Is Green the New Black?

Assessing the potential benefits and financial viability of green office buildings in Denmark

Mia Rud Bohnsen - Masters Thesis - Construction Management - Aalborg University - 2012

Is Green the New Black?

Assessing the potential benefits and financial viability of green office buildings in Denmark

Semester: BL4 - Spring 2012

Project Period: 1. April - 1. August 2012

Supervisor: Kjeld Nielsen

Mia Rud Bohnsen

Circulations: 3
Pages: 61
Appendix number/pages: 34

AALBORG UNIVERSITY
STUDENT REPORT

Synopsis

This report investigates the potential benefits and financial viability of building green in Denmark with a focus on office buildings. Research has been limited to new construction, thus excluding retrofit projects.
The approach has primarily been a review and analysis of existing publications and data regarding the costs and financial benefits of green buildings in the United States and exploration of how probable parallels to Danish conditions can be drawn.
Potential benefits for Danish green buildings are estimated based on this investigation and with that the potential viability of green buildings in Denmark, including a brief discussion on the future outlook for green buildings in Denmark.
The report concludes with a brief discussion on how to approach conducting further investigation into the subject in Denmark.

Danish Summary

- Dansk Resumé

Denne rapport undersøger de potentielle fordele og den finansielle bæredygtighed ved grønt byggeri i Danmark for kontorbygninger. Der er afgrænset til undersøgelse indenfor nyt byggeri. Derfor indeholder rapporten ingen betragtninger angående renoveringsprojekter.

Metoden har primært været granskning og analyse af eksisterende publikationer og data omhandlende fordele og ulemper ved grønne bygninger i USA samt undersøgelse af, hvordan sandsynlige paralleller kan drages til danske forhold.

Fordele og ulemper er vurderet for amerikanske LEED certificerede kontorbygninger og er opgjort relativt til konventionelle amerikanske kontorbygninger. Nogle resultater er baseret på egentlige realiserede resultater, mens andre er baseret på projekterede tal. Dette gælder blandt andet for undersøgelser af reduceringer i energiforbrug og vandforbrug. Alle tal er dog estimeret konservativt. I tilfælde hvor projekterede tal er brugt, frem for egentlige realiserede resultater, er en bedømmelse af potentielle forskelle mellem realiserede og faktiske tal foretaget.

Fordele er fundet i form af reducering i energi og vandforbrug, reducering af sygefravær, øget produktivitet og stigning i bygningens værdi og lejeindtægter. Endvidere er det fundet, at der potentielt kan opnås yderligere fordele i form af blandt andet markedsføringspotentiale, risiko håndtering og personale tiltrækning.

Paralleller til danske forhold er draget i form af overordnede betragtninger af klimaforhold, vand- og energiforbrug, standarder og forskrifter for henholdsvis USA og Danmark. På baggrund heraf er dansk potentiale indenfor de enkelte undersøgte områder blevet bedømt. Resultater fra amerikanske undersøgelser er blevet tilpasset efter disse betragtninger.

Det er fundet, at fordelene ved at bygge grønt langt overgår de ekstra omkostninger, der er – både nu og i fremtiden. Grønt byggeri vil være et vigtigt værktøj i forbindelse med reducering af CO_2 udledning og adressering af klimaforandringer generelt.

En øget produktivitet på blot 1% kan modsvare energibesparelser på 25% eller de totale ekstra omkostninger, forbundet med grønt byggeri. Generelt er det fundet, at produktiviteten i grønne bygninger er 2-3% højere end i tilsvarende konventionelle bygninger – så alene her er de potentielle fordele betragtelige.

Undersøgelser, foretaget i forbindelse med denne rapport, indikerer at besparelserne opnået igennem de fordele, der er ved grønt byggeri, overgår de ekstra omkostninger med mere end en factor 4 igennem energi besparelser og øget produktivitet alene. I betragtning af de øvrige fordele, der ikke er inkluderet i denne afvejning, må potentialet være endnu større. Dog vil det kræve mere præcise og omfattende data og resultater fra danske grønne byggerier, at fastslå præcis hvor stor den økonomiske fordel ved grønt byggeri i Danmark vil være.

Rapporten afsluttes med en kort introduktion til hvordan, videre undersøgelser kan gribes an i Danmark.

Preface

This thesis is submitted in support of candidature within Construction Management at The Faculty of Engineering and Science at Aalborg University by Mia Rud Bohnsen.

The report has been conducted in cooperation with Vestas Wind Systems A/S - Building Department, during the period April to July 2012.

Reading Guide

The report commences with a thesis statement and a presentation of scope and approach, followed by an analysis of costs and benefits of building green and a discussion on the future outlook for green buildings in Denmark. A brief discussion on how to approach possible future investigations concludes the report. Additional information that underlies assessments conducted in the report can be found as appendices and on the enclosed CD.

Throughout the report chapters and sections are consecutively numbered and appendices are indexed by consecutive letters. Figures and tables are numbered after which chapter they are placed in, e.g. the first figure in chapter two will be indexed as Figure 2.1. Cross-reference is based on these indexes.

If a reference is attached to a figure, this figure is taken from this source. If it says that the figure is based on a source it means that the information underlying the figure is from this source, but the figure is devised by the author. Figures with no reference are devised by the author.

Source references are consecutively numbered, and a bibliography in numerical order can be found at the back of the report. The bibliography contains information on author, year of publication, title, and any other relevant information. For web sources the date of visit is also given. If reference is placed before a full stop the reference is only for this specific sentence. If reference is placed after a full stop the reference is for the entire preceding section. Some places one or more overall primary sources are given at the beginning of a chapter or a section. In these cases this will be the source in the following unless other references are made. Source criticism of key sources is included in connection with the presentation of approach.

A vocabulary containing abbreviations used throughout the report can be found as Appendix E.

The terms sustainable and green will be used synonymously and interchangeably throughout the report.

Acknowledgements

Great thanks is owed to Rene Amini, Kim Christensen, Katja Meyer, Malo Bohnsen and Jonathan Smetana for their help throughout this project. For the many discussions, support, feedback and good advise along the way.

Introduction

Climate change was first suggested by Svante Arhenius from Sweden in 1896. He proposed that industrial era gas generation would augment gases such as CO_2, methane, and nitrous oxide already present in the atmosphere, and that these higher levels of green house gasses could cause warming of the planet. [1]

Since this postulate in 1896 a series of events have included environmental issues to the political agenda.

First it was the oil crisis of the 1970s and the energy scarcity this caused. During the 1980s issues such as global warming and the reduced ozone layer came into public awareness and the concept of sustainable development started to form. During the 1990s biodiversity, rainforest protection, water distribution and water quality was brought to the agenda. [2]

Today energy savings and CO_2-reductions have taken a central role in the public debate. Combustion of fossil fuels is widely recognised as being responsible for urban air pollution, regional acidification and human-induced climate change. [3] We are consuming coal, oil and gas in such large amounts that the planets natural uptake such as photosynthesis, can not keep up. Today we are emitting more than 15 times the amount of CO_2 to the atmosphere compared to 100 years ago. [4]

DID YOU KNOW

... At its peak the smog of London is thought to have caused the death of more than four thousand people in a single year. [5,p. 12]

... According to the World Wide Fund for Nature (WWF), forests the size of Greece are lost each year to serve the construction industry, resulting in the extinction of hundreds of species a year (most before they have been discovered). [2,p. 13]

... Higher annual temperatures in mountains in Africa have been linked to expanding malaria transmission.[5,53]

... The loss of biodiversity may shut off potentially important new drug and nutritional breakthroughs. [5,p. 58]

... Receding polar ice is resulting in the rapid expansion of flora; by late 1990s Antarchtic summers had lengthened by as much as 50% since the 1970s. [6,p. 128]

Global reserves of fossil fuels, [2,p. 86].

Oil	25 years
Natural gas	40 years
Coal	200 years

Global warming leaves its trace everywhere - oceans are rising, glaciers are melting, coral reefs are bleaching, coasts are flooding, forest fires are spreading, desserts are expanding and species are becoming extinct - the list seem never ending.[7] The implications of climate change are dire and over the last ten years projections have continued to worsen. [1]

We need to save energy and the worlds resources at large. The world population is expected to increase by 30% by 2050, resulting in an expected increase in energy consumption of 24% over the next 25 years. Fossil fuels are no longer found in abundant measures and as supply is getting less, prices are going up, adding to the argument of pursuing more sustainable resources.[8]

But what has actually been done over the years to face all these issues?

Global Environmental Conferences and Agreements

Over the years numerous conferences have been held and agreements have been written in order to address the issue of global warming and the climate changes this is bringing about. A few key events are listed on the opposite page.

In 1987 the Brundtland Report written by Norwegian prime minister, Gro Harlem Brundtland, about the findings of the World Commision on Environment and Development in 1983, was published. It gave the definition of sustainability that to date is the most widespread definition of the word.

In 1992 the Earth Summit in Rio de Janeiro resulted in the charter called Agenda 21 - that brought environmental politics into the mainstream and biodiversity to political attention. [5] Significant for this agenda is that it must be translated into local initiatives.

In 1997 the Kyoto Protocol was the result of the Kyoto Conference on Global Warming. The core of this protocol is a change from fossil fuels to alternative energy sources[5]. Countries that have ratified the Kyoto protocol have committed to limit and reduce the emission of Green House Gasses to the atmosphere. Today 183 countries have ratified this agreement - Denmark is one of them. [9]

The conferences and agreements are an expression of the good intentions found globally. However, the follow-up meeting to the Rio de Janeiro Earth Summit, ten years later, in Johannesburg in 2002 suggested that society had made very little meaningful progress. [5]

The United States, the most significant historic polluter, has not ratified the Kyoto Protocol as well as China and India, two significant emerging polluters, are refusing to take action until the United States does [1].

European countries fear that Europe's competitiveness will be lost under the ever expanding environmental law, when competing with the United States amongst others, who will not accept the same responsibility [2].

Major global environmental conferences and agreements, [2].

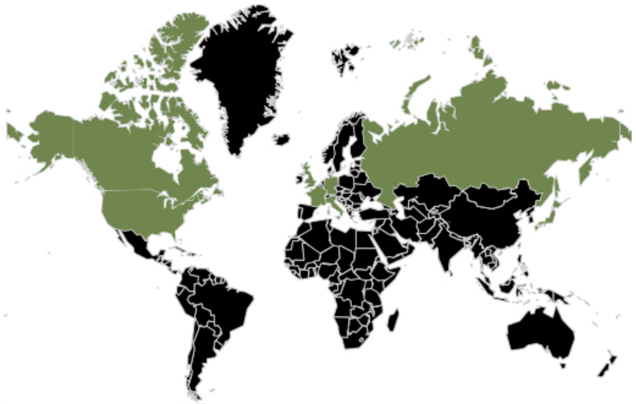
1972	Stockholm Conference on the Human Environment (UN)
1980	World Conservation Strategy (IUCN)
1983	World Commission on Environment and Development (UN)
1987	Montreal Protocol on Ozone Layer (UN)
1990	Green Paper on the Urban Environment (EU)
1992	Rio de Janeiro Earth Summit (UN)
1996	Habitat Conference (UN)
1997	Kyoto Conference on GlobalWarming (UN)
2000	The Hague Conference on Climate Change (UN)
2002	Johannesburg Summit on Sustainable Development (UN)
2006	Helsinki Conference on Carbon Trading and Global Warming (UN)
2007	Bali Conference on Climate Change (UN)
2008	Poznan Conference on Climate Change and Carbon Trading (UN)
2009	Copenhagen Conference on Climate Change (UN)
2010	Cancun Climate Change Conference (UN)
2011	Durban Climate Change Conference (UN)
2012	RIO+20 - Conference on Sustainable Development (UN)

... development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Gro Harlem Brundtland, 1987, [2,p. 25].

In July 2008 the G8 countries agreed to half CO_2 emissions by 2050, [7]. However, following the global economic crisis of 2008/09 the danger is, that in the scramble to regain economic stability, other important issues such as sustainability might suffer. [2]

G8 countries



Canada
France
Germany
Italy
Japan
Russia
United Kingdom
United States of America

Sustainable buildings

There is a need to address the issue of global warming by reducing CO_2-emissions, energy consumption and consumption of the planets resources at large and it is widely recognised that the building industry has a great potential to make a significant change in this context. [10] [2]

Globally buildings use 32% of the worlds resources in construction. Buildings are responsible for around 40% of global energy use and generate up to 30% of global green house gas emissions. [11]

It seems evident that green buildings can pose a major advantage for society at large. But how is the advancement of green development ensured?

Government mandates and policies along with increased experience with green buildings are all factors furthering sustainable building practice at the moment. But what is really the key factor to ensure that building green will become common practice is a greater understanding of the business case. [12]

Can green benefits outweigh the costs? The answer will largely determine whether green design can make the transition from environmentally motivated niche to cost conscious mainstream. If it can be proven that building green is financially viable, then there is real potential for transformation of the whole building sector. [5]

Contents

I Problemstatement 1

1. Are Sustainable Buildings Financially Viable? 3
1.1 Scope 5
1.2 Sources 5

II Cost and Benefits 11

2. Initial Costs 13
2.1 Establishing the Costs of Building Green 13
2.2 Review and Analysis 14
2.3 Assessing the Danish Potential 16
2.4 Preliminary Conclusion 17

3. Energy Consumption 19
3.1 Review and Analysis 19
3.2 Assessing the Danish Potential 21
3.3 Preliminary Conclusion 24

4. Water 25
4.1 Review and Analysis 25
4.2 Assessing the Danish Potential 27
4.3 Preliminary Conclusion 28

5. Productivity and health 31
5.1 Measuring Productivity 31
5.2 Review and Analysis 33
5.3 Assessing the Danish potential 35
5.4 Preliminary Conclusion 35

6. Value and Rent **37**
6.1 Building Value 37
6.2 Rent 38
6.3 Office Buildings 38
6.4 Assessing the Danish Potential 38
6.5 Preliminary Conclusion 39

7. Intangibles **41**
7.1 Operating Costs 41
7.2 Waste Reduction 41
7.3 Attracting and Retaining Workforce 42
7.4 Return On Investment - ROI 44
7.5 Marketing Value 44
7.6 Project Risks & Risk Management 45
7.7 Insurance 46
7.8 Lower Lending Rates 46
7.9 Preliminary Conclusion 46

8. Financial Assessment **47**
8.1 Ratio of Economic Costs of a Building 48
8.2 Assesing Costs and Benefits 49

9. Green Building Outlook Denmark **51**

10. Conclusion **55**

11. Further Investigation **57**
11.1 Post Occupancy Evaluation 57
11.2 Evaluating the Costs and Benefits of Green Buildings 58
11.3 Getting Started 61

III Appendix 63

A. Certificationschemes 65

B. Climate 71

C. Consumption 79

D. Building Regulations 83

E. Vocabulary 89

Bibliography 91

Problemstatement

I. Are sustainable buildings financially viable?

Sustainable development represents value to society at large, in the form of decrease in green house gas and CO_2 emissions, decrease in pollution from fossil fuels, independence of fossil fuels and a general fulfilment of political goals. But which value does building green constitute to the individual building owner? Many developers and owners struggle to measure the costs and benefits of building green to evaluate the financial viability of sustainable building.

This thesis will try to establish the potential benefits of sustainable buildings and to make probable the financial viability of sustainable buildings in Denmark.

However, in order to investigate the benefits of sustainable buildings a definition of what is regarded as a sustainable building must be established. In Denmark sustainable buildings can be found in many shapes and forms. Conducting an investigation between them will be like comparing apples and pears. There are energy-labelled buildings, 0-energy buildings, passive houses, low-energy houses, certified buildings etc. Some are simply energy efficient while others include sustainable attributes in a much wider context.

Several studies have been conducted into the subject in the United States, where certification of green buildings has become commonplace. In Denmark, however, certification is fairly new. Very few buildings have been certified in Denmark at the time of writing this thesis. A few buildings have been certified after either LEED or BREEAM, but now it has been chosen to adapt DGNB to Danish standards and use this as the Danish certification scheme under the Danish Green Building Council.

Ideally a dataset of Danish green buildings would have been collected to form the basis for this research. However research from the United States and the United Kingdom indicates that first generation buildings do not

"Sustainable design is the creation of buildings which are energy efficient, healthy, comfortable, flexible in use and designed for long life."

- Foster and Partners, 1999, [2,p. 29]

"Sustainable construction is the creation and management of healthy buildings based upon resource efficient and ecological principles."

- BSRIA, 1996, [2,p. 29]

perform as well as when there is local experience within the field. Therefore analysing the first few sustainable buildings in Denmark might not give the results that can actually be expected from Danish green buildings over time.

Therefore instead of trying to find available Danish data and establish a definition, which will comprise one or more of the various versions of sustainable buildings found in Denmark, emphasis is put on review of results from various American studies and on exploring how a probable parallel to Danish conditions can be drawn.

Both in the United States and the United Kingdom experience with sustainable buildings and investigations on the subject are extensive. Through an overall review of available literature it was concluded that more extensive research and specific data where available for the United States, thus this was chosen as a basis of comparison, even though buildings from the United Kingdom might be more readily comparable given the close proximity and the fact that European standards might be more similar.

The investigations conducted in the United States have established benefits of sustainable buildings compared to conventional buildings and standards within the United States. So in order to judge whether the same benefits can be expected in Denmark, it is necessary to compare the properties of conventional Danish buildings and conventional American buildings, to evaluate whether a similar improvement can be expected in Denmark. Likewise the difference in American and Danish regulations can have great influence on the potential improvements a sustainable building can offer compared to a conventional building. Finally political, cultural and climatic differences between the two countries can influence the potential benefits of sustainable buildings greatly.

This is not a thesis on the differences between Danish and American building regulations, or the difference in building performance in the United States compared to building performance in Denmark. Therefore these differences are only described in very general terms and with a focus on certain qualities in order to be able to make probable conclusions concerning performance of sustainable buildings in Denmark based on studies of sustainable buildings in the United States.

Moreover this thesis is not a comparison of certification schemes. Even though the results from the United States are based on studies of LEED rated buildings, and the certification scheme that is being adopted in Denmark is DGNB, an analysis of the possible implications of this difference will not be conducted. Even though the Danish green building council has decided to adopt DGNB, this does not mean that this will in fact become the common scheme for certification in Denmark. Several of the larger advisers in Denmark have experience with LEED and BREEAM and might push for these schemes over DGNB. Certification is voluntary - at least for now. Any type of certification can be chosen by Danish building owners in the future. A brief description of the two certification schemes is included in Appendix A, but a deeper analysis of the difference between the certification schemes is not included.

1.1 Scope

This study will focus on office buildings specifically. It is expected that generally a large amount of data will be available for this building type. The industry sectors with the highest penetration of sustainable building are education, health care and office [13]. Moreover this thesis will limit research to new construction and thus will not include research concerning retrofit projects. LEED is used as the common basis of comparison because it has become the dominant definition of green buildings in the United States.

Since the objective of the thesis is very general analysis and comparisons will also be kept at a very general level, so as not to indicate greater accuracy than what can be substantiated.

The approach will be to review and analyze existing publications and data regarding the costs and financial benefits of green buildings in the United States and the study relies in large part on a few meta-studies that have screened tens or hundreds of other studies and have evaluated and synthesized these findings. [14]

Using this approach results are very vulnerable to biased views, given that the people who have conducted surveys regarding sustainable buildings are often very involved in sustainable building themselves. A short presentation of the primary sources used as a basis for this thesis is given in the following.

1.2 Sources

These sources are chosen as the primary sources because they were found to be the most extensive and most reliable - most other publications found on the subject were actually reviewed in connection with these studies. And finally these sources have been widely cited in many other publications and by both the United States Green Building Council and the Danish Green Building Council.

1.2.1 Publications by Gregory Kats

The following is primarily based on 'Costs and Financial Benefits of Green Buildings - A Report to California's Sustainable Building' [14], 'Green Building Costs and Financial Benefits' [15] and 'Greening our built world' [16].

Gregory Kats is a senior director and director of climate change policy at Good Energies, a global private investor in clean-energy technologies. Furthermore he is a senior advisor and member of the investment committee of Osmosis Capital LLP, a London-based private equity fund of funds operating in the low carbon sector. Previously, Kats has served as the director of financing for energy efficiency and renewable energy at the U.S. Department of Energy, United States largest clean-technology development and deployment programme. He was the founding chair of the International Performance Measurement and Verification Protocol (translated into ten languages) and of the Energy and Atmosphere Technical Advisory Group for LEED.

Green Building Costs and Financial Benefits
- Kats 2003 study

This report was developed for the Sustainable Building Task Force, a group of over 40 California State government agencies. The study was funded by several Sustainable Building Task Force member agencies. This could hint that results might be biased, but all estimates seem very conservative and thus this is not found to be the case.

Beside the extensive report Kats wrote a paper based on this same study - which has also been reviewed.

This report was the first to fully aggregate the costs and benefits of green buildings in one comprehensive study. Although the report looks at the lessons offered from a range of green design programs, LEED is used as the common basis of comparison. For example, in seeking to quantify a building's "greenness", it is described by its LEED level or equivalent.

The report began with an aggregation of data on actual or modelled costs for 33 green buildings. Largely derived from several dozen conversations with architects, developers and others. These 33 buildings were chosen because relatively solid cost data for both green design and conventional design was available for the same building. These 33 buildings were composed of 25 office buildings and 8 schools with actual or projected dates of completion between 1995 and 2004.

Energy consumption was investigated through a detailed review of 60 LEED rated buildings, which were compared to conventional buildings.

Furthermore the report reviews and analyzes a large quantity of existing data about the costs and financial benefits of green buildings in California.

The size of the data set for this report is not large however this study still provides meaningful insights into the many green building attributes and estimates are to a great extent confirmed by his study from 2010 described below. However in general results from this later study are regarded as more reliable.

Greening our built world
- Kats 2010 study

In 2010 Kats conducted another survey - with the goal to explore the broader potential for green design, and to answer the question whether the benefits of green design outweigh the costs.

This survey included 130 U.S. buildings found for this survey, plus an additional 40 buildings, which had been included in previous studies by Kats, one of them being Costs and Financial Benefits of Green Buildings described above. For the 40 buildings for which data was reused a follow up data-collection was conducted.

The 170 buildings included buildings from 33 states and 8 countries (155 American Buildings and 15 non-American buildings), completed between 1998 and 2009 (the majority is from the later half of this period), from 2400 ft^2 to 2 million ft^2. 20 of the 170 building project included in the study where retrofit projects. They were either completed or under construction, certified or anticipating certification after LEED or a similar system (in this case LEED equivalent ratings were estimated).

A range of building types were included; affordable multifamily housing, health care facilities, schools, higher education, laboratories, offices, residential, retail etc. Offices were the 2nd highest represented (35 office buildings).

Data is not precisely representative of the population of green buildings, though there is great diversity in geography, performance and building type. Moreover all buildings participating in this survey do it voluntarily and consequently the results might be biased. Again conclusions in the report are found to be so conservative, that results still seem plausible. In comparison to the U.S. Green Buildings Council's records for LEED rated buildings, a higher percentage of LEED gold and LEED platinum rated buildings were found in Kats dataset than in general, and furthermore the buildings included in the survey seem to represent a slightly higher-performing population than LEED rated buildings in general.

Data for this survey was collected over a 20-month period starting in 2007, working with over 100 architects, developers, green building consultants, and building owners, by use of a standard data-collection sheet, which was e-mailed to the sources after agreement of participation along with a request for any relevant supplemental further information. Data regarding green premiums, energy savings and water savings was prioritised. The results from this data were synthesized with findings from other studies, to develop estimates of the present value of costs and benefits.

Data for added costs were based on estimates reported by architects (or other data source) compared to same building without green features.

Most of the data used to examine energy savings is based on projected energy reductions. However in 2007 the USGBC conducted a study of 121 LEED rated buildings (providing energy bills for at least one year of operation) comparing projected reductions to actually achieved reductions, using the energy consumption of buildings in compliance with ASHRAE standards, documented in the Department of Energy's Commercial Buildings Energy Consumption Survey (CBECS), see Appendix D, as a baseline. This study found average projected savings of 25% and average achieved reductions of 28% for LEED rated buildings. However there was a wide spread in the numbers - 30% of buildings achieved energy savings greater than projected and 25% used more energy than projected. Unfortunately the publication did not include any further information regarding the variations within this spread.

From this it is deduced that individual projected energy savings are not very reliable performance indicators for green buildings, but on average they are close to actually achieved energy reductions and thus the results from Kats survey can be taken as representable for actually achieved reductions in energy as well.

Data used to examine water use reductions are also based on projections used as approximate measures of actual savings. A study comparing actual water use and projections found that actual water use was found to be 15% higher than projected use on average. Estimates based on projections might therefore be slightly optimistic, but then Kats estimates based on these data are very conservative and it is deemed that results are still reliable. The water savings reported in this survey did not generally include irrigation or process water.

Data for the remaining areas like impacts on health and productivity were sparse and mainly evaluation of these aspects is based on a range of research, including surveys of occupants in green buildings and statistical analysis of real estate data from green buildings.

A detailed description of data gathering methodology, a list of major data points and description of baselines used for estimating costs and benefits can be found in the book.
Some of the McGraw-Hill publications described below and a 2008 CoStar analysis were widely cited in Kats publication. The CoStar analysis compared the value of LEED and Energy Star Buildings to non-green buildings that were matched on the basis of size, age, class, and submarket. The analysis pool included 973 Energy Star and 355 LEED buildings.

Office Buildings

Kats analysis include a number of different building types, but the scope of this thesis is office buildings. The data for office buildings from Kats 2010 study, which was available in the publication, was subtracted and subjected to further analysis. Data for buildings that were not American and were not new construction were not included in the analysis. The data and analysis can be found on the enclosed CD.

It should be noted that these results are only used to assess whether it seems plausible that the findings for green buildings in general can also be assumed true for office buildings specifically. By selecting a smaller sample of Kats complete dataset (31 buildings), the degree of uncertainty in the results is increased. Results are viewed as indications of reliability of the full dataset being representative for office buildings, rather than being applied as estimates themselves.

1.2.2 Publications by McGraw-Hill Construction

This following is primarily based on www.construction.com [17].

McGraw-Hill Construction is North America’s leading provider of construction project and product information, plans and specifications, industry news, market research, and industry trends and forecasts. In recent years, McGraw-Hill Construction has emerged as an industry leader in the critical areas of sustainability and interoperability as well.

This report draws from their expertise and large database through a variety of publications.

Green Outlooks

McGraw-Hill Construction created their first Green Outlook report in 2008 and have continued to do so yearly since then. These reports pull from the breadth of McGraw-Hill Construction’s intelligence and industry expertise - including the McGraw-Hill Construction Dodge database, 60.000 annual digitized plans and specifications, five-year construction market forecasts, market research and representative sample of the construction industry (some of which can be found in smart market reports) and secondary research.

The Green Outlook reports are compiled/created by McGraw-Hills' staff of researchers, economists and analysts - including LEED accredited professionals.

• **Green Outlook 2010 - Green Trends Driving Growth, (Several of the reviewed studies draw from this report)**
• **Green Outlook 2011 - Green Trends Driving Growth,** [18]

SmartMarket Reports
The SmartMarket Report series provides current, relevant intelligence about key trends and innovations, such as sustainability and technology that offer significant opportunities for players in the design and construction industry. The reports are designed to help firms in the design and construction industry to improve their competitive position by simultaneously expanding their knowledge and providing visibility of their leadership of key industry trends.

The intelligence in SmartMarket Reports is derived from research and interviews with thousands of key individuals in all aspects of the design and construction industry, conducted by professional reporters and editors from McGraw-Hill Construction. To date, McGraw-Hill Construction has produced over 20 issues and disseminated findings across the construction industry.

• **Key Trends in the European and U.S. Construction Marketplace** - SmartMarket Report 2008 (Several of the reviewed studies draw from this report)
• **Water Use in Buildings: Achieving Business Performance Benefits through Efficiency** - SmartMarket Report 2009, [19]

For further information see the individual reports.

"To date there has been a widespread perception that green buildings - though more attractive from a environmental and health perspective - are substantially more costly than conventional design and may not be justified from a cost benefits perspective."

- Gregory Kats, 2003 , [15, p. 2].

Cost and Benefits

Previous research on sustainability has primarily focused on cost reduction without studying how sustainability adds value to a business, but green initiatives need to be regarded as an investment instead of just cost. [20] There is growing evidence from built projects that green buildings do represent a sounder long-term investment than more conventionally designed buildings. [6]

In order to assess whether sustainable buildings are financially viable to the individual building owner, it is necessary to consider a range of possible benefits. These benefits range from seeming fairly easy to measure and track to being relatively uncertain and difficult to establish. Energy and water savings can be predicted with reasonable precision - measured, and monitored over time. In contrast, productivity and health gains are much less precisely understood and far harder to predict with accuracy.

The following six chapters will try to assess the costs and benefits of green buildings and subsequently a discussion of the future potential and financial viability of building green in Denmark will follow.

2. Initial costs

This chapter is primarily based on 'Costs and Financial Benefits of Green Buildings - A Report to California's Sustainable Building' [14], 'Green Building Costs and Financial Benefit' [15], 'Greening our built world' [16], and 'Cost of Green Revisited - Reexamining the Feasibility and cost impact of sustainable design in the light of increased market adoption' [21].

There seem to be a general public perception that green buildings are substantially more costly than conventional buildings, and may not be justified from a cost-benefit perspective. Surveys among American construction professionals and business leaders showed that 80% of construction professionals cited first costs as an obstacle to green building and that business leaders in general believed that on average green buildings are 17% (2007 survey) more expensive than conventional buildings. The expected costs of building green are significantly higher than actual figures found in recent studies. However, it is expected that, as all players get more experienced with green buildings, expectations of costs will start to align around real figures [18].

2.1 Establishing the costs of building green

The cost of building green can be examined from three different perspectives:

• The costs of incorporating individual sustainable elements
• The cost of green buildings compared to a population of buildings with a similar program
• The cost of green buildings compared to budget for the same building without green features

Looking at the costs of incorporating individual sustainable elements will not give a true picture of the total added costs of building green to a project. Additional up-front costs of one sustainable element might very well be offset from savings in other areas caused by this element. For example, improved insulation can reduce the size of the heating or cooling system; waterless urinals reduce plumbing requirements, and increased daylightning and views can decrease the need for electrical lighting. The costs are not necessarily cumulative.

Attempts to compare the cost of a specific green building with other buildings of similar size and function in a different locality may provide little help in understanding the cost of green design. The added cost impact of designing green may be very small compared with other building costs such as the cost of land or infrastructure. It may therefore be difficult to establish whether the difference in costs is due to building green or other factors influencing the initial costs in such a comparison.

It seems that the most meaningful assessment of the costs of building green requires a comparison of costs of conventional and green designs for the same building.

However, this data can be difficult to collect. Most green buildings do not have data on what the building would have cost as a conventional building and many developers choose to keep cost information to themselves. Even when this information can be obtained, a precise “green premium” is very difficult to determine.

It is complicated by the following factors:

• Developers typically only issue specifications and costs for the designed building, not for other options. Individual green items are sometimes priced out in comparison to non-green ones, but this is not the norm and does not provide a basis for cost comparison between green and conventional whole building design.
• Some green buildings being built today are showcase projects that may include additional and sometimes costly finish upgrades that are unrelated to the building being green but that, nonetheless, are counted toward the added costs.
• The design and construction process for the first green building of an owner or engineering/architectural firm is often characterized by significant learning curve costs, and design schedule problems such as late and costly change orders.
• The relative newness of green technologies and systems can make engineers, architects and owners conservative when using them. They may oversize green building systems and not fully integrate them into the building, thereby reducing cost savings and other benefits. Similarly, cost estimators may add uncertainty factors for new green technologies they are not familiar with, and these can compound, further inflating cost estimates.
• Very few projects, will report coming in under budget due to sustainable features, which means that the average reported added costs is typically higher, than the actual average added costs.

2.2 Review and analysis

The results from Kats 2010 data showed that added cost of green buildings compared to conventional buildings ranged from slight cost savings to 18% additional costs. However, more than three quarters reported only between 0% and 4% additional costs. The average added costs of green buildings ware as little as 1.5%. These findings were in keeping with Kats previous study from 2003, which had found that green buildings cost 1.84% more than conventional buildings on average.

Comparing the results from his two studies, Kats conclude that the average added costs when building green has been pretty much unchanged over the years, suggesting that maybe the green premium will stay constant in the future as well. However one could also choose to regard the decrease in added costs, from 1.84% on average in 2003 to 1.5% in 2010 as a sign; that the costs of green design has generally dropped in the last few years as the number of green buildings has risen. Many of the buildings included in the 2003 study were early adaptors and as experience has increased, which is indicated by a rising number of LEED accredited professionals and LEED rated buildings, and as prices of green products have declined with a rise in demand, the added costs of building green can be expected to have decreased. For example it can be noted that photovoltaic prices fell 40% between early 2008 and mid 2009, due to a significant increase in demand.

There is also a chance that the difference in results from 2003 to 2010 can be explained by a difference in the combination of building types in the sample. Maybe it is an expression of the fact, that the 2010 study is based on a far larger sample and thus the average result is not as easily influenced by a few high cost examples, which would mean that the 1.5% increase in costs could actually be closer to the true average. In any case the result from the 2010 study is more recent and build on a much more extensive basis of data. Thus uncertainty is smaller and the results more likely to reflect the actual current relationship between green buildings and costs.

2.2.1 Correlation between added costs and level of LEED rating

It is generally recognised that the added costs of building green increases with the level of LEED-rating, however none of the surveys reviewed for this thesis seem to be able to substantiate this perception.

Surprisingly Kats found, in his 2003 study, that reported cost levels for LEED Gold buildings were slightly lower than for LEED Silver buildings, whereas the higher performance level requirements to achieve Gold would be expected to cost more than Silver levels. Kats expected that this was probably a reflection of the uncertainties of the small dataset of this survey (the Gold-rated buildings represented an average across only six buildings). Thus he assumed that as additional data was collected costs would more closely follow the rising cost levels associated with higher levels of LEED-rating. Nonetheless his findings indicate that it is possible to build Gold buildings for little additional costs and that LEED silver buildings can be build with no added costs - if this is done by experienced professionals and green featuresare integrated from the beginning.

In his 2010 study Kats found that in his dataset there were more LEED Platinum buildings with little or no added costs (0-2%) than with large added costs (above 10%). These findings suggest that the cost premium depends more on the skill and experience of the design and construction team than on the level of LEED rating.

It seems that feasibility and potential cost impact in connection with LEED certification can be significantly increased or decreased by whether or not the members of the design and construction teams are familiar with sustainable practices.

Generally the earlier green building features are incorporated into the design process the lower the added costs. Architects, engineers, contractors and owners report almost exclusively that to achieve cost effective green design green goals must be concluded early in the design process. The most successful projects are found to be those that establish clear goals from the start, and that integrate sustainable elements into the project at an early stage. Projects that view sustainable elements as an added scope tend to experience greater budget difficulties.

Though Kats did not find a correlation between added costs and LEED rating level, he did find that green buildings that registered energy savings of 50% or more had an average added cost of 4% as opposed to the general average of 1.5% mentioned above - thus establishing a correlation between the added costs and reductions in energy consumption.

2.2.2 Office buildings specifically

From Kats 2010 dataset the data regarding new construction office buildings from the United States were subtracted and analysed separately, see Section 1.2.1. This resulted in slightly different results. Added costs of building green ranged from 0% to about 14%, with an average of 3.30% added costs. However, two thirds still reported between 0% and 4% added costs. For green office buildings with energy savings above 50% the average added costs compared to conventional buildings was found to be 6.16%, again a bit higher than for green buildings in general. As opposed to the results from Kats full study there was a clear indication of higher average added costs with higher LEED rating level. The average added costs for LEED Certified office buildings were 1.2%, for LEED Silver it was 2.4%, for LEED Gold 3.3%, and for LEED Platinum 6.7%. Furthermore there seemed to be an indication that the larger the building the lower the average added costs in proportion to the total costs.

These results are regarded as an indication that office buildings might have slightly higher average added costs than green buildings in general. The fact that the sample size was reduced from 170 buildings to 31 buildings for this investigation, has significantly increased uncertainty in the results. Just one building having much higher added costs can very easily influence an average of a sample of only 31 buildings. Thus to make any real conclusions about the added costs in office buildings specifically further investigations need to be conducted.

2.2.3 Costs of certification

It should be noted that the estimates on added costs above are all for LEED rated buildings, thus they include costs related to certification, which are not necessarily related to the building being green. In order to really assess what building green costs, the cost of certification should be subtracted from the numbers above. However, it has been chosen to base this study on results for LEED rated buildings and therefore the added costs must be the total added costs for LEED rated buildings including costs of certification. The benefits that are reviewed can also be partly correlated to the actual certification and the certification process. For example the cost of commissioning will be included in the costs estimates above, but commissioning is also found to be positively correlated to many of the benefits investigated in the following chapters.

2.3 Assessing the Danish potential

Building regulations in Denmark demand greater energy efficiency than American standards, see Chapter 3. Buildings in compliance with danish standards is estimated to use about half the energy of a building in compliance with American requirements. Therefore the measures that have to be taken to save additional energy in Denmark might be more expensive, as indicated above. It has been found that added costs where higher when energy savings were above 50%, which is almost where energy savings start in Denmark relative to the United States.

Furthermore certified buildings in Denmark will be first generation, thus costs might be slightly higher in Denmark at first and then decrease a bit again as experience with building green grows. Since it was concluded above that added costs are correlated with experience.

2.4 Preliminary Conclusion

Just as costs for conventional buildings can vary greatly it has been found that the costs of green buildings vary greatly. There are low-cost green buildings as well as high-cost green buildings. The added costs depend on the solutions that are chosen for the individual building.

On average the added costs of building green are found to be 1.5% in the United States. The studies that were reviewed could not establish a general relationship between the level of LEED rating and the added costs of building green. However, it was concluded that green buildings that registered energy savings of more than 50% had a higher added cost - on average 4%.

Further analysis for office buildings specifically indicate that the correlation between LEED rating and added costs and that added costs might be slightly higher for green office buildings than for green buildings in general. This is based on a much smaller sample and results are more uncertain, therefore this will have to be investigated further in order to establish whether this is actually the case.

It has been chosen not to corrigate the added costs for the cost of certification, since these costs will be difficult to quantify. Furthermore it has been chosen to define sustainable buildings as LEED rated buildings in connection with this thesis and thus the costs of certification must be counted. The actual certification and the certification process might also influence the subsequent benefits, which are sought quantified in the following.

The added costs for building green in Denmark will be higher than in the United States, because requirements for energy efficiency in general are currently higher in Denmark and thus additional savings must be achieved through more expensive measures. It is estimated that the average added costs are about the same as for American office buildings with energy savings of more than 50%. Therefore added costs are estimated to be 4%.

The added costs might be even higher at first, while experience with building green is achieved, but will decrease as experience grows. As energy efficiency already seem to be greater in Denmark it is estimated that some experience is already present in Denmark, within some of the areas of building green, and thus this difference will not be great. Furthermore this effect will decrease over time, therefore it has been chosen not to include this aspect in the estimate for added costs in Danish green office buildings.

3. Energy Consumption

This chapter is primarily based on 'Costs and Financial Benefits of Green Buildings - A Report to California's Sustainable Building Task Force' [14], 'Green Building Costs and Financial Benefits' [15] and 'Greening our built world' [16].

Reducing energy consumption has gone from being a "good idea" to a business necessity [13]. 73% of corporate leaders state increased energy costs as a motivator behind building green. High energy prices, worsening electric grid constraints, with associated power quality and availability problems and a general desire to reduce energy consumption are compelling arguments for building green. [18]

Energy efficiency is the single largest LEED rating cate-gory and represents 27% of the total points available in the LEED rating system. Energy consumption represents 30% of a typical commercial office building's operating costs and the fact that energy reductions are fairly easy to benchmark, measure and track over time, makes savings due to decreased energy consumption easily comprehensible to most building owners [22].

3.1 Review and Analysis

Kats study from 2003, concluded that green buildings, when compared to conventional buildings,

• were 30% more energy efficient on average compared to ASHRAE standards
• were characterised by even lower peak electricity consumption - average peak reduction about 40%
• were more likely to generate renewable energy on site - 2% of energy was generated on-site on average (the large majority of green buildings did not have on-site generation and the 2% on-site generation average reflected significant on-site generation from a few green buildings)
• were more likely to purchase grid power generated from renewable energy sources - for 21 buildings for which USGBC had collected data 6% of the electricity purchased was green. Thus the average green building's consumption of conventional energy was actually about 36% lower than conventional buildings on average.

Furthermore Kats found indications that energy efficiency increased with the level of LEED rating. Though a direct correlation could not be found in his data, reviewed analysis indicated that LEED Gold buildings were generally the most energy efficient and LEED Certified buildings the least efficient.

In his 2010 study Kats found reductions in energy use ranging from less than 10% to more than 100% (buildings that actually generated more energy than they consumed - for example by employing photovoltaics). This survey showed an average reduction in energy use of 34% compared to ASHRAE 90.1 standard - a slight increase from the 2003 numbers. Furthermore Kats noted in this study that generally reductions of 20% to 50% can be achieved through measures such as proper building orientation, cool roofs, highly insulated walls and roofs, daylight harvesting and the use of efficient lighting, heating, cooling, hot-water and ventilation systems. Whereas energy savings above 50% require new or innovative technology and is commonly costly, as mentioned in Chapter 2.

A USGBC study furthermore found that the level of energy savings increased, as the level of LEED rating increased. Average projected reductions were 23% for LEED Certified buildings, 31% for LEED Silver buildings, 40% for LEED Gold and 50 % for LEED Platinum. Thus confirming indications found in Kats 2003 study.

3.1.1 Office Buildings

Isolating data for new construction office buildings from Kats 2010 dataset, see Section 1.2.1, the average reduction in energy consumption was found to be 36%, which is not very different from the result for the complete dataset. Furthermore the correlation between reductions in energy consumption and LEED rating was investigated and it was found that reductions in energy consumption were greater the higher the LEED rating. LEED Certified office buildings showed 25% savings on average, LEED Silver 27%, LEED Gold 35% and LEED Platinum 59%. Thus confirming this correlation once again. It might be worth noting that a great increase in energy savings where found when going from LEED Gold to LEED Platinum rated buildings. However, this has not been further investigated.

3.1.2 Indirect Savings

However, average reductions in electricity peak consumption in green buildings are found to be even higher than the general average reduction. Kats give a preliminary estimate of an additional 10% reduction in energy consumption at peak demand. This could for example be achieved by including photovoltaics in the building design, which generate electricity at the time of peak power usage and consequently contributes to peak demand reductions. Thus at peak demand, when energy costs are greatest, and energy use in office building is typically greatest, reductions in energy consumption in green buildings are also greatest - adding to the financial benefits of energy use reductions.

The value of peak reduction is not just in avoided purchase of costly electricity, but also in avoided capacity, transmission and distribution costs. Generally capacity problems occur at peak demand, thus if peak demand is reduced, needed capacity is also reduced. If peak demand in general can be decreased through building green, capital investment to expand energy generation and infrastructure for transmission and distribution of electricity can be avoided.

"[...] *the link between projected electricity demand growth and approval of costly new power lines highlights the potential value of green buildings in reducing or even eliminating the large capital costs of line expansion.*"
- Gregory Kats, 2003, [14, p. 27]

In general substantial reductions in energy demand can be expected to drive down energy prices - thus one single green building will not have much impact in this regard, but as the amount of green buildings increase, this can have a significant effect. American surveys have shown that a 1% decrease in demand can cause price reductions of 0.8%-2%. Thus as the amount of green buildings increase financial benefits will be even greater to the individual building owner as well. However, future energy prices are very difficult to estimate and greatly influenced by politics - therefore assumptions regarding price changes in the future will always be connected with some uncertainty.

In his publication Kats estimates indirect savings connected to energy consumption to be about 25% of direct savings in energy consumption, which, according to Kats, is probably even a conservative estimate.

3.1.3 Summary
Reductions in energy consumption in green buildings can vary between 10% and more than 100%. However, savings above 50% seem to result in greater added costs. The average projected reductions in energy consumption for green buildings in general was found to be 34%, which is also found to be representative for office buildings specifically.

The surveys above indicate that energy savings increases with level of LEED rating. Reductions of 23%-25% were found for Certified buildings, 27-31% for LEED Silver, 35-40% for LEED Gold and 50-59% for LEED Platinum. Some results are based on benchmark comparisons, whereas others were set against national ASHRAE standards. Comparison showed that the difference between the two results was not great. Therefore the difference between the two will not be further evaluated.

The value of reductions in energy conumption in green buildings include both lowered energy costs and some value of peak demand reduction.

3.2 Assessing the Danish Potential

The question now remains whether similar energy reductions can be achieved in Denmark. In order to assess the potential of obtaining similar results in Denmark, differences in climate, energy consumption and building regulations in the two countries are reflected upon in the following. Reflections are based on information on the subjects, which can be found in Appendices 'B. Climate', 'C. Consumption' and 'D. Building Regulations'

3.2.1 Climate
The Danish climate does not vary greatly over the year. Therefore the Danish building stock does not need to compensate great differences in temperature. Many regions in the United States experience much greater variations over the year and thus buildings in such areas must be equipped to compensate a much wider temperature variation by either heating or cooling. In Denmark the temperature varied 43.7ºC over the year in 2011, whereas in the United States the temperature varied approximately 83ºC in some areas and 43ºC in others areas in 2011 (estimated from climate maps on temperature

extreames). This means that buildings in Denmark can generally manage with much smaller systems for heating and cooling than American buildings.

Furthermore, extremes that can be found in the United States spans a much greater temperature scale than in Denmark. In the United States some areas experience extreme lows down to -42.2^{o}C while in other areas the temperature never falls below 10.5^{o}C. Likewise some areas in the United States experience extreme highs of up to 46.7^{o}C while others never reach temperatures of more than 21.7^{o}C. This means that some buildings must deal with extremely low temperatures, consequently having a very high energy consumption for heating, while other buildings must deal with very high temperatures, consequently haveing a high energy consumption for cooling. Over the entire American building stock the need for space conditioning will probably vary greatly.

The greater variations in temperature that needs to be addressed by American buildings both within the entire building stock and in individual buildings indicate that the average need for space conditioning in American buildings will be greater than in Denmark.

More detailed information with regards to heating and cooling needs could probably be derived through analysis of regional degree-days. However this would demand a much more extensive amount of data and much more detailed analysis, which does not fall within the scope of this thesis.

A very general comparison of national averages of hours of sunshine give a very limited ground for comparison in lighting needs for the two countries. In America the national average of hours of sunshine is 2600 and in Denmark the average is only 1495. This means that in general it should be expected that the need for lighting in Denmark is greater than in America. The hours of sunshine are spread more evenly over the year in the United States than they are in Denmark, because the United States in general are closer to the equator. In Denmark 2/3 of the hours of sunshine occur in the six months from April to September, whereas in the United States the variation is slightly smaller and 60% of the hours of sunshine occur from April to September. Again this indicates a greater need for lighting in Denmark, because the uneven distribution will mean that more hours of sunlight can fall outside office hours.

3.2.2 Consumption

The average energy consumption in a Danish office building is 140 kWh/m^2/year. In American office buildings the average energy consumption is 252 kWh/m^2/year. This average probably covers a much wider spread than the Danish average, as mentioned above. The American average is based on 2006 numbers, whereas the Danish average is based on 2010 numbers. That means that really the two averages are not ideally comparable. Energy consumption has generally risen steadily over the years. Therefore the 2006 average for energy use in American office buildings might be slightly less than the actual average consumption in American office buildings today. However, energy awareness has also increased significantly and thus the average might have been unchanged or even a bit high. For the purpose of this thesis it is deemed accurate enough for comparison, since the purpose is not to conclude exact figures but to distinguish probable indications of costs and benefits that can be achieved in Danish green buildings. For now it is established that the average energy consumption in Danish office buildings is only 56% of the average energy consumption in American office buildings.

In American office buildings space conditioning (heating and cooling) represent 70% of the total energy consumption, in Danish office buildings only 40% of the total energy consumption is used for space conditioning. If the amount of energy used for space conditioning is subtracted, from the average energy consumptions mentioned above, the energy consumption in American office buildings is 76 kWh/m2/year and in Danish office buildings it is 84 kWh/m2/year. Thus if the energy used for space conditioning is left out of account the average energy consumption in Danish and American office buildings is not very different.

In Danish office buildings office equipment represents 50% of the total energy consumption on average. In American office buildings only 20% of the total energy consumption is used for powering office equipment. This corresponds to an average energy consumption by office equipment of 70 kWh/m^2/year in Danish office buildings, compared to 50 kWh/m^2/year in American office buildings.

Lighting represents 10% of the total energy consumption (in Danish office buildings), whereas for American office buildings lighting represents 17% of the total energy consumption. This corresponds to 14 kWh/m^2/year for Danish office buildings and 43 kWh/m^2/year for American office buildings - approximately three times as much as in Denmark. Given that the United States have many more hours of sunshine per year and that these are spread more evenly over the year, meaning that a greater part of these sunshine hours will fall within office hours, the lighting requirements in the United States would be assumed to be much smaller. This difference might be influenced by demands in Denmark for daylight at permanent workstations. To the knowledge of the author similar demands does not exist in the United States. Thus buildings in the United States might be much deeper and require electrical lighting in a much greater part of the building, where no daylight is available.

3.2.3 Regulations

American regulations varies between the states but is generally based on the same standards - ASHRAE 90.1 or IECC. Compliance with ASHREA 90.1 also ensures compliance with IECC, therefore the following will only take into account the ASHRAE standard.

ASHRAE 90.1 does not give an overall energy performance framework, but set requirements for various building features. However, investigation has shown that office buildings in compliance with ASHRAE 90.1 use between 123 kW h/m^2 /year and 142 kW h/m^2 /year on average - dependent on the size of the building.

Using an average to describe energy consumption in accordance with building regulations is not ideal, since regulations set requirements for maximum energy consumption. Some buildings will have even lower energy consumption than what is required through regulations and some will have close to the maximum, but none should be above the maximum. This means that an average will actually indicate values lower than what regulations require.

The Danish building code BR10 give specific frameworks for energy performance which varies between 71.3 kWh/m^2/year for large offices and 87.8 kWh/m^2 / year for small offices (assuming a small office building corresponds to a 100m2 office building). However, these numbers cannot be compared directly to the averages given above. First of all; Danish building regulations does not include energy used for office equipment like computers, copiers, coffee etc., because these are not a permanent part of the building. As mentioned earlier office equipment represent 50% of energy consumption in Danish office buildings. Secondly; Danish building regulations do not just set requirements for total energy consumption but also weight the energy consumption after the amount of CO_2 this causes. For example electricity is weighted a factor 2.5 due to the high environmental impact of electricity supply. 79% of energy consumption in a typical new office building in Denmark is electricity.

In order to have comparable values, energy consumption for office buildings meeting the requirements of Danish building regulations have been calculated. Maximum energy consumption for Danish office buildings in compliance with building regulations was estimated to be between 76 kWh/m^2/year and 94 kWh/m^2/year, see Appendix D for calculations. However these values might be to low as well. Danish building regulations subtract sustainable energy when calculating the energy performance. So depending on the amount of sustainable energy used in Danish office buildings the values above should be somewhat higher.

None of the values above are very specific and both Danish and American estimates seem to be a bit to the low side - but what is evident is that Danish regulations are stricter than American regulations. The maximum energy consumption in Danish buildings in compliance with national regulations is about 2/3 of the average energy consumption in American buildings in compliance with regulations. Since averages and maximum values cannot really be compared it is estimated that buildings in compliance with Danish building regulations use about half the energy of an American building in compliance with American regulations.

3.3 Preliminary Conclusion

Climate comparison suggest a greater need for space conditioning in the United States which is corroborated by analysis of energy consumption in office buildings in the two countries. However, climate data also suggest a greater need for lighting in Denmark, but the energy use for lighting in Denmark is only approximately one third of the energy use in the United States. It seems that both within space conditioning and lighting the potential for reductions is greater in the United States compared to the average energy consumption in office buildings in the two countries.

Both average energy consumption and requirements for energy consumption in office buildings in the United States are almost twice as high as in Denmark. Therefore it is concluded that green office buildings in Denmark are not likely to achieve the same average energy reductions as in the United States. However, estimating the potential reductions in energy consumption in Danish office buildings compared to the reductions achieved in the United States is difficult. It is estimated that the potential relative savings in Denmark will be about half of the savings found in the United States - which correlates to a relative reduction in energy consumption of 17%. Furthermore it was found that in the United States indirect savings due to reductions in energy consumption could be estimated at about 25% of direct savings. However these savings seem more uncertain and thus will be calculated separately, as potential added savings.

4. Water

This chapter is primarily based on 'Costs and Financial Benefits of Green Buildings - A Report to California's Sustainable Building' [14], 'Green Building Costs and Financial Benefits' [15] and 'Greening our built world' [16].

Water efficiency and conservation are rapidly becoming major concerns on the global agenda. The need for capital-intensive expansions and renovations of water systems, increased population in regions with limited water supplies, and the increasing cost of energy used to treat and transport water is causing water rates to increase globally - at rates, which are well above inflation.

Up until 2009 water efficiency was not given much priority in the LEED rating scheme. Categories such as energy and atmosphere and indoor environmental quality received substantially higher point allocation. However, the increasingly recognised importance of water efficiency has led to significant changes and additions in the 2009 version of LEED. For the first time there is a prerequisite for water use reductions, and point allocation towards water efficiency measures is increased. [19]

4.1 Review and Analysis

Kats 2003 study found that of 21 reviewed green buildings submitted to the USGBC for LEED certification all but one used water efficient landscaping, cutting outdoor water use by at least 50%. Seventeen buildings, or 81%, used no potable water for landscaping at all and over half cut water use inside buildings by at least 30%. So even though water efficiency measures were not yet a pre-requisite, measures for water efficiency were still taken, to some extent.

In Kats 2010 survey 119 of 170 buildings reported or projected reductions in indoor potable water use of between 0% and 80% with an average of 39% compared to conventional buildings. Where rainwater or recycled wastewater was used in place of potable water for irrigation or toilet flushing, this was included in the water-reduction. In general water savings were found to increase with LEED rating level. Average water savings were 21% for LEED Certified buildings, 36% for LEED Silver, 39% for LEED Gold and 55% for LEED Platinum. Registrations by USGBC show that roughly 60% of LEED rated new construction buildings use no potable water for irrigation.

4.1.1 Office Buildings

Isolating data for office buildings from Kats 2010 data, see Section 1.2.1, shows an average reduction in water consumption of 40%. The connection between LEED rating and water savings is not clear from the isolated data, but this is put down to the fact that the data set is so small, so that just one LEED Silver building with a large percentage of water savings and one LEED Gold building, with no savings, can greatly influence the average. However, LEED Platinum rated buildings show significantly higher reductions in water consumption than the rest.

It was observed that there seem to be a correlation between energy savings and water savings. Buildings with energy savings of less than 50% showed an average reduction in water consumption of 35% on average, whereas buildings with energy savings of more than 50% showed water use reductions of 53% on average. Whether this is solely due to the fact that decreased water consumption also cause decrease in energy used to treat, convey, heat and pump the water or it is because the improvements in energy and water consumption are both influenced by the level of LEED rating - so that a high LEED rating command both high reductions in water and energy consumption - has not been investigated further.

Furthermore a correlation between added costs and reductions in water use was investigated, but a clear connection could not be found within this limited dataset.

4.1.2 Indirect Water Savings

With water savings as with energy savings there are direct and indirect financial benefits. The direct financial benefits stem from reduced charges for the provision of water and the treatment of wastewater.

Indirect benefits can be reductions in infrastructure costs, reductions in energy used to treat, convey, pump and heat water and reductions in water-rates due to an overall decrease in demand - as for electricity rates, as mentioned in Chapter 3.

Industry investigations by McGraw-Hill reveal expectations of water efficiency decreasing energy use by 10-11% [18]. However, according to Kats only about 4% of electricity used annually in the United States is used for water and wastewater conveyance and treatment, so this seems a bit optimistic. Thus it is simply concluded that water-use reductions can also lead to energy use reductions.

Furthermore as average water consumption is decreased in general, by an increasing population of green buildings, needs for expansion of public infrastructure can be expected to decrease and thus expected increases in water rates will decrease.

4.1.3 Summary

The effort to reduce water consumption in LEED rated buildings has increased significantly over the years.

On average a reduction in indoor use of potable water of 39% was found for green buildings and roughly 60% of LEED rated buildings use no potable water for outdoor irrigation. An average reduction in outdoor use of potable water has not been investigated. Furthermore a clear correlation can be found between LEED rating and water use reductions.

The results above are also found to be representative for office buildings specifically.

Finally water savings are likely to have indirect benefits in the form of energy savings and some influence on future water rates as well.

4.2 Assessing the Danish Potential

The question now remains whether similar water reductions can be achieved in Denmark. In order to assess the potential of obtaining similar results in Denmark, differences in climate, water consumption and building regulations in the two countries are reflected upon in the following. Reflections are based on the information on the subjects, which can be found in Appendices 'B. Climate' and 'C. Consumption'.

4.2.1 Climate

More than half of the United States experience less precipitation than Denmark. Some areas get more than twice the amount and some less than one 10th. This could mean that in some areas of America measures have to be taken to accommodate large amounts of rainfall over the year and rainwater collection might be very attractive. In other areas the limited amount of precipitation might cause water scarcity and on top of that an increased need for irrigation, thus reductions in water consumption in these parts will be very advantageous. In Denmark precipitation is fairly even over the country and in general water scarcity does not seem to be a threat.

The variation in precipitation over the year in the two countries has not been investigated in detail, but this could yield further useful information. It makes a big difference whether precipitation is generally spread evenly over the year or all rain falls within one month each year. In Denmark there is not much variation in precipitation over the year. Variation in precipitation over the year in the United States varies between the regions. Climate data for two American cities has been compared as an example. New York from the east coast and Los Angeles from the west coast. In New York precipitation does not vary greatly over the year, whereas great seasonal variations in precipitation is found in Los Angeles - where July is completely dry and almost no rain falls between may and august in general (total precipitation is 9 mm in those four months out of 308 mm annually). Variations over the year in the national average in the United States are not great.

A large part of the United States have average temperatures well above Danish average temperatures - in some areas the average temperature almost corresponds to the Danish maximum temperature. In Denmark there is not generally a great need for cooling, whereas this need is great in some areas of the United States, thus the need for cooling is likely to be higher in the United States on average and consequently water use for cooling will also be higher. However this extent is very difficult to estimate based on overall observations.

4.2.2 Consumption

The average water consumption in Danish office buildings is 0.28 m^3/m^2/year. In the United States the average water consumption in office buildings is 1.97 m^3/m^2/year - 7 times higher. Out of these 1.97 m^3/m^2/year, 38% is used for outdoor landscape irrigation. Unfortunately no information has been found on the end use of water in Denmark. However, it is assumed that the amount of water used for irrigation in Denmark is very small and can be disregarded for now. Thus if we subtract 38% from the American water consumption, to make the numbers more comparable, this is now down to 1.22 m^3/m^2/year - still more than 4 times the consumption found in a Danish office building.

When reducing the consumption of indoor potable water in American office buildings by an average of 39%, water consumption is still more than twice the total consumption found in Danish office buildings on average. This indicates that conventional Danish office buildings already feature many of the water saving features that are implemented in American green buildings. For example; in Denmark it is standard to install toilets with “double-flush” function. Therefore water savings of the same magnitude cannot be expected in Denmark.

In the United States a 39% reduction in the use of indoor potable water corresponds to a reduction of 0.48 m^3/m^2/year, which is more than the total water consumption in a conventional Danish office building. If the same relative reduction was achieved in Denmark the reduction would be 0.11 m^3/m^2/year - just more than one 5th of the amount of water saved in American office buldings.

In order to further evaluate water consumption and potential reductions in the two countries more data is needed. The distribution of water end-use in Denmark could tell if the distributions in the two countries are similar.

23% of water consumption in an American office building is used for cooling. In general there is a widespread perception in Denmark, that the United States use air conditioning excessively, but how great a part of water consumption in Danish office buildings is used for cooling? Is it really much less? Furthermore, no data on how savings are achieved in the buildings included in the American surveys. Are savings largely due to a decreased need for cooling in American green buildings or can it simply be put down to opting for water saving fixtures? In order to really assess the potential in Danish green buildings this information is needed.

4.2.3 Building standards and certification requirements

Requirements for certification of a Danish building will not be the same as for an American office building. Certification schemes must be adapted to national standards in order to have any meaning. The purpose of certification is always to achieve improvements compared to the norm. So if, for example, water saving features are already the norm in Denmark, points awarded for this in connection with certification will not make sense. Then requirements or the allocation of points might be for rainwater collection instead. A comparison between national standards and certification schemes in such detail will be very comprehensive and is not possible within the timeframe for this thesis, but such comparisons could yield valuable information for comparison and estimating potential savings in Denmark based on reductions found in the United States.

4.3 Preliminary Conclusion

In Denmark precipitation is distributed fairly even over the country and over the year and in general water scarcity does not seem to be a threat. There is not a great need for cooling in Denmark and thus not a great water consumption in this regard.

It is assumed that irrigation for Danish office building is so small, that it can be disregarded. Whereas irrigation counts for 38% of water consumption in American office buildings. Therefore the potential for reductions in the water used for irrigation is far greater in the United States.

On average the water consumption in Danish office buildings is only about 1/8 of the water consumption of an American office buildings. Therefore it is assessed that in the general potential reductions in water consumption in Denmark are very small compared to the reductions found in the United States. Some reduction might be achieved through collection of rainwater, which would potentially reduce water consumption.

Measures to reduce run-of from the property might be advantageous as a means of avoiding otherwise necessary upgrading of infrastructure. However there is no direct financial gain in this for the individual building owner under current conditions. Diversion of water is paid through water rates for the water that is consumed, not according to the amount of water that is actually diverted by the building. (Some discount can be achieved, if it can be documented that water is not discharged into the sewer system). The potential reductions in water consumption in Danish office buildings are deemed to be very small and thus no reductions will be included for further calculations. This will be a conservative estimate - but even the slight reductions that might be achieved through rainwater harvesting is assumed to have little effect on the bottom line.

5. Productivity & Health

Financial benefits of green buildings have generally-been related to lower operational costs - especially energysavings. However, it is increasingly recognised that the human costs are much greater than operating costs and that this is reflected in a relatively large impact of productivity and health gains on the company bottom line. [24]

People in Northern Europe spend more than 90 per cent of their time indoors. Employed people spend anything from 20 to 60 hours per week in offices or factories of various kinds. It is estimated that productivity gains (or losses) of up to about 20% are attributable to the effects of buildings on their occupants, this assumption is mainly based on data from office buildings. [25]

Both productivity and health issues relate directly to worker well being and comfort and thus increased productivity is closely linked to improved worker health. Therefore these two issues are treated jointly in the following. [14]

Healthier buildings achieve increases in productivity and register reduced absenteeism in the form of sick days. The USGBC have found that LEED features affecting ventilation, temperature, lighting, acoustics, and the indoor environment in general are associated with both absenteeism and productivity. [13] There are thousands of studies, reports and articles on the subject of indoor environment that find significantly reduced illness symptoms, reduced absenteeism and increases in perceived productivity as a result of improved indoor environment [15].

5.1 Measuring Productivity

This section is primarily based on 'Creating the productive workplace' [25].

Productivity is a measure of the quality and quantity of accomplishments actually completed by an employee and is dependent on four cardinal factors: personal, social, organisational and environment.

Productivity can be dependent on a wide range of factors in a building - physical aspects such as thermal comfort, lighting and ventilation can all affect energy performance, but these can also highly influence occupant satisfaction and in this way productivity. [8]

„[...] healthier buildings are also more productive ones. The human environments that architects create influence health - both physical and psychological. [...] Buildings can lead to stress or relieve it; buildings can cause cancer or help prolong life.“

Brian Edwards, 2010, [2, p. 164]

A healthy, natural and stimulating workplace will lead to less staff absenteeism, to greater personal wellbeing and to increased commitment to the company that provides the building.

Brian Edwards, 2006, [23, p. 202-203]

Linkages between buildings and occupant health and productivity are complex. Assessing the effect of green buildings on productivity is complicated by the fact that the building is only one of the factors affecting employee productivity, which makes distinguishing the cause of productivity gains difficult. There are so many interdependencies and also much is psychologically determined. Furthermore each building has a different set of technologies and design attributes, and each building population has different health attributes and comfort needs. Thus health and productivity impacts are inherently more difficult to measure than for example energy and water consumption, and would be expected to vary not only with building characteristics, but also with the characteristics of the populations using the buildings, the company culture, and the activities performed in the building. [16] [14]

Productivity can be either measured or subjectively estimated:

• Measured values includes sales, profits, the number of errors per hour or actual time at work.
• Subjective values include personal evaluation of productivity, benchmarked satisfaction of either employees or customers.

Regardless of the method measuring and reporting productivity is difficult. Studies of individual occupants often miss out the wider context of physical and locational differences between buildings, and how they are managed and operated. Buildings and occupying organisations are rarely similar. And it is almost impossible to really measure productivity objectively - results are mostly based on subjective responses or samples of occupants drawn from cross sections of users. And this all complicates investigating productivity.

Furthermore one has to be aware that results might be influenced by the simple fact that investigation is conducted. In a study investigating the correlation between productivity and illumination it was found that workers productivity increased whether illumination was decreased or increased. Thus it was concluded that the simple fact that the company was taking an interest in their working conditions resulted in increased motivation. This is known as the Hawthorne effect.

„In buildings people are the best measuring instruments: they are just harder to calibrate"
- Raw and Aizlewood, 1996, [25,p. 154].

There are many factors one must be aware of when measuring productivity and health (the implications when investigating health effects are fundamentally the same as for productivity). Current research suggests that green buildings improve indoor environments, but generally does not indicate the magnitude of impacts [16].

Studies simply comparing a sample of green buildings to a population of conventional buildings will have difficulties distinguishing the exact cause of productivity and/or health benefits that might be found. Productivity benefits measured this way may also be influenced by other factors such as for example the social environment - either positively or negatively. Therefore factors not related to the building can greatly influence these results.

Measuring the before and after for a population of workers moving from a conventional building to a green building might eliminate some of these uncertainties, but still there are other aspects to consider - such as the *Hawthorne effect*, for example.

A different approach is to investigate the individual attributes associated with green buildings and estimate results based on this research, which then is not necessarily based on research of green buildings. An example could be to estimate productivity improvements in green buildings based on laboratory results investigating the correlation between improved indoor air quality and productivity and similar studies investigating attributes associated with green buildings, which might influence productivity in the building.

Since there are no uniform methods for linking productivity to indoor environment qualities, assumptions are often based on conservative estimates. In the following a review of literature on the subject is summarised.

5.2 Review and Analysis

This section is primarily based on 'Costs and Financial Benefits of Green Buildings - A Report to California's Sustainable Building' [14], 'Green Building Costs and Financial Benefits' [15] and 'Greening our built world' [16].

In 2009 CBRE, the world's largest commercial real estate services firm (in terms of 2011 revenue), conducted a survey among 500 tenants, who had moved into either LEED or ENERGY Star labelled buildings to establish perceived productivity benefits from these buildings. They found an average perceived increase in productivity of 4.88%, with slightly better results for the LEED rated buildings alone at 5.24% perceived increased productivity on average. This difference was not investigated further, but it does hint that the benefits which LEED represents, that go beyond energy savings alone, makes a positive difference. It should be noted that 45% of respondents suggested no change in productivity, thus the averages above must really be an expression on some tenants having reported perceived productivity increases well above the average found in this study. Furthermore this study found that tenants reported 2.88 days lower sick leave in LEED and ENERGY Star buildings on average. When asked 45% agreed that workers had fewer sick days since moving, 45% found that it was the same as before, while 10% found an increase in sick days. These 10% were actually tenants of ENERGY Star rated buildings. None of the tenants of LEED rated buildings reported increases in sick leave. [26] [18]

In his studies Kats used a different approach. Kats received very little data concerning health and productivity - despite the fact that the buildings in the data set undertook a range of measures to improve indoor environment. Thus he was not able to analyse productivity and health benefits from his own datasets and instead based the evaluations of this issue on reviews of other studies. The studies that Kats reviewed did not specifically document impacts in green buildings, but the attributes that were addressed were those common to green buildings.

Four of the attributes associated with green building design have been positively and significantly correlated with increased productivity through varies studies:

• Increased ventilation control,
• Increased temperature control,
• Increased lighting control
• Increased daylighting

The effect of these various attributes on productivity have been investigated in various surveys and show improvement in productivity, which suggest that green buildings in general will have a positive effect on productivity through these attributes.

In his 2003 study Kats found that on average productivity increased by

• 7.1% with increased lighting control
• 1.8% with increased ventilation control
• 1.2% with increased thermal control

Furthermore he concluded that significant measured improvements had been found with increased daylighting, but gave no estimate as to the productivity increase this would yield.

Based on these findings, and an extensive review of additional studies, Kats recommended attributing a 1% productivity and health gain to LEED Certified and LEED Silver rated buildings and a 1.5% gain to LEED Gold and LEED Platinum rated buildings. These percentages were found at the low end of the range of productivity gains and were consistent with or well below the range of additional studies reviewed by Kats. LEED Gold and LEED Platinum rated buildings were viewed as providing larger productivity and health benefits than LEED Certified or LEED Silver rated buildings, because they were thought to be more comprehensive in applying measures related to indoor environment quality.

In his 2010 study Kats found average productivity improvements of:

• 3.3% with improved indoor air quality
• 5.5% with improved temperature control
• 3.2% with high performance lighting systems

He doesn't recommend a specific percentage to ascribe for productivity gains in this case, but simply calculates a couple of scenarios. However, when he calculates the effect of just 0.5% productivity improvement he does comment that just through improved indoor air quality alone productivity increase is 3.3%. Looking at the results from this study, and the basis for the increases recommended in his 2003 study, a 3% improvement in productivity for LEED Certified and LEED Silver rated buildings is estimated and a 3.5% productivity improv ment for LEED Gold and LEED Platinum rated buildings.

5.2.1 England and Australia

In England productivity improvements in a green office building, the Barclaycard Building, was investigated. Monitoring by the company suggested that staff productivity in the building was 2-3% above that of its comparable air-conditioned offices. Increases of 2-3% in productivity have been recorded in various studies of green offices in England, according to Brian Edwards - author of several books on the subject of building green. [23]

In Australia a fairly recent study from a law firm tracked the before and after sick days after a move to a Green Star Five-rated building (a high rating within Green Star) and found sick days reduced by 39% overall, to 0.28 days per month. [26] This corresponds to sick days having been reduced by 0.18 days per month or 2.15 days a year on average.

5.2.2 Summary

The CBRE study found increases in perceived productivity of approximately 5% among tenants just having moved into LEED rated buildings. Kats first study recommends attributing a 1%-1.5% increase in productivity and health. However, his later study seem to indicate that greater attributes could easily be attributed. Assessing average increases from attributes associated with green buildings he found increases of between 3.2% and 5.5% in productivity from individual attributes associated with green buildings. A conservative estimate, based on these findings, seem to be around 3%. Furthermore several studies from England have found increases in productivity of 2-3%.

Kats did not measure health separately. Consequently data in this regard is more limited. CBRE found that workers had 2.88 fewer sick days a year on average and an Australian study found a decrease in sick days a year of 2.15 days on average. The CBRE study further found that the average covered some spread in that only about half the tenants reported a decrease in sick days, and thus the ones that did report a decrease must have reported improvements even greater than the average.

None of the tenants that moved into LEED rated buildings reported an increase in sick days.

5.3 Assessing the Danish Potential

Since the same results have been found in the United Kingdom and the United States, both countries of fairly similar development and culture as Denmark, it is assumed that the same improvements can be achieved in Denmark. Results from the reviewed studies are based on conservative estimates, thus even if the potential in Denmark should be slightly smaller than for the United States and the United Kingdom, it still seems to be a probable estimate.

5.4 Preliminary Conclusion

The increases in productivity of 2-3% found in England also seem to be a good median for the results found in American literature. This will be the estimate used for potential productivity improvements.

Furthermore a conservative estimate seem to be that health improvements in green buildings result in a decrease in sick days of about 2 days a year on average.

6. Value and Rent

This chapter is primarily based on 'Greening our built world' [16].

Analysis suggests that building green has a positive impact on building value, rent and occupancy. And moreover this impact seem to go beyond what would be expected from energy savings alone - and beyond what was anticipated by industry opinion surveys.

6.1 Building value

Industry opinion surveys among architects, owners, engineers and contractors, conducted by McGraw-Hill, found that respondents expected a 10.9% increase in property value for green buildings compared to conventional buildings.

This expected increase seems to be supported by surveys of actual increases in property values for green buildings. A 2008 CoStar analysis found an average increase in property value of 9% for LEED rated buildings, using a statistical model to remove the effects of age, location, size, and other factors on the variations in property values. Actual sales prices for these LEED rated buildings could not be judged, since there was a limited number of sales transactions available. Furthermore this analysis found a much higher increase in property value for LEED rated buildings than for ENERGY Star Buildings (for which building value increases were also evaluated) indicating that consumers place substantial value in the many benefits LEED represents, that go beyond energy savings alone.

A financial analysis of commercial real estate found increases in sales prices for buildings certified as energy efficient of 8%-26% depending on the market [20]. Considering the fact that consumers seem to value sustainable buildings even higher than simply energy efficient buildings, it might be expected that increases in sales prices for green buildings will be at the higher end of this range.

6.1.1 Indirect Benefits

As environmental standards rise it seems likely that green buildings will retain their value better than conventional buildings [6]. Thus green buildings will not only have a higher value at the time of completion, but as conventional buildings might lose in value over time the relative increase in value for green buildings compared to conventional buildings will increase.

6.2 Rent

Increases in rents found in different surveys vary greatly. The McGraw Hill Green Outlook Report for 2011 found rent increases, reported by owners, of 6.1% on average for new green buildings compared to conventional buildings [18].

A 2008 CoStar analysis found an increase in rent of 35% for LEED rated buildings and 11% for ENERGY Star-buildings, which again suggest preference of sustainable buildings over simply energy efficient buildings.

A financial analysis within commercial real estate found that buildings certified as energy efficient command leasing premiums of 3% - 20%. Again it might be expected that sustainable buildings feature at the higher end of this scale, based on the indications from the CoStar analysis. [20]

6.2.1 Indirect Benefit

Not only do the rent rates increase, but also occupancy rates increase - further adding to the income potential from renting out green buildings. The McGraw Hill Green Outlook Report for 2011 found average occupancy increases reported by owners of 6.4% [18], which was slightly higher than results from the CoStar analysis that found an increase in occupancy rates of 5% on average, compared to conventional buildings.

6.3 Office Buildings

Unfortunately none of these values are available for office buildings specifically. However, for want of anything better, these results will be assumed representative for office buildings as well.

Both building value and rent rates are very dependent on supply and demand. What really determines how great the increase in building value and rent will be, is how much more people are willing to pay for green buildings - and how much they are able to pay. Office buildings are generally owned or rented commercially and a green building can have many benefits to a company residing in a green building, which will be further discussed in Chapter 7. Therefore office buildings compared to other building types should not command lower increases. However, this is merely speculation.

6.4 Assessing the Danish Potential

Since both building value and rent are dependent on supply and demand it becomes a question of economy and culture. Is awareness of sustainability greater or lower in Denmark? This is really what can affect these values. It is the willingness to pay for sustainability in buildings that decides the building sales price or value - as well as the rent. Denmark prides itself in being a pioneer within sustainability. If this is actually the case, increases of at least the same magnitude as in the United States should be achievable.

Whether the relative increases in value and rent compared to conventional buildings will be the result of a decrease in the value of conventional buildings or an increase in the value of sustainable buildings compared to conventional buildings is difficult to predict.

It is deemed that the tendency observed in the United States is also a probable estimate for Danish office buildings. However, the only way to really assess this parallel would be to investigate the general take on sustainable building among owners and tenants.

6.5 Preliminary Conclusion

An average increase in building value of 9% was found in the United States. Analysis within commercial real estate suggest that increases in sales prices might actually be even higher. Furthermore green buildings seem to retain their value better than conventional buildings.

Average rent increases of 6.1% and 35% were found for green buildings, however the 35% seem very high and might have been influenced by a few very high values. The increases found in the financial analysis of 3%-20% seem more realistic though these are not limited to sustainable buildings but also include simply energy efficient buildings. An average increase in rent rates of 15% for green buildings is estimated from this. Furthermore occupancy increases of 5%-6.4% were found, which will add to the potential income from green buildings.

The potential difference in American and Danish potential is difficult to assess. However it was found that the result above pose probable estimates for Danish green office buildings, though no actual data for office buildings specifically were available.

7. Intangibles

In the previous 5 chapters costs and benefits that have been fairly straightforward to asses relative to conventional buildings and which have been documented through several studies have been evaluated.

However, there seem to be a number of additional benefits, which are more difficult to quantify, and have not been as extensively investigated or documented. In the following these possible additional benefits will be discussed.

7.1 Operating Costs

Operating costs include costs of both energy and water consumption, which are some of the key aspects adressed in green buildings. Therefore these issues have been investigated as isolated subjects in Chapters 3 and 4. However operating costs also include maintenance.

Generally it seems that green buildings cost less to operate and maintain, this is what all investigation show. LEED Gold buildings have been shown to have 19% lower maintenance costs. [13] In McGraw Hills Green Outlook 2011, owners reported a decrease in operating costs of 13.6% for new construction [18].

7.2 Waste Reduction

This section is primarily based on 'Costs and Financial Benefits of Green Buildings - A Report to California's Sustainable Building' [14].

Green buildings promote waste reduction both at the time of construction and throughout the life of the building.

Construction waste reduction options include.
[14, p. 47]

- Reuse and minimization of construction and demolition (C&D) debris and diversion of C&D waste from landfills to recycling facilities.
- Source reduction, e.g., use of building materials that are more durable and easier to repair and maintain, design to generate less scrap material through dimensional planning, increased recycled content, use of reclaimed building materials, and use of structural materials in a dual role as finish material (e.g. stained concrete flooring, unfinished ceilings, etc.).
- Reuse of existing building structure and shell in renovation projects.

"For many in the construction and real estates industries, it is the value of keeping up - that is, reducing the risk of obsolescence in non-green buildings."

Gregory Kats, 2010, [16, p. 80].

"... the resulting building embodying green principles will inevitably influence the company that uses it. As a consequence the building leads to subtle changes in the culture of the company and the outlook of the workers."

Brian Edwards, 1998, [6, p. 6].

Building lifetime waste reduction includes [14,p. 48]:

• Development of indoor recycling program and space.
• Design for deconstruction.
• Design for flexibility through the use of moveable walls, raised floors, modular furniture, moveable task lighting and other reusable building components.

In his 2003 study Kats, in a review of 21 buildings submitted to the USGBC, found that 81% reduced construction waste by at least 50%, while 38% reduced construction waste by 75% or more.

In his 2010 study Kats found that green buildings diverted more than twice as much waste from construction and demolition through recycling or reuse than conventional buildings. On average he found that green buildings diverted 79% of C&D waste, it is estimated that 30% of C&D waste is diverted for recycling and reuse in the United States generally. [16]

Though it is clear that green buildings divert substantially higher levels of waste for reuse and recycling, and incorporate greater amounts of recycled or re-used materials than conventional buildings it is very difficult to estimate the relative total waste reduction compared to conventional buildings and research on the subject seem to be very limited.

In the absence of good data on present rates of waste diversion in green and conventional buildings during both construction and operation, it is impossible to quantify the relative advantages of either one.

Though benefits to the environment are obvious, waste diversion for reuse and recycling might not necessarily yield financial benefits for the individual building owner. Higher fees for recycling collection will probably result from the necessity to sort and collect different types of recycled waste. Additionally, hauling costs may be higher for recycling, because the waste must often be transported further in order to be processed. However a reduction in waste should yield some savings.

7.3 Attracting and Retaining Workforce

Attracting and retaining the best employees can be linked to the quality of benefits that workers receive - including the physical, environmental and technological workplace. - *Kats, 2003,* [15, p. 6]

Office workers expect a working environment, which is responsive to their needs at a personal level by giving them control over their workspace, while also expressing a concern for wider global problems in the values of the building. - Brian Edwards, 1998, [6, p. 4]

Green office buildings lead to enhanced levels of staff satisfaction and performance, which in turn leads to lower turnover of staff through greater job satisfaction, thus demonstrating increased recruitment and retention rates. [2] [13] The enhanced image, which flows from green building design, allows the company to attract and retain high calibre staff. [23]

Personal association to a company and the values it stand for can help attract and retain employees. In a survey amongst 500 tenants who had moved into either LEED or ENERGY Star labelled buildings 61% saw residing in a green building as a favourable amenity for attracting and retaining employees. Furthermore this survey found that advantages pointed out by tenants was higher employee morale (22%), lower employee turnover (19%) and easier recruitment of employees (22%). [26]

Gary Jay Saulson, the Senior VP and Director of Corporate Real Estate for PNC Realty Services, describes the benefits of the LEED Silver PNC Firstside Center building in Pittsburgh as follows: *"people want to work here, even to the point of seeking employment just to work in our building. Absenteeism has decreased, productivity has increased, recruitment is better and turnover less."* - Gary Jay Saulson, 2003, [14, p. 56] Two business units experienced 83% and 57% reductions in voluntary terminations respectively after moving into the new Firstside facility. [14]

Thus there is a clear indication that green office buildings can be a key factor in attracting a high calibre workforce and retaining this workforce.

When we met with the chairman of Bank of America, Ken Lewis, he told us he wanted a building that would be an icon for New York City, one that would help attract and retain the best employees. What better way to attract and retain employees than to create an exceptionally healthy working environment? Like other financial institutions, Bank of America wants to hire the overachievers, the best talent out there. We'll be able to help them do that, and show them productivity impacts as well.

- Robert F. Fox Jr., Partner, Cook + Fox Architects, 2010, [16,p. 32]

„Increasingly we believe that employees want an office that is healthy and respectful of the environment. This affects us in a very direct sense: we are able to attract talented people who want to be in this kind of environment. The money spent on a green building could be offset by one good hire."

- Tom Darden, Chief Executive Officer, Cherokee Investment Partners, 2010, [16,p. 79]

> [...] firms that have pursued sustainable practices tend also to outperform their competitors, although the casual direction of this relationship is ambiguous.
>
> - Conlon and Glavas, 2012, [20,p. 5].

7.4 Return On Investment - ROI

There are not many investigations into actually achieved increases in return on investment caused by building green. However, an industry survey conducted by McGraw-Hill has found an expected increase in ROI of 9.9% for new green buildings [18]. And in an internal investigation PNC, a large bank, found increased revenue in bank branches residing in LEED rated buildings, compared to branches in conventional buildings, even though these branches offered the same products and services [13].

Indication of correlation between company ethics and ROI seem to have been found in comparing Ethisphere Institues Worlds Most Ethical Companies Index and Standards & Poor's S&P 500 Index, see Figure 7.1.

However, the influence of building green on company ROI can be very difficult to distinguish. Many factors can influence a company's ROI. The results found by PNC seem to establish that there is a connection, which also seem to be widely recognised within the industry according to the McGraw-Hill survey mentioned above.

This is a subject that needs to be investigated further in order to be able to include this as a benefit in a cost benefit perspective. However, it is another benefit that should be considered, when considering the costs of building green, compared to the benefits this can trigger.

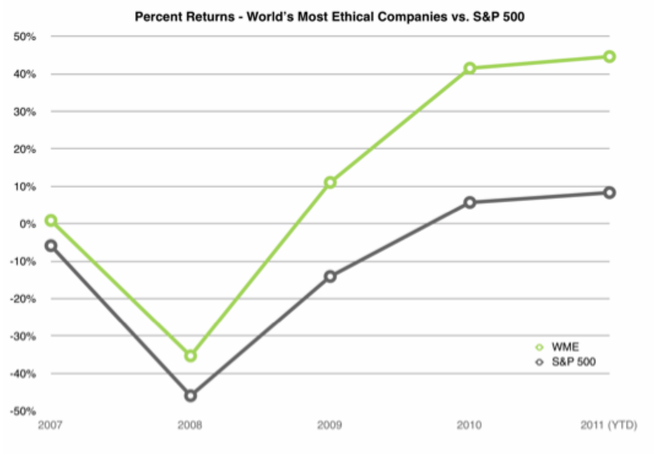


Figure 7.1: Percent returns - World's Most Ethical Companies vs. S&P 500. [27]

7.5 Marketing Value

In their often very unusual design green buildings seem to always attract publicity - whether this publicity is always favourable can probably be discussed. Nevertheless building green can pose an important benefit in terms of marketing value [6]. Studies suggest a positive relationship between conscious environmental practices and market value. Companies that pursue the wider agenda of sustainable design appear to achieve a higher degree of user satisfaction. Furthermore it has been observed that companies, that have received environmental achievement awards, have experienced a positive impact in terms of increased market value. [20] [23]

In a survey among 500 tenants who had moved into either LEED or ENERGY Star rated buildings 74% of tenants believed that residing in a green building was good for the company image, related to the public and clients, and 70% believed that it was good for the image with owners/shareholders. [26]

This perception seems to be the common consensus in corporate America. In an industry survey by McGraw-Hill it was found that 75% of firms view sustainability as consistent with their profit missions. 61% of corporate leaders believe that sustainability leads to market differentiation and improved financial performance - only 9% disagree. Furthermore 73% expect to attract and retain customers as a direct result of their sustainability efforts. [18] [12]

7.6 Project Risks & Risk Management

„Gaps - or fear of gaps - between promises and outcomes increase the perceived risks of greener buildings.“
- Bill Bordass, 2000, [28,p. 1]

There is a wide perception that building green cause an added risk in the project with regards to keeping budgets and meeting the performance standards promised in the design phase. Certain green approaches and failed projects have decreased confidence in greener building. [6] Thus perception is that green buildings tend to be riskier, in the sense that their performance varies more widely across the sample [29].

Perceived risks when building green [6]:

• Will the building perform as predicted?
• Are the green costs affordable?
• Is the technology reliable?

However, these are all risks that can be managed and addressed by ensuring a project team with experience within green building, as mentioned in Chapter 2. In actuality building green have many risk management benefits, of which some are mentioned in the following.

• Higher focus on potential risks in the project can be expected to reduce the overall project risks, as these are now being addressed in a timely manner.
• Building green can provide a cost-effective hedge against the risk of future inflation and volatility in energy prices, by reducing energy consumption [16].
• There is a reduced investment risk through reduced vulnerability to changes environmental legislation and rising energy costs [23].
• Business interruption risks can be reduced in facilities that derive their energy from on-site resources and/or have energy-efficiency features, including risks resulting from unplanned power outages. [14]

For American companies avoidance of litigation has been found to be a major risk management benefit of green buildings. Improved indoor environmental quality, reduced likelihood of moisture damage, and other factors enhancing workplace safety help reduce the risk of litigation. LEED certification and the commissioning this requires, have been found to ensure a higher quality in the building. All LEED rated buildings undergo full commissioning of energy systems and most go through energy modelling. These steps significantly reduce post-occupancy problems with mechanical systems [16]. Commissioning facilitates detection of property and/or health risks, at an early stage, thus not only reducing risks for owners, but also for architects and engineers involved in the project. [25] [14]

7.7 Insurance

This section is primarily based on 'Costs and Financial Benefits of Green Buildings - A Report to California's Sustainable Building' [14] and 'Greening our built world' [16]

Reduced insurance premiums is another potential benefit of building green, which is connected to these considerations regarding risks.

> Improved ventilation in green buildings is likely to combat mould problems. Many insurance companies have dropped all coverage for mould and IAQ. Although there are a few policies that cover mould losses, these have become very costly.

> An experiment identifies a link between improved lighting design and a 27% reduction in the incidence of headaches, which accounts for 0.7% of the overall cost of employee health insurance. [13]

> Evidence from closed-claims studies suggests that risks can be reduced through the use of building commissioning. Research conducted by an insurance company found that green building systems should be less likely to malfunction, generating fewer insurance claims.

Little has been done to quantify or monetize these benefits and only a small fraction of insurance companies have realised these advantages. Most insurers and risk managers have yet to make the connection between green buildings and reduced risk. So far only one insurance company in the United States have recognised these qualities of building green and introduced a 5% discount on casualty insurance for LEED rated buildings.

7.8 Lower Lending Rates

One bank has been found to offer lower lending rates for new green construction on the grounds that green buildings are expected to have a higher net operating income. Therefore green building owners are considered less likely to default. Furthermore the higher value of green buildings, results in lower risk for the bank, in case default should occur. [16]

7.9 Preliminary Conclusion

Because of the limited investigation into these subjects' considerations regarding applicability for office buildings specifically and assessment of the potential according to Danish conditions has not been included.

These are all subjects that need to be investigated further, in order to be included in a cost-benefit perspective. An estimate of the financial impact these benefits may have on a company, is difficult to estimate on the current basis of information.

For now these benefits will be left out of further financial evaluation. However these are all potential benefits, which ought to be regarded when weighing the costs and benefits of building green

> **NB. Tax Benefits and Incentives**
> There are also possible tax benefits and incentives available for green buildings and green building strategies [13]. These could very well help to further green building and ought to be investigated further.

8. Financial Assessment

Studies in the United States of LEED rated office buildings have suggested that over a 20-year period, the productivity benefits of green design outweigh the energy benefits by a factor of six [2]. A 1% reduction in absenteeism is estimated to correspond to the energy costs of a typical commercial building in the United States [6].

The aim of this report is simply to asses whether it is probable that building green will be financially viable in Denmark. Estimates are based on very overall considerations. Therefore the financial analysis will also be kept very simple, so as not to indicate a greater accuracy than what can be warranted.

„*Measuring the exact financial impact of healthier, more comfortable and greener buildings is difficult*." - Kats, [15,p. 5-6].

Observations have been limited to estimates on costs and benefits relative to conventional buildings. Ascribing a value to the water and energy savings would only render greater uncertainty in the comparison. Determining the costs and the consequent financial savings can be difficult. Firstly water rates and energy rates can vary regionally, and secondly the future cost is difficult to estimate and is dependent on supply and demand, the political landscape (incentives, legislation) and climate change impacts [14]. The rates would be estimates with great uncertainty and these would then be used in connection with estimates of reductions in either water or energy consumption also with some uncertainty - consequently uncertainties would simply magnify each other.

These same considerations could be applied for costs or productivity benefits. The cost of staff can vary greatly depending on the type of company. There will be a great difference in the amount if the building houses top lawyers, engineers or unskilled workers. Consequently the financial benefits of increased productivity can be difficult to estimate and again will be very uncertain.

[...] financial benefits of green design are [...] over 10 times the additional cost associated with building green.

- Gregory Kats, 2003, [15,p. 8].

„From energy savings alone, the average payback time for a green building is six years."

- Gregory Kats, 2010, [16,p. xv].

8.1 Ratio of Economic Costs of a Building

In *Rough Guide to Sustainability* [2] the life expectancy for a building is estimated at 50 years. Based on this the following ratio of economic costs of a commercial building over its lifetime in the United Kingdom has been estimated:

United Kingdom:
1 : 2 : 10
Cost of design and construction : Operating costs : Staff costs

In *Creating the Productive Workplace* [25] the following ratios are proposed, based on a review of several sources on the subject, as a guide for the whole life cost of operation of office buildings in the United States:

United States:
0.1 : 1 : 5-9 : 200
Design : Construction costs : Maintenance and building Operation : Business operating costs

The ratio will vary from country to country. In less developed countries, the costs of staffing are much lower, and thus will comprise a much lower percentage of the overall costs of the company.

Many different ratios have been proposed. They all have in common, though, that staffing costs are significantly higher than both design and construction and operation.

It should be noted that the ratio for the United Kingdom is for commercial buildings in general and the American ratio is for office buildings. Some of the difference in the two ratios of staffing costs might therefore be explained by the fact that employees in office buildings in general have higher salaries than employees working in commercial buildings in general, which will comprise factory workers, sales assistants etc. that generally have low salaries. The two ratios above are therefore not to be taken as simply representing national differences, but also differences in building types.

The Danish green building council estimates that staffing costs account for 60%-75% of company costs and operational costs about 10% in Danish companies. [30] If it is assumed that what is left, are the costs for design and construction, this would yield that construction and design costs amount to 15%-30% of company costs.

Based on this two scenarios are defined - one were staff costs amount to 60% and thus construction and design amounts to 30%, and one where staffing costs are set at 75% and thus costs of construction and design are set at 15%. This translates into the following two ratios:

Denmark scenario 1:
3 : 2 : 15
Cost of design and construction : Operating costs : Staff costs

Denmark scenario 2:
3 : 1 : 6
Cost of design and construction : Operation costs : Staff costs

These ratios are based on commercial buildings in general like the ratio for the United Kingdom and therefore estimates for staffing costs are probably very conservative as representative for office buildings. Scenario 2 where the relative costs of design and construction are very high and staff costs are very low is probably to conservative an estimate to represent Danish office buildings. Scenario 1 seems more probable, but still very conservative when looking at the ratio that have been found for office buildings in the United States.

8.2 Assessing Costs and Benefits

Based on the ratios above the relative added costs and benefits, found in the previous chapters, are assessed.

When calculating the effect of energy savings it is estimated that 30% of operating costs are for energy, see Chapter 3. The relative impact of the individual items is found by multiplying the relative differences found in the previous chapters to the ratios above. This renders the following results for costs, energy savings and productivity gains:

	Relative difference	United States Scenario	Denmark Scenario 1
Cost	4%	0.04	0.12
Energy	17%	0.26-0.46	0.10
(Energy Indirect)	4.25%	0.07-0.11	0.03
Productivity	2-3%	4-6	0.3-0.45
Cost-benefit ratio		1/100-1/165	1/4-1/6

Assessing after the United States ratio gives by far the most positive results – with benefits outweighing the costs by a factor of more than 100. However, even with the conservative Danish scenario, it is evident that building green is financially viable - with benefits outweighing the costs by at least a factor 4. Benefits from energy savings alone can counter the added costs, if indirect savings are counted. Productivity benefits amount to about three times the added costs.

The fact that staffing costs are significantly higher than the costs of both design and construction and operation, means that even small improvements in productivity and health pose great value to the company. The value of a 1% increase in productivity corresponds to the value of a 25% reduction in energy consumption using the ratio from the Danish scenario above.

However, the assessment above does not give the full true picture. It is a very overall assessment of the financial viability of green buildings in Denmark.

In order to assess the financial impact of the various benefits more accurately the added costs of building green should be viewed as an investment. Investments are normally calculated for a given period when assessing the financial viability, which makes it possible to assess the payback time for the investment. In order to conduct such an assessment, each item above would have to be appraised and then the values would have to be discounted. Given the many uncertainties, which enter into this assessment, as mentioned at the beginning of this chapter, an analysis in such detail would give no useful results. It must be considered, though, that since the value of the benefits is not discounted, the values will be somewhat more positive than actual results. However, the benefits outweigh the added costs so plentily, that it can still be concluded that financial viability of green buildings in Denmark is probable.

Furthermore the assessment above only includes some of the benefits of building green, which have been found through this study. Further analysis of the additional benefits is expected to add significantly to these benefits.

The assessment above generally applies if the building owner is also the occupant of the building. This is not always the case. If the owner is not the occupant of the building, benefits must be assessed through increases in building value and rent income. Relative increases found for costs, building value, rent and occupancy are stated below.

	Relative increases
Cost	3%
Value	9%
Rent	15%
Occupancy	5-6.4%

By building green the costs are raised 3%, but then the building value increases by 9% and rent increases by 15% and on top of that occupancy is also increased. These benefits ought to outweigh the added costs. Increases in rent and value are caused by the benefits assessed above, and are therefore expected to yield similar results on the bottom line for the building owner. However no further analysis is conducted in order to analyse this correlation.

9. Green Building Outlook Denmark

Certification of green buildings in Denmark has been a fairly recent development, but with the adaptation of DGNB as a Danish certification scheme and an ever-increasing awareness of sustainability in general, it is expected that green buildings will become more common in Denmark in the future.

The rapid growth of green buildings in the United States, has shown that green practices and certification have the potential to become construction industry standard. According to McGraw-Hill calculations the green building marketplace increased fivefold between 2005 and 2008 and it is estimated that the market will have tripled again by 2013. [19] In many areas of the United States sustainable design has been embraced to such an extent that sustainable design requirements are no longer regarded as an addition - but a matter of course. [21]

„Those who have ignored [...] to design buildings for greater occupant comfort and operating efficiency will find not a premium for green but a discount for brown.“
- Norman Miller, 2010, [24, p. 2].

Many factors can contribute to further green development in the building industry. As new materials and technologies are developed these lead to new design approaches and as fossil fuels, minerals and other global resources become scarce, the price rises and this influences design choices. [2]

New laws will demand new thinking. Building regulations and standards, as well as financial incentives, are expected to help further the advance of green buildings in the future. [2] Government goals of cutting CO_2 emissions call for increased use of sustainable energy and a decrease in energy consumption in general and building regulations continuously tighten up requirements regarding energy consumption. By building green these developments are forestalled. Green buildings will be able to meet the requirements of the future and will not be outdated as quickly. Heating demand has decreased over the years and is expected to continue to do so, but at the same time electricity consumption has increased and is also expected to continue to increase. Building green might be able to influence this development. Furthermore energy prices are expected to increase with

„If you aren't at least meeting LEED standards in new construction, there's an increasing risk - one likely to accelerate in the next five years - that your project may falter. Most cutting edge developments in the years ahead will... look to exceed LEED - not just meet it"

- Ernts & Young's
Real Estate Market Outlook,
2008, [16, p. 73]

time, adding to the potential financial incentives of reductions in energy consumption.

As a result of climate changes precipitation seem to continue to increase in Denmark and occurrences of extreme downfalls become more frequent. In Denmark annual precipitation has increased by approximately 20% since 1874. Winter precipitation is expected to continue to increase, while summer precipitation is expected to decrease slightly. Longer periods with no precipitation, and an increase in evaporation, is expected to increase the risk of periods of water shortages. Furthermore, episodes of heavy precipitation is expected to become more frequent and at the same time the magnitude of the 2 heaviest downfalls is forecast to increase by 20% or more. The current infrastructure might struggle to cope with these increased volumes of water.

In the United States some areas experience sewers overflowing several times a year. In Denmark the cloudburst in Copenhagen last summer, caused extensive damage due to flooding. Unless these developments are addressed, this can very well be reality in Denmark in the future as well. As the amount of paved surface is increased replacing grassed areas in many places, runoff is significantly increased and strain is put on existing infrastructure.

These changes might cause changes in government regulations and incentives and influence future water prices. For example it seems that run-off will become an increasing problem, whereas water use is decreasing, therefore it seems likely that payment for water supply and water diversion will be separated in the future. This would mean that reductions in run-off will potentially pose an advantage to the individual building owner in the future.

LEED requirements anticipate such developments and as climate changes become increasingly apparent, building green will become increasingly attractive.

It seems likely that areas such as waste management might gain focus in the future; just as water efficiency has become increasingly prioritised over the years. This could mean that the future will bring financial incentives for not only waste reduction but also reuse and recycling.

Staffing costs are continuously increasing in Denmark and as globalisation is increasing, it becomes difficult to compete with the much cheaper workforce found in places like Asia. Therefore the productivity of staff in Denmark becomes an ever more important factor. Benefits that green buildings can offer in this regard might potentially become even more attractive in the future. Furthermore it seems that in general workers have high standards for the quality of their working environment. Consumers are increasingly demanding green living and working environments [2]. The improved indoor environment and working conditions that green buildings seem to offer will very likely have an even greater impact on attracting and retaining workforce in the future.

Given that benefits within areas of risk management become evident and is increasingly recognised, insurance discounts for green buildings might become more widespread. In the future it might be expected that the costs of insuring green buildings will be less than for insuring a similar conventional building. And as green building benefits within other areas become more obvious, building value and rent will be likely to increase further relative to conventional buildings. This might either manifest itself by a decrease in value and rents for conventional buildings or an increase for green buildings.

Finally the costs of building green can be expected to decrease as building green become common practice and experience within green building increases. Marketing value of building green might decrease - in the sense that profiling the company through building green will become less effective as green buildings become common practice. However, it is probable that not building green will then have a negative effect from a marketing perspective instead. And in this way building green can become a necessity for avoiding bad publicity.

In general it seems that the benefits found in building green today will be at least as great in the future and likely even greater.

10. Conclusion

Green buildings have been found to exhibit several benefits. The most extensively investigated and documented are water and energy efficiency and productivity and health benefits. Water efficiency does not seem to pose a great potential for financial benefits in Denmark today, however both energy efficiency and benefits of increased productivity and health can potentially represent benefits that outweigh the added costs of building green several times.

Staffing costs are much greater than both operating costs and cost of designing and constructing an office building. Therefore even small increases in productivity or decreases in sick leave can account for a great difference on the company bottom line. The value of a 1% increase in productivity corresponds to the value of a 25% reduction in energy consumption or the total added costs of building green. It has been found that building green increases productivity 2%-3%.

Building value and rent have been found to increase for green buildings. Occupancy also seems to be greater for green buildings. Furthermore additional potential benefits have been found within areas such as marketing, worker attraction and retention and risk management - to mention a few. In order to really conclude and capitalise the full extent of green benefits these areas must be investigated further.

As with buildings in general there are expensive green buildings and cheaper green buildings. The added costs of building green really depend on the individual building and the green solutions chosen for this building. In general it has been found that building green is financially viable in Denmark - not just today but in the future as well. Building green seem to stay at least as viable in the future - where building green can be a means of achieving CO_2 -reductions and addressing climate changes.

The magnitude of the financial benefits of building green can not be concluded from this investigation. This would take a more accurate and extensive basis of data. However results from this study indicate that benefits can outweigh added costs of more than 4 to 1, just in energy savings and productivity gains. Considering the additional benefits, which have not been included in this assessment - the potential is even greater.

In order to assess how great the green benefits really are, additional potential benefits must be investigated and results from Danish green buildings must be gathered. This report will conclude with a brief discussion on how such investigation could be approached in Denmark.

Conducting investigation of green buildings in Denmark could potentially pose an advantage for the green building industry in Denmark, beyond establishing the financial benefits of green buildings. It has been found that an important factor affecting the amount of added costs is experience. Experience from completed green buildings can be secured and fed forward to future green building projects and thus help bring down added costs of building green in Denmark in the future.

11. Further Investigation

To really assess the financial viability of building green in Denmark it is necessary to conduct investigation of green buildings in Denmark. In the following a brief discussion of the possible methodology for such investigation is presented.

Building evaluation spans many professions (architecture, services engineering and facilities management being the most prominent), it is multidisciplinary, often to a confusing extent (design, psychology, economics, planning, sociology, engineering, etc.), it draws on laboratory research and physical measurement and thus a building evaluation needs to be planned carefully before it is conducted. [31]

Investigating all the various issues included in the previous chapters requires several methods of investigation. Some issues like energy and water consumption can be reported directly by the building facility manager, other more occupant related issues, such as health and productivity benefits, need to be investigated via for example an occupant survey.

As an overall framework for investigation Post Occupancy Evaluation is considered a good starting point.

11.1 Post Occupancy Evaluation

The POE include measures related to organizational and occupant performance, worker satisfaction and productivity, as well as measures of building performance (e.g., acoustic and lighting levels, adequacy of space and spatial relationships). [32]

POE is often employed as a tool for problem resolution, but a POE can also provide very useful benchmark data with which projects can be compared [33]. As POE becomes more routine, findings and benchmarks from previous POE surveys can be used further to help calibrate client and design expectations, to ensure a greater level of consistency between expected performance and actual performance [34].

POE is not a case of one size fits all [35] and numerous considerations go into planning the POE. An overall framework does exist - this must be adapted for the specific use, depending on the purpose and context of investigation, resources at hand etc. Inspiration concerning the overall framework for evaluation can be found in the PROBE series and the Soft Landings Framework.

PROBE

Probe was a series of POE's published in the Building Services Journal from 1995 to 2002 in England. [36]

The backbone of the Probe series was the following three surveys [37]:

• An occupant survey - based the questionnaire used by BUS (which will be described subsequently)
• An energy survey.
• A walk-through survey - where the building is examined by experts in discussion with users.

Soft Landings Framework

The Soft Landings Framework is an open-source procedure that draws on recommendations from PROBE among others. It is designed to smooth the transition into use and to address problems that post occupancy evaluations (POE) show to be widespread, the aim is to create a "golden thread" through building projects and make sure that feedback is collected and fed forward to subsequent projects. It employs post occupancy evaluation and describes a process where POE is integrated in the building process from the beginning. Building use and energy performance is monitored for the first three years of operation and a POE is conducted after one year of operation and again after three years of operation. The type, coverage, method and timing of these POEs depend on the project. [38] [34]

11.2 Evaluating the Costs and Benefits of Green Buildings

Before an overall framework for investigation can be established the individual areas of evaluation must be considered.

11.2.1 Costs
When investigating the costs of green buildings in Denmark, it should be considered whether a distinction between the costs of certification and the added costs of actually building green should be made.

The added costs of building green compared to a conventional building of the same size, use, location etc. can be difficult to estimate. However this estimate is most likely made in the design-phase of a project, when choosing whether or not to build green. Therefore estimates regarding added costs can most likely be collected from architects, engineers or contractors on the project.

11.2.2 Energy and Water
Information regarding energy and water consumption should be accessible from utility bills or Building Management Systems. However, a distinction between the distributions of end-use could also be interesting to see. This would make it possible to assess where green buildings outperform conventional buildings - if this is the case. Furthermore statements regarding on-site production of sustainable energy and water measures not directly associated with water consumption should be collected.

Some of the investigations reviewed in the previous chapter were based partly on design expectations rather than actual numbers. This goes for both water and energy consumption. In Denmark initial results can be based on estimates like this as well, but should be further substantiated through actual measured consumption, as these data become available.

This information's can most likely be collected from facility managers or the like.

11.2.3 Productivity and Health

Productivity and health benefits can be either measured or subjectively estimated, as mentioned in Chapter 5.

A subjective estimate could be based on results from occupant surveys. Inspiration on how to conduct an occupant survey can be drawn from the Building Use Studies or Building In Use - both briefly introduced in the following. Measured values and inspiration on how to measure these benefits can be found through the Building Investment Decision Support also described subsequently.

Building Use Studies - BUS

The following is based on 'BUS Methodology' [39].

The Building Use Studies - BUS was founded in 1981 to bring the human dimension into view of the building industry. In 1985 the BUS occupant survey was started and has since been used by over 200 organisations worldwide, 600 buildings worldwide and the current database comprise data from 380 buildings from 17 countries, about half of these buildings are from the UK and Ireland.

In 1995 Benchmarks were introduced for the UK and in 2006 an international green building benchmark was introduced as well. Today the BUS database comprises a comprehensive reference system.

The main analysis tool of BUS is the questionnaire. The original questionnaire was 16 pages, but was significantly shortened in 1985 and now exists in 1,2 or 3 page versions. A range of questionnaires is available. These all have a common set of ten rating scales, which are used for benchmarking. Questions can be added or subtracted for the individual study outside these ten questions.

The method covers a range of quantitative and qualitative data:

• Background information about age, sex, time in the building, time at desk, time at VDU (visual display unit), workgroup size, window seats and other basic information about the sample and the respondents.
• Ratings and feedback for design, needs, image, cleaning, storage, meeting facilities.
• Response times for key variables.
• Perceived productivity.
• Perceived health.
• Thermal comfort.
• Ventilation.
• Lighting, including glare.
• Noise, including interruptions.
• Furniture and space in the building.
• Other workplace performance variables including e.g. perceived control.

Building-In-Use - BIU

The following is based on 'Learning from Our Buildings: A State-of-the-Practice Summary of Post-Occupancy Evaluation' [32].

BIU is a technique for measuring user comfort, which was developed in 1988 in Canada in connection with a survey of eight Canadian government buildings. The aim was to integrate the feedback from the users with data collected with instruments measuring indoor air quality, thermal comfort, lighting, acoustic conditions, and energy performance and it is actually very similar to the PROBE studies conducted in the UK.

The conclusion of this survey was, that there are seven major conditions that affect building users.

- Air Quality
- Thermal Comfort
- Spatial Comfort
- Privacy
- Lighting Comfort
- Office Noise
- Building Noise
- Workability

This led to the development of a short questionnaire as a standardized measurement tool.

The following advantages was found with this approach:

- Cost-effective
- Not data heavy
- No excessive consumption of staff time
- Provides single-digit indicator of environmental quality
- Easy to benchmark

Today BIU have assembled a database of 60 North American Buildings to benchmark against.

Building Investment Decision Support - BIDS

The following is based on 'Costs and Financial Benefits of Green Buildings - A Report to California's Sustainable Building' [14].

The Building Investment Decision Support (BIDS) data set includes a number of controlled laboratory studies where speed and accuracy at specific tasks was measured in low and high performance ventilation, thermal control and lighting control environments. These studies used a range of speed and accuracy performance measures including: typing, addition, proof reading, paragraph completion, reading comprehension, and creative thinking.

The program has reviewed over 1000 studies that relate responses, such as productivity. Of these studies, 95 were identified that are sufficiently rigorous and quantitative to meet the criteria for inclusion in the BIDS database and decision making tool.

Based on the presented methodologies investigation of health and productivity benefits in Danish green buildings can be planned.

11.2.4 Value and Rent

Information regarding building value and rent can either be reported by owners or investigation can be conducted through real estate agencies, as has been seen in the United States.

11.2.5 Intangibles

These benefits are generally more difficult to assess and will not all be scrutinised individually for now. It would take further investigation into these areas to assess how to evaluate them.

However many of the benefits are closely related to the public mentality regarding sustainability. This is the case for some of the areas mentioned already but also with regards to for example attracting and retaining workforce and marketing.

The green mentality in Denmark could potentially be investigated through a public opinion poll - like the Gallup poll. Questions examplified to the right.

The answers to all these questions could be very interesting. However when conducting a survey like this, questions need to be carefully and professionally planned. For example it might be that answers should be made on a scale, some questions might have predetermined possible answers and others might be open. Before conducting such a poll careful planning must take place and the questions might also be tested on a smaller scale before commencing an actual poll.

11.3 Getting Started

Once all areas of interest have been considered and it has been established which information is needed, detail planning of the evaluation can commence. The considerations above are based on areas included in this report, however it should be considered whether all these areas should be included for evaluation of green buildings in Denmark. The more detailed and extensive the evaluation the more time-consuming and expensive it will be to conduct.

Techniques should be relatively inexpensive and not too intrusive or time-consuming. It is very important to consider what the data is going to be used for and how, before data collection is commenced, so only appropriate data is collected - this will both limit costs, intrusion and time consumption. [31]

A good starting point for establishing a Danish basis of data regarding green buildings could be to conduct case studies on a number of green buildings - very much like it was done for the PROBE studies conducted in the United Kingdom, see 11.1.

„Unfortunately, case studies by themselves still do not carry much weight with academic researchers unless there are enough of them to provide some sort of statistical data with generalizable outcomes. This results in building performance research that investigates only a few factors across a broad study but without the depth or understanding of a case study.“
- Fionn Stevenson, Adrian Leaman and Bill Bordass, 2010, [31,p. 568].

These case studies could provide qualitative data from which basic assumptions can be derived until sufficient data can be collected for a quantitative assessment of the costs and benefits of green buildings in Denmark. Moreover they can provide detailed data for in dept analysis. And finally it will form a good basis for designing the framework for further quantitative investigation.

As the population of green buildings in Denmark grows it will become possible to collect further quantitative data. Such investigation must be planned carefully. A few sources of inspiration have been presented in the preceding sections. Based on these methodologies and the experience from the conducted case studies a framework for a quantitative evaluation can be established.

Appendix

A. Certificationschemes

The following introduction is based on 'Bæredygtigt byggeri - afprøvning af certificeringsordninger til måling af bæredygtighed i byggeri' [40].

The purpose of the green building certification schemes is to bring focus to sustainability and verified documentation hereof and that this can be summed up in a classification, which simply communicates that an extra effort has been made to create a sustainable building.

The certification schemes are typically intended as tools for promoting and sustaining sustainability in the building from planning to completion of the building and often into use as well. Generally the certification schemes promote incorporating concepts of sustainability already in the early programming.

All certification schemes are based on existing regulations and building praxis with an eye to move the market in a more sustainable direction and, to the extent possible, to employ existing standards and methods of evaluation in measuring this. Therefore it is necessary to adapt the various schemes to the individual countries in which they are to be employed.

Certification requirements are based on government regulations in the country for which the scheme is developed. The stricter the government regulations, the stricter the certification requirements. The purpose of certification is to further sustainability, thus certification should not be achievable by simply meeting minimum requirements set by government regulations. Furthermore it must not be too easy to achieve the highest level of certification. There must be a motivational factor for continuous improvement within sustainability. On Figure A.1 the developers of BREEAM have tried to illustrate how requirements should be determined.

To a great extent the schemes comprise the same criteria that address the same topics. What distinguish the various certification schemes is, in how great detail and with which prioritisation they address the individual topics.

Common to all the certification schemes is that they are constructed around categories that each represents a well-defined focus area. For each category a number of criteria's are specified, which collectively ensure that the focus area is covered. The criteria each encompass a definition of applied indicators, required documentation, and the minimum requirements that must be met

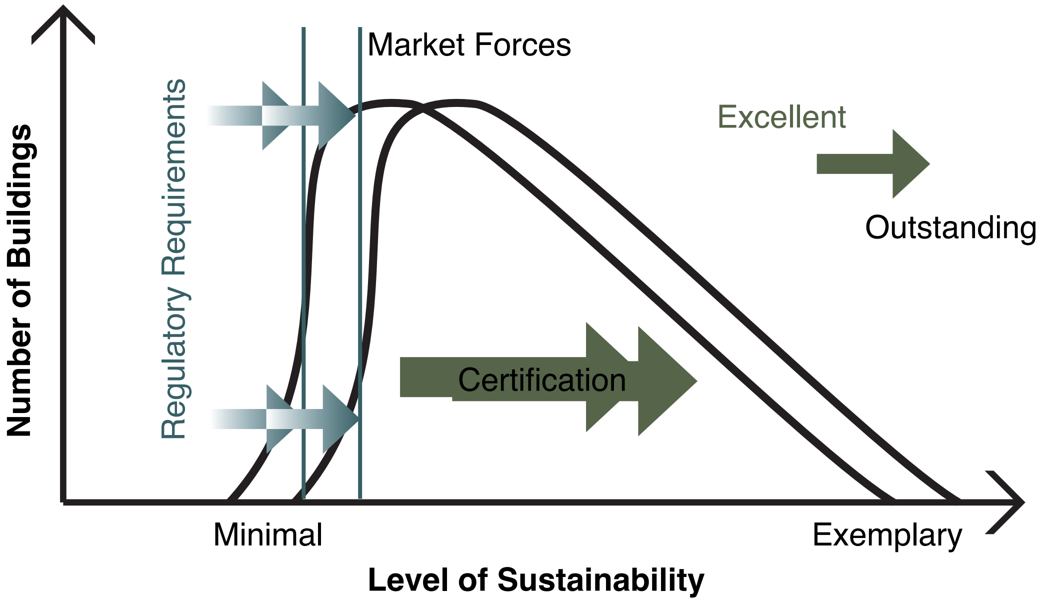


Figure A.1: The overall purpose of the certification schemes is to achieve improvements compared to the norm. Based on [40]

and which further requirements yield how many points. Finally some certification schemes weight the individual categories and criteria according to their sustainable significance. Figure A.2 and A.3 illustrates how LEED and DGNB are both divided into categories and how these categories are weighted among themselves.

In comparison DGNB is very thorough, posses high professional competence and sets high demands for documentation, which results in significant costs in connection with certification whereas LEED on the other hand is based on very simple methods of evaluation, which results in great user friendliness and cheaper certification. Furthermore LEED builds on many years of experience, whereas DGNB is a comparatively new certification scheme.

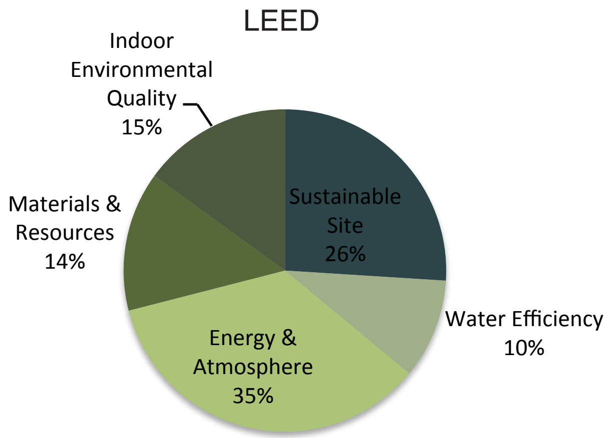


Figure A.2: Weighting of the categories within the 5 key areas of LEED certification. Based on [40]

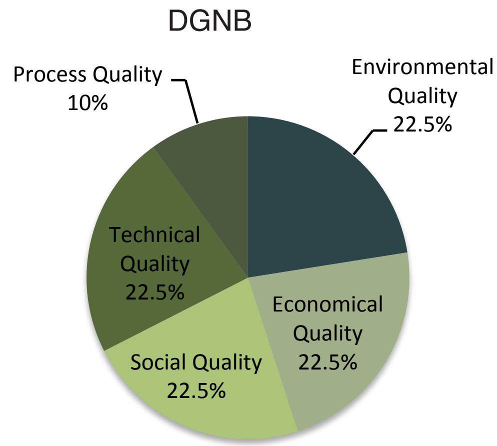


Figure A.3: Weighting of the categories within DGNB. Based on [40]

A.1 LEED - Leadership in Energy and Environmental Design

The section is based on 'Bæredygtigt byggeri - afprøvning af certificeringsordninger til måling af bæredygtighed i byggeri' [40] and 'www.usgbc.org' [41].

LEED is an American certification scheme whose development started in connection with the establishment of the United States Green Building Council (USGBC) in 1993. The first version of LEED was launched in 1998.

LEED is an internationally recognised green building certification scheme. Today there are over 45.000 commercial projects participating in the LEED green building certification system, comprising over 8.4 billion square feet of construction space in 50 states and in 120 countries [13]. (12,675 LEED-certified commercial projects (5-2-12), 33,849 LEED-registered commercial projects (5-2-12)) [42].

With LEED it is possible to certify new construction, renovation of existing buildings, use of existing buildings and district plans under various versions. Within new construction various documents of criteria have been set up for different building types - office, retail, residential, schools etc.

The criteria that are employ for LEED certification is essentially related to American standards and practice. However a few adjusted versions have been developed e.g. LEED Emirates and an Italian version that was published in 2010 and was the first European adaptation.

A.1.1 Evaluation

The LEED classification system awards points based on social, environmental and economic considerations. The points are awarded on the basis of a weighting process, where the significance of the initiative to the relative effectiveness in correlation with the overall objective is assessed in one or more LEED points. The classification system works as a sort of guide for the construction parties, so that they can prioritise efforts in a complex building, where competing parameters are often present. LEED is organised to further initiatives within the following 7 categories, of which the first 5 are characterised as key areas:

- Sustainable Sites
- Water Efficiency
- Energy and Atmosphere
- Materials and Resources
- Indoor Environmental Quality
- Innovation
- Regional Priority

Each of these headlines encompasses a number of criteria's of which some are obligatory and some are optional. The obligatory criteria must be met in order to achieve any level of LEED certification, whereas the optional criteria's each yield a number of points. This way LEED has incorporated a degree of flexibility that allows project teams to select initiatives appropriate to their specific requirements or purpose.

From the collected point system buildings can be certified in the following four categories:

- LEED Certified: 40-49 point
- LEED Silver: 50-59 point
- LEED Gold: 60-79 point
- LEED Platinum: 80-110 point

A.1.2 Stated Objective

LEED has stated an objective, which is divided into the following 7 areas:

- Reverse Contribution to Global Climate Change
- Enhance Individual Human Health and Well-being
- Protect and Restore Water Resources
- Protect, Enhance and Restore Biodiversity and Ecosystem Services
- Promote Sustainable and Regenerative Material Resource Cycles
- Build a greener economy
- Enhance Social Equity, Environmental Justice, Community Health and Quality of Life

The point system described above is designed to support this objective.

A.1.3 The process

When an owner has decided to LEED certify a project the project is registered online. After registration and payment of a registration fee, the necessary tools for conducting and structuring the certification can be accessed online.

It is possible to employ a LEED-consultant in connection with certification. This is voluntary, but does yield a "bonus-point" in the collective assessment. Reviews are always conducted by a LEED professional approved and appointed by the Green Building Certification Institute (GBCI).

The actual certification process can be split into two phases - design and construction. This gives the opportunity to submit documentation from the design phase when this is completed and then submit additional documentation again once construction is completed. If the process is not split all documentation is submitted when construction is completed. When documentation has been submitted this is subjected to a preliminary/initial review and feedback regarding which criteria is regarded as fulfilled, possibly fulfilled and not fulfilled as well as which documentation can be approved and which cannot be approved. Based on this feedback one can choose to either accept this review or submit further information for a final review. When splitting submission into two phases two preliminary reviews are conducted instead of just one. This can reduce the effort needed to collecting documentation and can ensure a greater awareness regarding certification earlier in the project.

A.2 Deutsche Gesellshaft für Nachhaltiges Bauen - DGNB

This section is based on 'Bæredygtigt byggeri - afprøvning af certificeringsordninger til måling af bæredygtighed i byggeri' [40], 'Ejendomscertificering er mere end et mærke' [43] and 'www.dkgbc.dk' [44].

DGNB is a German certification scheme developed by DGNB. First initiatives for this scheme were taken in June 2007 and the first version was published in October 2008. In January 2009 the first German building was DGNB certified.

By 2010 DGNB was adapted for Austria and agreements for adaptation had been entered with Bulgaria and China. And at the moment we are adopting it in Denmark. Furthermore a European version is under development, which is based on European standards rather than German standards to an even greater extent than now.

Today there is 120 DGNB certified buildings in Germany and 100 on-going projects aiming to be DGNB certified. In the rest of Europe there is now 2 certified buildings and 14 currently on-going projects. This is in Austria, Switzerland and Luxembourg. [45]

It is greatly emphasised that DGNB is a certification of sustainability - not an environmental certification scheme, which is also why the German word for sustainability (nachhaltig) is used instead of just green building. DGNB embrace encompass all three aspects of sustainability, has great focus on Life Cycle Assessment (LCA) and great freedom in choice of method, which allows for new and innovative initiatives from the building owner.

Like for LEED there are several versions of DGNB - new construction, existing buildings and district planning. Within new construction criteria's have been developed for various building types - offices, schools, retail etc. The New Construction - Office and Administrative Buildings is the first and the best tested. [45]

A.2.1 Evaluation

The evaluation is based on life cycle assessments of the building (over a 50 year period) and supplementary criteria. DGNB works with 6 categories:

- Environmental Quality
- Economical Quality
- Social and Functional Quality
- Technical Quality
- Process Quality
- Quality of Location

In DGNB the three aspects of sustainability - environmental, economical and social, are weighted evenly - each with 22.5% weight. Technical Quality is weighted 22.5% as well and Process Quality is weighted 10%. Quality of location is assessed separately in DGNB, unlike with LEED.

These 6 categories encompass 47 criteria, of which some are assessed quantitatively and some are assessed qualitatively. Collectively all these make up a number of weighted points within each category. These points are converted into percentage-wise fulfilment of the individual criteria and then percentage-wise fulfilment of the individual categories.

The building can be certified at three levels.

• Bronze ≥ 50%
• Silver ≥ 65%
• Gold ≥ 80%

DGNB does not have any minimum requirements like LEED, however a sort of prerequisite is encompassed in the individual categories, so that to achieve a collected silver certification all categories must fulfil the requirements for bronze as a minimum and to achieve gold certification all categories must fulfil the requirements for silver as a minimum.

A.2.2 The process

When certifying with DGNB it is a requirement that an assessor, who is educated and approved by DGNB, is associated. The job of the assessor is, as a minimum, to quality assure documentation and submit this to DGNB. When submitting the assessor recommends how many the building should achieve within each category.

The assessor verifies that all necessary information is available, submits this to DGNB, who then verifies the material and issue the certificate. This verification encompass a thorough review of the correlation between documentation of what was expected to build, which might have been pre-certified, and what was actually build.

At DGNB one can apply for a pre-certification, which is a temporary certification, which is done after completed design. If certification is a decision from commencement of the project pre-certification can be a good way to promote an integrated planning and realise potential optimisation both within construction and management and it can be used in marketing of the building from an early stage.

B. Climate

This chapter is primarily based on information from 'www.DMI.dk' [46] and 'www.weather.gov' [47]. In particular the following publications [48], [49], [50] and [51].

„Denmark has a typical coastal climate with mild, humid weather in winter and cool, changeable weather in summer, and mean temperatures do not vary greatly between the two seasons. However, the climate and weather in Denmark is strongly influenced by the country's proximity to both the sea and the European Continent. This means that the weather changes according to the prevailing wind direction. The westerly wind from the sea typically brings relatively homogeneous weather both summer and winter: mild in winter, cool during summer, always accompanied by clouds, often with rain or showers. If the wind comes from the east or south, the weather in Denmark tends to resemble the weather currently prevailing on the Continent: hot and sunny during summer, cold during winter. Thus, the wind direction and the season are key factors in describing Danish weather.“

[49,p. 13].

Compared to the United States the Danish climate is fairly easy to establish and describe. The country is small and thus geographical variations are almost non-existent and the variances between the seasons are also not great. USA on the other hand is divided into 9 different climate regions; see Figure B.1 between which variations can be great.

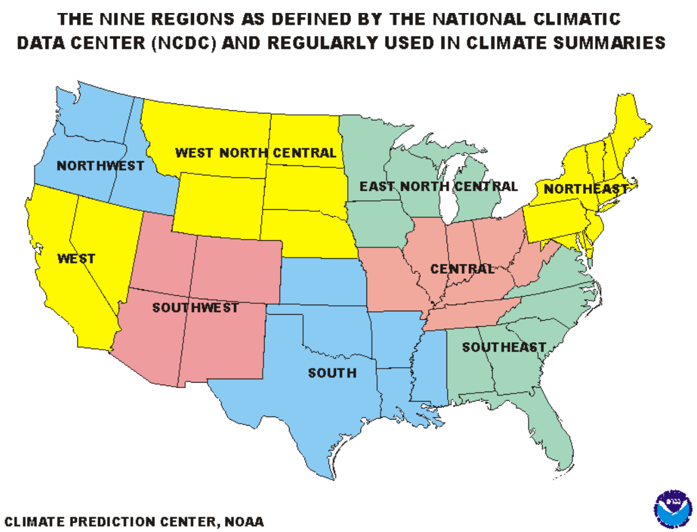


Figure B.1: The nine regions as defined by the national climatic data center (NCDC), [51].

The American climate varies greatly with the seasons unlike the Danish climate and thus the yearly averages also covers great yearly variations as well as geographical variations. The average temperature for the United States is illustrated on Figure B.2. The median average temperature seems to be between 50° F and 60° F, however the spread is between 30° F and 80° F, corresponding to between -1° C and 27° C. The Danish average for 2011 was around 9° C, with slight geographical variations in the average of about 0.5° C. In the period between 1961 and 1990 the normal average temperature in Denmark was 7.7° C. In United States the average for the same period varied geographically from about 4.5° C to about 24° C from north to south.

The lowest measured temperature in Denmark in 2011 was -16.5° C and the highest was 28.2° C. In the United States the lowest temperatures varied geographically from -42.2° C to 10.5° C and the highest measured temperature varied from 21.7° C to 46.7° C. In some areas the temperature varied from approximately -45° C to 38° C within the year and in other areas the temperature only varied between approximately 5° C and 38° C.

From 1873 to 2011 the annual mean temperature in Denmark has risen steadily from app. 7.1° C to about 8.7° C (corrected values), see Figure B.5.

Between 2000 and 2008 5 of the 7 warmest years ever to have been recorded in Denmark were recorded. 2006, 2007 and 2008 were the warmest years registered in Denmark since 1874 when the first temperature measurements were recorded. [52]

NB - Project engineering of energy consumption and indoor environment is based on climate data from 1975 to 1989. If the previous 30 years is compared to the 30 years from 1961 to 1990, which are used in meteorological context, the average outdoor temperature is now 0.5° C higher. Thus there is a great chance that new buildings that are designed based on these climate data, will overestimate the need for heating and underestimates the need for cooling. [52]

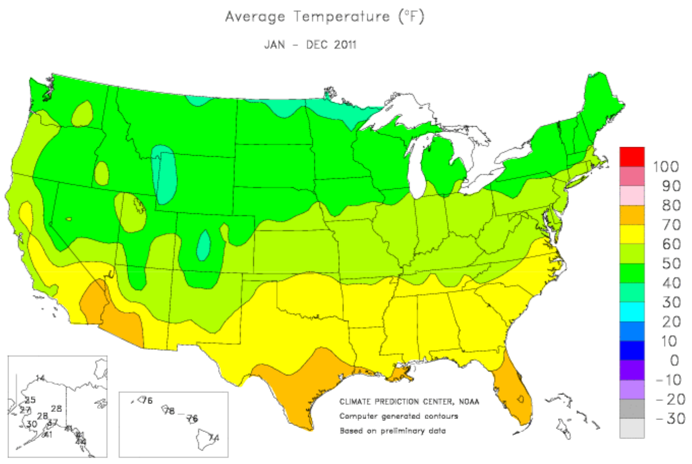


Figure B.2: Average temperature for the United States, Jan-Dec 2011 [F], [51].

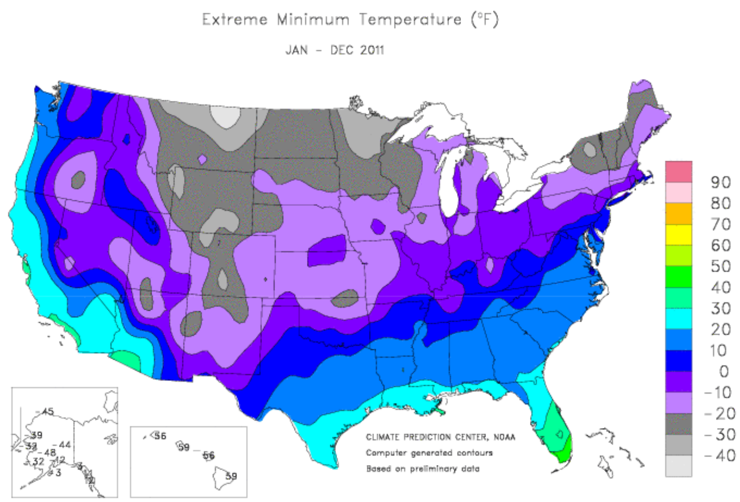


Figure B.3: Minimum temperatures, United States 2011. [51]

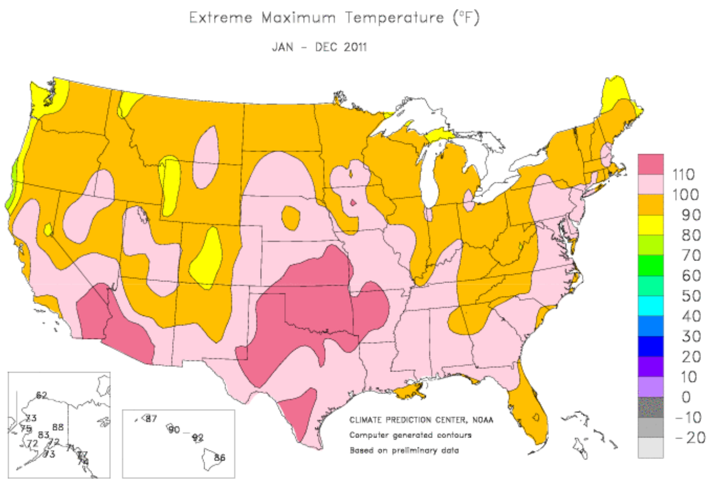


Figure B.4: Maximum temperatures, United States 2011. [51]

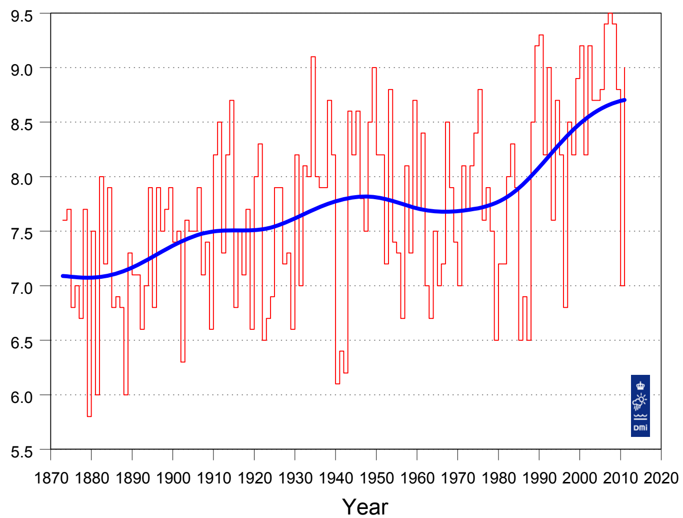


Figure B.5: Annual Mean Temperature, Denmark 1973-2011, [49].

B.2 Hours of sunshine

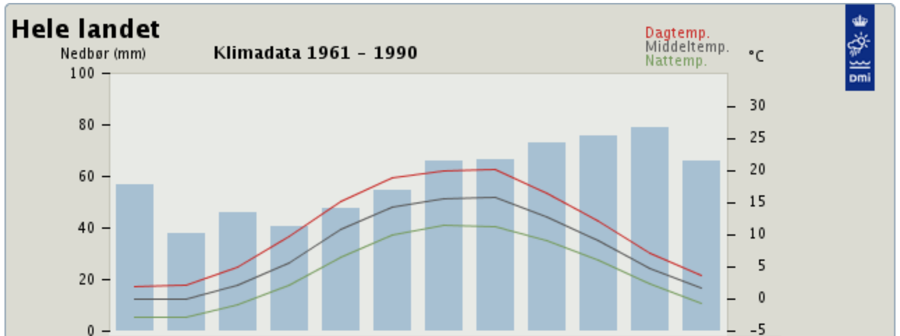
In 2011 1683 hours of sunshine was registered in Denmark, which is 188 hours or 13% above the norm of 1495 hours of sunshine. However as can be seen on Figure B.6 these are not spread evenly over the year. In fact two thirds of these hours of sunshine occur in the six months from April to September. On balance there are 2601 sunshine hours annually in the United States, which are spread more evenly over the year because of the general closer proximity to the equator [53].

B.3 Precipitation

The annual precipitation in the United States for 2011 is shown on Figure B.7. It varies geographically between what corresponds to about 50 mm and 2032 mm. In Denmark precipitation in 2011 was 779 on average over the country, with geographical variation of 695 mm to 832 mm. Judging from Figure B.7 more than half of the United States experience less precipitation than Denmark, however some areas get more than twice the amount and some less than one 10th.

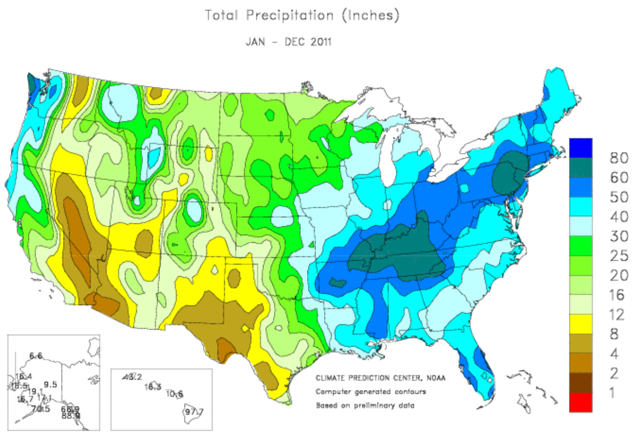
To exemplify how precipitation can vary over the year and the great differences that can be found within the United States, both in total precipitation but also in how much precipitation varies over the year, data for New York and Los Angeles are included below.

The precipitation normal in Denmark based on the period 1961-1990 is 712 mm; in United States it varies geographically between 254 mm and 3302 mm. Denmark's annual accumulated precipitation has risen from about 640 mm to about 760 mm from 1874 to 2011.



	JAN	FEB	MAR	APR	MAJ	JUN	JUL	AUG	SEP	OKT	NOV	DEC	ÅR
Nedbør (mm)	57	38	46	41	48	55	66	67	73	76	79	66	712
Nedbørdage	11	8	10	9	8	9	10	10	11	11	13	12	121
Dagtemp.	2.0	2.2	4.9	9.6	15.0	18.7	19.8	20.0	16.4	12.1	7.0	3.7	10.9
Middeltemp.	0.0	0.0	2.1	5.7	10.8	14.3	15.6	15.7	12.7	9.1	4.7	1.6	7.7
Nattemp.	-2.9	-2.8	-0.8	2.1	6.5	9.9	11.5	11.3	9.1	6.1	2.3	-0.7	4.3
Solskinstimer	43	69	110	162	209	209	196	186	128	87	54	43	1495

Figure B.6: Climate data, Denmark 1961-1990, [49].



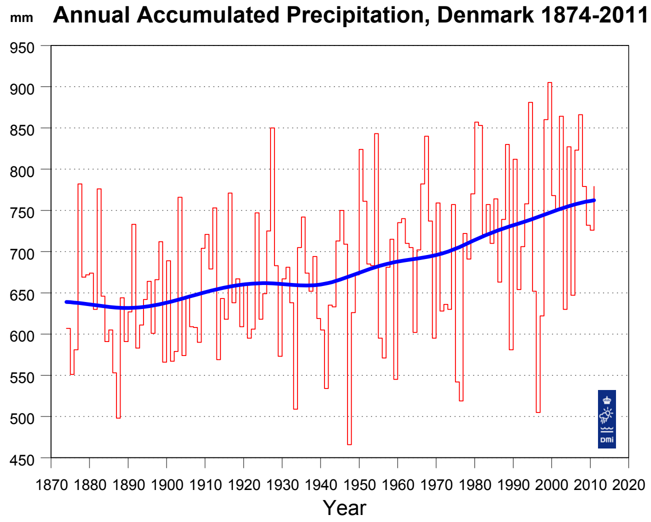
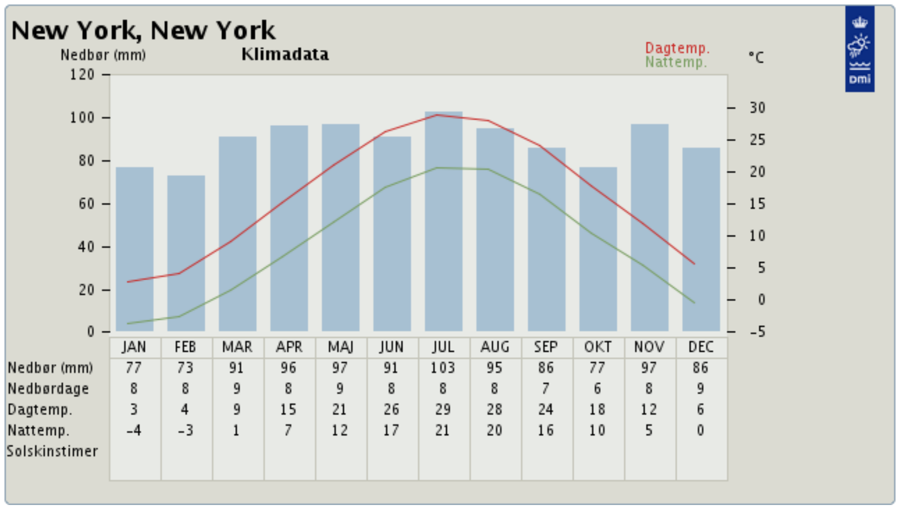


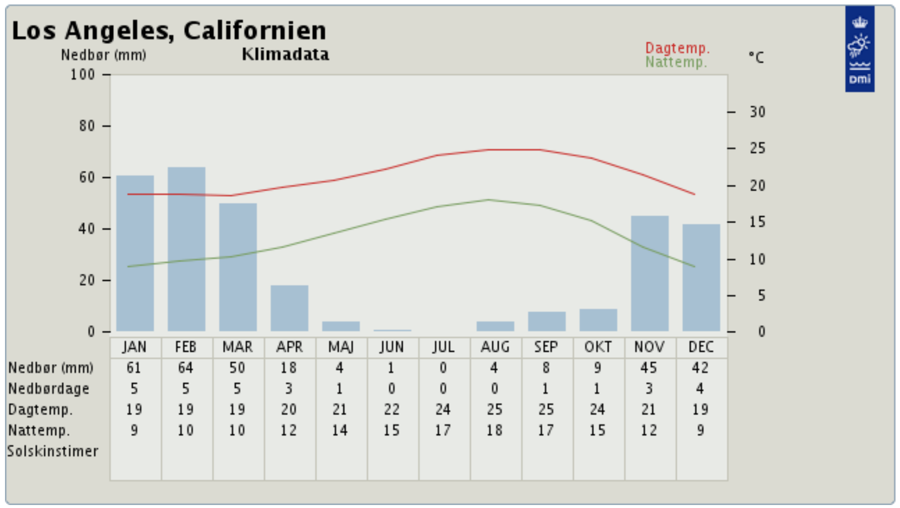
Figure B.7: Total Precipitation Jan-Dec 2011 [Inches], [51]

Figure B.10: Annual accumulated precipitation, Denmark 1873-2011, [49].



	JAN	FEB	MAR	APR	MAJ	JUN	JUL	AUG	SEP	OKT	NOV	DEC
Nedbør (mm)	77	73	91	96	97	91	103	95	86	77	97	86
Nedbørdage	8	8	9	8	9	8	8	8	7	6	8	9
Dagtemp.	3	4	9	15	21	26	29	28	24	18	12	6
Nattemp.	-4	-3	1	7	12	17	21	20	16	10	5	0
Solskinstimer												

Figure B.8: Climate summary, New York, [46]



	JAN	FEB	MAR	APR	MAJ	JUN	JUL	AUG	SEP	OKT	NOV	DEC
Nedbør (mm)	61	64	50	18	4	1	0	4	8	9	45	42
Nedbørdage	5	5	5	3	1	0	0	0	1	1	3	4
Dagtemp.	19	19	19	20	21	22	24	25	25	24	21	19
Nattemp.	9	10	10	12	14	15	17	18	17	15	12	9
Solskinstimer												

Figure B.9: Climate summary Los Angeles, [46]

B.4 Scenarios for the Future/Climate Changes

This section is based on 'Dansk Meteorologiske Institut. Fremtidens Klima' [54].

B.4.1 Globally

Scenarios are not prognoses but possible future developments. Thus various scenarios can be formulated based on different assumptions. FN's Intergovernmental Panel of Climate Change (IPCC) has conducted a extensive scenario study in 2000, which concludes a variety of alternative developments. The specific scenarios and their assumptions will not be described further here, but some extracts of the possible outcomes will be reported in the following.

Future climate changes as a consequence of increased greenhouse effect seem inevitable. Even if we succeed to reduce global emissions of greenhouse gasses and stabilise the atmosphere at the current level an additional temperature rise of about 1C will take place over the next 40-50 years due to the emissions that have already occurred.

The increase in the global mean temperature by 2100 is very dependent on the development in emissions - especially in the second half of the century. Between 2090-2099 the increase is between 1.1^{o}C and 2.9^{o}C if looking and the lowest scenario and between 2.4^{o}C and 6.4^{o}C looking at the highest scenario. These increases are greater that the temperature rise that has been observed in the 20th century and thus the effects on ecosystems must be expected to be greater.

Precipitation will change in amount and distribution as well and at the same time evaporation will increase in a warmer climate, so even areas with increased precipitation can end up drier. Global water levels are expected to have increased between 18 and 38 mm for the lowest scenario and between 26 and 59 mm for the highest scenario by 2100.

Processes in the ecosystem are the cause of human induced climate changes and sea level increases continuing for centuries after the atmospheres content of green house gasses has been stabilised. If the atmosphere is stabilised at 2100 level according to the lowest scenario we will experience an additional temperature increase of 0.5^{o} C after 2100 and additional rise in sea levels of 0.3-0.8 metres by 2300 due to heat expansion of the water and after that stagnating increases.

B.4.2 Denmark

Based on the scenarios mentioned above the Danish Meteorological Institute (DMI) have made the following calculations for the future climate changes in Denmark from 1990 to 2100:

- An increase in the annual mean temperature of 0.7°C-4.6°C. Warming is greatest for nighttime. There is little difference in the temperature increase for summer and winter.
- A moderate increase in winter precipitation to about 120-140% of the current precipitation and a probable decrease in summer precipitation to about 75-90% of current precipitation.
- A tendency of more episodes of very heavy precipitation - especially during autumn. The magnitude of the heaviest rainfall within one day will increase by 20% or more.
- Longer periods with no precipitation during periods of plant growth (increased risk of periods of draught)
- Evaporation will increase by 0-6%.
- Soil humidity decreases - especially in spring and summer.
- A tendency towards an increase in winds from western directions at the same time storm paths over the north Atlantic will presumably move a bit to the east which will bring about a small increase in storm activity over Denmark and adjoining waters.
- A maximum water level increase on the West coast of between 0.6 and 0.9 m, which is the sum of an increase of 0.3 m due to changes in wind directions and strength and a global sea level increase of 0.3-0.6m.

C. Consumption

This section is primarily based on 'Bygninger, Energi, Klima - Mod et nyt paradigme. Statens Byggeforskningsinstitut ' [52], 'Office Building Energy Use Profile ' [55] and 'www.esource.com' [56].

C.1.1 Denmark

Since the oil crisis of the 1970s energy consumption in buildings have changed. Heating demand has decreased and use of electricity has increased. Climate changes are expected to cause future buildings to have an even lower heating demand but an increased demand for cooling instead.

For many years energy savings have primarily been focused on reducing heating, however energy use in buildings consist of many different variables and in a holistic perspective it is electricity that dominates energy consumption in buildings and this tendency seems to only increase in the future. Over the last 30 years there has been a shift in the employment within private and public service trades in Denmark - especially there has been significant growth within IT- and consultancy trades. These changes have brought with them a general increase in floor area in office buildings of 55% from 1975 to 2005. At the same time the collected heating demand for office buildings has only increased by 10%,

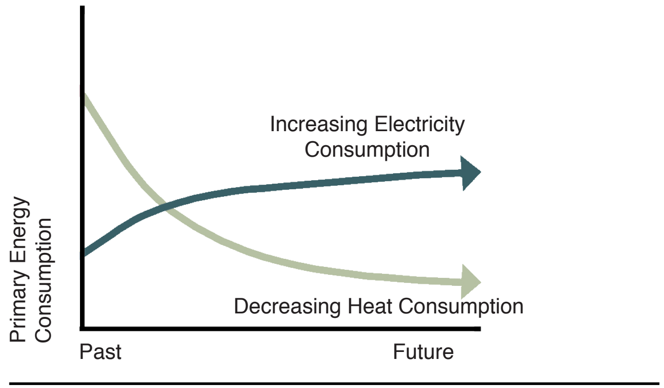


Figure C.1: Development in energy consumption. Based on [52]

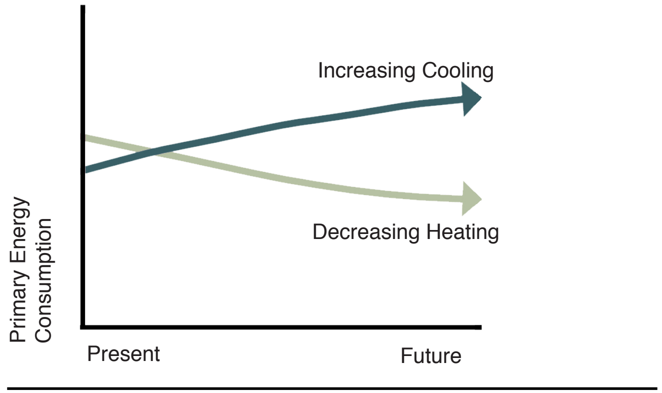


Figure C.2: Development in energy consumption. Based on [52]

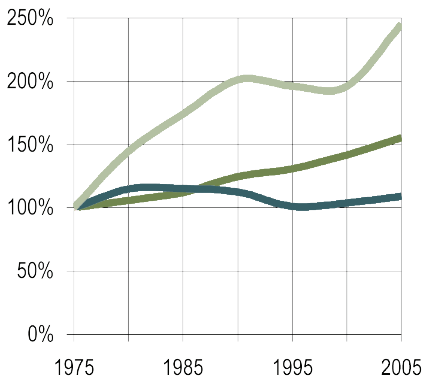


Figure C.3: Relative change in floor area and energy consumption for all offices from 1975 till 2005 (1975 = 100%), [52].

Total Heating
Total Electricity
Total Floor Area

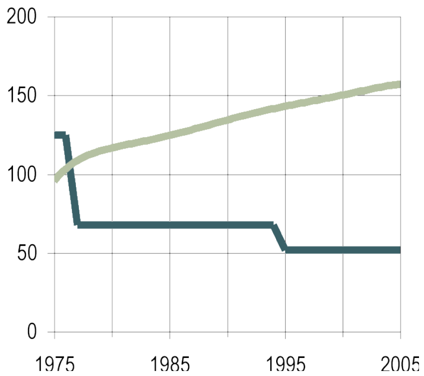


Figure C.4: Development in primary energy consumption for new construction offices from 1975 to 2005 [kWh/m^2], [52].

Heating
Electricity

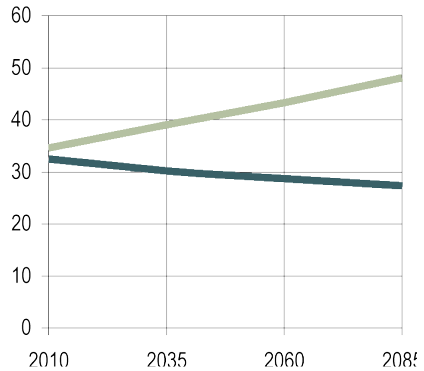


Figure C.5: Development in primary energy consumption for heating and cooling for typical offices build in accordan-ce with BR08 with expected climate changes from 2010 to 2085 [kWh/m^2], [52].

Heating
Cooling

while energy consumption has increased by 160% within the same period of time, see Figure C.3.

If the energy consumption is viewed per m^2 the energy consumption for heating and hot utility water has been reduced by 60% from 1975 to 2005. However the consumption of electricity for office appliances, lighting, cooling and technical installations has increased by 55% within the same period of time, see Figure C.4.

Prospectively energy use for heating is expected to decrease a further 15% for a typical new office building however at the same time energy use for cooling is expected to increase by 40%, see Figure C.5.

Historically building regulations for energy consumption have only addressed heating, however in 2006 new energy regulations were introduced and these comprise more/additional aspects of energy consumption.

• Heating: Heating demand for transmission- and ventilation loss
• Cooling: Electrical demand for mekanic cooling, air treatment etc.
• Hot utility water: Energy demand for heating water
• Lighting: Electrical demand for artificial lighting (not for residential buildings)
• Technical: Electricity demand for pumps, ventilators etc.
• Installation loss: Energy loss for utilities, distribution etc.

Use of electricity amount to about 79% the energy consumption in a typical new office building in Denmark. However, even with the new energy regulations described above only about 25 of these 79% are included in the regulations. Office equipment is not included but this represents half of the buildings energy consumption, to target 100% of the buildings energy consumption office equipment must be included in regulations, see Figure C.6.

In Denmark the national average annual energy consumption for office buildings is about 140 kWh/m^2.

C.1.2 United States

In the United States the average annual energy consumption for office buildings is 252 kWh/m^2. Of the total energy consumption 66% is for electricity and 34% is for natural gas and other fuels, see Figure C.7.

70% of energy consumption in a typical office building is for space conditioning (heating and cooling),

20% for office equipment and the remaining 10% is used for water heating, cooking, and refrigeration systems, as well as other miscellaneous uses, see Figure C.8.

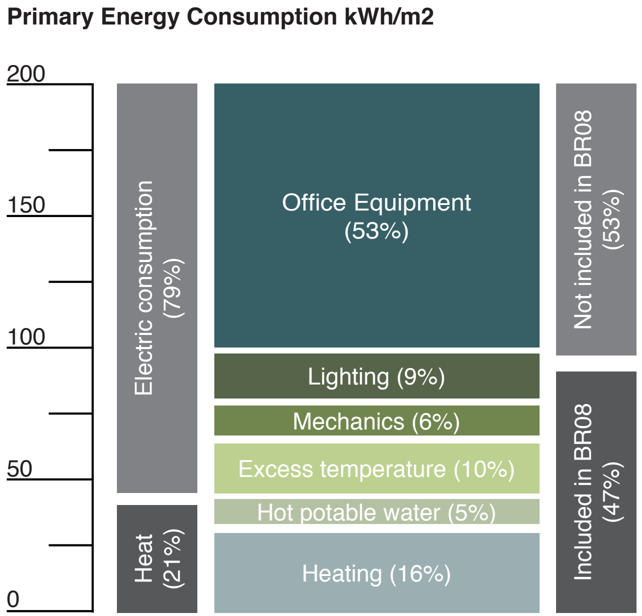


Figure C.6: Distribution of energy consumption in a typical new Danish officebuilding. Based on [52]

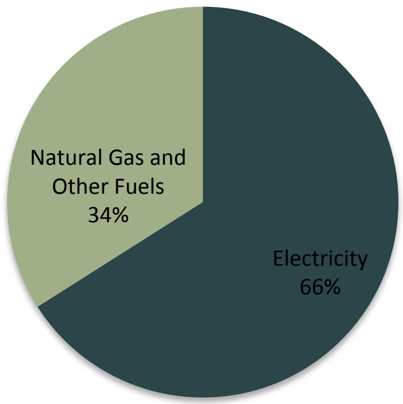


Figure C.7: Energy consumption by fuel type - based on 2003 IEA Commercuial Building Energy Consumption Survey (CBECS). Based on [56]

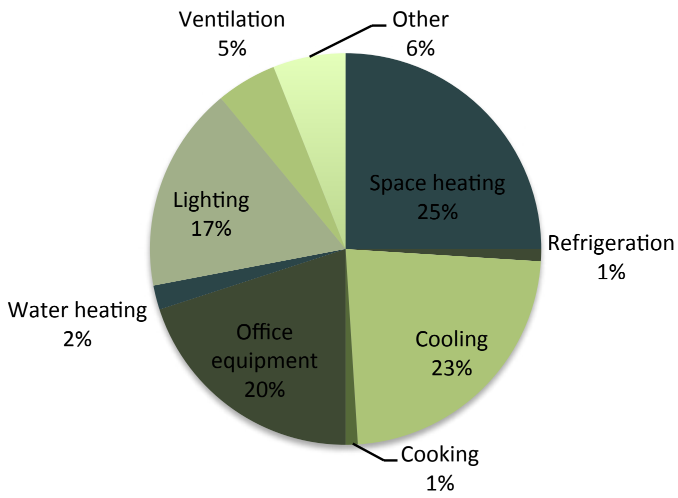


Figure C.8: Distribution of energy consumption in office buildings in the United States (2006 numbers). Based on [56]

C.1.3 Normalisation and Averages

To normalise energy consumption relatively to a primary determinant of energy use (e.g. building floor area) energy use intensity (EUI) is used to benchmark energy use in buildings. EUI is expressed in kWh/m^2 in this thesis. While this normalizes for one determinant, EUI can still vary greatly and thus does not represent a reliable benchmark, even though this is a widely utilised technique. There is a strong dependence between energy consumption and floor area, but this is also the case between energy consumption and number of workers in the building. Moreover energy consumption can be dependent on the number of personal computers, number of operating hours, whether the building is owner occupied and many more determinants could be mentioned.

A 1992 survey of electrical energy consumption of 1443 U.S. office buildings (1358 after some where excluded due to missing values and area screening) concluded a median EUI for all office buildings of 149 kWh/m^2 and an average energy consumption of 183 kWh/m^2. Averages can be strongly influenced by a small number of buildings with excessive individual EUIs. Averages should therefore be used with caution. In contrast, buildings with excessive EUIs proved to have little impact on EUI medians.

C.2 Water

This section is based on ‘Go’Energi, Uvildig offentlig organisation under Klima. Fakta om vandforbrug‘ [57] and ‘Details of Commercial Water Use and Potential Savings, by Sector’ [58].

The average annual water consumption in Danish office buildings is 0.28 m^3/m^2. In United States the average annual water consumption for office buildings is 1.97 m^3/m^2. Out of this 38% is used for landscape irrigation and 23% for cooling. These are both items that do not constitute a large amount of water consumption in Denmark. Air conditioning is utilised to a lesser extent and irrigation as well - largely due to the climate. But even subtracting these 61% from the total water consumption for an American office building still leaves a water consumption of 0.77 m^3/m^2 - still almost triple the Danish consumption. This however might very well be explained by a very high proportion of Danish buildings being fitted with water saving fixtures and fittings and a much lesser degree hereof in the United States. Nonetheless the average annual water consumption for office buildings in the United States is 7 times higher than in Denmark.

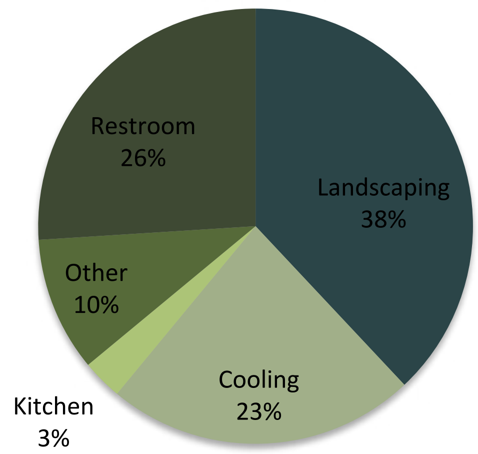


Figure C.9: Distribution of water use in office buildings in the United States. Based on [58].

D. Building Regulations

Building energy codes are minimum requirements for energyefficient design and construction for new and renovated residential and commercial buildings. [59]

D.1 Denmark

This section is based on 'Bygningsreglementet 29.08.2011- BR10' [60].

In Denmark regulations for energy consumption is stated in the danish Building Regulations. The newest version of building regulations is BR10 from 2010. In the following a short recap of relevant regulations regarding energy consumption in office buildings will be given:

7.2.1(1) The energy performance framework covers the total requirements of the building for supplied energy for heating, ventilation, cooling, domestic hot water and, where appropriate, lighting. Energy provided by different types of energy supply must be weighted.

In the energy supply system there is an energy loss, which varies for the type of energy beeing supplied - the production of the energy as well as distribution and use all influence this. The weightings reflect the CO_2 emissions from the energy beeing consumed. [52]

7.2.3(1) For offices, schools, institutions etc., the total demand of the building for energy supply for heating, ventilation, cooling and domestic hot water and lighting per m^2 of heated floor area must not exceed 71.3 kWh/m^2/year plus 1650 kWh/year divided by the heated floor area.

When calculating the total energy consumption electrical consumption is weighted with a factor 2.5 due to the greater CO_2-load from producing electricity. Sustainable heat- and electrical production on the other hand can be substracted from the energy frame.

Low energy buildings

7.2.4.2(1) Offices, schools, institutions and other buildings not covered by 7.2.4.1 may be classified as class 2015 low energy buildings when the requirement for supplied energy for heating, ventilation, cooling, domestic hot water and lighting per m^2 heated floor area does not exceed 41 kWh/year plus 1100 kWh/year divided by the heated floor area.

7.2.1(11) For buildings supplied with district heating, an energy factor of 0.8 for district heating applies to verification of compliance with low energy performance framework.

The energy factor for district heating reflects the fact that district heating is generally produced more energy efficiently than other heating supplied. The district heating factor of 0.8 can only be used in connection with low energy buildings. For regular buildings a factor of 1.0 is used as with other types of heating supply.

7.2.5 Building Class 2020

7.2.5.3(1) Offices, schools, institutions and other buildings not covered by 7.2.5.2 may be classified as building class class 2020 when the requirement for supplied energy for heating, ventilation, cooling, domestic hot water and lighting per m^2 heated floor area does not exceed 25 kWh/year.

7.2.1(12) For buildings supplied with district heating, an energy factor of 0.6 for district heating applies to verification of compliance with low energy performance framework for building class 2020. An energy factor for electricity of 1.8 is must always be applied in verification of compliance with energy performance regulations for Building Class 2020.

The energy factor for district heating of 0.6 reflects the fact that district heating is generally produced more energy efficiently than other heating supplied. A gradual development towards greater employment of solar heating and heat pumps driven by wind and solar cells within district heating is expected in the future.

The energy factor of 0.6 can only be used for building class 2020 buildings.

The energy factor of 1.8 reflects the fact that wind-, solar- and geothermal energy is credited the supply network as sustainable energy. For conventional buildings a factor of 2.5 i applied.

(Building Class 2020 is expected to be made mandatory for new construction public buildings by the end of 2018 and new construction in general from 2020.)

NB. In Denmark 52% of homes are served with district heating from combined heat and power (CHP) plants, in Europe as a whole the figure is 18%; and in the UK 8%. [2]

D.1.1 Summary of Energy Performance Framework

	[kWh/m^2/year]	Energy performance framework
BR10	71.3 + 1650/A	H + 2.5 E - SE
Low energy buildings 2015	41 + 1100/A	0.8 DH + NDH +2.5 E - SE
Building class 2020	25	0.6 DH + NDH + 1.8 E - SE

A - Heated floor area
H - Heating [kWh]
DH - District Heating [kWh]
NDH - Heating - not district
E - Electricity [kWh]
SE - Sustainable Energy [kWh]

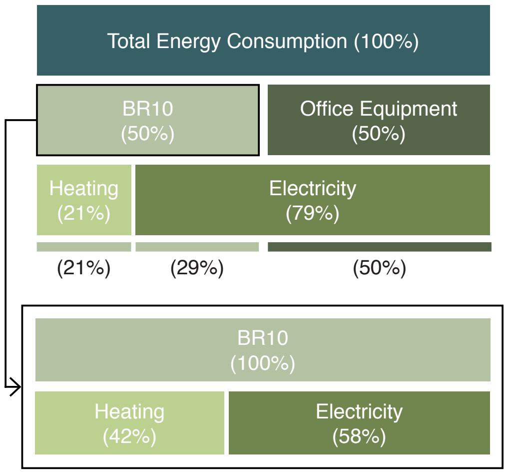
D.1.2 Calculating maximum energy use for office buildings in compliance with BR10 requirements

The danish building code give a specific frameworks for energy performance of 71.3 kWh/m^2/year for large offices and 87.8 kWh/m^2/year for small offices (assuming a small office building corresponds to a 100 m^2 office building).

Danish building regulations does not include energy used for office equipment like computers, copiers, coffee machines etc., because these are not a permanent part of the building. As mentioned earlier office equipment represent 50% of energy consumption in danish office buildings. Secondly, danish building regulations does not just set requirements for total energy consumption but also weight the energy consumption after the amount of CO_2 this causes. Forexample electricity is weighted a factor 2.5 due to the high environmental impact of electricity supply. 79% of energy consumption in a typical new office building in denmark is electricity.

In order to be able to compare danish building regulations with american regulations an estimate of the maximum total energy consumption in office buildings in compliance with BR10 has been estimated, see calculations to the right.

It is estimated that maximum energy consumption in a Danish office building in compliance with building regulations is 76 kWh/m^2/year for large office buildings and 94 kWh/m^2/year for small office buildings.



$$BR10 \approx 2.5 \times E + H$$

$$BR10 \approx 2.5 \times 58\% + 42\%$$

$$BR10 \approx 145\% + 42\%$$

$$BR10 \approx 187\%$$

$$BR10 \approx \frac{71.7kWh/m^2}{187\%} \text{ or } \frac{87.8kWh/m^2}{187\%}$$

BR10 ≈ 50% total energy consumption

Total energyconsumption ≈ 2 x BR10

Total Energyconsumption

$$\approx \frac{71.7kWh/m^2 \times 2}{187\%} \text{ or } \frac{87.8kWh/m^2 \times 2}{187\%}$$

Total Energyconsumption

≈ 76 kWh/m^2 or 94 kWh/m^2

When calculating the energy performance framework given by the danish building regulations sustainable energy supply can be substracted from the use thus, by replacing some of the energy supply with sustainable energy, compliance with regulations can be achieved with energy consumptions that are actually larger than the numbers mentioned above. Thus really the numbers above should be calibrated according to this and thus might be slightly higher, depending on the percentage of sustainable energy used in Danish office buildings.

D.2 USA

This section is based on 'An introduction. Technical report, U.S.' [59].

D.2.1 Building Energy Codes

In America two primary baseline building energy codes may be adopted by states and local jurisdictions to regulate the design and construction of new buildings:

• International Energy Conservation Code (IECC) - Current version 2012 IECC
• ASHRAE 90.1 Energy Standard - Current version ASHRAE 90.1-2010

The IECC addresses all residential and commercial buildings. ASHRAE 90.1 covers commercial buildings, defined as buildings other than single-family dwellings and multi-family buildings three stories or less above grade. Both are upgraded every three years.

Compliance with ASHRAE 90.1 qualifies as compliance with IECC for commercial buildings, because the IECC has adopted ASHRAE 90.1 by reference.

IECC

„*The IECC is developed under the auspices of the ICC using a government consensus process. [...] The IECC is one of 14 model codes developed under the auspices of the ICC that combined provide the foundation for a complete set of building construction regulations.[...] Because the IECC is written in mandatory, enforceable language, state and local jurisdictions can easily adopt, implement, and enforce the IECC as their energy code. Before adopting the IECC, state and local governments often make changes to reflect regional building practices, or state-specific energy-efficiency goals*." [59,p. 5].

ASHRAE

„*ASHRAE 90.1 is developed under the auspices of the American Society of Heating, Refrigerating and Air Conditioning Engineers using the ANSI consensus process, which requires a balance of interests. [...] The final vote of the project committee includes members from a balance of all interests, not limited to government representatives [as with the IECC]. [...] Before adopting ASHRAE 90.1, state and local governments often make changes to reflect regional building practices, or state-specific energy-efficiency goals*." [59,p. 5].

D.2.2 Average Energy Use for Office Buildings in Compliance with ASHRAE 90.1

This subsection is based on 'DOE Commercial Building Benchmarks - New Construction' [61].

ASHRAE does not prescribe a framework for energy performance like the danish building regulations. However benchmarks have been established with the intent to establish a quantitative definition of ASHRAE 90.1.

The benchmarks below are based on Energy Use Intensities (EUIs) in annual energy use per square foot ($kBtu/ft^2/yr$) for new construction buildings in compliance with ASHRAE 90.1 in sixteen climate zone cities. To ease comparison benchmarks have been translated into $kWh/m^2/yr$.

Building type	**Benchmark Weighted Average** [$kBtu/ft^2/yr$]	**Benchmark Weighted Average** [$kWh/m^2/yr$]
Large Office	39	123
Medium Office	43	136
Small Office	45	142

E. Vocabulary

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BSRIA	Building Services Research and Information Association
Btu	British Thermal Units (Traditional unit of energy equal to about 1,055 joules. 1 Btu = 0.293071 Wh (watt hours))
C&D	Construction & Demolition
CoStar	Commercial Real Estate Information Company
DKGBC	Danish Green Building Council
Energy Star	A voluntary labeling program designed to identify and promote energy efficient products
EUI	Energy Use Intensity (Normalisation of energy use expressed in kWh/ft^2)
GHG	Green House Gasses (The primary greenhouse gases in the Earth's atmosphere) are water vapour
ROI	Return On Investment
USGBC	United States Green Building Council

Bibliography

[1] Richard Caputo (2009)
Hitting the Wall: A Vision of a Secure Energy Future.
Morgan & Claypool publishers series.

[2] Brian Edwards (2010)
Rough Guide to Sustainability.
RIBA Publishing, 3rd edition.

[3] Per Heiselberg (2007)
Energy Performance of Buildings - The European Approach to Sustainability.

[4] Danmarks Vindmølleforening (2011)
Vindmøller og drivhuseffekt.
www.dkvind.dk.

[5] Joe Smith (2006)
What Do GREENS Believe.
Granta Publications.

[6] Edited by Brian Edwards et al. (1998)
Green Buildings Pay.
E & FN Spon.

[7] Annemarie Balle (2008)
Tema: Det vigtige indeklima.
Folkevirke.

[8] Dejan Mumovic and Mat Santamouris (2009)
A Handbook of Sustainable Building Design and Engineering.
Earthscan.

[9] Klima og energiministeriet (2011)
Klima og energiministeriet. Ministeriet – Kermin.
www.kemin.dk/DA-DK/KLIMAOGENERGIPOLITIK/Sider/klimaogenergipolitik.aspx

[10] USGBC (2012)
Buildings and Climate Change - industry call to action.
USGBC.

[11] UK Green Building Council (2012)
International Policy and Practice.
UK Green Building Council.

[12] Harvey M. Bernstein (2011)
The Green Outlook 2011: Green Trends Driving Growth through 2015.
McGraw Hill Construction.

[13] United States Green Building Council (2012)
USGBC Press Kit.
www.usbgc.org/DisplayPage.aspx?CMSPageID=97&#presskit

[14] Gregory H. Kats (2003)
Costs and Financial Benefits of Green Buildings
- A Report to California's Sustainable Building Task Force.

[15] Gregory H. Kats (2003)
Green Building Costs and Financial Benefits.
Massachusetts Technology Collaborative.

[16] Gregory H. Kats (2010)
Greening our built world.
Island Press.

[17] McGraw Hill Construction (2012)
McGraw Hill website.
www.construction.com

[18] McGraw Hill Construction (2011)
Green Outlook 2011 - Green Trends Driving Growth.
McGraw Hill

[19] McGraw Hill Construction (2009)
Water Use in Buildings: Achieving Business Performance Benefits through Efficiency.
McGraw Hill

[20] Conlon and Glavas (2012)
The relationship between corporate sustainability and firm financial performance.
University of Notre Dame

[21] Davis Langdon (2007)
Cost of Green Revisited - Reexamining the Feasibility and cost impact of sustainable design in the light of increased market adoption.
www.DavisLangdon.com

[22] Meryl Gonchar (2011)
The financial benefits of green building.
Greenbaum, Rowe, Smith and Davis

[23] Brian Edwards (2006)
Sustainable Development.
Wiley Interscience

[24] Norman Miller (2010)
Does green still pay off.
The Journal Of Sustainable Real Estate

[25] Derek Clements-Croome et al.(2006)
Creating the productive workplace.
Taylor & Francis, second edition.

[26] Norman Miller, Dave Pogue, Quiana D. Gough, Susane N. Davis (2009).
Green Buildings and Productivity.
The Journal Of Sustainable Real Estate.

[27] Ethisphere (2011)
World's Most Ethical Companies.
www.Ethisphere.com.
Visited: July 2012

[28] Bill Bordass (2000)
Cost and value: fact and fiction.
W T Bordass.

[29] Leena Thomas, Adrian Leaman and Monica Vandenberg (2007)
Green buildings: What australian building users are saying.
Ecolibrium.

[30] Nikolaj Hertel (2011)
Præsentation fra formand i bestyrelsen for Green Building Council Denmark.
Green Building Council Denmark.
www.dk-gbc.dk/media

[31] Fionn Stevenson, Adrian Leaman and Bill Bordass (2010)
Building evaluation - practice and principles.
Building Research & Information.

[32] Federal Facilities Council Board on Infrastructure and National Research Council the Constructed Environment (2012)
Learning from Our Buildings: A State-of-the-Practice Summary of Post-Occupancy Evaluation. National Academy Press, 2002.

[33] Anthony Gilby, Alastair Blyth and Mel Barlex (2006)
Guide to Post Occupancy Evaluation.
HEFCE

[34] Mark Way and Bill Bordass (2009)
The Soft Landings Framework. For better briefing, design, handover and building performance in-use.
BSRIA

[35] Joanna Eley Bill Bordass, Andrew Derbyshire and Adrian Leaman (2004)
Beyond probe: Making feedback routine. Closing the Loop - Post-Occupancy Evaluation - The Next Steps.

[36] Bill Bordass and Adrian Leaman (2004)
Probe: How it happened, what it found, and did it get us anywhere? Closing the Loop - Post-Occupancy Evaluation - The Next Steps.
American Council for an Energy-Efficient Economy.

[37] Bill Bordass (2006)
Poe and feedback - getting started.
The Usable Buildings Trust.

[38] BSRIA (2012)
The Soft Landings Core Principles.
BSRIA

[39] Usable Buildings Trust (2012)
BUS Methodology.
www.usablebuildings.co.uk/WebGuideOSM/
Visited: June 2012

[40] Harpa Birgisdottir, Klaus Hansen, Kim Haugbølle, Peter Hesdorf, Ib Steen Olsen, and Simon Mortensen (2010)
Bæredygtigt byggeri - afprøvning af certificeringsordninger til måling af bæredygtighed i byggeri.
Technical report, Byggeriets Evalueringscenter.

[41] Green Building Council GBC (2011)
www.usgbc.org
Visited: June 2011

[42] U.S. Green Building Council (2012)
www.usgbc.org
Visited: May 2012

[43] Nikolaj Hertel (2011)
Ejendomscertificering er mere end et mærke.
www.realdaniadebat.dk/erhvervsforum/pages/mereendetmærke.aspx
Visited: December 2011

[44] Green Building Council Denmark (2011)
www.dkgbc.dk
Visited: May 2012

[45] Harpa Birgisdottir (2010)
Sammenligning af certificeringsordninger for bæredygtig byggesektor - Metodemæsig gennemgang BREEAM vs. DGNB.
Statens Byggeforskningsinstitut - Aalborg Universitet

[46] Danmarks Meteorologiske Institut (2012)
www.Dmi.dk
Visited: July 2012

[47] National Oceanic and Atmospheric Adinistration (2012)
National Weather Service.
www.weather.gov
Visited: July 2012

[48] John Cappelen (2012)
Dansk Meteorologisk Institut. Vejret i Danmark - Året 2011.
www.dmi.dk/dmi/vejret_i_danmark_- _aret_2011, 2012
Downloadet: 13.07.2012.

[49] John Cappelen (2012)
Technical report 12-02, Denmark - dmi historical climate data collection 1768-2011 - with danish abstracts.
Technical report, Dansk Meteorologiske Institut.

[50] Jr. Michael Burgin, Devoyd Ezell, James Owenby, Richard Heim (2009)
CLIMATOGRAPHY OF THE U.S. No. 81 - Supplement 3 - Maps of Annual 1961-1990 Normal Temperature, Precipitation and Degree Days.
www.ncdc.noaa.gov/oa/documentlibrary/clim81supp3/clim81.html, 2009.
Downloadet: 13.07.2012.

[51] National Weather Service Climate Prediction Center. Regional Climate Maps (2012)
www.cpc.ncep.noaa.gov/products/analysis_monitoring/regional_monitoring/
Downloadet: 13.07.2012.

[52] Vibeke Grupe Larsen Rob Marsh and Jake Hacker (2010)
Bygninger, Energi, Klima - Mod et nyt paradigme.
Statens Byggeforskningsinstitut, first edition.

[53] Climatemps (2012)
www.usa.climatemps.com
Visited: June 2012

[54] Anne Mette K. Jørgensen (2008)
Dansk Meteorologiske Institut. Fremtidens Klima.
www.dmi.dk/dmi/index/klima/fremtidens_klima- 2.htm
Downloadet: 13.07.2012.

[55] National Action Plan for Energy Efficiency, Sector Collaborative on Energy Efficiency,
Office Building Energy Use Profile.
www.iluvtrees.org/wp-content/uploads/.../iltofficebuildingprofile.pdf
Downloadet: 13.07.2012.

[56] E Source. Managing Energy Costs in Office Buildings (2006)
www.esource.com/BEA/demo/PDF/CEA_offices.pdf
Downloadet: 13.07.2012.

[57] Energi og Bygningsministeriet - Go'Energi, Uvildig offentlig organisation under Klima. Fakta om vandforbrug (2011)
www.goenergi.dk/erhverv/teknologier/varmeanlaeg/vandforbrug/fakta-om-vandforbrug
Downloadet: 13.07.2012.

[58] Appendix E - Details of Commercial Water Use and Potential Savings, by Sector.
www.pacinst.org/reports/urban_usage/appendix_e.pdf.
Downloadet: 13.07.2012.

[59] Building energy codes 101 (2010)
An introduction. Technical report, U.S.
Department of Energy - Energy Efficiency & Renewable Energy.

[60] Erhvervs og Byggestyrelsen (2011)
Bygningsreglementet 29.08.2011- BR10.
www.ebst.dk/bygningsreglementet.dk
Downloadet: 13.07.2012.

[61] U.S. Department of Energy (DOE).
DOE Commercial Building Benchmarks - New Construction.