between exposed concrete and acoustic quality. Exposed concrete is thermal mass which contributes to the indoor comfort because it dampens temperature swings. At the same time, exposed concrete reflects sound, leading to a lower acoustic quality.

Technical installations and the building construction played a minor role in the potential assessment, because the building was stripped completely, with only the load-bearing construction remaining. During the interview the contractor pointed to some minor constraints. In a renovation project it is for example not possible to make openings in the floor on every spot. The new installations are described in the next section.

8.3.2 REFURBISHMENT STRATEGY

The main refurbishment strategy is to fulfil at least the passive house requirements. According to the contractor the main innovation in this project is the combination of several well-known technologies. The new façade will be airtight and well-insulated and include external solar shading as is presented in Figure 8.8. Prefab elements where not possible because of time restrictions.
The contractor highlighted the application of displacement ventilation as most innovative solution. A central air cooling system with mechanical and displacement ventilation is installed (Førland-Larsen, 2013). In Powerhouse Kjørbo large air volumes are brought in at the bottom of the middle interior walls. The air velocity is low. The staircase acts as a large exhaust duct. In theory less energy is needed than a traditional mixing-air system, because the air mixes better (less air needed) and the velocity is lower (less energy needed for pumps). However, displacement ventilation has not often been applied, and it is difficult to predict if the air will mix enough. Several actors were sceptical about this solution. The design team has conducted several experiments and is confident that a good indoor climate will be obtained. The ventilation strategy is presented in Figure 8.9.

An important part of the strategy was to reuse materials. First of all, the complete concrete loadbearing structure is reused. Secondly, exterior windows were deconstructed and are to be reused in the interior design, as is shown in Figure 8.10 on the next page. In Powerhouse Kjørbo the goal is to sort at least 90% of the construction waste (Skanska, 2013). Some of this waste, such as the glass, is directly reused, while most of it is transported to a recycling facility. Although it is interesting to find out what happens with the waste, it is not inside the scope of Powerhouse Kjørbo to deal with this problem.

The strategy to generate renewable energy is earlier described in Section 8.2 - Sustainability as design parameter. A complete list of energy saving measures is given in Table 8.4.

### 8.3.3 BARRIERS AND OPPORTUNITIES

To summarize, this section discussed the refurbishment strategy, for which the zoning regulation plan and the energy goal had set the most important restrictions. Main barriers and opportunities found are summarized in Table 8.5.

The main opportunity found in the refurbishment task is the use of known components. Only displacement ventilation is seen as an innovative solution. This solution is therefore tested in a laboratory setting first. A barrier is formed by the deconstruction work that should be done carefully. This lead to the possibility to reuse material directly in the building.

Next, the organization of the design process is discussed.

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**Table 8.4**

<table>
<thead>
<tr>
<th>Applied energy measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Window area 40%</td>
</tr>
<tr>
<td>Low window U-value (~ 0.8 W/m²K)</td>
</tr>
<tr>
<td>Low façade U-value (~ 0.15 W/m²K)</td>
</tr>
<tr>
<td>Thermal bridge value (~ 0.03 W/m²K)</td>
</tr>
<tr>
<td>Airtightness (well below 0.6 h⁻¹)</td>
</tr>
<tr>
<td>Ventilation heat recovery</td>
</tr>
<tr>
<td>Displacement ventilation</td>
</tr>
<tr>
<td>Possibly heat pump</td>
</tr>
</tbody>
</table>

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**Table 8.5**

<table>
<thead>
<tr>
<th>Barriers</th>
<th>Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacement ventilation had to be tested</td>
<td>In principle all components necessary to obtain the passive house standard are known</td>
</tr>
<tr>
<td>Deconstruction work should be done carefully</td>
<td>Materials such as glass can be reused directly</td>
</tr>
</tbody>
</table>
8.4 ORGANIZATION OF THE DESIGN PROCESS

In this section the organization of the design process will be described and compared to the theory of integrated design processes as described in Chapter 4. First early actor involvement will be discussed. Secondly a paragraph is devoted to the role of goal setting and quality assurance. Thirdly, evaluation and knowledge transfer will be described. The section ends with barriers and opportunities implementing sustainable solutions.

8.4.1 EARLY ACTOR INVOLVEMENT

All actors were involved from the earliest phases. The Powerhouse alliance includes the client, supplier, architect, and contractor. The future tenant was involved as ‘user representative consultant’, although a lease contract was not directly signed. The presence of the contractor in the design team was never experienced as a restriction, according to the interviewed architect.

During the earliest design stages several processes ran parallel: the client was in negotiation with the tenant, while at the same time the design was under development. Most important for the tenant was a strict deadline of delivery in February 2014. In the earliest stages it was not yet known how the planning would look like and what the exact consequences of the goals would be. The lack of planning was seen as major challenge by the tenant. For example, although the tenant had a room program ready, the alliance wanted to use a new approach to find out what the room program should look like by interviewing the tenant. Suddenly time was running out, and in the end the tenant’s room program was used. This could have been planned earlier with more clear deadlines.

In the concept design several focus groups gathered in large workshops to decide about starting points for the energy budget and first design proposals. All actors pointed to this workshop as a necessity to realize the highly ambitious goals. In practice the workshops were also held to create a common decision-making forum. No decision was taken before consensus was achieved about the goals and the way forward. The supplier pointed out that this way of working is more fun. It is possible to create better and still cost-effective solutions than when everyone only competes on price.

8.4.2 GOAL SETTING & QUALITY ASSURANCE

The design process, with close collaboration between architects and engineers was learningful and perhaps easier than a conventional process, according to the architect. The
dialogue led to better starting points, so a more holistic design quality could be assured. A starting point for this way of working mentioned by the architect is that every actor should be willing to both give and take in the process. This is only possible if everyone is committed to project with a clear goal as well as if the top management of every project organization has anchored the goals. In this way the complete organization supports individual efforts. The supplier agreed with these findings but complemented that it was sometimes hard to keep the own organization interested in the Powerhouse goals.

All actors confirmed that the Powerhouse goal was most important in this project. The biggest challenge related to this the experience of the architect that every choice had to be checked with the energy goals. For example, if gypsum was planned to be used on internal walls, it should not only fulfil the architectural and function goal but it should also be checked with the embodied energy and overall energy goals. The architect pointed out that in practice everyone was available for questions. However, it makes all actors more dependent on each other than in a normal project.

8.4.3 KNOWLEDGE TRANSFER & EVALUATION

Related to the more advanced decision-making process is the notion of the architect that the energy calculations are complex. It is for example hard to judge on intuition alone which façade proposal will lead to the lowest energy use. However, the architect recalled that in future projects maybe more questions can be asked in early phases about the relationship of architecture and energy use. In general the architect believes that many building professionals are ready to implement more sustainable solutions.

Although all actors were involved from the beginning and stayed involved during the whole process, the contractor still mentioned a small gap of knowledge transfer from the concept design to building practice. The concept design is made by a different department within the contractor’s organization. The knowledge of that department was important in the process of translating the design to practice. Without key persons staying involved it was more difficult to interpret the concept design according to the interviewed contractor. Another gap of knowledge is mentioned by the supplier. This actor told that there should be more learning from Europe. In other countries techniques and processes are common that are not used in Norway.

Another way of knowledge transfer applied in this project was testing. First of all, a 1:1 mock-up was build to test the construction principles. The mock-up is displayed in Figure 8.11. Especially the placement of the windows and airtightness was checked, and the carpenters learned the
### Table 8.6
Barriers and opportunities for Powerhouse Kjørbo from a design process perspective

<table>
<thead>
<tr>
<th>Barriers</th>
<th>Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long negotiation time between client and tenant before a lease contract was signed. Lack of planning was experienced as a challenge</td>
<td>All actors, including contractor and tenant’s representative consultant involved from early phases</td>
</tr>
<tr>
<td>More communication required (in workshops, decision-making process)</td>
<td>Importance of goals (project commitment and internal organization commitment)</td>
</tr>
<tr>
<td>Lack of time/knowledge gap between concept and construction</td>
<td>Motivation of partnership to evaluate solutions</td>
</tr>
</tbody>
</table>

construction method Nevertheless, the supplier mentioned that this testing was performed relatively close to the real construction phase and that the cost responsibility was not clear. Perhaps more benefits could have been reaped. During the construction phase several times an intermediate airtightness test is conducted, as is shown in Figure 8.12. In this way the contractor got an idea about the reached quality. The tests were also used to show the carpenters again what the influence of their work was. The first tests in the corner room revealed an airtightness of 0.3 h⁻¹ (Skanska, 2013)

Because this project is still under construction it is not yet known how the building will perform in use. User equipment can influence the actual operational energy use, but is not taken into account in the Powerhouse definition. It can be assumed that the tenant has in-house competence to ensure good operation of the building. The tenant is currently already ’ISO 14001’ and ’Miljøfyrtårn’-certified, and has specific focus on low energy use of equipment. The Powerhouse alliance is also explicitly motivated to follow up and evaluate the project.

### 8.4.4 BARRIERS AND OPPORTUNITIES

This section provided an overview of issues around the organization of the design process. The found barriers and opportunities are summarized in Table 8.6.

Opportunities are the involvement of all actors, including the tenant and the contractor in the earliest stage. The tenant’s involvement was two-sided: they where in negotiation about the lease contract, as well as provided consultancy about possible tenant’s requirements. The long negotiation time between client and tenant can be seen as a barrier. Besides, the lack of planning was seen as a major challenge. The ambitious sustainability goals in combination with the tight deadline led to an integrated design process. The extra communication requirements in this process can form a barrier. In practice the importance of the main goal, within the project as well as within all partner organizations, can be seen as a driving force. Finally, although a partnership was formed and an integrated process followed, still knowledge gaps were found and improvements could be made. However, all Powerhouse partners are willing to evaluate the solutions.

Next, lessons learned will be given.
This last section combines the barriers and opportunities from the previous sections into several main lessons learned. These lessons are summarized in Table 8.7 and will now be explained in more detail.

The first lesson is that, although all actors called Powerhouse Kjørbo a pilot project, commercial conditions have been applied on all levels. All involved actors have made a profit out of the project. Even though solar panels are principally not feasible in Norway under the current conditions, this project generates a considerable amount of renewable energy, while at the same time the building itself fulfills the passive house standard.

The second lesson is the importance of a common goal. All actors in the Powerhouse alliance committed with their organization to the project goals. If the project succeeds all actors will gain in reputation, while at the same time all actors have an equally shared risk of reputation damage. Of course, it is a question if other actors also see the importance of reputation benefits in the field of sustainable construction. Nevertheless, as the supplier exemplified, working in this way also was more fun.

As third lesson, this project shows process innovation. Passive house components and solar energy technology are both well-known and often applied. However, the combination of all technology leads to the fulfillment of the ambitious sustainability goals. Whenever innovative solutions are used, such as the displacement ventilation, this is tested before appliance.

Testing is also related to the importance of planning, which is the fourth lesson. In this project several tests were carried out, such as a mock-up and airtightness tests. This leads to more knowledge transfer and education of for example the carpenters. However, some tests could have been carried out earlier to reap more benefits. Furthermore, in the earliest phases a lack of planning was experienced.

Although the partners were working together in all phases of the project, still different persons are responsible for different phases of the project. The contractor for example highlighted there were still difficulties transferring the concept design thoughts to construction practice. The contractor can play a crucial role in this knowledge transfer. In Powerhouse Kjørbo the contractor was motivated to stick to the design because they were involved from the beginning on.

<table>
<thead>
<tr>
<th>#</th>
<th>Lesson learned from Kjørbo</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Project realized under commercial conditions</td>
</tr>
<tr>
<td>2</td>
<td>Importance of common goal (reputation gains)</td>
</tr>
<tr>
<td>3</td>
<td>Process innovation by combining known technology</td>
</tr>
<tr>
<td>4</td>
<td>Importance of knowledge transfer (planning/testing/evaluation)</td>
</tr>
<tr>
<td>5</td>
<td>Importance of contractor’s role.</td>
</tr>
</tbody>
</table>
PART 3
conclusions
CHAPTER 9
COMBINING THEORY AND PRACTICE
9.1 INTRODUCTION TO CHAPTER 9

In this chapter conclusions are derived by comparing barriers and opportunities from theory (Part 1) with the practical findings (Part 2). The position of this chapter in the total research structure is displayed in Figure 9.1. This first section provides a general overview of the five cases and describes the structure of the remaining chapter.

9.1.1 OVERVIEW OF THE FIVE CASES

Three detailed case studies and two pilot cases were researched in Part 2. The three detailed case studies show a development in time of sustainability goals. Lysaker Park, realized in 2009, was the first renovation project to achieve Norwegian energy label B, while FS4 obtained the passive house standard. Powerhouse Kjørbo takes the next step and offsets operational energy use and embodied energy with the generation of renewable energy. In all three projects the owner also acted as client.

The two pilot case studies are used as reference line. The Monarch provides evidence on a shift in investment direction. The investor was willing to invest if a BREEAM certificate was guaranteed, otherwise the project had not started. Nesøyveien 4-6 shows that Norwegian energy label B, or obtaining the low energy standard, is experienced as minimum standard a project nowadays should achieve to be in line with market requirements. It also shows that not every company is interested in highly ambitious sustainability goals for reputation gains in corporate social responsibility. The owner of Nesøyveien 4-6 focusses on other issues than sustainability in buildings.

9.1.2 STRUCTURE OF THIS CHAPTER

By comparing barriers and opportunities derived in Part 1 with practical experiences from the detailed cases in Part 2, it is possible to reach conclusions and find recommendations for the organization of the design process.

In the remainder of this chapter respectively sustainability as a design parameter, the refurbishment tasks, and the organization of the design process will be discussed. In each section theoretical and practical findings will be compared to reach a conclusion. The chapter ends by comparing the lessons learned from the detailed case studies.

The following discussion is based mainly on findings in the three detailed case studies. The pilot cases are used to further illustrate a finding, not to derive this finding in the first place.
In this section barriers and opportunities found in Chapter 2 are compared with the practical experiences of the detailed cases. First, design approaches and strategies will be discussed. Subsequently energy efficient design will be described. Then a paragraph is devoted to BREEAM. The section ends with a conclusion on barriers and opportunities using sustainability as a design parameter in practice.

## 9.1.3 Design Approaches and Strategies

The analysis on design approaches and strategies described in Section 2.2 led to three findings. In theory it was found that design approaches can confuse, that sustainability can facilitate many designs and finally that design strategies can be used as overall vision to guide the design process. These findings will now be compared with practical experiences in the three detailed cases.

Firstly, confusion about design approaches and sustainability is found in all case study projects. For example, the architect in Powerhouse Kjørbo mentioned that energy calculations are so complex that a cooperation with engineers is always needed. In practice extra competence was hired in the form of an energy, environment and/or BREEAM consultant. Nesøyveien 4-6 shows that the budget to hire external consultants might be limited. Perhaps the acceptance of costs in the design phase are related to the commitment to goals and anticipated work. In turn, this might relate to the commitment and competence of the client. In the end it is the client who has to invest in a solution.

Secondly, sustainability influenced the design of the three projects. The design teams used the sustainability requirements as inspiration rather than limitation. For example, the façade choice in FS4 is based on the weight and environmental performance of the material. In Powerhouse Kjørbo the focus on embodied energy in combination with strict zoning regulations led to choice of burned wood. These examples show that sustainability provided new design ideas.

The final opportunity mentioned in Section 2.2 is the use of design strategies as the Kyoto Pyramid or the New Stepped Strategy to form the overall vision of a project and guide the design. None of the researched projects mentioned the use of a design strategy to guide the design. Rather the goal, such as the Powerhouse goal or obtaining the passive house standard was mentioned as overall vision of the project.
9.1.4 DESIGNING FOR ENERGY EFFICIENCY

Energy efficiency as design parameter is described in Section 2.3. Barriers and opportunities are found for 'energy use' in general, the passive house concept, and net zero energy buildings. Practical experiences for these themes will now be discussed in detail.

Because cases with ambitious sustainability goals are researched, no evidence can be provided that the building code acts as norm rather than minimum. In all projects the energy goals were set well above the required minimum. Only the pilot case study Nesøyveien 4-6 referred explicitly to the building code as a high standard, and even this project aims to realize a low energy building. Perhaps the availability of ENOVA subsidies makes it easy to aim for higher standards. All projects have used an ENOVA subsidy which can cover 60% of the additional cost, which is around 2 to 5% of the total building costs (ENOVA, 2013).

Two of the projects obtained the Norwegian passive house standard and all projects including the pilot cases focused on energy efficiency. Many actors highlighted the availability of economically feasible solutions. The phrase 'it is no hocus pocus to build sustainably' was heard from several actors during the interviews. The opportunity that economic solutions are available can thus be supported. Often actors highlighted that building sustainable had more to do with process innovation than product innovation, which provides evidence for the need of integrated design processes.

Two other barriers found in theory are the need for extra design skills and more skills required at the construction site. This is seen in practice, although the projects did not experience it as a barrier. For example, the contractors state that it is within their competence to construct buildings with airtightness levels below 0.6 h⁻¹. Furthermore, more consultancy costs were made in all projects. As described under design approaches and strategies, this might relate to the commitment to goals and anticipated work as well as the commitment of the client to obtain these goals.

A larger barrier was experienced with perceived inflexibility of the passive house concept. Specifications from the tenant had to be changed to comply with the energy goals at Lysaker Park and FS4. Scepticism among tenants was taken away by presenting the tenant simulations on indoor comfort for and after renovation, showing that indoor comfort would actually improve instead of the experienced decrease. Time and resources had to be devoted to this process.

In general, tenants were unaware of their influence on energy use. A tenant influences employee density, internal heat loads, lighting levels, ventilation rates, and thermal set points, which
in turn determine actual energy use (Baker, 2009). However, this relation is not always known in practice. The tenant of FS4 told for example that ‘sustainability is mainly a competence of the developer of the building’. Limited awareness of tenants is also found by Miller & Buys (2008). At Powerhouse Kjørbo no problems were experienced because the tenant has consultancy competence in sustainable construction.

Only one project aimed to become ‘energy producing’. At Powerhouse Kjørbo the lack of a common definition was indeed experienced as a barrier. In practice a passive house was constructed with extra focus on embodied energy and renewable energy generation. All actors involved stated that a profit was made.

9.1.5 DESIGNING WITH BREEAM-NOR

This paragraph is devoted to the practical experiences with BREEAM. Nesøyveien 4-6 chose to not use BREEAM. Lysaker Park did not use BREEAM because a Norwegian version was at that time not yet available. In Section 2.4 BREEAM is analysed from a theoretical perspective. This resulted in three findings: BREEAM sets stringent documentation requirements, BREEAM is a rating system with holistic view on environmental performance and finally BREEAM is means to facilitate sustainable design decisions. These findings will now be compared with practice.

The two projects using BREEAM both mentioned the extensive documentation requirements. In FS4 BREEAM was brought into the project after the construction phase had started. At Powerhouse Kjørbo the main Powerhouse goal was seen as most important. BREEAM was thus used only to document and proof that a certain level of quality is achieved, which is one of the aims of BREEAM (NGBC, 2012). This supports the idea of the project manager at Nesøyveien 4-6 that BREEAM is not a design tool.

During the interviews almost all actors agreed that BREEAM provided an holistic view on environmental performance. Most actors referred to BREEAM as a smart and simple framework for goals that the building sector already knows, such as energy and material use. However, as noted in the previous paragraph, the holistic framework was not the main reason to use BREEAM. The pilot case project Nesøyveien 4-6 shows that not every actor sees the benefit of using an environmental assessment method. No assessment is undertaken since the owner will use the building themselves.

As mentioned by Schweber (2013), the use of BREEAM obscures value choices. In Chapter 2 several approaches are given to obtain sustainable construction. These approaches are wider than only BREEAM. During this research several themes are touched up on that can be included in sustainable
projects but are not directly addressed in BREEAM, such as an increased focus on waste and recycling, social sustainability and the possibility for future renovation projects.

9.1.6 CONCLUSIONS
To conclude, many theoretical barriers were found when assessing sustainability as design parameter. In practice these barriers are overcome by hiring competent people, both in the design and construction phase. The need and willingness to hire competent people is perhaps related to the goals and ambitious set in the earliest phases, as well as the commitment of the client to stick to those goals.

In practice many actors are aware of the availability of components to construct sustainably. Process innovation is required rather than product innovation, providing evidence for the need of integrated design processes. BREEAM is seen as smart system, but in practice more used to check the final design than to steer the project.

The next section will focus on the findings of Chapter 3. Barriers and opportunities from the refurbishment task will be compared with the practical findings.
9.3 REFURBISHING THE CURRENT OFFICE STOCK IN PRACTICE

This section compares barriers and opportunities found in Chapter 3 with practical experiences from the detailed cases. First the refurbishment potential will be discussed. Then the application of refurbishment strategies in practice will be described. The section ends with a conclusion on refurbishing post war offices in practice.

9.3.1 REFURBISHMENT POTENTIAL

First the refurbishment potential is discussed. The theoretical analysis in Section 3.2 led to two findings: firstly, a building assessment is often neglected. Secondly, renovation solutions can lead to cost savings. This barrier and opportunity will now be compared with the practical experience.

The notion that a building assessment is often neglected is partly confirmed by the projects. A renovation project starts because the building does not fulfil current functional and/or economical requirements. In practice, the tenant and owner had the desire to start with a blank paper. For example, at FS4 the requirement that the building would feel new dominated the decision making process. Only the pilot case study Monarch mentioned explicitly the use of a building assessment. It can thus be concluded that an extensive building assessment is not informing the design process. New wishes and requirements are more important than the existing buildings installations, façade and function. As in all three projects the façade and installations were replaced completely, the lack of an extensive building assessment was perhaps less noticed.

The related opportunity, smart renovation solutions lead to cost savings compared to new buildings, is confirmed in all projects, including the pilot case studies. Actors highlighted the reuse of the loadbearing structure as a major benefit of renovation, both in economical as in environmental terms. Another large cost savings is achieved when the foundations and basements are reused, because no excavation works have to be carried out.

9.3.2 REFURBISHMENT STRATEGY

Secondly, refurbishment strategies are discussed. In Section 3.4 the status of the existing architecture, the possibility to obtain an up to date façade and limited future renovation possibilities are described as barriers and opportunities. These findings will now be compared to the practical experiences.

The three projects had different architectural strategies.
A limitation of the status of existing architecture is not experienced, which can probably be traced back to the notion that no project had a monumental status. Most limited in architectural possibilities was Powerhouse Kjørbo who had to maintain the appearance of a black cube. In all projects the architects created a new feel for the building. The existing architecture formed an inspiration rather than a limitation.

The façade refurbishment strategy is determined both by costs and environmental performance. A façade replacement can be favoured, because the architectural appearance is subject to change anyway, and it makes it easy to upgrade towards a high energy standard. Lysaker Park showed that the extra embodied energy can be offset by the better energy performance. On the other hand, a minor façade upgrade can lead to lower investment costs and less material use. However, as Nesøyveien 4-6 showed, still interior insulation is added, as well as thermal bridge problems have to be solved. The extra embodied energy is merely offset by the energy use savings. Different alternatives thus exists. The best alternative can only be assessed on a project-by-project basis. Figure 9.3 provides an indication how such an assessment would look like.

None of the assessed projects has implemented strategies that take care of future renovation possibilities.

9.3.3 CONCLUSIONS

It can be concluded that although a building assessment can be helpful in determining the qualities of the buildings, in practice the focus is mainly on new requirements.

Renovation can lead to cost-savings compared to new construction, especially if the loadbearing structure is to be reused. The status of the existing architecture is not seen as a limitation but rather as inspiration. It should be assessed on a project-by-project basis if a façade upgrade or replacement is the best alternative both in environmental as economical terms.

Next the third research perspective, the organization of the design process, will be discussed.

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<table>
<thead>
<tr>
<th>Figure 9.3 Renovation and/or demolishing alternatives have different environmental impact in time when considering the initial embodied energy and operational energy use holistic. The most economical and environmental friendly alternative should be assessed on a project-by-project basis. This figure indicates how such an assessment could look like (based on Baker, 2009)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embodied energy</td>
</tr>
<tr>
<td>Time</td>
</tr>
<tr>
<td>1. demolish + new built (low energy standard)</td>
</tr>
<tr>
<td>2. renovation to low energy standard (i.e. by facade upgrade)</td>
</tr>
<tr>
<td>3. demolish + new built (passive house standard)</td>
</tr>
<tr>
<td>4. renovation to passive house standard (i.e. by facade replacement)</td>
</tr>
</tbody>
</table>

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| | PART 3 | Conclusions |

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9.4 ORGANIZATION OF THE DESIGN PROCESS IN PRACTICE

In this section findings from Chapter 4 will be compared with practical experience. First general findings about the integrated design process (IDP) will be discussed. Then, three paragraphs will be devoted to the three prerequisites of IDP: early actor involvement, goal setting and quality assurance, and knowledge transfer and evaluation. Subsequently a short discussion on contract forms is given. The chapter ends with a conclusion.

9.4.1 INTEGRATED DESIGN IN PRACTICE

In this first paragraph general findings are described. In theory it is found that sustainability requires integrated architecture because contradictory parameters have to be optimised (see Chapter 2). The management of this process is called integrated design. All three projects provided evidence for this notion.

Powerhouse Kjørbo started with an ambitious goal and reasoned how the design process should be organized. The project team was unaware of existing integrated design guidelines (e.g. Löhnert et al., 2003; Jørgensen, 2010) and thus reinvented this process. At Lysaker Park the environmental consultant had a central position in the organization to steer with regard to cost, time and environment. However, a change of architects without changing the delivery deadline led to a short concept design period. At FS4 the integration principles were mainly applied by the energy consultant.

In practice all three projects thus took an holistic perspective. Most actors agreed that an integrated design process is required to obtain integrated architecture, although in differences in the exact application occurred. These differences will now be discussed based on the three prerequisites of IDP: early actor involvement, goal setting and quality assurance, and knowledge transfer and evaluation. The findings can be used to improve the IDP theory.

9.4.2 EARLY ACTOR INVOLVEMENT

The first prerequisite of IDP is early actor involvement. The IDP models state that integrated design requires a shift of time and budget in comparison to the traditional process. More work is done in the early program and concept phases.

The amount of actors involved in the first phases differed slightly per project. At Powerhouse Kjørbo and Lysaker Park all actors were involved from the beginning on, although Lysaker Park did not had much time to redo the concept design.
Moreover, the large amount of design-bid-build contracts at Lysaker Park caused a division between contractors and designers. At FS4 and pilot case study Nesoyveien 4-6 the design process was more traditional. The design was made first, after which the contractor was found.

At Lysaker Park many actors mentioned the short design time as a barrier. For example the interviewed contractor thought that a slightly longer design time would have paid back both in costs as in construction time saved because of better planning. This supports the notion in IDP that the concept time is the most important phase and should not be too short. On the other hand, the project outcome shows that even under this strict conditions the goals can still be achieved within budget and time, which is probably due to the commitment of the client. In the end the client has to pay for the solution, and has to decide about the required quality and available time and budget.

In general the role of the contractor is underexposed, both in existing IDP models as in the practical application. Only in Powerhouse Kjørbo the contractor was involved in the concept design, while in the other project the contractor was involved from the detailed design or construction phase. The inclusion of the contractor in the earliest phases can lead to increased knowledge about construction methods, and increased commitment from the contractor to stick to the design in later phases. Disadvantages can be inside the box thinking and budget cuts (Hagen & Jørgensen, 2012). These disadvantages were not experienced at Powerhouse Kjørbo, which provides evidence that the disadvantages can be solved.

9.4.3 GOAL SETTING & QUALITY ASSURANCE

The second prerequisite of IDP is clear goal setting and quality assurance. In theory it is described that ambitious goals should be set by committed actors.

The importance of clear goals set by committed and competent actors is found in practice. For example, both Lysaker Park and Powerhouse Kjørbo had goals set on a project level which where also anchored in the organizations participating in the project. This implies that both project commitment as well as organizational commitment is necessary when goals are discussed.

Most actors highlighted the importance of the goal in the project. However, goal setting is not free of disadvantages. Goal setting can for example lead to a narrow focus, distorted risk taking behaviour, and reduced intrinsic motivation (Ordóñez et al., 2009). It can also lead to strategic behaviour when actors try to maximise their own interest (Bruijn & Heuvelhoef, 2008). For example a contractor who is involved from the beginning on and knows what type of goals are to
Clear goal setting to guide the design is a prerequisite of IDP. It is proposed to set clear goals, with upper and lower limits. Besides one should be aware of the limitations of goal setting.

However, these disadvantages can be solved when goals are applied knowledgeable (Ordóñez et al., 2009) and good process and project management is applied. The practical findings show the importance of goal setting, the disadvantages were not experienced. IDP theory can be improved by recalling the boundary limits of goal setting in theory.

Clear goals should thus be used to guide the design. It is a way to involve actors and keep them committed throughout the project, especially if project and organizational commitment is guaranteed. It is proposed to use goals with a range, as visualized in Figure 9.4. This provides the opportunity to generate more alternative designs, and shows that a design team can be satisfied with a result even if the goal is not absolutely fulfilled. Of course goals should be set on a project-by-project basis. Furthermore, one should always be aware of the parts of a design that are not enclosed in the goals.

9.4.4 KNOWLEDGE TRANSFER & EVALUATION

The final prerequisite is knowledge transfer and evaluation. In practice both parts of this prerequisite are undervalued and difficult to achieve.

First, an example of knowledge transfer and evaluation from the design to construction phase is found at Powerhouse Kjørbo. Airtightness tests and a mock up were used to educate the carpenters. This has proven to be valuable, because mistakes are only made once in a test phase. However, it was unclear who had the responsibility to pay for the mock up. Furthermore, if the mock up was build earlier in the design phase more lessons could have been learned.

Only Lysaker Park is completed and can thus be used as example in the knowledge transfer and evaluation from the construction to operation phase. In the first years energy use was much higher than expected. Three years later energy use is almost in line with the theoretical budget. However, the client has still problems measuring under posts of the energy budget. It is difficult to measure energy use in detail, and a good plan has to be made during the design.

9.4.5 CONTRACT FORM

Finally a short discussion is given on the form of contract. In theory integrated contracts provide opportunities for knowledge transfer and a more important role of the contractor. In practice the contractor is only involved from the detailed design.

Findings earlier in this chapter indicate that the role of the contractor should be extended to the earliest concept design.
phases. Furthermore, the importance of evaluation shows that backward integration can also be of importance. The contractor and other design team members should highlight the importance of follow-up in the design phases, and stick to this plan.

Every contract form has advantages and disadvantages. In the researched projects different types of contracts are used, as is shown in Table 9.1. It seems that the contract form is independent of sustainability, which is in line with advise from the American Institute of Architects (AIA) that integration can be achieved within all contract forms (AIA, 2007). However, AIA (2007) also notes that the contract form is determined by the competence, risk willingness and required level of commitment of the actors involved. In the previous paragraphs it is discussed that these are important parameters of an integrated design process, which thus also should influence the contract form. More research may be needed.

### 9.4.6 CONCLUSIONS

To conclude, it is argued that integrated architecture requires integrated design processes, although differences in practical application occur.

In general the role of the contractor is underexposed in IDP models. A committed and competent client is helpful in achieving goals within budget. Subsequently, the importance of goal setting is shown, although also goal setting has its boundaries. Knowledge transfer and evaluation in practice is undervalued and difficult to achieve.

The role of sustainability and the choice of contract form is shortly discussed. All sorts of contract forms are used in the researched projects, and no clear answer can be given to the importance of the contract on the achieved result. More research may be necessary.

The final section of this chapter will draw conclusions by summarizing and comparing the lessons learned of the different projects.

<table>
<thead>
<tr>
<th>Table 9.1</th>
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<tbody>
<tr>
<td>Contract forms of the different projects</td>
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<tr>
<td><strong>Project</strong></td>
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<tr>
<td>Lysaker Park</td>
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<td>FS4</td>
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<tr>
<td>Powerhouse Kjørbo</td>
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<td>Nesøyveien 4-6</td>
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9.5 LESSONS LEARNED FROM PRACTICE

This final section compares the lessons learned from the three detailed cases and the two pilot cases to derive conclusions and recommendations. First general findings are discussed. Second, the lessons learned are combined into common lessons learned.

9.5.1 GENERAL FINDINGS

Three general findings can be observed from the projects. First, sustainability goals are developing over time. Second, in all projects the client was committed, competent, and the owner of the building. Third, most actors involved in the three detailed case studies mentioned the reputation gain as main reason to get involved in the project.

First, as described in Section 9.1 - Introduction to Chapter 9, it becomes apparent that sustainability goals have developed over time. The oldest project, Lysaker Park, aimed for Norwegian energy label B, while subsequent projects aimed for a passive house renovation and ‘energy producing’. The pilot case studies confirm this finding. Nesøyveien 4-6 has set goal towards the low energy standard, because it is experienced as the minimum level a building should achieve. The Monarch provided evidence for a shift in investment direction by investors.

The second finding is that the three detailed case studies were driven by a committed and competent client, who was also the future owner of the building. The ownership of the building may provide an incentive to accept higher construction costs when better quality and/or lower life cycle costs are obtained. In the organization of the design process the competence of the client may lead to trust instead of stress, even when goals are raised as was for example the case at the FS4 project.

The final finding is the observation that most actors mentioned the reputation gain in corporate social responsibility (CSR) as main reason to get involved in the project. This is in line with Dutch research (Volker, 2011), but contradicts the main thought of sustainability consultants that a comfort and resulting productivity improvement is the main reason to start a sustainable renovation project (e.g. Baker, 2009). Furthermore, the pilot case study Nesøyveien 4-6 provides evidence that the reputation gain in CSR from the building’s improvement is not always a prioritized goal. This implies that if more sustainable construction and integrated design processes are to be promoted either the reputation gain should be acknowledged by building owners that do not have
construction as their core business, or the other benefits should be made more apparent (as exemplified by Nesøyveien 4-6). Other benefits could be improved indoor comfort and productivity, lower operating costs, higher asset value, and risk mitigation as described in Chapter 1.

The three detailed case studies all applied integrated design in their process, although differences were visible in the exact approach. The lessons learned will be combined in the next paragraph to derive common lessons learned.

9.5.2 COMMON LESSONS LEARNED

Three lessons can be learned when all lessons are combined: First, it is possible to steer a project on environment, time and budget. Second, the importance of goal setting by a committed client is acknowledged. Finally, improvements for the integrated design process can be found.

All three projects showed that it is possible to steer a project on environmental goals, budget and time at the same time. Integrated design is applied in all projects. Solutions in the projects could cost more when the quality is raised, or the costs should go down. The solutions are thus experienced as cost-effective. All projects were realized on time and within budget according to the involved actors. Furthermore, all actors made a profit out of the projects.

The importance of goals is found in two cases, while the third case led to the conclusion that a committed and competent client is important. Furthermore the importance of early actor involvement and enough time in the concept design is recognized.

Finally, the lessons learned shows improvement areas for the integrated design guidelines. First, the role of the tenant and the contractor can be enlarged. At this moment tenants are often following the design team, while their specifications, such as required computers and office concept have a large influence on the outcome of a project. Tenants can take a more active role and should be involved in design discussions. Also the contractor can be involved earlier than the detailed design. The contractor can add valuable knowledge about construction methods. Furthermore it commits the contractor to hold on to design thoughts.

Secondly, the case studies provide evidence for the importance of knowledge transfer between subsequent phases and the importance of evaluation, and planning for evaluation. For example, a good measurement and verification plan for monitoring real energy use should be made.

To conclude, this chapter analysed the differences between practice and theory. Based on this discussion the research questions are answered in the next section.
CHAPTER 10
CONCLUSIONS AND RECOMMENDATIONS
In the first section of this chapter the sub research questions are answered based on the discussion in Chapter 9. Subsequently, the main research question is answered in the next section. The last section is devoted to recommendations for further research.

1. Sustainability as design parameter: what are barriers and opportunities with respect to economic available sustainable solutions?
The projects confirmed the availability of economically feasible components for sustainable buildings. An integrated design process is seen as a prerequisite to obtain cost-effective solutions. The main barrier was the need for competence in the design process. Contradictory parameters, such as daylight and energy use, have to be optimised. In practice competence is hired in the form of an energy, environmental and/or BREEAM consultant. The extra consultancy costs are seen as a necessity by committed and competent clients. Focussing on sustainability can provide a competitive advantage as legislation is getting more stringent and the market share of BREEAM is rising.

2. Refurbishment task: what are barriers and opportunities when refurbishing post war offices?
Renovation can lead to savings both in environmental as well as in economical terms. Especially reuse of the load bearing structure and the foundations is mentioned as a large cost saver. The status of the architecture before renovation was not seen as a limitation. However, the researched projects did not have a monumental status. A major barrier is the lack of a good building assessment. Often the new requirements are more important than a thorough analysis on existing qualities in the façade, structure, function and installations.

3. Management of the design process: what are barriers and opportunities in the design process itself?
The case study projects show that integrated architecture indeed requires integrated design processes (IDP). The three detailed projects all applied a form of an integrated design process. The need for a committed client and the three prerequisites of IDP: early actor involvement, goal setting and quality assurance, and knowledge transfer and evaluation are confirmed. Differences in practical application showed improvement areas, such as the role of specific actors, and the difficulty to achieve knowledge transfer and evaluation.

The combination of answers of the sub research questions allows answering of the main research question, which is done in the next section.
10.2 HOW SHOULD THE DESIGN PROCESS BE ORGANIZED?

With the answers of the sub research question, the main research question can be answered. Furthermore, it is possible to provide an idea why not every project is sustainable.

Main research question: “How can a design process be organized to overcome barriers to involve sustainable solutions in an office refurbishment projects?”

The cases show that an integrated design process is a prerequisite to apply sustainability. Components are available. For example, the phrase ‘it was no hocus pocus to design this building’ was heard several times during this research.

Guidelines for integrated design process exist (e.g. Löhnert et al., 2003, Jørgensen, 2010). An integrated process is focussed on three prerequisites: early actor involvement, goal setting and quality assurance, and knowledge transfer and evaluation. The outcome of the research suggests that improvements can be made especially in the role of the contractor and tenant, as well as in the evaluation and knowledge transfer. This is shown in Figure 10.1 and Figure 10.2. Besides sustainability aspects, integrated design processes can also be used to obtain other qualities, such as lower costs, lower risks, and other functional requirements.

Analysing refurbishment aspects leads to the conclusion that design teams often focus more on new requirements, instead of starting with an extensive analysis of the existing building. In principal there is no difference between organizing a new-built project compared to a renovation project, rather than technical limiting factors and design inspiration that can be taken from the existing building.

So, why is not every project sustainable?

The research projects have crossed the gap as is displayed in Figure 10.3. Many actors recalled that sustainable construction is becoming more mainstream. Committed clients are able to overcome the barriers presented earlier in Chapter 1.

However, implications are found by looking at the experienced benefits (also presented in Chapter 1). A reputation gain in corporate social responsibility (CSR) is the most important reason to get involved in the project. Other benefits, such as improved indoor comfort and lower energy use are experienced more as a bonus than as a driving force at the project start up. This has implications for the adoption of sustainability as not all actors are interested in CSR of buildings. These actors are less likely to adopt sustainable goals in their projects.
10.3 RECOMMENDATIONS FOR FURTHER WORK

Limitations in scope lead to a list of recommendations for further research. The list is split up in two themes: new research themes and methodology related themes.

New research themes
During the interviews and the subsequent case study analysis it became apparent that many more sustainability topics are available than ‘energy use’ and ‘BREEAM-NOR’-solutions, which were the initial focus of this research.

For example, waste recycling is mentioned by several interviewees as important research areas. The project manager of FS4 highlighted that, although it is common to sort over 90% of the waste at the building site, often the destination of the waste is unknown. Furthermore, the quality of the waste is not taken into account. The percentage is based on weight, so if a lot of concrete is sorted and reused as road foundation, a high percentage is achieved.

Other research themes can be devoted to design for disassembly, which is currently not taken into account. An example of a circular economy concept where the contractor stays responsible for the building materials over the complete life cycle is the Dutch Turntoo initiative (Turntoo, 2013).

Furthermore, the debate of façade replacement (with lower operational energy use) versus façade upgrade (with lower embodied energy) can be explored in more detail, as well as the difference between operational energy use and the theoretical budget.

Methodology related research themes
Three methodology related research themes can be distinguished. First, this research takes integrated design theory as a starting point. IDP is developed by engineers and architects working in the construction industry. Future research can be devoted to the combination of IDP with existing project and process management literature to justify and extend IDP.

Second, more social and anthropological research can be performed on the role of IDP in practice. Perhaps this research showed only best practice, as highly ambitious projects were researched. It would be interesting to redo the case studies with less ambitious projects.

Finally, research should be conducted on the role of the contractor and tenant, and the role of contract forms.
References
REFERENCES

In this section all references are given. The references are ordered per chapter. If a reference is used in two or more chapters, it is placed under both chapters. The amount of references per chapter is in line with the basic assumptions of this work: a lot is known about sustainability (Chapter 1 and 2) but a lot less is known about the application in refurbishment projects (Chapter 3) and how to organize the design process (Chapter 4). The first four chapters refer mainly to journal articles and scientific reports. The case study chapters refer to journal articles, project reports, internet pages and powerpoint presentations.

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Volk, L. (2011). Success and fail factors in sustainable real estate renovation projects. In conference proceedings of Management and Innovation for a Sustainable Built Environment, Amsterdam, Netherlands, 20 - 23 June 2011,

CHAPTER 10 - CONCLUSIONS

In this section the list of figures is given. Four types of figures are distinguished:

- “based on” means the figure is based on information from the referred source, while the figure is original.
- “after” means the figure comes directly from the referred source; the figure is only graphically changed.
- only the name of a reference means that the figure (or photo) is taken directly from the referred source.
- no reference means the figure is made by the author.

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This first appendix provides a more thorough explanation of commonly used terms in the report. Traditionally a glossary is ordered alphabetically. However, in this thesis it is chosen to order terms per theme, following the same order of appearance in the main report.

This Appendix A.1 provides general terms. Subsequently Appendix A.2 describes design strategies. In Appendix A.3 energy terms are discussed. Appendix A.4 provides a short explanation on BREEAM, while Appendix A.5 ends with design process terms.

**GENERAL TERMS**

**Sustainable building**  
Building with focus on sustainability parameters. In this thesis defined as focus on energy use and/or broader implications as defined in BREEAM. Can also be called green building or energy-efficient building.

**Conventional building**  
Building constructed according to the minimum requirements set in the building code applicable at time of construction.
APPENDIX A.2 DESIGN STRATEGIES

In this section the three design strategies given in Section 2.2 are described in more detail: Trias Energetica, Kyoto Pyramid and New Stepped Strategy.

Trias Energetica

Lysen (1996) proposed an integral design strategy to implement solar- and renewable energy in buildings by focusing on energy-efficiency, renewable energy and the clean use of fossil fuels, known as the Trias Energetica. The strategy is wide-spread applied in the Netherlands. The strategy is shown below and consists of three steps:

1. Reduce the energy demand, for example by applying energy reducing measures as insulation, air tightness and heat recovery
2. Increase use of sustainable resources, for example wind, solar and biomass
3. Use fossil fuels in the cleanest possible way, for example by using highly-efficient boilers.


Kyoto Pyramid

This strategy is invented by Dokka & Rødsjø (2005). The method is an extension of the Trias Energetica and especially useful in analysing and designing energy-efficient buildings. The method is wide-spread applied in Norway and consists of five steps:

1. Reduce heat loss by building compact and area-effective, for example using superinsulation, good airtightness and ventilation with heat-recovery. Focus should be on short ventilation ducts and low pressure to prevent high energy use from fans and pumps as well as noise problems.
2. Reduce electricity demand with energy-efficient appliances
3. Optimise free solar heat by window orientation, solar thermal and PV panels
4. Show energy consumption and where possible use automatic control devices
5. Chose an energy system that covers the remaining energy demand, for example district heating or biofuel.

New Stepped Strategy

The New Stepped Strategy is developed by Dobbelsteen (2008). It is based on the Trias Energetica and inspired on the cradle-to-cradle philosophy. The New Stepped Strategy includes the following four steps:

1. Reduce demand by using passive design and employing smart and bioclimatic design. Use local characteristics intelligently into the design of the building.
2. Reuse and recycle internally, so even less input is needed.
3. A. Supply resulting demand sustainably, B. Let waste be food

This section provides a list of energy terms used throughout the report. Most terms are used for the first time in Section 2.3 - Energy efficiency as a design parameter. First three types of energy in buildings are given. Then, operational energy definitions are described. Subsequently the types and definitions are translated into practical applicable concepts such as the passive house concept.

**TYPES OF ENERGY IN BUILDINGS**

**Embodied energy**  
Energy used to produce building materials. This energy is thus ‘stored’ or ‘embodied’ in the material. Traditionally embodied energy accounts for around 20% of the buildings energetic footprint. This can raise to 50% of the footprint at low energy buildings, mainly because operational energy is lower (and thus the embodied energy becomes relatively more important). Besides, more material as insulation is used.


**Operational energy**  
Energy used to operate the building. Can be measured as net energy demand, delivered energy or primary energy and is dependent on the overall heat losses (see next page). In a heat balance of a building several aspects can be taken into account such as heating, ventilation, fans & pumps, lighting, user equipment.

**Construction energy**  
Energy used to transport building materials to the construction site and erect or renovate the buildings. This energy flow is sometimes included in the embodied energy calculation. Research has shown that construction energy accounts for 1% or less of the total energetic footprint of the building (Sartori & Hestnes, 2007).

*Further reading:*  

<table>
<thead>
<tr>
<th>EMBODIED ENERGY</th>
<th>CONSTRUCTION ENERGY</th>
<th>OPERATIONAL ENERGY</th>
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<tbody>
<tr>
<td>(20-50%)</td>
<td>(≈1%)</td>
<td>(50-80%)</td>
</tr>
<tr>
<td>- Energy used to produce building materials</td>
<td>- Transport of materials</td>
<td>Energy used for operation (often accounted yearly):</td>
</tr>
<tr>
<td>- Initial at first construction</td>
<td>- Construction equipment</td>
<td>- Heating</td>
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<tr>
<td>- Recurring at maintenance and renovation phases</td>
<td>(sometimes included in embodied energy calculation)</td>
<td>- Cooling</td>
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<td>- Ventilation</td>
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<td>- Lighting</td>
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<td></td>
<td></td>
<td>- User equipment</td>
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**OPERATIONAL ENERGY DEFINITIONS**

**Primary energy**
Amount of energy embodied in the non-renewable natural resources necessary to create a certain amount of delivered energy. For example, oil, coal, natural gas or other energy sources that have not yet undergone a transformation or conversion into another energy type as electricity. The amount of primary energy has a direct relationship with carbon emissions. Measured in kilowatt hour, megajoules or CO₂-equivalents. Number 1 in the figure below.

**Delivered energy**
Energy entering the building envelope in order to be converted into useful energy (net energy demand), thus the amount of energy delivered to the building. This is the amount of energy to be found at the energy bill. Measured in kilowatt hour or megajoules. Also called final energy. Number 2 in the figure below.

**Net energy demand**
Energy used to accomplish a certain service or benefit, for example the energy used to heat a room to a certain temperature. Measured in kilowatt hour or megajoules. Also called useful energy or effective energy. Number 3 in the figure below.

**Overall heat losses**
The heat losses of the building from ventilation, infiltration and transmission. Measured in kilowatt hours or megajoules. Number 4 in the figure below.

**Energy calculation**
In the Norwegian Standard NS3031 (NS3031, Norsk Standard, 2011) the same four definitions as described above are used. The net energy budget [3] is calculated including both building-related energy demands (e.g. heating demand), and user-related energy demands (e.g. lighting). Differences between practice and theory can occur, mainly because user-related energy demands, such as lighting and equipment, are calculated with fixed values and can thus differ in practice. The Norwegian Standard defines also primary energy emission factors. These factors are relatively low compared to other European countries, because electricity is generated with water power.


---

![Diagram of energy components](image-url)
The current Norwegian building code. Chapter 14 describes the energy requirements based on the net energy demand (number 3, see previous page). The calculation is performed according to the rules set in NS3031, and thus include building-related energy demand and user-related energy demand, although some parameters are fixed (see also the previous page). Furthermore, requirements are set on the energy supply. It is announced that the requirements will become more stringent in 2015. The current voluntary passive house standard (see next page) will become the new required minimum level.

Further reading: TEK10 (2010). FOR 2010-03-26 nr 489: Forskrift om tekniske krav til bygverk (Bygge teknisk forskrift) – Kapittel 14: Energi [FOR 2010-03-26 nr. 489: Regulations on technical requirements for building works (technical regulations) – Chapter 14: Energy] (in Norwegian)

Measures method
Building components should fulfil certain requirements (see table below). Requirements with regard to the transmission losses can be interchanged, as long as the total heat loss factor (W/m²K) does not change. For example an outer wall U-value of 0,20 W/m²K can be compensated with better roof insulation.

Budget method
With the energy budget no requirements are set on building components. Instead the total building should use less than 150 kWh/m²a in terms of net energy demand.

Minimum req.
Although freedom is provided to exchange building components in both the measures and the budget method, minimum requirements are set to prevent use of building components below a certain quality. The minimum requirements are among the most stringent in Europe (Schild et al., 2010).


Energy supply
At least 60% of the energy supply should be covered by non-electrical or non-fossil fuels for buildings over 1000 m² (40% for smaller buildings). Allowed sources are: solar thermal systems, district heating systems, biofuel boilers, heat pumps, pellet fire places, wood ovens and biogas

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Energy measures method</th>
<th>Energy budget method</th>
<th>Minimum requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net energy budget (3) [kWh/m²a]</td>
<td>-</td>
<td>&lt; 150</td>
<td>-</td>
</tr>
</tbody>
</table>

Transmission components

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Energy measures method</th>
<th>Energy budget method</th>
<th>Minimum requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Window area [%]</td>
<td>&lt; 20 %</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>U-value outer wall [W/m²K]</td>
<td>&lt; 0,18</td>
<td>-</td>
<td>&lt; 0,22</td>
</tr>
<tr>
<td>U-value roof [W/m²K]</td>
<td>&lt; 0,13</td>
<td>-</td>
<td>&lt; 0,18</td>
</tr>
<tr>
<td>U-value floor [W/m²K]</td>
<td>&lt; 0,15</td>
<td>-</td>
<td>&lt; 0,18</td>
</tr>
<tr>
<td>U-value window (including frame) [W/m²K]</td>
<td>&lt; 1,2</td>
<td>-</td>
<td>&lt; 1,6</td>
</tr>
<tr>
<td>Normalized thermal bridge value [W/m²K]</td>
<td>&lt; 0,06</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Infiltration and ventilation components

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Energy measures method</th>
<th>Energy budget method</th>
<th>Minimum requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air leakage (at 50 Pa) [h⁻¹]</td>
<td>&lt; 1,5</td>
<td>-</td>
<td>&lt; 3,0</td>
</tr>
<tr>
<td>Heat recovery [%]</td>
<td>&gt; 80%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SFP (kW/(m³/s))</td>
<td>&lt; 2,0</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
NORWEGIAN ENERGY LABEL

Energy label

Energy label to provide information about the delivered energy to the building and the amount of non-renewable energy used for heating. Between 2010 and May 2013 around 15,000 offices obtained an energy label. The distribution of marks and colours is presented in the figure below.


<table>
<thead>
<tr>
<th>Energy mark</th>
<th>Heating character (colour)</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.0 %</td>
<td>1%</td>
</tr>
<tr>
<td>B</td>
<td>2.1 %</td>
<td>7%</td>
</tr>
<tr>
<td>C</td>
<td>13.0 %</td>
<td>22%</td>
</tr>
<tr>
<td>D</td>
<td>19.4 %</td>
<td>29%</td>
</tr>
<tr>
<td>E</td>
<td>12.0 %</td>
<td>18%</td>
</tr>
<tr>
<td>F</td>
<td>13.6 %</td>
<td>18%</td>
</tr>
<tr>
<td>G</td>
<td>4.0 %</td>
<td>5%</td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td>100%</td>
</tr>
</tbody>
</table>

Further reading: Energimerking.no > Statistics May 2013

Energy mark

A label between A (best) and F (worst) is given after calculating the amount of delivered energy to the building (number 2 previous page) according to the calculation rules defined in NS3031. Below the range of energy marks is presented.

<table>
<thead>
<tr>
<th>Mark</th>
<th>Delivered energy</th>
<th>Comparable use</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>&lt; 85</td>
<td>Passive house standard (NS3071)</td>
</tr>
<tr>
<td>B</td>
<td>&lt; 115</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>&lt; 145</td>
<td>Building code 2010 (TEK10)</td>
</tr>
<tr>
<td>D</td>
<td>&lt; 180</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>&lt; 220</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>&lt; 275</td>
<td>Building code 1969</td>
</tr>
<tr>
<td>G</td>
<td>&gt; 275</td>
<td>&gt; F</td>
</tr>
</tbody>
</table>

Energy colour

The colour at the energy label provides an indication of the amount of non-renewables used for heating, ranging from green (best) to red (worst). The scale and typical installations are presented in the table below.

<table>
<thead>
<tr>
<th>Colour</th>
<th>Non-renew.</th>
<th>Typical installations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dark green</td>
<td>&lt; 30 %</td>
<td>- Water based heating system fuelled with bio fuel and electricity</td>
</tr>
<tr>
<td>Green</td>
<td>&lt; 47,5 %</td>
<td>- District heating</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Water based heating system fuelled with a heat pump, thermal solar and electricity</td>
</tr>
<tr>
<td>Yellow</td>
<td>&lt; 65 %</td>
<td>- Water based heating system fuelled with a heat pump and electricity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Water based heating system fuelled with wood pellets and electricity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Air-to-air heat pump and a closed wood stove, combined with electrical heating</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Thermal solar with an air-to-water heat pump, combined with electrical heating</td>
</tr>
<tr>
<td>Orange</td>
<td>&lt; 82,5 %</td>
<td>- Electrical heating and a closed wood stove</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Thermal solar combined with electrical heating</td>
</tr>
<tr>
<td>Red</td>
<td>&lt; 100 %</td>
<td>- Air-to-air heat pump combined with electrical heating</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Electrical heating</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Water based heating system fuelled with oil and electricity</td>
</tr>
</tbody>
</table>
ENERGY EFFICIENT CONSTRUCTION CONCEPT

Passive house

Low energy concept originally developed in Germany and defined as buildings that have a comfortable indoor climate in summer and winter, without the need for a conventional heating system. The net heating demand should be below 15 kWh/m²a and primary energy demand below 120 kWh/m²a. In Norway the concept is translated into a voluntary passive house standard which complies with other legislation. A slightly higher heating demand is accepted, based on the notion that the climate is colder. No strict requirement is set for the primary energy demand. The same set of solutions are required, as can be seen in the comparison table below.


Net zero energy house

No standard definition exists. Often defined as a building that generates more renewable energy than it uses over a defined period of time (usually a year). A grid connection is used to balance over- and underproduction. It depends on the project team if embodied energy, operational energy and construction energy are all taken into account. For operational energy it should also be defined if building-related energy use and user-related energy use both are included.


<table>
<thead>
<tr>
<th>Building components</th>
<th>TEK10</th>
<th>Low-energy (NS3071)</th>
<th>Passive (NS3071)</th>
<th>EU-Passive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy requirements</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) Primary energy demand [kWh/m²a]</td>
<td>-</td>
<td>-</td>
<td>&lt; 120</td>
<td></td>
</tr>
<tr>
<td>(2) Delivered energy [kWh/m²a]</td>
<td>(energy labelling scheme)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3) Net energy demand [kWh/m²a]</td>
<td>&lt; 150</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Net heating demand [kWh/m²a]</td>
<td>-</td>
<td>&lt; 35</td>
<td>&lt; 20</td>
<td>&lt; 15</td>
</tr>
<tr>
<td>Net cooling demand [kWh/m²a]</td>
<td>-</td>
<td>&lt; 14</td>
<td>&lt; 9</td>
<td>&lt; 15</td>
</tr>
<tr>
<td>U-value wall [W/m²K]</td>
<td>&lt; 0.22</td>
<td>(0.15 – 0.16)</td>
<td>(0.10 – 0.12)</td>
<td>(0.15)</td>
</tr>
<tr>
<td>U-value roof [W/m²K]</td>
<td>&lt; 0.22</td>
<td>(0.10 – 0.12)</td>
<td>(0.08 – 0.09)</td>
<td>(0.15)</td>
</tr>
<tr>
<td>U-value floor [W/m²K]</td>
<td>&lt; 0.18</td>
<td>(0.10 – 0.12)</td>
<td>(0.08)</td>
<td>(0.15)</td>
</tr>
<tr>
<td>U-value window [W/m²K]</td>
<td>&lt; 1.6</td>
<td>&lt; 1.2</td>
<td>&lt; 0.8</td>
<td>(0.8)</td>
</tr>
<tr>
<td>Normalized thermal bridge value [W/m²K]</td>
<td>(&lt; 0.06)</td>
<td>&lt; 0.05</td>
<td>&lt; 0.03</td>
<td>-</td>
</tr>
<tr>
<td>SFP-faktor [kW/(m²/s)]</td>
<td>(&lt;2,0)</td>
<td>&lt;2,0</td>
<td>&lt;1,5</td>
<td>(&lt;1,6)</td>
</tr>
<tr>
<td>Airtightness n₅₀ [h⁻¹]</td>
<td>&lt;3</td>
<td>&lt;1,5</td>
<td>&lt;0,6</td>
<td>&lt;0,6</td>
</tr>
<tr>
<td>Heat recovery [-]</td>
<td>(&gt; 80)</td>
<td>&gt; 70 %</td>
<td>&gt; 80 %</td>
<td>(&gt; 75 %)</td>
</tr>
<tr>
<td>Persons [W/m²]</td>
<td>4,0</td>
<td>4,0</td>
<td>4,0</td>
<td></td>
</tr>
<tr>
<td>Equipment [W/m²]</td>
<td>11,0</td>
<td>6,0</td>
<td>6,0</td>
<td>3,5(4)</td>
</tr>
<tr>
<td>Lighting [W/m²]</td>
<td>8,0</td>
<td>4,0</td>
<td>4,0</td>
<td></td>
</tr>
</tbody>
</table>

(1) = This value holds for Oslo-climate and a floor area >1000 m2. For smaller buildings and/or colder climates the allowed heating demand is slightly higher according to a specific formula. The value also changes for other categories than office buildings.

(2) = When the value is given in brackets it is a guideline, not a strict requirement.

(3) = In NS3701 it is assumed that the internal heat gains are similar to the energy demand. For example a computer uses energy and emits heat (and thus contributes to the heating and cooling balance. In NS3071 these values are the same.

(4) = Passive house planning package (PHPP) calculates with a normalized value for the internal heat gains, while the Norwegian calculation method uses unnormalized internal heat gains in the next s. In practice, this means that the value in PHPP with 3,5 W/m² in 24 hours is comparable with the 14 W/m² (=6+4+4) during 8 hours operation as specified in the Norwegian passive house standard.
BREEAM

The Building Research Establishment Environmental Assessment Method is a checklist method to rate and certify the environmental performance of a building. Five different levels can be achieved: pass, good, very good, excellent and outstanding, dependent on the amount of credits achieved. How to obtain credits is written down in a freely available ‘BREEAM manual’ (NGBC, 2012). Country specific BREEAM schemes exist, although the main focus is the same throughout the world. In this thesis reference is made to BREEAM as the Norwegian adaptation. Boonstra (2013) provides an introduction for first time BREEAM users.


Checklist approach

BREEAM uses a checklist format to rate the sustainability of a building. Every positive feature thus adds points to the total score of the building. No negative points are given if a building performance under a certain limit.

Categories

There are nine categories in BREEAM which each have their own section weighting factor. Each category has several credits. The nine categories are: management (17 credits possible, section weighing 12%), health and wellbeing (19 credits, 15%), energy (24 credits, 19%), transport (9 credits, 10%), water (9 credits, 5%), materials (12 credits, 13.5%), waste (7 credits, 7.5%), land use & ecology (10 credits, 10%) and pollution (12 credits, 8%). Besides, it is possible to obtain maximum 10 extra innovation credits, if exemplary performance is achieved within specific credits.

Minimum scores

Some issues are considered as so important, that they are obligatory. The amount of credits that is mandatory depends on the required rating. An ‘outstanding’ certificate has more obligatory credits than a ‘pass’ certificate.

Calculation example

As long as the final BREEAM score is higher than the score required for a certain rating BREEAM credits are tradable. However, some credits require a minimum score. An example how to calculate the BREEAM score is given below.

<table>
<thead>
<tr>
<th>BREEAM section</th>
<th>Credits achieved</th>
<th>Credits available</th>
<th>% Credits achieved * Section weighting</th>
<th>Section score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management</td>
<td>12 / 17</td>
<td></td>
<td>70 % * 0.12</td>
<td>8.47 %</td>
</tr>
<tr>
<td>Health &amp; Wellbeing</td>
<td>15 / 19</td>
<td></td>
<td>79 % * 0.15</td>
<td>11.84 %</td>
</tr>
<tr>
<td>Energy</td>
<td>12 / 24</td>
<td></td>
<td>48 % * 0.19</td>
<td>9.5 %</td>
</tr>
<tr>
<td>Transport</td>
<td>5 / 9</td>
<td></td>
<td>55 % * 0.10</td>
<td>5.55 %</td>
</tr>
<tr>
<td>Water</td>
<td>5 / 9</td>
<td></td>
<td>67 % * 0.05</td>
<td>2.77 %</td>
</tr>
<tr>
<td>Materials</td>
<td>6 / 12</td>
<td></td>
<td>50 % * 0.135</td>
<td>7.00 %</td>
</tr>
<tr>
<td>Waste</td>
<td>3 / 7</td>
<td></td>
<td>43 % * 0.075</td>
<td>3.21 %</td>
</tr>
<tr>
<td>Land use &amp; ecology</td>
<td>4 / 10</td>
<td></td>
<td>40 % * 0.10</td>
<td>4.00 %</td>
</tr>
<tr>
<td>Pollution</td>
<td>5 / 12</td>
<td></td>
<td>42 % * 0.08</td>
<td>3.36 %</td>
</tr>
<tr>
<td>Innovation</td>
<td>1 / 10</td>
<td></td>
<td>10 % * 0.10</td>
<td>1.00 %</td>
</tr>
</tbody>
</table>

Example final BREEAM score: 56.7 %

Example final BREEAM rating: Very good 😎😎😎
This section provides terms used in the design process, design phases, and actors involved.

**DESIGN PROCESS TERMS**

**Design process**
The process from generation of an idea to the delivery of a constructed building that can be operated. Can also be called design and construction process.

**Traditional design process (TDP)**
Design process characterized by a linear design order. The client and architect come up with a design, after which engineers suggest systems and installations to translate the concept design into detailed design. Subsequently the construction is built by the contractor. Actors involved later in the process can only sub optimise the design. A TDP is often steered only on time and budget.

**Integrated design process (IDP)**
Design process characterized by an integrated and non-linear design order. Three main characteristics can be distinguished: early actor involvement, goal setting and quality assurance, and knowledge transfer and evaluation. First, early actor involvement implies that all relevant actors are involved in the earliest phases to apply there knowledge. The design is made by a team. Second, goal setting and quality assurance implies that clear targets are set and communicated by a committed and competent client. In this way all actors no what to expect from the process. Third, knowledge transfer and evaluation means that knowledge should be transferred between subsequent phases. Furthermore each design phase should be evaluated to provide feedback.


**PHASES OF A DESIGN PROCESS**

**Idea**
Project initiative is taken, often by the client or owner of the building. Preliminary studies and team set up can be performed.

**Program**
The project is defined, requirements are set and a building programme is written. The program is based on the first ideas, a site analysis and building assessment.

**Concept design**
A the design team generates alternatives to develop the building system, structure and construction method, façade and installations.

**Detailed design**
The concept design is translated into a detailed design. Based on life cycle costs final systems are chosen as well as building materials and other components.

**Construction phase**
The detailed design is translated into a construction via construction documents. The responsibility of the construction phase is defined by the contract form.

**Operation phase**
During operation the tenant or owner uses the building for its purpose. It should be evaluated if the assumptions from the design phase are applied.

**End-of-life scenario**
Each building has a final lifespan. For example after 30 years the economical and functional requirements might be changed to such extent that the building is considered as out-of-date. A decision should be made to renovate or demolish the building. Ideally, this end-of-life scenario is already developed in the idea phase.
**ACTORS INVOLVED**

**Actors**
Persons, organizations and companies involved in the design process with influence on the final result. In this thesis actors with influence on the sustainability of the building are researched.

**Builders**
The actors actually delivering the construction. Often led by the main contractor. The main contractor relies on subcontractors, suppliers and manufacturers.

**Designers**
Actors responsible for the design of the building. Often led by architect, responsible for architectural design and assisted by engineers to supply expert knowledge on technical details.

**Clients**
The client sets the main requirements on the design and invests money in the project. The client can be the owner of the building or a project developer. The client side can also include an investor, who speculates with buildings and/or the future tenant of the project.
APPENDIX B
MARKET SHARES OF FAÇADE TYPOLOGIES (EBBERT, 2010)
Ebbert (2010) found 22 façade typologies, numbered by the following the parameters:
1. Position of the thermal barrier
2. Structural form
3. Amount of layers.

Ebbert (2010) performed a spot check analysis in Germany, the Netherlands and the United Kingdom. The resulting average market share for the three countries together is shown below. Typologies with more than 5% market share in Western Europe are marked in dark blue. It is assumed that the dark blue façade typologies are representative also for an analysis on barriers and opportunities in the Norwegian stock.

<table>
<thead>
<tr>
<th>FACADE TYPOLOGY GER UK NL (avg. market share)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TYPE 1 [1.1 planar, 1.2 skeleton]</td>
</tr>
<tr>
<td>TYPE 2 [2.1 planar, 2.2 skeleton]</td>
</tr>
<tr>
<td>TYPE 3 [3.1 planar, 3.2 skeleton]</td>
</tr>
<tr>
<td>TYPE 4 [4.1 planar, 4.2 skeleton]</td>
</tr>
<tr>
<td>TYPE 5 [5.1 parapet+wind., 5.2 heavy unitised, 5.3 light unitised, 5.4 stick system]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TYPE 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 planar</td>
</tr>
<tr>
<td>1.2 skeleton</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TYPE 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 planar</td>
</tr>
<tr>
<td>2.2 skeleton</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TYPE 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 planar</td>
</tr>
<tr>
<td>3.2 skeleton</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TYPE 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 planar</td>
</tr>
<tr>
<td>4.2 skeleton</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TYPE 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1 parapet+wind.</td>
</tr>
<tr>
<td>5.2 heavy unitised</td>
</tr>
<tr>
<td>5.3 light unitised</td>
</tr>
<tr>
<td>5.4 stick system</td>
</tr>
</tbody>
</table>

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1.2</td>
<td>1%</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>1.2.2</td>
<td>2%</td>
<td>1%</td>
<td>0%</td>
</tr>
<tr>
<td>2.1.1</td>
<td>2%</td>
<td>5%</td>
<td>7%</td>
</tr>
<tr>
<td>2.1.2</td>
<td>1%</td>
<td>4%</td>
<td>5%</td>
</tr>
<tr>
<td>2.2.1</td>
<td>0%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>2.2.2</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>3.1.1</td>
<td>11%</td>
<td>15%</td>
<td>9%</td>
</tr>
<tr>
<td>3.1.2</td>
<td>2%</td>
<td>3%</td>
<td>1%</td>
</tr>
<tr>
<td>3.2.1</td>
<td>10%</td>
<td>19%</td>
<td>16%</td>
</tr>
<tr>
<td>3.2.2</td>
<td>7%</td>
<td>0%</td>
<td>4%</td>
</tr>
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APPENDIX C
CASE STUDY APPROACH
## APPENDIX C.1 INTERVIEWED ACTORS

This appendix provides an overview of the interviewed persons, ordered per project and chapter in which the interview is used. The tables contain information about the type of actor, company name, and name.

### LYSAKER PARK (CHAPTER 6)

<table>
<thead>
<tr>
<th>Actor</th>
<th>Company name</th>
<th>Interviewed person</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client</td>
<td>Storebrand Eiendom</td>
<td>Unn Hofstad and Petter Schach</td>
</tr>
<tr>
<td>Tenant</td>
<td>Storebrand Livsforsikring / Storebrand ASA</td>
<td>Yngvar Christiansen</td>
</tr>
<tr>
<td>Architect</td>
<td>Link - Signatur</td>
<td>Johan Korff and Elisabeth Meyer</td>
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<tr>
<td>Subcontractor</td>
<td>AF Gruppen</td>
<td>Philip van de Velde</td>
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<tr>
<td>Project management</td>
<td>Skansen</td>
<td>Arne Renning</td>
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<td>Energy consultant</td>
<td>Esbensen Rådgivende Ingeniører</td>
<td>Arne Ferland Larsen</td>
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<td>Environmental consultant</td>
<td>Hambra</td>
<td>Katharina Bramsliev</td>
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### FREDRIK SELMERS VEI 4 (CHAPTER 7)

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<td>Tenant</td>
<td>Skattetaten</td>
<td>Egil Kongsvold</td>
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<tr>
<td>Architect</td>
<td>LPO Arkitekter</td>
<td>Jan Knoop</td>
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<td>Contractor façade</td>
<td>AF Gruppen</td>
<td>Torjus Myre Ulsaker</td>
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<tr>
<td>Project management</td>
<td>Optimo Prosjekt</td>
<td>Morten Steinkjer</td>
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<td>Energy consultant</td>
<td>Energetica</td>
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<td>Environmental consultant</td>
<td>Hambra</td>
<td>Katharina Bramsliev</td>
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</table>

### POWERHOUSE KJØRBO (CHAPTER 8)

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<td>Einar Børve</td>
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<td>Tenant</td>
<td>Asplan Viak</td>
<td>Inger Støle</td>
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<td>Architect</td>
<td>Snøhetta</td>
<td>Camilla Dalen Moneta</td>
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<td>Contractor</td>
<td>Skanska</td>
<td>Fredrik Daehli</td>
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<td>Supplier façade</td>
<td>Hydro</td>
<td>Thomas Aasen and Frank Foleide</td>
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<tr>
<td>Energy consultant (partly)</td>
<td>Asplan Viak</td>
<td>Arne Ferland-Larsen</td>
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### OTHER INTERVIEWS (CHAPTERS 1-5, 9-10)

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</tr>
</thead>
<tbody>
<tr>
<td>Architect Varner building</td>
<td>Link Signatur</td>
<td>Johan Korff and Elisabeth Meyer</td>
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<tr>
<td>Client Varner building</td>
<td>Varner Gruppen</td>
<td>Ulf Eirik Larsen</td>
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<td>Project developer Monarch (NL)</td>
<td>Provast</td>
<td>Anton Koomen</td>
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<td>Sustainability consultant (NL)</td>
<td>WE Consultants</td>
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<td>Woonbron</td>
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<td>Sustainability organization (NL)</td>
<td>Dutch Green Building Council</td>
<td>Maarten Dansen</td>
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<td>Sustainability organization</td>
<td>Norwegian Green Building Council</td>
<td>Sverre Tiltnes</td>
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<td>Sustainability organization</td>
<td>FutureBuilt</td>
<td>Ulla Hahn</td>
</tr>
<tr>
<td>Sustainability consultant</td>
<td>Asplan Viak (IEA Task 47/MaTRID)</td>
<td>Fritjof Salvesen and Per Jørgensen</td>
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</table>
APPENDIX C.2 INTERVIEW FORMAT

In this appendix the semi-structured interview format is given. The semi-structured format means the following questions are meant as a framework for the interview. In practice a fluent conversation found place based on these topics, instead of only posing questions and getting answers.

INTRODUCTION TO THE THE RESEARCH

“The following questions are part of a research into integrated energy design in practice at the TU Delft, Netherlands. I am interested in the different roles of persons involved in highly sustainable projects and the way people collaborate.”

INTRODUCTION TO THE PERSON, COMPANY AND PROJECT [CASE DESCRIPTION]

- What is your background (study field, working field)?
- Can you describe the project (with focus on sustainability) and your specific role/function, as well as the role of your company?
- Was the project different than normal? What was different? What is the difference between a conventional project and a sustainable project (or: this project)?
- How did the project organization look like? (answer can be used in organization of the design process)

ROLE OF SUSTAINABILITY

- Which actor took initiative for sustainability?
- What was the vision of the project with respect to sustainability? What was the projects definition of sustainability?
- Where sustainability goals already set in the beginning phase of the project?
- How did the sustainability goals develop over time?
- What do you think of the goals? Where they hard to achieve or easy?

ORGANIZATION OF THE DESIGN PROCESS

- How were the goals aligned with all different stakeholders? (team meetings, workshop?)
- Was sustainability the most dominant parameter or just one of the many to consider (for example: usability, aesthetics, economics, etc),
- In what way did sustainability change the design?
- How important was the budget? And how was sustainability integrated in the budget process? Was budget an important constraint?
- How would an optimal project organization look like?

BARRIERS AND OPPORTUNITIES

- What was the most important experienced barrier during the project? How was this solved?
- What would you advice next project teams to do? Main lesson learned? Do you take lessons with you to the next project?
- Is this conclusion the same for every actor?
APPENDIX D
REVISED DESIGN PROCESS GUIDELINES
In this appendix a booklet is presented that can be used to disseminate the findings of this master thesis to relevant actors. The booklet consists of two pages and gives a brief introduction into integrated design, the researched cases and where to find more information. Most important are the design process guidelines consisting of 15 steps.
Integrated design covers the complete life cycle of a building. In the earliest design stages, where the impact of a design change on costs is low and the impact on performance is high, clear goals should be set by a multidisciplinary design team, preferably including the contractor and future tenant.

Integrated design also includes knowledge transfer and evaluation, for example by monitoring real energy use and providing feedback to improve future projects. A committed and competent client is necessary to keep all project members on track towards the design goal.

Three projects are analysed in detail. For each project six to seven involved actors are interviewed, including the client and owner, tenant, architect, and sustainability engineer.

The three detailed case studies show a development in time of sustainability goals. Lysaker Park, realized in 2009, was the first renovation project to achieve Norwegian energy label B, while FS4 obtained the passive house standard. Powerhouse Kjørbo takes the next step and offsets operational energy use and embodied energy with the generation of renewable energy. In all three projects the owner also acted as client.

**REVISED DESIGN PROCESS GUIDELINES**

For sustainable office renovation based on research on integrated design processes in Norwegian practice.

The guidelines in this booklet are the result of a master thesis project at Delft University of Technology performed in 2013. 25 actors with decision-making power in office renovation projects are interviewed to research the best way to organize a design process to involve sustainability.

The complete master thesis, including detailed descriptions of the case studies, can be found online:

- Go to [http://repository.tudelft.nl](http://repository.tudelft.nl), and search on “Daan Boonstra” or “sustainable office renovation”
- Contact the author via daan.boonstra@gmail.com

Two pilot cases are used as a reference. The cases provide evidence of a shift in investment direction, as well as evidence of a shift in minimum standard revealing.

**Two pilot cases**

- De Monarch (Section 5.4)
  - Location: The Hague
  - Size: 19,500 m²
  - Sustainability goal: BREEAM-NL excellent
  - Completed in February 2012

- Nesøyveien 4-6 (Section 5.5)
  - Location: Asker
  - Size: 15,000 m²
  - Sustainability goal: energy label B
  - Expected completion: 2015

**Three detailed cases**

- De Monarch (Section 5.4)
  - Location: The Hague
  - Size: 19,500 m²
  - Sustainability goal: BREEAM-NL excellent
  - Completed in February 2012

- Nesøyveien 4-6 (Section 5.5)
  - Location: Asker
  - Size: 15,000 m²
  - Sustainability goal: energy label B
  - Expected completion: 2015

**Introduction**

Sustainability is a hot topic, both in the construction industry and on the global agenda. Sustainability in buildings requires to optimise contradictory parameters, such as daylight and operational energy use. Therefore, an integrated design process is needed.

An integrated design process focuses on achieving high performance by coordinating design and construction. A multidisciplinary design team is necessary to keep all project members on track towards the design goal. By including the contractor, the design process can be improved.

An integrated design process reduces risk by including the contractor early on. A multidisciplinary design team should set clear goals. By doing so, the design team can focus on achieving high performance.

The main challenge in sustainability is to find a balance between cost and performance. An integrated design process is needed to achieve this balance.

**Appendix D | Revised design process guidelines | 181**
INTEGRATED DESIGN PROCESS (IDP)

1. START OF PROJECT
2. Determine objectives and goals
3. Set up a multidisciplinary design team
4. Program
5. Clear goal
6. Building assessment
7. Early actor involvement
8. Detailed design
9.Holistic non-linear design optimization from a systems perspective
10. KNOWLEDGE TRANSFER & EVALUATION
11. Goal setting & quality assurance
12. Construction
13. Commissioning
14. Evaluate & reality
15. End-of-life solutions
16. Innovation
17. Test
18. On-site
19. Educate workers that will work on-site
20. Evaluation
21. Track changes
22. Maintenance
23. Recall importance of tenant
24. Finalize refurbishment strategy
25. Developing measurement and verification plan
26. Develop program
27. Assess building requirements
28. Evaluate concept design
29. Try new concept design
30. Evaluate & reality
31. Idea
32. Commissioning & hand-over
33. Construction
34. Evaluate & reality
35. End-of-life solutions
36. Innovation
37. Test
38. On-site
39. Educate workers that will work on-site
40. Evaluation
41. Track changes
42. Maintenance
43. Recall importance of tenant
44. Finalize refurbishment strategy
45. Developing measurement and verification plan
46. Develop program
47. Assess building requirements
48. Evaluate concept design
49. Try new concept design
50. Evaluate & reality
51. Idea
This report is the result of a master research project in the master programme building engineering at Delft University of Technology. The project aimed at finding evidence from practice on how to organize the design process. Interviews are performed with actors around five office renovation projects in Norway and the Netherlands. Of these five projects, three Norwegian projects with ambitious sustainability goals are analysed in detail.

All actors that potentially influence the sustainability goals are interviewed, including the client, tenant, architect, contractor and sustainability consultant. In some projects also the supplier is interviewed. The final result is an inspiring read for all building professionals, interested in sustainability or not.