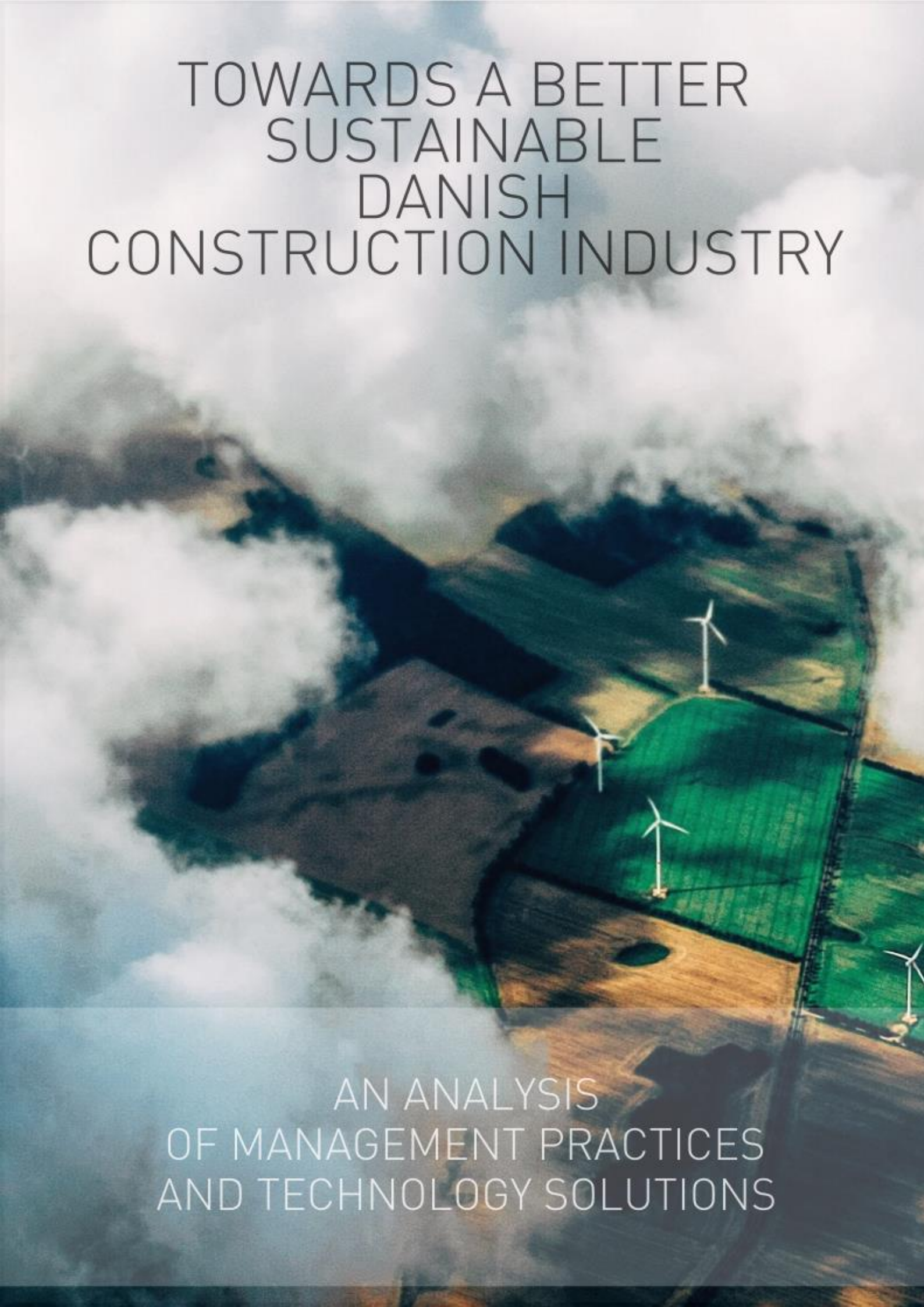
TOWARDS A BETTER SUSTAINABLE DANISH CONSTRUCTION INDUSTRY



AN ANALYSIS OF MANAGEMENT PRACTICES AND TECHNOLOGY SOLUTIONS

Title: Towards a Better Sustainable Danish Construction Industry: An Analysis of Management Practices and Technology Solutions

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By signing this document, each member of the group confirms participation on equal terms in the process of writing the project. Thus, each member of the group is responsible for all the contents in the project report.

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Synopsis

This report investigates how and with what concepts can the Energy Strategy for 2050 in Denmark be achieved. First, the current state of the construction industry is described in relation to current global environmental issues. Afterwards the key concepts and the participants within construction that are important to the feasibility of the 2050 Energy Strategy are introduced. The second part of the report focuses on analysing the concept introduced in the first part, through various methods: PESTEL, SWOT, etc. Further on, the barrier that these concepts may face with implementation are considered, as well as how they can be viewed as enablers to the 2050 Energy Strategy. Towards the end of the report, incentives for change as well as possible solutions are given by the report team.

The core problem was investigated diligently, and the report team is by the opinion that optimal solutions were given in relation to the core problem. The final parts of the report show perspectives for the future and a short criticism on the sources and methods used by the report team.

SUMMARY - English

The primary purpose of the Master Thesis Towards a Better Sustainable Danish Construction Industry: An Analysis of Management Practices and Technology Solutions is to investigate the status of sustainable development within the building industry in Denmark in regards to the current environmental challenges, linked to the 2050 Energy Strategy.

In light of the current environmental challenges, the aim of the thesis is to observe the status quo and consequently evaluate what action can be taken in order to overcome the challenges and changes that the industry must tackle. It examines in what manner they can be implemented in order to create increasingly energy efficient built environments that would meet the Energy Strategy's demands. The main research areas addressed used as reference points are:

- Energy contracts (ESCO)
- Environmental performance rating systems (DGNB, LEED, BREEAM, etc.)
- Smart buildings

The data for the thesis were obtained mainly through research of both national and international data, focusing mainly on Denmark, whenever applicable. Furthermore, two interviews with professionals from the industry were performed to support the research.

The thesis is composed of nine chapters and a conclusion, each of them dealing with a different aspect of the issue. The report itself is divided into two main bodies, divided by the problem formulation; the first one serving as a background theory basis, providing information for the second one, consisting of analyses and suggestions for implementation of an action plan.

The first chapter is introductory and presents the general idea of the report. It is followed by a methodology review, setting the general framework of how the research is conducted, along with presenting the authors' Pragmatic worldview and a combination of quantitative and qualitative research.

Chapter 3 provides an insight into the status quo of the building industry in Denmark, presenting the environmental challenge it faces, its chosen strategy and explains the idea behind energy contracting as well as sustainability rating systems. Chapter 4 follows up by describing the roles of the process participants, to show their mutual influences and connections.

Chapter 5 is the centerpoint of the report, setting a foundation for its remainder by establishing the main research question, followed by a chapter delimitating the report's scope.

The rest of the report is analytical in its nature. In Chapter 6, a PESTEL analysis is performed, followed by a criticism of environmental rating systems and Smart buildings. It concludes with a SWOT analysis of these concepts, laying a foundation for Chapter 7, which concentrates on what obstacles could prevent the three focus points respectively from being implemented in the industry on a large scale; Chapter 8 subsequently reveals which initiatives are, on the other hand, serving as an aid for them to get recognized and drive them to success. The final chapter draws the investigations to one whole and suggest specific scenarios to be implemented to make the suggestions reality. The outcome consists of two main sections: the first one elaborates on the role of the authorities and their power to establish legal incentives, subsidies for funding the research and implementation of environmentally suitable building solutions together with changing the way public projects are being procured. Secondly, methods of knowledge sharing across the industry are overviewed, both via extensive educational systems and various platforms for professionals.

The thesis is summed up by a conclusion, indicating its main outcomes as well as weaknesses. The bottom line remains that in order to make the change happen, a shift in the general mentality needs to occur first, and the major role of the authors is to provide arguments for how this can happen: predominantly by raising awareness of the issues, promoting extensive communication between building process participants as well as legislative incentives coming from the Government.

RESUME - Dansk

Formålet med vores speciale *Mod forbedring af den danske bæredygtige byggeri: En analyse af ledelsesmetoder og tekniske løsninger* er at udforske tilstanden inden for Danmarks byggebranchen vedrørende nuværende miljøudfordringer, særligt i forbindelse med den 2050 Energi Strategi.

Inden for disse rammer, målet af denne rapport er at betragte status quo og følgelig vurdere hvad for en handlingsplan kunne besejre udfordringerne såvel som ændringerne, byggebranchen skal gennemgå. Måden, på hvilken ændringerne kan blive gennemført for at skabe stigende energieffektive bebyggende omgivelser ifølge 2050 Energi Strategi-en, bliver undersøgt. Hovedområder, rapporten takler, er følgende:

- Energikontrakter (ESCO)
- Miljø- og Bæredygtighedscertificering systemer (DGNB, LEED, BREEAM, osv.)
- SMART bygninger

Data for specialen vare opnået primært gennem undersøgelse af både nationale og internationale data. Den koncentrerer sig primært om Danmark, hvor end det er brugbar.

Endvidere fik vi chancen at have et interview med to eksperter fra branchen for at støtte vores forskning.

Hver af de 9 kapitler og en konklusion, rapporten består af, handler om en særskilt perspektiv af problemet. Rapporten er opdelt i to dele, med problemformuleringen imellem dem. Den første del forsyner den teoretiske baggrund for den anden del, som består af analyse og forslager for handlingsplanens implementering.

Den første kapitel er en indledning og præsenterer ideen bag specialet. Efterfølgende findes der den anvendte metodik, som redegører hvordan forskningen var opført, sammen med forfatternes pragmatisk begreb og en blanding af kvantitativ og kvalitativ analyse.

Kapitel 3 viser status quo af Danmarks byggeindustri og fremsætter den store miljøudfordring vi står overfor, den udvalgte strategi og forklarer ideen bag ESCO-kontrakter såvel som Bæredygtighedscertificering systems. Kapitel 4 beskriver roller af byggeprocessens deltagere og undersøge deres indflydelse indbyrdes.

Kapitel 5 er rapportens hovedpunkt, som lægger fundamenter for resten af den. Problemformulering etableres her og rækkevidden afgrænses.

Resten af specialet har en analytisk karakter. Kapitel 6 indeholder en PESTEL analyse, følget af et kritisk overblik af Bæredygtighedscertificering systemer og SMART bygninger. Det afsluttes med en SWOT analyse af disse koncepter, som bygges et grund for den næste kapitel. Nummer 7 fokuserer sig på hvilke forhindringer kunne blive problematisk for de tre hovedområdernes implementering i byggebranchen. Kapitel 8 påfølger med at afsløre hvilke

initiativer hjælper disse tre koncepter med at blive genkendt og veloverstået. Den afsluttende kapitel samler undersøgelserne og foreslår miljøvenlige tiltag, som skal hjælpe med at få ændringen til at ske.

Slutresultaten består af to dele: den første handler om myndighedernes rolle i processen og deres lovgivende magt, som kan forsyne et tilskud for at finansiere miljøtiltag sammen med ændring af den måde, offentlige projekter bliver håndteret. Den anden giver et overblik over videndelingsmetoder i byggesektor, både gennem videregående uddannelse og diverse andre måde.

Specialet afsluttes med en opsummering, hvor de vigtigste slutresultater såvel som de største mangler indiceres. Bundlinjen med rapporten er, at for at gøre en forskel, den første ting som skal gennemgå en stor ændring er folkens mentalitet, og deres videnskab om miljøsagen skal opbygges. Samtidig er det forfatternes rolle at sørge for hjælpende måder overvejende ved at øge bevidstheden om problemerne, fremme af omfattende kommunikation mellem deltagere i byggeprocessen samt lovgivningsmæssige incitamenter, der kommer fra regeringen.

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Glossary

3D - three-dimensional space

4D - Four-dimensional space

AAU - Aalborg University

BACnet - communications protocol for Building Automation and Control networks

BIM - Building Information Modelling / Building Information Management

BP - British Petroleum

BRE - Building Research Establishment

BREEAM - Building Research Establishment Environmental Assessment Method

BR - Building Regulations

BRICS - five major emerging national economies: Brazil, Russia, India, China and South Africa

CASBEE - Comprehensive Assessment System for Built Environment Efficiency

CHP - Combined heat and power

CIVITAS - The Institute for the Study of Civil Society

COWI - Danish engineering company

DER - Distributed energy resources

DGNB - Deutsche Gesellschaft für Nachhaltiges Bauen

DK - Denmark

DKK - Danish Kroner (monetary currency in Denmark)

EIP-SCC - The European Innovation Partnership on Smart Cities and Communities

EPBD - Energy Performance of Buildings Directive

EPC - Energy Performance Contracting

EPD - Environmental Product Declaration

EPI - Environmental Performance Index

ESCO - Energy service company (contracting)

ETS - Emissions Trading System

EU - European Union

FM - Facility Management

FSC - Forest Stewardship Council

GDP - Gross domestic product

GICS - Global Industry Classification Standard

HQE - Haute Qualité Environnemental

HVAC - Heating, ventilation and air conditioning

ICLEI Europe - Local Governments for Sustainability Europe

IEE - Intelligent Energy Europe

IFC - Industry Foundation Classes

IFMA - International Facility Management Association

IPD - Integrated Project Delivery

ISO - The International Organization for Standardization

IT - Information Technology

LEED - Leadership in Energy and Environmental Design

MSc - Master of Science

NATO - The North Atlantic Treaty Organization

NCC - Swedish construction company

NGO - Non-governmental organization

OECD - The Organisation for Economic Co-operation and Development

O&M - Operations & Maintenance

PESTEL analysis - Political, Economic, Socio-cultural, Technological, Environmental and Legal analysis.

PHI - Passive House Institute

PHPP - Passive House Planning Package

PM - Project Manager

PPP - Public-private partnership

PV modules - Photovoltaic modules

ROI - Return on Investment

R&D - Research and Development

SGI - Sustainable Governance Indicators

SME - Small and medium-sized enterprises

SRES - Special Report on Emissions Scenarios

SWOT analysis - Strengths, Weaknesses, Opportunities, Threats analysis.

TL Byg - Danish construction company

UCN - University College Nordjylland

UK - United Kingdom

UN - United Nations

US - United States (of America)

USGB - US Green Building Council

UX - User experience design

VDC - Virtual Design Construction

VR - Virtual Reality

VVS - Danish terminology for HVAC

Preface

This report has been prepared as the final, 4th semester thesis within the Master programme "Management in the Building Industry" (*Cand. Tech. i Byggeledelse*) at Aalborg University, in accordance with the semester syllabus, by a team consisting of two members. The period of writing the report was from the 1st of September 2017 to 10th of January 2018.

The report starts with an introduction chapter that familiarizes the reader with the background of the project and the premises upon which it is written; it continues with the methodology, which will highlight the research purpose and the chosen research design. Moving further on, the report will look into the background of the current state of Danish construction industry and reviews the present environmental situation in order to lay a foundation for the remainder of the report. It proceeds with describing the situation in energy contracting as well as environmental assessments in Denmark and the process participants. These lead towards the problem formulation, where the core problem of the report to be investigated further is established. With the scope of the issue set, the thesis proceeds with an analysis section: First performing a PESTEL analysis of Denmark in regards to the building industry, then creating a critical overview of the rating systems and initiatives, further analysing it by a SWOT analysis and lastly, evaluating Smart building systems. The analysis proceeds by assessing the barriers and enablers of implementing energy contracting and rating systems and concludes with a strategy suggesting incentives for change from various perspectives. Finally, the report concludes with a summary and reflections about the project outcomes.

All additional information not included in the main body is enclosed in the appendices (containing documents created by the team members) and the annex (containing already existing material). The chapters, subchapters in the report are consecutively numbered and the annexes as well as appendices are labelled with letters in alphabetical order. The figures (pictures, tables, diagrams, etc.) are numbered correspondingly to the chapter they can be found in.

All the resources, such as books, journal articles, reports, websites and other sources of information are marked throughout the text and listed in the Bibliography section.

Acknowledgement

The report team would like to express their gratitude and thank Kjeld Svidt for the supervision given to the team during the writing process of the project report. His knowledge and experience helped guide the team throughout the duration of the report.

1. Introduction

The aim of the introduction chapter is to make the reader familiar with the general area of interest concerning this master thesis. The reader will be introduced to the subjects and topics that the report team has been working on. Lastly, this chapter explains the purpose of the project itself and finally points out the focus areas that have been identified at the beginning of the report writing period.

The topic selection process the team went through is shortly summarized and its relevance to the Management in the Building Industry MSc programme's curriculum is clarified.

Since the Curriculum states the students must "*be able to critically assess knowledge and identify emerging scientific issues within the specialization area*" (The Faculty of Engineering and Science The Study Board for Civil Engineering, 2012), the team started off with analysing the three main focus areas which connected the course's contents with emerging issues: technology, sustainability and management. Therefore, the team looked into ways of incorporating the subject of energy with management as well as technology, specifically in construction, aiming at making it more related to the Master Programme's content as well as to provide the chance to conduct a deeper analysis.

At the same time, the team was determined to investigate a topic that fulfils the following criteria:

- Related to the Danish construction industry;
- Relevant to the future of the industry's development, in both technical and managerial terms;
- Related to global issues - more specifically, sustainability.

Inspired by the initially conducted research, the report team discovered the potential embodied by these topics. More specifically, the Danish 2050 Energy Strategy and its future implications for the building industry was taken as the starting point. Therefore, this master thesis will analyse the challenges and changes that the Danish construction industry must face and implement in order to be able to create increasingly energy efficient built environments that will meet the ambitious 2050 DK Energy strategy's demands. The report team decided to focus on three concepts that, in their opinion, would be most suitable for achieving the goals of the Energy Strategy. These three concepts are: ESCO, Smart Buildings and Sustainability rating systems. This core problem will be further expanded in the problem formulation.

The next chapter clarifies the methodology the team used for the research process.

2. Methodology

The Preface and Report Introduction chapters set the general framework and what the outcome of the report is. Compared to the previous chapters, the Methodology describes how the report team will conduct the necessary research for the report. To give the report reliability, validity and consistency, several topics related to the research method/design shall be discussed. The report authors' worldview is specified and afterwards, the report research method is presented.

The report team members have previously collaborated on several reports during the Master course. This long-term collaboration established that the most suitable worldview for both contributors is the Pragmatic worldview, based on the following reasons:

1. The report team consists of two members, each with their own personality, understanding and preferences, that complement each other, akin to the Pragmatic worldview. Benefits of having such a team is that topics are looked at from different angles and a more holistic and objective outcome can be reached, compared to an individual viewpoint.

2. The specialty the report team is enrolled in is *"Management in the Building Industry"*, which deals with both hard data such as economy, time, etc. as well as soft data, which is more linked with human behaviour. Based on this, the Pragmatic worldview fits in nicely, because it encompasses using both hard and soft data, providing an ideal compromise.

The Pragmatic worldview results in a mixed research design consisting of both Qualitative and Quantitative research. As previously stated, this means that both numerical (economy, time, etc.) and behavioural aspects (mentality, public opinion, etc.) will be taken into consideration. As a consequence of both Qualitative and Quantitative data being used, data enquiry is also diverse. The information that the report team uses is collected via various means, such as:

- Relevant literature (see report bibliography) taken from reliable sources such as accredited journals (Automation in Construction, Energy Policy, etc.); search engines and databases (Scopus, ScienceDirect, Elsevier, Google Scholar), as well as various webpages belonging to governmental organizations, non-governmental organizations, private institutions and companies, etc. The report team aimed to use preferably literature from the past 5-10 years, especially when dealing with technological advances, so as to keep the report as much up to date as possible and to also use literature that had been cited before. However, if an article was deemed interesting and relevant, and the author(s) had previously published articles in accredited journals, then the material was considered suitable. With newer articles that have the publishing years of 2017 and even 2018, it is often difficult to find them with a high number of citations.

- Interviews & questionnaires sent via e-mail. The report team composed a list of contacts to whom they sent out questions relevant to the report. Answers were received in Danish, which were afterwards translated to English.
- Meetings with the assigned supervisor to the report. The report team was assigned one supervisor, with whom regular meetings (every two weeks) were held. In these meetings feedback and guidance related to the methods, structure, literature and report content was given.

All of these have been used to gain knowledge and understanding, and to validate the conducted analysis. This is in order to deliver a report that is up to the expected level.

In terms of research method, the report is split into two main bodies by the problem formulation. Before the problem formulation (Chapters 1 to 4), the report is intended to be more descriptive than investigative, although analysis is still present to some inevitable degree. Concepts, issues and key actors that are relevant to the core problem of the report are presented and analysed briefly. The second part of the report (Chapters 5 to 9), starting with the problem formulation and delimitation and continuing with deeper analysis afterwards, relies heavily on investigating the concepts and issues presented in the starting chapters. From there, the concepts are taken, possibly combined, and then applied to the 2050 Energy Strategy in Denmark, to see how they could become enablers and aid progress towards the goals stated in the strategy. Subsequently, the barriers that exist towards implementing the enablers are analysed. The role of the authorities is also analysed regarding legislation (both existing and the one yet to be introduced/yet to take effect) governmental incentives and motivation - all aimed at future energy goals. Lastly, different options how the identified enablers could be implemented from the perspective of authorities are investigated. The final chapters of the report bring a conclusion to the core problem and issues investigated throughout, as well as a perspective on future issues that can be built upon this report, and concludes with a criticism of the methods and sources used by the report team.

To sum up, the report authors worldview is stated to be Pragmatic, with usage of multiple methods of enquiry and proportionately quantitative and qualitative data. Also, the report specifies the research method, so it fits with the necessary requirements of the semester curriculum. This draws the Methodology chapter to a close, and now the research itself can start.

3. Status quo: Description of the current state of the construction industry

This chapter sets an informative foundation for the rest of the report and aims to show the underlying problems and concepts which have the biggest influence on the topics discussed in it. First of all, the global environmental status is introduced, followed by the role construction industry has there; it moves on to describing the Danish 2050 Energy Strategy and its overall purpose. Thereafter, it elaborates on the more specific initiatives that are currently being undertaken in order to achieve the following decades' ambitions to go fossil fuel free.

3.1 The environmental challenge

The fact this world is facing a huge environmental issue is undeniable. (Bohr, 2017; Tollefson, 2011)

Regardless of the political disputes on whether global warming is happening or not, one thing is definitely real - given that mankind continues its fossil fuel consumption on the current rate, it will very soon face considerably dire consequences. Not only will the resources based on fossil fuels be depleted, but "*There is now scientific consensus that the increase in these emissions is having a noticeable effect on climate. Raised global temperature is expected to cause climatic disturbance, desertification, rising sea levels and spread of disease.*" (Building Research Establishment Ltd , 2017). Some say the Earth is facing a global warming and is heating up, others claim that we are standing on the verge of another ice age; some say it is a part of a completely natural process and it is how the planet has always been evolving and constantly shifting, others claim that it is all mankind's fault. Regardless of which of these stances is closer to the truth, one fact remains indisputable: the global energy and resource consumption is on the rise. An entire report could be filed just on this matter, but only a few key figures can suffice for the purpose of this one in order to create a picture about its seriousness.

"As of 2010, world oil production remains around 85 million barrels per day (Mb/d) or 3900 million tons of oil equivalents (Mtoe) annually, with coal and natural gas at 3700 respectively 2900 Mtoe per year (BP, 2012). Some scenarios foresee a tenfold increase in world gas production, while others depict future oil production to reach 300 Mb/d by 2100. For example, 16 of the 40 coal scenarios contained

in SRES simply grow exponentially until the year 2100." (Höök & Xu, 2013) Due to the many factors that influence the climate change rate, opinions and predictions vary on the specific date. What is clear is that the carbon dioxides level in atmosphere are creeping upwards year by year (Pappas, 2013). In other words, it means that at this rate, within a few decades the levels will hit prehistoric levels, when the global average temperature was around 3.5°C higher and sea levels were up to 40 m higher than they are today, thanks to thermal expansion (Mimura, 2013), atmospheric pressure changes as well as gradual shift in ocean currents' direction and velocity. Islands such as Kiribati or Tuvalu are already now experiencing the first visible effects of the climate change, facing the danger of eventually disappearing (Astaiza, 2012). According to *Energy for a Sustainable World*, "*If we wish to maintain the trend of increasing energy consumption of the past 60 years up to 2050, we need to build every day about 3 carbon-burning power plants, or 2 nuclear plants, or 10 km² of PV modules.*" (Armaroli & Balzani, 2011, p. 315) This sounds rather alarming, but at the same time, "*on average, covering ~0.6% of European territory by PV modules should theoretically satisfy its entire electricity demand.*" (Armaroli & Balzani, 2011, p. 317). To put things into perspective, considering that Europe stretches over approximately 10.18 mio km², 0.6% of this number represents an area the size of Latvia, or around 1.4 times the area of Denmark (Wikipedia, 2017). In other words, it would require each of the 44 European countries to use 0.013% of their land for this purpose, which suddenly sounds more feasible.

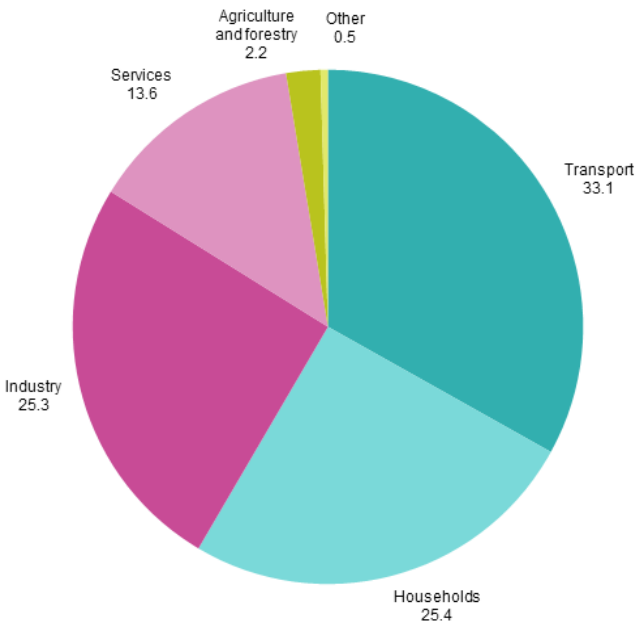


Figure 1 – Energy consumption by sector

Taking a more local look, at the moment, only 13% of European energy is sourced from renewables (European Commission, 2016); all the rest comes from oil, gas, nuclear plants, petroleum, coal and other non-renewables. The graph in Figure 1 below created by Eurostat shows that a quarter of final energy consumption can be assigned to households and another to industry (Eurostat, 2016).

Zooming in on Denmark, the diagram below in Figure 2 by Nordic Energy Research shows that almost half of all energy used in the country can be accounted to buildings, two thirds of which goes to residential buildings (Nordic Energy Research, 2013). However, these figures only take into account the amount of energy the existing households' users are using; it does not take into account the energy embodied within the resources necessary for their construction.

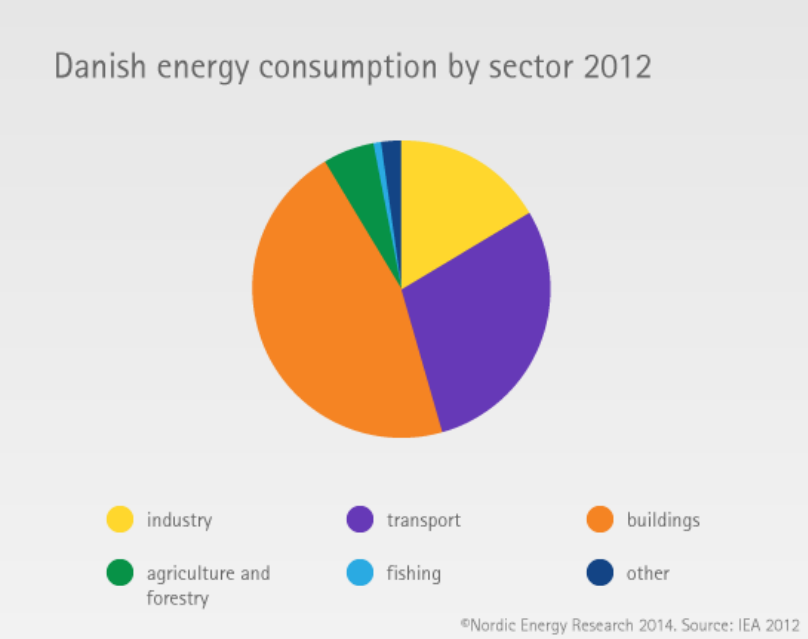


Figure 2- Danish energy consumption by sector, 2012 (Nordic Energy Research, 2013)

These facts altogether point towards the incredible complexity of the environmental issue and the sheer impossibility to find its single source, or solve it simply by taking only one area into account. Thus, the problem clearly needs to be tackled from a holistic viewpoint. Restrictions in resources will inevitably affect global energy supplies. Furthermore, *"Energy constraints pose a threat to the economy (Nel and Cooper, 2009), and similarly changes in human energy-related behaviours can lead to a broad range of effects on natural ecosystems"* (Höök & Xu, 2013). Regardless of what the main cause of the climate issue is and what exactly the outcome will look like, it is clear that we do have the means to slow the process down or reverse it - all it takes is a good initiative and change of attitude, which will be discussed in the next subchapter.

3.2 The 2050 Energy strategy in Denmark

The Energy strategy in Denmark was worked out by the Danish Ministry of Climate and Energy in February 2011. It is based on the prediction that *"within the next 25 years, the world's total energy consumption is expected to increase by one-third."* It further elaborates that an energy race can be expected, resulting in increasing prices and uncertainty, as most of the fossil fuel

energy resources are located in rather politically unstable countries - and Denmark has no wish to take part in this race. Since no country can achieve complete success in decreasing its carbon footprint without mutual tolerance and collaboration with its neighbours, the EU has already set up a commitment for 30% carbon emission reduction by 2020 (The Danish Ministry of Climate and Energy, 2011, p. 3), as well as a long-term objective to cut carbon emissions by at least 80% compared to the 1990 level in a feasible and affordable way. (European Commussion, 2017)

According to EPI (Environmental Performance Index), which *ranks countries' performance on high-priority environmental issues in two areas: protection of human health and protection of ecosystems* based on 20 indicators (EPI 2016), Denmark ranks on the quite impressive 4th place, just after Finland, Iceland and Sweden. What these countries all have in common is their recent initiative to rapidly cut their fossil fuels usage - as none of them appeared in the top 5 in the 2014 issue of the same report and the results are already showing. (Environmental Performance Index, 2016, p. 111). Moreover, Denmark "*already has a successful track record of securing economic growth without energy consumption growth. Since 1980, the Danish economy has grown by 78%, while energy consumption has remained more or less constant.*" (The Danish Ministry of Climate and Energy, 2011, p. 3) Now, the incentive is to take it further and make Denmark completely independent from coal, oil and gas by 2050. At the same time, it has a high ambition to maintain a safe environment for the companies by maintaining *high security of supply and ensure stable, affordable energy supply*; instead of focusing on new, financially demanding technologies, the focus is aimed at *research, development and demonstration*. This way long-term competitiveness at a lower cost can be achieved with minimised impact on the country's budget (The Danish Ministry of Climate and Energy, 2011, p. 6). At the same time, it also binds Denmark to contribute to the overall EU 2050 low-carbon economy. The graph below in Figure 3 (The Danish Ministry of Climate and Energy, 2011, p. 10) demonstrates the development of resource consumption with and without implementing the new initiatives.

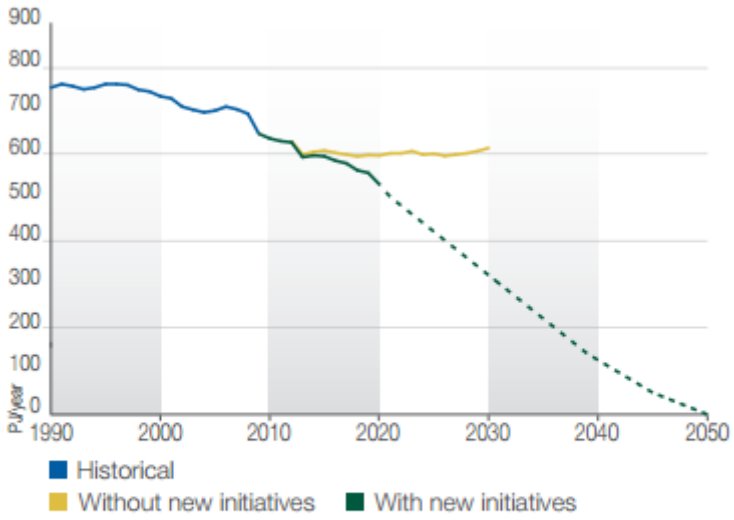


Figure 3 Consumption of coal, oil and natural gas 1990-2050. Source: Danish Energy Agency

It presents a target - to reach the goal by 2050 - as well as a strategy describing how to achieve this by presenting three main tracks. These, when combined, are expected to bring about the necessary change: the conversion track, the planning and preparation track, and the technology development track (which, as previously mentioned, is mostly aimed at research). Within each of them, specific measures and initiatives are defined. One of the main focus is on broadening the wind power across the country and improving framework for biogas plants, introducing energy saving obligations in all sorts of buildings including public institutions, businesses and households; find strategies to utilise local resources more efficiently. The goals with the closest proximity towards construction are tighter energy efficiency standards for new buildings in 2020 (and onwards); promotion of smart grids; funding demonstration of projects that involve solar heating, etc. Furthermore, it encourages entering partnerships with the business community and thus create tighter coordination - in other words, PPP.

The possible drawback in current planning is the fact that it is not possible to predict the scale of technological advancement up to the next three decades very accurately. A good image of how difficult it is to make an accurate prediction about the future can be made by looking at how people imagined what life in this decade would be like back in the 80s (see Figure 4), according to a rather thrilling issue of the LA Magazine from 1988. (Yorkin, 1988). While we still don't have 4D cinemas in every household and robots don't normally cook our dinners as predicted, the authors did not have a single idea that phenomena such as the World Wide Web, wi-fi, smart phones or even cloud storage would come into everyday use - yet today they form the very foundation of our daily survival (Bennett, 2013). It is, therefore, extremely hard to predict what it will be possible to count with for the next 30 years, as it will most likely develop way out of the scope of our current perception and understanding of the world. Picture - illustration from the LA magazine What we do know is the approximate areas this technology will most likely be centred around: solar, wind and wave energy and their implementation in various areas.

Figure 4 – Original illustration from L.A. Times, April 1988

Another building-related tricky part is the fact buildings have a rather long life span - they are expected to operate up to a century, or even more. Naturally, renovation is also an unavoidable part of their life cycle; nevertheless, it is necessary to "future-proof" newly built buildings, as they are not likely to undergo renovation before the 2050 strategy takes full effect. At the same time, according to the Danish Ministry of Climate and Energy, new buildings only account for ~1% of the current building stock - thus a lot of the attention

should be directed at retrofitting the existing ones. This can be done through enhancing insulation, replacing windows, sealing possible leaks and in combination with ongoing maintenance, *"heating consumption in existing buildings can be reduced by approximately 50% of consumption levels today at a reasonable cost."* Achieving this will call for a fuel shift and replacement of the currently operating oil and gas heaters with more district heating, heat pumps and solar energy (The Danish Ministry of Climate and Energy, 2011, p. 18). The next section will amongst other topics take a closer look at how energy performance contracts can make such retrofits more feasible.

3.3 ESCO & ESCO Contracting

The construction process is complex, with many parties involved throughout the lifecycle of the building, starting all the way from conception to demolition. These parties are in many instances legally bound by some sort of contract. In construction, the "traditional" contracting types are considered to be the trade-by-trade, main contract and turnkey. One of the reasons why these contracting types are undoubtedly popular, is because they are easy to understand by all the parties involved as well as simple to uphold. Newer forms of contracting, such as PPP and Partnering, have only come around in recent years and are gaining popularity.

3.3.1 Introduction to EPC and ESCO

While all the above mentioned contracting types fulfil their intended purposes and provide good solutions depending on the projects they are applied to, none of them focuses specifically on providing energy savings in new buildings and energy reduction in retrofit projects. In light of this, and also because of increasing global concerns in reducing the consumption of energy, as well as a trend to build "greener" and more sustainable buildings, a certain contracting type - EPC, and concept - ESCO, have been gaining popularity. At its core, EPC is actually a turnkey contract which guarantees a building will be able to provide *"high energy-saving"* and well as *"low energy consumption costs"*, throughout the operational phase of the building (Zhang, et al., 2015, p. 3).

EPC (Energy Performance Contracting) has multiple definitions, even to this date, which vary from country to country. However, *The Directive on Energy efficiency (Directive 2012/27/EU)* defines EPC as "*a contractual arrangement between the beneficiary and the provider of an energy efficiency improvement measure, verified and monitored during the whole term of the contract, where investments (work, supply or service) in that measure are paid for in relation to a contractually agreed level of energy efficiency improvement or other agreed energy performance criterion, such as financial savings"* (European Council, 2012). In spite of this definition being given in an EU directive from 2012, the EPC concept appeared in EU already in the 1980s, yet only in the last couple of years has it gained more widespread use, especially in Denmark, which is concurrent with the increasing concern for energy savings. In Denmark, the term EPC is not so commonly used, with the term ESCO-contract being better accepted. This

report shall also be using the term ESCO-contract, as it is focuses more on Denmark, than the entire EU.

ESCO (Energy Service Companies) are defined by the *Directive on Energy end-user efficiency and energy services (Directive 2006/32/EC)* as "*a natural or legal person that delivers energy services and/or other energy efficiency improvement measures in a user's facility or premises, and accepts some degree of financial risk in so doing. The payment for the services delivered is based (either wholly or in part) on the achievement of energy efficiency improvements and on the meeting of the other agreed performance criteria*" (European Council, 2006, p. 5) . As stated in the definition, the ESCO transfers some of the risk from the client that wishes to engage in an ESCO-contract. Because of this, more and more entities and companies are interested in engaging in projects that include an ESCO-contract. But at least for now, it is mostly the public entities or companies working on public contracts that seem to be more open to ESCO-contracting.

3.3.2 ESCO around the world

In regards to ESCO and ESCO contracting, it is quite difficult to look at it from a singular global perspective, because of the differences in how it is implemented around the world, as well as the varying viewpoints and attitudes towards it. The US ESCO market will be briefly summarized in the first place, as it is one of the most prominent and powerful ESCO markets. Afterwards, the EU ESCO market will be looked into, with a deeper focus on Denmark, because it suits the scope of this report. Other strong ESCO markets around the world include China, India and Australia.

In the US, the ESCO market is very well-established, as it started developing back in the 1970's and 1980's, due to rising costs in energy. The US market embraced the ESCO model and energy savings performance contracts (ESPC), and has since grown to a multibillion dollar revenue industry. The Ernest Orlando Lawrence Berkeley National Laboratory provides some details on this fact, stating that *"In 2011, ESCOs reported aggregate industry revenues of about $5.3 billion, with expectations of growing to about $7 billion by the end of 2014."* (Short, et al., 2016, p. 14) When comparing the revenue from the US ESCO industry to that of the US construction industry annual revenue of 2016, which according to *Statistic Brain* was $1.731 trillion (Statistic Brain, 2016), it can be observed that revenues from ESCOs are just a small part of the total revenue of the US construction industry. This does not mean that the future of ESCOs isn't optimistic, with expectations being that the industry would continue growing in the US, despite the fact that between 2011 and 2014, the market did not register growth, but instead remained steady. Even in spite of this setback in growth, The Ernest Orlando Lawrence Berkeley National Laboratory states again that *"ESCO industry executives anticipate revenues of ~$7.6 billion in 2017*" (Short, et al., 2016, p. 45). Based on the statement, it seems that once more, confidence is high within the US ESCOs, but it remains to be seen if the prediction turns out to be true.

Moving on to the EU, here the ESCO market behaves differently, with each country having their own ESCO market. However, even if each country has its own market, the EU

regulations and directives provide some common ground for the member states. The legal framework was developed for the EU ESCO market, by the way of the Energy Service Directive (ESD - 2006/32/EC) and Energy Efficiency Directive (EED - 2012/27/EU), also referenced in 3.3.1 Introduction to EPC and ESCO. These were drafted in order to make the ESCO model more appealing, raise awareness and try to spur growth in the EU countries that do not have established ESCO markets.

Some of the larger EU markets include Germany and France, which are compared to the US in the article *Analysis of barriers and drivers for the development of the ESCO markets in Europe*: *"U.S. ESCO industry is similar in size to the ESCO industries in Germany, France, and China."* (Bertoldi & Boza-Kiss, 2017, p. 2). This comparison seems somewhat far-fetched, because according to the same publication, "*the total EU market was estimated at ca. €2.4 billion in ESCO revenue in 2015"*. Based on this, it can be observed that the total EU market revenue is more than two times smaller than its US counterpart. The difference is more or less based on several factors, which amongst others include the difference in popularity of the ESCO concept, the demand of energy savings, and the number of projects that require or demand low-energy solutions. The level of development for each national ESCO market within the EU can be seen in Annex 2.

3.3.3 ESCO in Denmark

Looking specifically at the ESCO market in Denmark, in the past years a substantial growth was recorded and the number of ESCO project rose considerably, as evidenced by *Analysis of barriers and drivers…*, *"markets grew between 2010 and 2013, with the strongest growth experienced in Denmark, France, Ireland and Spain."* (Bertoldi & Boza-Kiss, 2017, p. 3). The market in Denmark grew from €8-25 million to €140-150 million, with a potential estimate for the market between the years 2012-2013 being €1 billion (Bertoldi & Boza-Kiss, 2017, p. 3). When it comes to Denmark, the companies that offer ESCO services are usually big companies, that operate at an international level. Companies that offer ESCO services in Denmark include: the engineering company Kemp & Lauritzen, the multinational corporation Schneider Electric, the construction company NCC and the energy provider Eniig, etc. It can be observed from which type of companies provide ESCO services in Denmark, that there are many opportunities that a client in construction industry could look into, if they wish to engage in an ESCO project. In Denmark, the main clients that also contributed a lot to the growth of ESCO are the municipalities. According to *Greening Public Buildings: ESCO-Contracting in Danish Municipalities*, in 2013 *"30 municipalities (out of 98 municipalities in Denmark) have signed ESCO-contracts or are preparing to do so."* (Jensen, et al., 2013, p. 1)

It is by the opinion of the report team, that by now, in 2017, the number of municipalities and even private clients that engage in ESCO projects in Denmark has increased; however, no hard data for such growth could be found. Chapters 6.4, 7 and 8 will return to the concept of ESCO, where a detailed analysis of the ESCO industry within Denmark shall be done and will include amongst others, a SWOT Analysis as well as the drivers and barriers of ESCO

within Denmark, recent market trends and also some insights from people that have worked with ESCO.

The next subchapter describes various initiatives from around the world that assess, rate and certify the sustainability of buildings, and provide some details on how they are useful for promoting a better and greener future.

3.4 Sustainability and environmental performance rating systems

In current times, the concepts of sustainability and sustainable development are key issues within society. The three main foundation pillars of sustainability are often considered to be: social sustainability (effects of a system on society), environmental sustainability (impact on the environment) and economic sustainability (economic implications). Together they are known as the triple bottom line of sustainability, which can be seen in Figure 5.

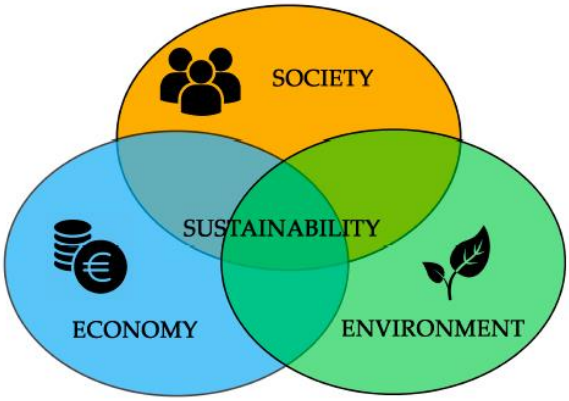


Figure 5 - Triple bottom line of sustainability, from An Analysis of the Most Adopted Rating Systems for Assessing the Environmental Impact of Buildings

In the construction industry, an increasing number of clients are asking for the projects they are envisioning to be built "green" or sustainable. This means that a building must be resource- and energy efficient and have a reduced environmental impact throughout the building's life cycle: planning, design, construction, operation, maintenance, renovation and demolition. In order to help assess a building's level of environmental performance, several assessment schemes have been developed over the years. A definition of these schemes can be phrased as follows: *"The rating systems for assessing the environmental performance of buildings are intended to establish an objective and comprehensive method for evaluating a broad range of environmental performance. The aim of these schemes is to measure the performance of a building in a consistent and harmonized manner with respect to pre-established standards, guidelines, factors, or criteria."* (Bernardi, et al., 2017, p. 2) In short, the main purpose of these schemes is to measure performance, and furthermore it also gives buildings a certification that the requirements for sustainability are fulfilled. The following paragraphs describe several of the more popular

rating systems for assessing the environmental performance of buildings. A more detailed listing of their assessment categories can be found in Appendices A and B.

3.4.1 BREEAM

The Building Research Establishment Environmental Assessment Method, more commonly known as BREEAM, published by the Building Research Establishment (BRE) in the UK in 1990, is the oldest method of assessing the environmental impact of a building. It paved the way for a multitude of rating systems, and according to *An Analysis…*, over 70 such rating systems having been developed worldwide, with most of them being in Europe (54), Asia (15) and North America (8) (Bernardi, et al., 2017, p. 5). The most popular by far is BREEAM, with over 550,000 certified projects all over the world. Bernardi et al. described the scheme as *"composed of ten categories describing sustainability through 71 criteria in total. A percentage-weighting factor is assigned to each category, and the overall number of 112 available credits is proportionally assigned."* (Bernardi, et al., 2017, p. 8)

Different rating systems exist within BREEAM, and are to be used according to the scope of a specific project. These rating systems are: BREEAM New Construction (new non-residential buildings in UK), BREEAM International New Construction (new residential and non-residential buildings outside of UK, and countries that have their own national BREEAM scheme), BREEAM In-use (existing buildings), BREEAM Refurbishment (refurbishment projects), and BREEAM Communities (master planning of whole communities). BREEAM has seen some application in Denmark, but not on a large scale, when compared to worldwide usage. Only 18 certified BREEAM projects currently exist in Denmark, 4 of them having the "Very Good" certification, according to The Green Building Information Gateway (GBIG, 2017).

3.4.2 LEED

Leadership in Energy and Environmental Design, or LEED, was first developed in the USA in 1998, by the US Green Building Council (USGB). LEED has gone through many versions since its inception, and as of 2016, LEED Version 4.0 is being used. As of 2017, there 89,600 LEED Certified projects. LEED is a bit different when it comes to how it evaluates performance, when compared to BREEAM AND DGNB. *"The LEED® Green Building Rating Systems are voluntary and are intended to evaluate the environmental performance of the whole building over its life cycle. Different schemes are designed for rating new and existing commercial, institutional, and residential buildings. Each scheme has the same list of performance requirements set out in five categories, but the number of credits, prerequisites, and available points change considerably according to the specific area of interest and the building type."* (Bernardi, et al., 2017, p. 11) When it comes to LEED in Denmark, the rating system is somewhat used, but it has no national adaptation. According to The Green Building Information Gateway, there are currently 13 LEED certified projects in Denmark, 5 of them having Platinum certification (GBIG, 2017).

3.4.3 DGNB

The Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB), launched in 2009 by the German Sustainable Building Council aims to promote sustainability in construction in Germany, and also grant a German certificate for sustainable buildings. As of April 2017, there are more than 718 projects with certification in DGNB. Bernardi et al. describe it as follows: "*The evaluation is based on 63 criteria, subdivided into six categories that are weighted by a specific weighting factor. The sum of the points obtained in all the categories provides the overall score for the building. Each criterion can receive a maximum of 10 points. Four categories (ecological quality, economical quality, socio-cultural and functional quality, and technical quality) have equal weight in the assessment, while process quality is less important.*" (Bernardi, et al., 2017, p. 9)

DGNB is one of the more popular rating system that is used in Denmark, having also received a national adaptation. Its use is being promoted by Green Building Council Denmark, which is a non-profit member organisation with over 281 members. Their vision is to expand sustainability in the construction industry, and support a green change in Denmark, whilst their mission is to improve the sustainability of building and the surrounding environment by various objectives, which includes increasing the use of the Danish DGNB certification scheme. As stated by Green Building Council, there are 39 certified DGNB projects in Denmark, with another 24 buildings having pre-certification. According to the Sustainable Building Alliance, "*DGNB Pre-Certification supports integrated planning, providing early optimisation potential for construction, management, conversion and disassembly with an emphasis on optimising costs. Pre-Certificates are fully valid certificates in their own right; however, they only remain valid until the building is completed.*" (Green Building Council Denmark, 2017)

Based on the above described rating systems (BREEAM, LEED and DGNB) some similarities between them can be observed. Each have a number of criteria, categories and make usage of weighting factors, and ultimately fulfil the same role of attributing a performance rating regarding sustainability, to a building or project. The interesting question arising from looking at the huge amount of different ratings systems being used worldwide, is why there are so many to begin with, if they primarily serve the same purpose. Why doesn't one rating system exist that can be used around the world, and provide a sort of standardization? A thorough analysis of the similarities and differences of these rating systems, as well as considering how a singular rating system would affect the industry, will be done later in the report, in Chapter 6.2.

The next chapter takes a look at the different participants within construction projects, and describe what their role currently is, and how it should change in order to facilitate a more energy efficient and sustainable construction industry.

4. Process participants

This chapter presents the actors within the construction industry the report is focused on by analysing how their roles are shifting and changing. Additionally, it investigates how much influence these actors have on the process of enabling sustainable practices. For the sake of making the overview clearer, each of the actors will be analysed from two main perspectives: firstly, how they are contributing currently and what practices are not ideal; and secondly, hint a suggestion how these could be addressed to provide a foundation for further analysis in Chapter 8 - Enablers.

4.1 Clients

The client's role in construction projects is crucial, as he is the one that envisions the project, and then relays his vision to the architects, engineers and other consultants. The client is also the one that pays for the project, and it is in his ultimate interest that his needs, desires and requirements are fulfilled.

There are multiple types of clients in construction, ranging from public to private; government, local authorities, real estate companies, private home owners, etc. These clients have a lot of things in common, but also a lot of dissimilarities. One thing that most clients have in common is mentality. For example, a lot of them prefer to have their project built as cheap as possible, by way of the lowest price criterion. This is in contrast to the three main attributes of a "good" client, as stated by the journal *Engineering, Construction and Architectural Management "(1) Clear and consistent about their needs from the outset (helped by the industry); (2) An understanding that successful project delivery is not necessarily guaranteed by awarding the contract to the lowest bidder; (3) Active involvement in the project and working closely with the whole project team as it proceeds."* (Loosemore & Richard, 2015, p. 7)

However, in recent years a trend has emerged where more and more clients request their projects be built not by the lowest price, but by best value for their money. This could mean requesting usage of higher quality materials, achieving better indoor climate, increased energy efficiency in buildings, and so on. This change in mentality could be attributed to higher demands from end users, the rising global concern in regards to environmental issues, but also in response to newer and stricter national regulations regarding materials, indoor comfort, energy, etc. In spite of this positive change, the rate of clients that request low-energy building projects is not growing at a fast-enough rate in the opinion of the report team, if the 2050 goals are to be reached. As an example, according to DGNB System, as of January 2018, 233 projects have received DGNB certification for the year 2017, compared to 193 projects that have received the same certificate in 2016, which is only an increase of 18.7% (DGNB, 2017). In an ideal situation, at least 25% of all buildings that are to be finalized by 2020, should be eligible for one certification or the other, DGNB, BREAAM, etc, and the

number should gradually increase by 2050, in order to ensure that global energy goals can be met.

Because of this, a powerful catalyst is needed in order to motivate the majority of clients to start being more innovative and also request low-energy buildings. In Denmark, such a catalyst could be considered the 2050 Energy Strategy. Furthermore, it seems that at least in terms of ESCO contracting, the municipalities are trying to act as drivers, in order to make the ESCO concept more popular even amongst private clients. ESCO projects will be more expensive at first, but the return on investment will even out with time, and the clients will actually end up saving money after 10-20 years, because of the reduced energy consumption. Moreover, with ESCO, the clients have a guarantee, and the amount of risk they undertake is reduced.

Regardless whether it is related to ESCO or other trends and technologies within construction, clients should be more open towards innovation and newer, relatively unexplored concepts. In the opinion of the report team, only a small number of clients are willing to risk their money in order to try and build projects that require innovative concepts, or even just dare to go outside of the traditional methods. Also, in the opinion of the report team, the role of the client and the mindset towards the cost of investing in new practices, must change if the construction industry wishes to start developing at a faster pace. Lastly, the clients should also start trusting consultants and experts within the industry more and more, because in most cases these experts have a broader knowledge of the new trends and practices, that ultimately can help clients achieve better projects, but also better value for money.

The next sub-chapter describes how the design team (architects & engineers) in a construction project currently is set up, and how they must adapt and change to be able to contribute to developing the construction industry.

4.2 Design team (architects & engineers)

The design team's role in construction is the one that requires the most creativity, but also precision. It is quintessential that architects and engineers collaborate together with all the parties involved, to make sure that the client's vision is made reality, whilst attaining a project that is buildable by the contractor. There are many examples of projects that at one point were considered impossible (Burj Khalifa, Sydney Opera, etc.), but the advances in technology, both in the design and execution phases, made the inconceivable come true. With the inevitable future developments in construction technology, it is a necessity for architecture and engineering firms to keep up with the pace.

The skillsets that must exist within an architecture/engineering firm, has somewhat shifted and expanded, when compared to a decade ago or so. Some of the necessary skills,

competences and knowledge a design team need to possess in today's construction industry are highlighted below.

- Good skills with various BIM and IT software has become a key attribute of successful architects and engineers alike.
- Keeping up with current technological trends in construction is a must.
- Having of good overview of the entire construction process, from "cradle to grave", coupled with solid project management skills is what defines good designers from outstanding designers.
- Good communication and coordination is vital. Client counselling is also very important, considering client demands are increasing and becoming more complex.
- Knowledge of building laws, codes and regulations (this is especially vital if designers engage in projects that aim to be energy efficient, sustainable or trying to achieve a good rating in a sustainability rating system such as BREEAM or DGNB)

Architects nowadays must be capable of designing a project in a 3D BIM program (Revit, ArchiCad etc.), and engineers must be capable of using structural BIM programmes (Tekla Structures, Revit Structure etc.), clash-detection software (Solibri, Navisworks, etc.), simulations, HVAC, building performance analyses, amongst others. This is to make sure that the execution phase goes as smoothly as possible, and no major time delays or cost overruns occur. The main point is that architects and engineers must be familiar with various BIM & IT tools, in some cases from different developers, in order to be able to properly contribute to the design of a building. This is especially important for buildings that want to be sustainable and as energy efficient as possible, as BIM can help greatly in the design of such buildings; "*BIM allows for multi-disciplinary information to be superimposed on one model, which creates an opportunity for sustainability measures to be incorporated throughout the design process.*" and "*With the aid of these BIM applications, architects and engineers can more effectively share information related to sustainability, such as daylighting and energy consumption, and thus the sustainability analysis can be seamlessly integrated into the design process.*" (Lu, et al., 2017)

In almost every complex project, the design team has to collaborate very closely together, and the exchange of documents and models will happen many times throughout the design process. In this sense, the process has changed, requiring constant collaboration, instead of how it used to be: that the architect finished his part, and then sent the drawings or model to the engineers, who after completing their tasks would hand it over further down the process line. In the worst case, both parties would send their separate documentation to the contractor, who would have some very hard times making sense of it, and fitting it together. Consequently, most of the mistakes in the project would happen at this time.

Collaboration with contractors is also becoming more and more common, due to the increased use of concepts such as Integrated Project Delivery (IPD), which is furthermore facilitated by the usage of BIM. In IPD, the client, consultancy team and the contractor collaborate on a project from the start, until the handing over and maintenance. This puts the

designers in a position that they must be able to have an overview of the entire project, as their input and help might be required in the latter stages of a building's lifecycle.

As the demands of clients are progressively increasing (desire for low-energy buildings at a decent cost, higher quality of materials, shorter construction time, etc.), so does the workload of the design team, not only in terms of meeting these expectations, but counselling the client in order to make sure that what they desire isn't unrealistic, or too ambitious for the budget set to the project. Because of this, it is imperative that architects, engineers and other consultants have very good negotiation skills. It is not an easy task to convince a client that his ideas might not be the best, and that there are better alternatives on the market.

Lastly, because of the ever-shifting legislation, as well as the introduction of laws specifically designed to reduce energy consumption, designers must be familiar with the latest legislative. It also helps to be familiar with different sustainability rating systems used in Denmark, for example DGNB. If a building is intended to be designed and built in such a way to meet a specific rating within the system, for example Gold certificate in DGNB, the designers must be aware of the criteria that need to be met and the categories they need to focus on. Furthermore, it is necessary that a building meets the national building code and regulation in regards to energy, buildability, comfort, safety, etc. A summary of the necessary skills, competences and knowledge that designers must possess in the future, in the opinion of the report team, is given in Figure 6.

The next sub-chapter will look into the issues being faced by contractors in the construction industry, and how these issues can be overcome through various means.

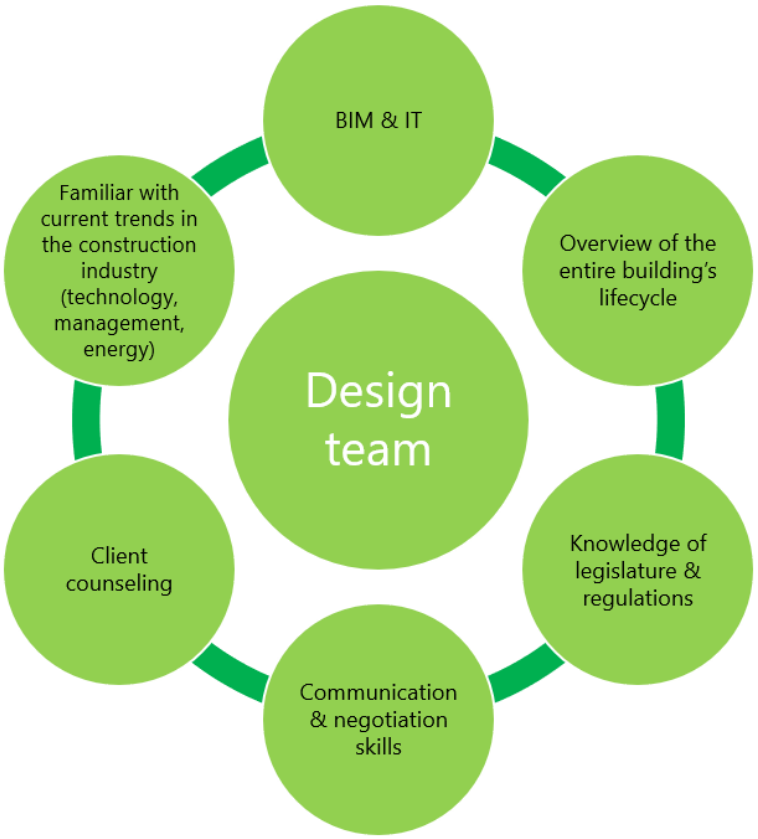


Figure 6- Skills, competences and knowledge future design teams must possess

4.3 Contractors

There are quite a few categories of companies and figures that fall under the *contractor* label. It can be an architectural or engineering consultancy company (such as Friis & Moltke or Grontmij), a main/total contractor (such as NCC or TL Byg) a subcontractor in different areas of expertise from VVS to carpentry (Thomsen og Fals, Skjøtt) and even a materials manufacturer and supplier (Spæncom, Ambercon). Having the ESCO initiatives in focus, energy providing companies can also be regarded as a contractor in this context. Since a chain is only as strong as its weakest link, all the participants of a building process are bound to receive equal attention in order to achieve optimum results. Naturally, the specific details of what skills and responsibilities the individual parties shall have would differ according to the contract type, yet for this thesis' purpose, a more general approach is used.

A general issue that is seen globally at the moment is that many contracting companies are proclaiming themselves to be "sustainable", but the more this word gets repeated, the vaguer its actual meaning becomes. Looking at GICS - the Global Industry Classification Standard - an industry taxonomy tool, it puts together into one category businesses from diametrically opposing backgrounds (MSCI Inc., 2016) . For example, the same "Energy" category would be used for both a wind energy company and a fossil fuel giant. Similarly, no difference can be noted between palm oil forestry firm or a FSC certified business (section 15 - Materials) (MSCI Inc., 2017; S&P Dow Jones Indices LLC, 2017). Looking at their current initiatives, instead of trying to establish a somewhat more efficient taxonomy actually distinguishing between real sustainable solutions and those which only claim to be such, they seem busy fixing their telecommunication structure and adding a section for real estate instead (S&P Dow Jones Indices LLC, 2017). It is also often hard to tell to what extent are these rankings relevant, as their criteria for making the list are somewhat questionable - for example, a list of 100 "most sustainable corporations" made by Corporate Knights Capital is promoted as "The most transparent and objective corporate sustainability assessment in existence", naming companies from "the top overall sustainability performers in their respective sector" (Corporate Knights, 2017). Looking at the criteria the list is based upon, out of 33 categories, only 9 seem to have a strong link with sustainability. Others include ranking in sections such as "women on board" or "pension fund status", which seem to be quite off topic, thus devaluating the credibility of the whole ranking quite significantly. No wonder it becomes troublesome for a common user to find the correct information and actually decide to pursue an environmentally friendly strategy when realizing their project. Although some of the criteria do comply with the three sustainability pillars - namely the social, the balance between the three is of utmost importance. In other words, performing well in one of the pillars but completely failing in the others should exclude the possibility of the company gaining a ranking at all, in order to avoid devaluation of the whole ranking and preserve its meaning as well as its public image. The more misleading concepts are involved within the sustainable movements, the more detrimental effect it will have on its overall public perception, which is completely contradictory to its original purpose.

Based on this observation, it can be partly answered why environmental issues are quite often not addressed seriously. This starts a vicious loop (see Figure 7 below):

Figure 7 - The vicious loop of low demand and performance

1. There is not enough demand from customer side, possibly created by his disinterest or even mistrust;
2. In a demand-driven economy/market, there is not enough motivation for the enterprises to improve their competencies;
3. As a result, the company lacks high quality resources necessary to improve their services;
4. Consequently, its skill range is affected: it lacks the newest technology or knowledge about how this can be incorporated, and its experience falls behind;
5. Finally, these factors combined create overall poor performance of the company in environmental terms - which is leading back to the low demand.

To show the bright side as well, due to the 2050 Energy Strategy, more and more contractor companies are including a "sustainability" mark and showcase their strategies and certificates on their websites (NCC, COWI, Ramboll - who even includes calling these "megatrends"). They stress out the importance on working on energy focus throughout the entire construction process from design to management so as to create ideal conditions for demonstrating the building's energy use as intended. For instance, NCC has their process strategy well anchored within the so-called Kyoto pyramid. It takes its roots in the famous Maslow's hierarchy of needs, often used for depicting the path of human motivation - starting with fulfilling the very basic needs and moving up the hierarchy once they have been achieved. Similarly, the Kyoto triangle (named after the Kyoto protocol of 2005, an international treaty which extends the United Nations Framework Convention on Climate

Change), the process shall be started with reduction of heat loss and afterwards followed by going deeper into detail (see figure 8 below). The same parallel can be observed with companies: They also start with fulfilling their basic needs in order to at least break even, so that they can "move up" and have some sustainable concepts - although mostly they maintain their current position (so-called *defender companies*, according to the Miles & Snow Typology); most companies are *analysers* and stress maintaining the status quo with a moderate level of innovation and growth, meaning that implementing sustainable solutions is a long-term process in their case. The most ideal model of a business is the *prospector* - a company seeking innovation, growth and new opportunities at all times, using creative and flexible solutions to ensure an ever-changing flow towards achieving change; such firms are the most likely to seize the opportunities that environmental approach will inevitably mean in the future and start benefiting already now. (Miles et al., 1978; Barnat, 2014)

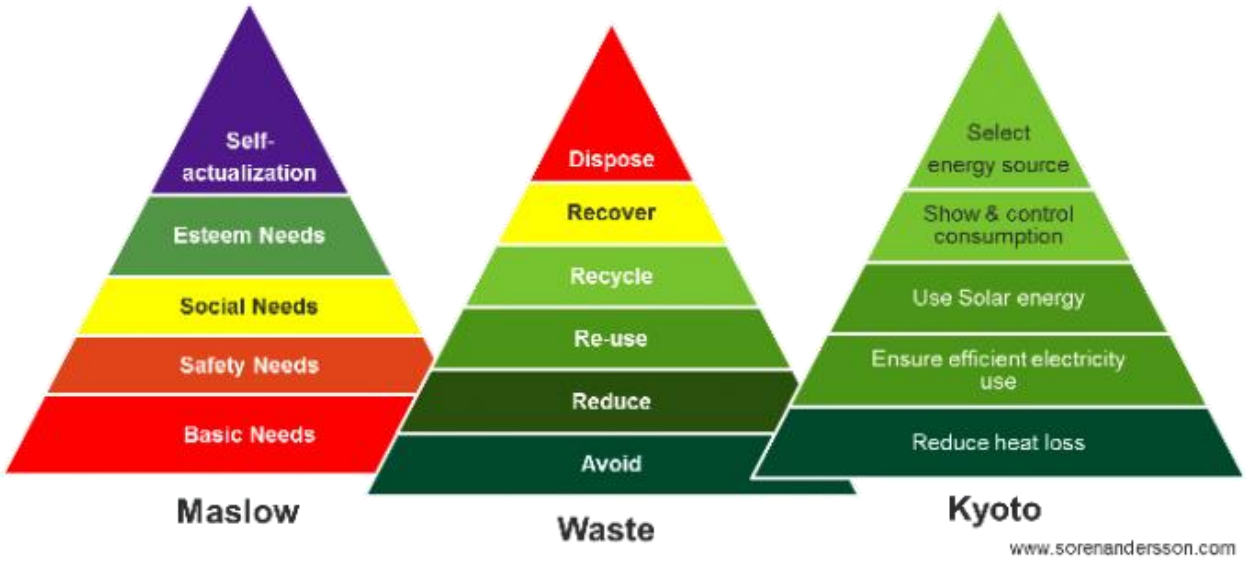


Figure 8 - The three pyramids. Source: sorenandersson.com

As a rule of thumb of markets, supply is driven by demand. Thus, one of the very crucial initial steps to take from the companies is to actively participate in creating such demand. Therefore, the supplier companies must take the initiative to inform the consumers about all opportunities they have in order to contribute to energy saving and alternative options. NCC also states that the final energy choice shall always be governed by the client (NCC, 2017) - and a well-informed client with whom a sensible dialogue can be led is the best a company can wish for. As David Wargert interestingly points out in his work on energy contracting models in Germany and Sweden, another factor that can possibly induce doubt in customers is the vision of conflicting objectives: "*If a company which normally gets paid for selling energy units now start to lower the need of these energy units, the credibility might not be that high from the customer stand point.*" (Wargert 2011). This stresses out the importance of good communication between the service providers and the end user, as well as involving them as early in the process as possible, so that they are able to get insight on all aspects of the process and gain knowledge about why different parts of it are necessary.

To summarize, multiple issues to be addressed have been presented in this section. It is indeed a great challenge for any contractor company to employ a strategy in such way that it has a true impact. It is clear that the beginnings in incorporating entirely new strategies, especially when it is not written anywhere what universal approach should be adhered to and each company has to work out their own strategy, are challenging.

4.4 Project Managers

What defines a good project manager? According to Robert Gilbreath, "*good project managers break the project into pieces and make sure each piece is well managed".* (Gilbreath, 1986**)** At the same time, since each project is unique, including one-of-a-kind circumstances and processes to which adjustments must be made on the spot so that they are tailored to the specific outcome's needs. Hence a project manager must possess the ability to zoom in on the small details while keeping an eager overview of the whole and obtain an integrated project oversight in order to deliver a high-quality result. In this section, first, the overall managerial qualities are discussed, followed by analysing how these competences shall be further enhanced in order to fit ESCO (and other energy) contracting forms.

To begin with, a project manager must encompass business, technical and communication skills in one unit. On the **business** side, he must have a profound understanding of the business's organization and its general management, including marketing, accounting, contracting, purchasing, law, personal administration. He shall keep informed about contract terms and their implications throughout the project; be familiar with the processes necessary to execute the project so that he can draft out the scheduling of work in a realistic manner to meet delivery dates. Further on, he must be able to *translate the business requirements into project and system requirements*, bringing us to the **technical skills,** which make it possible for him to make informed decisions. These can be divided into "low-tech" skills, which can be gained through mere experience of informal training, and the more rigorous "high-tech", which require a previous education in the scientific/engineering sector. (Nicholas & Steyn, 2008). Lastly, **communication** skills are needed so that all the project requirements can be relayed to the employees efficiently and integrated into the project's execution.

Zooming in on the project manager's role in energy contracts, it can be said that a good project manager should simply encompass all the skills mentioned in the previous sections on the design team as well as the contractor, since he is the one who acts as the bridge and the main communicator between all these parties, ensuring that a smooth flow of the process is maintained. Hence, it is vital for him to maintain a good grasp of the responsibilities of all the contract parties and ensure good communication at all times while being kept up to date with the progress. Since in 2007 it became a requirement that all public projects use BIM (BuildingSMART, 2014) and digital administration in Denmark was introduced (Ministeriet for By, Bolig og Landdistrikter 2013). Since this trend is likely to increase due to technology constantly evolving, it only makes sense for the project manager to become as knowledgeable in this area as possible. Furthermore, a good grip of ESCO requirements and their

implications on the participants' roles, tasks and responsibilities is a valuable asset. This is a feature which is often lacking in building managers, simply because they have not been instructed thoroughly about all the aspects of ESCO and it can seem overwhelming to become familiar with them on one's own. Due to the fact ESCOs have not been that widespread in Denmark, it is not yet a common practice to be familiar with the way it influences the construction process. Ideally, a manager should be able to foresee from the early stages of the project what different measures have to be taken in comparison to a "standard" project and perform them as early on as possible to avoid future expenses. This belief was confirmed in one of the interviews the team held with people from the building branch: According to the words of Alex Røge Hermansen, who has been familiar with the concept since 2008 through his work at Hjørring Kommune: "*it doesn't cost much more to think about energy efficiency from the beginning of the building process, while it can cost a lot when the house is first drafted out according to the normal standards and only afterwards, the green solutions are glued on that. There should be more focus on passive energy saving initiatives early in the process.*" (Interview 1 - see Appendix C)

Due to the holistic nature of ESCO contracts and the way they affect the entire building's lifetime, it is reasonable to take into consideration a concept that stretches further behind just the procurement, ending with the handing-over and to also look at the building's operation phase. This is embedded within facility management, an area which is often underestimated but has great potential in changing the way people look at buildings. After all, the building is built to last decades - and it is quintessential to make it as usable as possible, which can be achieved right through FM. According to International Facility Management Association, FM is a way of managing facilities by incorporating various services into an integrated solution (IFMA, 2017); by another definition by a FM providing company Engineering Unit, it is the "*integration of processes within an organization to maintain and develop the agreed services which support and improve the effectiveness of its primary activities.*" (Engineering Unit 2017) It starts with basic services such as cleaning and catering, but it can also extend into IT solutions and, in light of this thesis, energy services. Implementing facility management into ESCO contracting has great potential to support and maintain the efforts laid out during the design and construction phase during the building's operation, while lowering the demand on the end user. At the same time, it would be ideal to have the FM option within one of the contractors which have been involved since the early project stages, so as to ensure most detailed knowledge of the building from all perspectives. Due to the considerable benefits Facilities management can bring, a manager well-acquainted with FM can increase the quality of overall project cooperation by being actively engaged in the whole process, thus providing a bridge between the client and the end user, able to assist him to achieve the optimal result in operation.

It can seem a lot to ask from one person to be aware of literally all aspects of the process from its economy, through scheduling all the way to IT solutions and energy saving systems. This is why sometimes, companies resort to hiring two project managers - one for the business and one for the technical part. Just like in the movie industry, there is a producer taking care

of the resources, schedules and budgets for the shooting (basically an equivalent of a PM) and the director, who is in charge of the technical-artistic matters - these two have to cooperate and coordinate their efforts to achieve an optimal result (Nicholas & Steyn, 2008). However, it can be reasonably argued that it can become even more challenging, since they will inevitably often have opposing opinions on priorities, thus possibly endangering the workflow of the project's best outcome. Therefore, it may be advisable to instead have only one responsible manager, yet make sure he has all the necessary competencies "in one package" - perhaps by further courses or other training. Alternatively, in projects where this is not a feasible option due to their extent, there could be a main project manager assigned together with assistant managers, to whom some of the tasks would be delegated.

4.5 End Users

Buildings are typically designed and constructed to meet the end-user's needs. Clients can end up being end-users, but there is also the case where end-users are a separate entity, and have little to no connection to the client of a project, or the construction industry. Common types of end-users include: *"building inhabitants, external service providers, operation and maintenance personnel, and building administration"* (Christiansson, et al., 2011, p. 4).

If a project wishes to attain the most success, especially in the case of specialized projects (hospitals, universities etc.), the end-users' opinion and knowledge must be taken into account from early in the design stage, a sentiment shared by the article *"User participation in the building process"*, where it is stated that *"users hold a unique knowledge, which should be integrated properly in the design to ensure a successful building project."* (Christiansson, et al., 2011, p. 2) In the case of green buildings, the importance of the end-user's input is greatly enhanced, because these types of buildings are designed in such a way to cater to the exact needs of the specific end-user. Furthermore, end-users might not be familiar with what a "green building" is meant to do, or how it differs from a typical building, and they might require guidance and counselling regarding this subject. Tamer El-Diraby stresses this fact with his statement that, *"it is important that end-users are involved in the design process early on to make sure that they receive adequate information/ education before they make decisions."* (El-Diraby Tamer, et al., 2017, p. 1)

End-users should first and foremost be made aware of the concept of sustainability and low energy or "green" buildings, and given a presentation on what benefits such concepts bring to them. This could make end-users become sustainable themselves, and make changes in either their mentality, lifestyle or even both, in order to promote a "greener" future. Getting end-users educated with concepts such as sustainability and low-energy buildings will lead to them being aware that there is added value in living in such buildings, apart from helping out the environment, and reducing pollution. For one, because of the lower energy consumption, the bills that they would be required to pay every month will be lower. The indoor quality, and quality of life in general in such buildings is higher, when compared to standard buildings.

Once awareness is raised towards the concept of low-energy or "green" buildings, with this type of buildings start becoming increasingly popular worldwide and more and more end-users start becoming educated in sustainability, being environmentally conscious change can be easier to bring about. For example, more pressure should be put on building developers, designers, contractors and other entities involved in the construction industry, by the end-users, in order to increase the number of environmentally friendly buildings, both new and retrofit.

Until this point, the report looked into describing concepts and participants within the construction industry that have an important role in ensuring that the Energy Strategy for 2050 is on the path to becoming attainable. These chapters can be considered as "foundation chapters" for the rest of the report, with them laying down the background information as to why the problem that will be described in the next chapter is relevant.

5. Problem statement

The problem statement chapter includes both the problem formulation and problem delimitation. In the problem formulation, the team will specify which core problem the report focuses on, alongside several sub questions to support this core problem. The core problem is based on the research and area of interest that the team chose in the beginning of the report research process, as previously mentioned in Chapter 1 - Project Introduction. Because the subject areas of management, technology and energy are quite broad, a problem delimitation will be set up, as it would be impractical to cover all of these subject's aspects.

5.1. Problem formulation

The previous chapters have set up a good basis for highlighting why sustainability and an environmentally friendly attitude in construction are topics necessary to pay attention to. From the general trend pointing to a lack of knowledge and interest from the general populace regarding these matters, to the unwillingness of clients to be locked up in long term investments, a change in both mindset and an increase in awareness is imperative. All the global initiatives agree on the necessity of lowering the environmental impact, carbon footprint and overall consumption - yet energy expenditure, raw material use as well as the carbon emissions are still on a continuous rise. (*CSR Report 2016*, Linde Group 2016). This might have a link to the new emerging markets, the BRICS countries, which compared to the already established ones, such as the US and EU do not have such extensive energy regulations in place yet.

Almost half of all the energy worldwide as well as in Denmark is consumed by buildings, as they are the main component of cities (Zhang, et al., 2015, p. 166), which brings the report team's concern mainly to them. It is clear that an action has to be taken on the way we are looking at our built environment, how the materials for it are being sourced and how its operation works. Although there are currently several movements and innovative forms of contracting, such as ESCO, PPP and IPD, their implementation is still facing many challenges and their overall use is still struggling with multiple obstacles. Sustainability is a concept that is being broadly discussed and surrounds our daily lives, yet it has gone somewhat astray from its original meaning. Its reputation has recently suffered - we live in a world where oil refining and car manufacturing enterprises are found on the list of 100 top sustainable companies (Kauflin, 2017; Corporate Knights, 2017) - including Spanish Enagás, Norwegian Statoil, German BMW or French Peugeot. This makes one wonder how much credibility there is in the word "sustainable", when this sounds rather as a joke than a serious statement. How can a company whose main business concept is to exploit non-renewable resources ever make it to a sustainability top-list, and how can these lists retain any integrity? At the same time, what sort of image does it leave to the general public?

Moreover, what is contributing to the skewed public image in Denmark even more is the way some companies are treating and displaying the sustainability concept. First of all, most buildings with a DGNB certificate are either public buildings, social housing or the headquarters of mid- to large sized companies - in other words, projects with media attention. Thus, it is easy for these projects to be perceived as a sign of status or a prestigious image tool used for attracting clients. Instead, it would send a much more positive message if seen as an action demonstrating the company's core beliefs to battle the environmental challenge.

The aim of this thesis is to investigate what changes must take effect in order to raise the awareness of the general public. According to the burning platform theory, unless there is an overall sense of urgency, change is unlikely to happen. Because of the huge contribution the construction industry is making, it is sensible to take action right there, as that means it can also make the greatest and most tangible impact. In other words, seeing the huge negative impact the industry brings about, the opportunity can be seen in reversing it and making the same scaled impact on the opposite side, in a positive way. A great opportunity can be spotted in numerous places: the emerging technologies; energy contracts as discussed in Chapter 3.3, and lastly, proper usage of sustainability rating systems.

Therefore, the three main focus areas that this report addresses and works with further can be seen in Figure 9 below: Smart buildings, energy contracts (mainly ESCO) and sustainability rating systems.

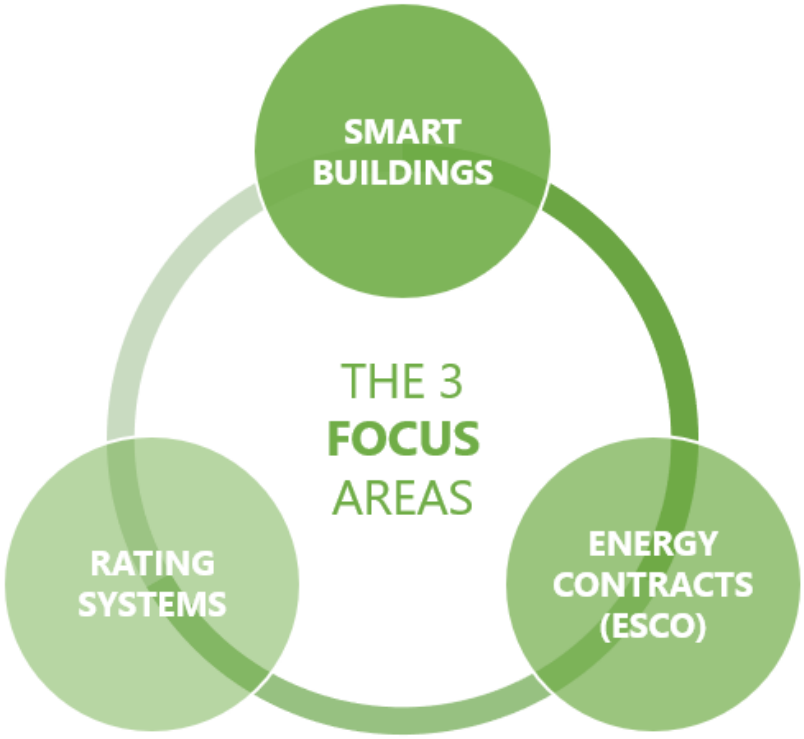


Figure 9 - The Report's Three Focus Areas

To summarize, the main question this report will be researching is:

How to overcome the challenges and changes that the DK construction industry must face and implement in order to be able to create increasingly energy efficient built environments to meet the 2050 Energy Strategy's demands?

- *How can energy contracts, Smart buildings and sustainability rating systems help achieve this?*
- *What are the barriers and enablers regarding the implementation of these?*
- *What is the role of the authorities in the implementation process?*

5.2. Problem delimitation

The limited scope, timeframe and page requirements of this report makes it necessary that the focus areas defined in the problem statement will be thoroughly analysed and scrutinized. This means that some ideas, areas and concepts shall be left out of the report partially or entirely.

Firstly, in regards with sustainability, because the term is so broad and contains a multitude of concepts, the report team will mainly look at sustainability in construction. Furthermore, within sustainability, the most attention will be given to environmental sustainability, with economic and social sustainability being used as a complementary tool to help with analysing the environmental one.

Concerning rating systems for assessing the environmental impact of buildings, attention will be given to the ones that focus mainly on environmental sustainability. The report team will be looking at multiple rating systems, regardless of popularity, country of use and buildings certified.

In terms of technology within construction, because of the huge amount of possible technologies to analyse, the report team will not be focusing on popular concepts such as VR, robotics or augmented reality. Due to the nature of the report team's study background, technological solutions will not be analysed in depth, but more as support arguments to help with implement managerial solutions.

In terms of the markets that will be analysed, the EU market will be given focus when talking about ESCO, with a particular attention to the Danish ESCO market. However, because environmental sustainability is a global issue, it is impossible to disregard the implications of international markets. Therefore, Denmark will be featured more specifically when talking about the legal implications in Chapter 9 as well as how to implement the enablers detailed in Chapter 8.

While this report will provide insights on the current legislation and in what ways it could be made more efficient, due to the research team's lack of background in legislature and politics, the suggestions will be given more from a construction manager's point of view, on

how the industry could benefit from certain laws being changed, or new laws being adopted. Hence, for proper implementation, a person or entity specialized in law would need to continue the work of the report team.

Now that the problem formulation and delimitations have been set up, the report can move on the next chapter, which will be Chapter 6 - Analysis of the construction industry.

6. Analysis of the construction industry

This chapter will have the aim of analysing the construction industry within Denmark, with links to the external factors that affect it, as well as the three main concepts that are the focus point of the report, as established in Chapter 5.1. The chapter starts off with a PESTEL Analysis, to analyse the external factors, and afterwards continues with a critical overview of the sustainability rating systems previously discussed in Chapter 3.4. After that an analysis and overview of Smart technology within construction is made. Lastly a SWOT Analysis, that incorporates the strength and weaknesses of all the three main concepts, as well as the opportunities and threats that exist is done.

6.1. PESTEL analysis of Denmark with connections to construction

The PESTEL framework (Political, Economic, Social, Technological, Environmental, and Legal) is a tool to help analyse the macro-environment factors, usually used to determine the impact the macro-environment has on an organization. However, in this report, the PESTEL shall be used to analyse how the Danish construction industry is influenced by national politics, the economy, society, technology, environmental concerns and legal provisions. The role of the PESTEL in this report is to see how the different concepts explored thus far (initiatives, certifications, contract forms) are affected by the macro environment; more specifically, what the link between them is, and to what degree they influence each other.

Based on the core problem which this report focuses on, the Technological, Environmental and Legal factors will be given slightly more attention than the Political, Economic and Social factors. Lastly, traditionally, to get the maximum benefit from the PESTEL analysis, 3 scenarios would have to be worked out: the most optimum, the catastrophic and the most likely. Due to the constraints regarding scope and time in this report, only the most likely scenario will be assessed.

6.1.1 Political (P)

Denmark is situated in Northern Europe, Scandinavia. It is a sovereign nation governed as a constitutional monarchy based on parliamentary democracy. The country has been a member of NATO since 1949, being actively engaged in NATO activities. Since 1973, it has also been a member of the European Union, and although it has been a member for so long, it has refused to adopt the euro as currency, preferring to keep the Danish kroner.

Denmark has a very good worldwide reputation when it comes to its political situation. In 2016, Denmark ranked number 1 with a score of 90 on the Corruption Perceptions Index 2016 from Transparency International (Transparency International, 2017), and has been at the top of the charts since 2012 onwards. This helps solidify Denmark's strong international reputation as a secure country to do business in, having ranked number 6 according to Forbes list of Best Countries for Business (Forbes, 2017). Low corruption and strong reputation helps Denmark in attracting foreign companies, and investors that seek to conduct business within the country. It also helps Danish companies that wish to carry out business abroad. For example, many companies within the Danish construction industry, regardless of whether they are architectural, engineering or contractor companies, regularly manage to secure contracts abroad, and the political stability within Denmark could be considered as one of the positive factors that contribute to this.

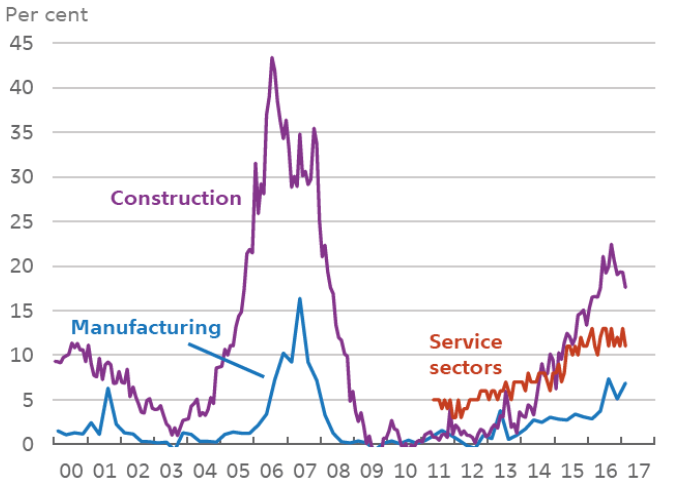
Internally, the relative political stability creates an open market and offers the possibility for foreigners to work in Denmark and according to Jobindsats, there are 167 196 registered full-time employed foreign workers (Styrelsen forArbejdsmarked og Rekruttering, 2017). In the construction industry, many workers come from Eastern European countries such as Poland, Lithuania, Romania, etc. Up until now, the presence of foreign workers in Denmark has not been an issue; however, because of the rise of anti-immigration sentiments and nationalist movements in some European countries, this trend has not avoided Denmark completely. In the last elections, the populist DPP (Danish People's Party) gained 21.1 % of votes, with their agenda including removing Denmark from the free movement Schengen area, and to reduce the number of non-Western immigrants to Denmark. However, the situation has not reached an alarming point and it is yet to have a negative impact on Denmark's international reputation.

6.1.2 Economic (E)

The Danish economy was hit quite hard by the economic crisis of 2009. This was due to a high degree of openness to international trade and to the high degree of financialization of its economy (Banco Santander, 2017). However, the situation has been gradually improving since then, and economic performance is expected to improve in 2017, with a GDP growth of 2.1% (Banco Santander, 2017). In addition, according to an economic forecast from OECD, economic growth is expected in Denmark due to *"stronger private consumption, stronger foreign demand and a very accommodative monetary policy stance"* (OECD, 2017). Denmark is considered to be a wealthy country, and the GDP per capita is ranked amongst the highest in the world. Expected GDP per capita is $53,941 for 2018, which is equivalent to around 345,680 DKK, as of November 2017. The tax rates are also the highest in the world.

The unemployment rate is low, 6 % in 2016, and it is expected to decrease even further in the coming years. Because of this, in certain sectors, a lack of skilled workers and a shortage of labour is expected in the upcoming years. The construction industry might be the first to get affected by this - after all, according to an analysis from Danmarks Nationalbank *"In this sector, unemployment is already low and a growing number of firms are stating that the shortage of*

labour is an impediment to production" (Danmarks Nationalbank, 2017, p. 5) Figure 10 highlights the signs that a shortage of labour is emerging in the Danish construction industry.



Note: Share of firms (adjusted for employment), stating that shortage of labour is an impediment to production.
Source: Statistics Denmark.

Figure 10 - Clearer signs of labour shortages (source: Danmarks Nationalbank)

The construction industry in Denmark is set to see public investments of 50 to 60 billion euros in areas such as infrastructure, hospitals, universities and urban development for the upcoming years. The private sector is also expected to experience growth due to incentives coming from a number of government initiatives such as tax deductibility of home repairs and improvements, and a rise in the limit for the Danish National Building Fund's renovation of subsidized housing (Ministry of Foreign Affairs of Denmark, 2017, p. 1). Regarding the GDP from construction in Denmark, it has increased to 22,174 mio. DKK in the second quarter of 2017 from 20,472 mio. DKK in the first quarter of 2017. This is close to the all-time high of 23,893 mio. DKK which was recorded in the third quarter of 2006, previous of the financial crisis. The gradually rising quarterly GDP from construction in Denmark, from the last quarter of the year 2014, until the second quarter of 2017, can be seen in Figure 11 below (Statistics Danmark 2017).

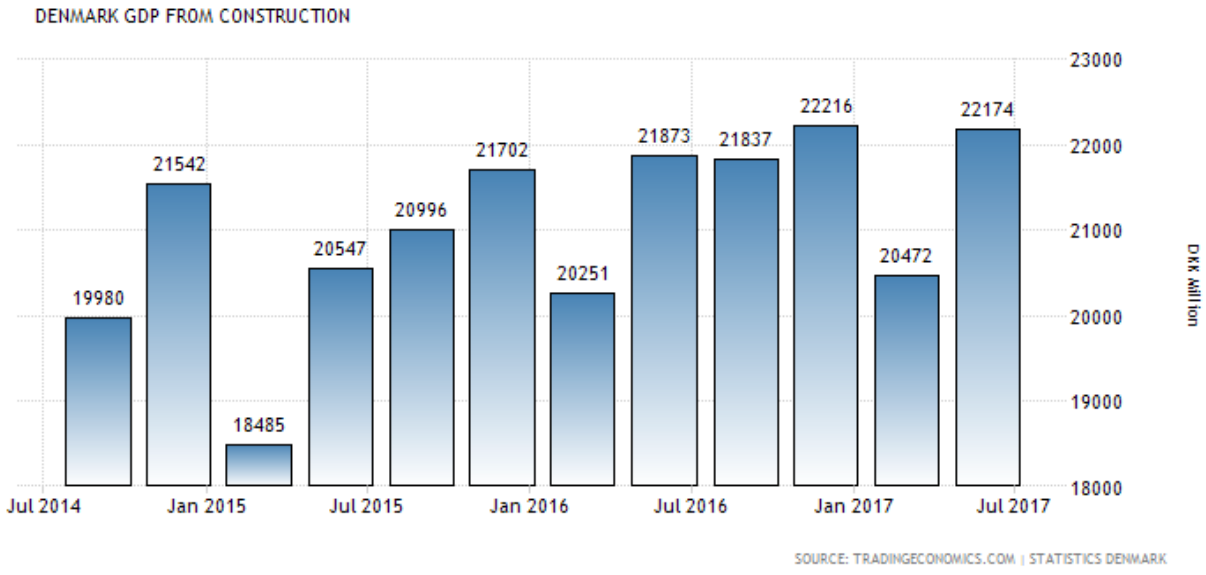


Figure 11 - GDP from Construction in Denmark (TradingEconomics.com, 2017)

Danish economy is also under the influence of the economic evolution of the other European countries, as well as other advanced economies such as the US. The overall outlook is that of moderate global growth. Lastly, due to trade agreements with the United Kingdom, the Danish economy is vulnerable to Brexit risks & transitions, up until the final departure of the UK from the EU on the 29th of March 2019.

6.1.3 Social (S)

Denmark is a state that has strong welfare and equality in society is high. Denmark frequently ranks within the top 10 best countries to live in, and recently it ranked 2nd in the World Happiness Report 2017 for happiest countries in the world, losing the number 1 spot to Norway (Helliwell, et al., 2017, p. 20). The population of Denmark is 5,760,694 in the 3rd quarter of 2017, according to Danmarks Statistik (Danmarks Statistik, 2017). The vast majority of population is made up of Danes, followed by other Scandinavian nations, Inuit, Faroese, German, Turkish, Iranian, Somali (Commisceo Global, 2017).

In 2015, immigrants and their descendants made up 11.1 % of the population of Denmark, corresponding to 600,674 persons (Danmarks Statistik, 2015, p. 6). Even though the population of Denmark has been increasing in recent years, the number of elderly people has been growing as well. According to the report Denmark in Figures 2015, *"almost one in four Danes has now passed 60 years, while this was only one-fifth in 2000"* (Danmarks Statistik, 2015, p. 6). The gradual aging of the population might result in labour shortage for certain industries in the near future, if this trend continues, and the influx of immigrants lowers, or the birth rate does not increase. For the construction industry, the increase in population is good news, because it means that the number of projects for residential housing will increase.

Denmark also has seen an increase in foreign students in the last years, and according to statistics from Aalborg University and University College Nordjylland, in 2017, there were a around 4800 foreign students just in Aalborg. This can lead to a number of these students opting to continue living in Denmark after finishing their studies, and therefore contributing to Danish society long after their study period. On another hand, because of the increased number of students, the need for student accommodations has risen, which is again beneficial for the construction industry, because it means more projects related to student housing. When it comes to construction and immigration, a sizable number of workers are foreigners, as mentioned in Chapter 6.1.1. These foreign workers are exposed to the risk of social-dumping, which means they are at risk of getting a lower salary and inferior employment when compared to their Danish colleagues, for performing the same tasks. Active steps are being taken by the Danish unions and the Ministry of Employment to combat the dangers of social-dumping.

6.1.4 Technological (T)

Denmark ranks very high compared to other countries, when it comes to technological development. It has one of the most developed renewable energy technology sectors in the world (OECD, 2016). Innovation is closely linked to growth and technological development, and in 2012 Denmark launched a strategy for innovation named "Denmark - a nation of solutions", which is meant to enhance cooperation and give improved frameworks for innovation in enterprises. In 2015, this strategy was further enhanced by a new strategy called "*Vækst og Udvikling I Hele Danmark*", which translates to "*Growth and Development Throughout Denmark*", which is supposed to encourage equal development in all the regions of the country.

	Denmark	OECD
GERD		
USD million PPP, 2014	7 921	1 181 495
As a % of total OECD, 2014	0,7	100
GERD intensity and growth		
As a % of GDP, 2014	3,05	2,38
Annual growth rate, 2009-2014	(+0,6)	(+2,3)
GERD publicly financed		
As a % of GDP, 2014	0,93	0,61
Annual growth rate, 2009-2014	(+4,7)	(+2,5)

Figure 12 - Gross domestic expenditure on R&D (GERD) – OECD 2016

In 2014, the gross Research & Development (R&D) expenditures were more than 3% of the GDP of Denmark (Figure 12), which was quite high. However, when the new government took office in 2015, the budget for research was decreased to around 1% of the GDP (OECD, 2016). This could have a negative impact in the long term, regarding the Danish innovation system and strategies that have been made thus far. In the opinion of the report team, lowering the budget for research and development is a mistake for a country such as Denmark, that greatly contributes to technological advancements, especially in the field of renewable energy.

Looking at the Danish construction industry, new technologies are being embraced, and the industry is somewhat quick to adapt to them. For example, in 2007, Denmark started requiring all public projects to be made in BIM. A set of conditions named *Bygherrekravene* were set up, alongside an e-government strategy. Since then, BIM has gained immense popularity and widespread use in Denmark, with a lot of companies within the construction industry (architectural, engineering, contracting etc.) making use of BIM tools. The rapid increase in usage of BIM can also be attributed to user-driven organizations such as *bips*. Nowadays, with BIM aiding or helping to connect various technologies together, construction companies are experimenting with concepts such as VR, augmented reality, drones and robots, smart technologies and green technologies. In addition to this, because of the increased use of smartphones, tablets together with specialized applications, such as *Byggeweb*, efficiency in collaboration and communication has never been higher.

In light of the increasing concerns regarding energy consumption, damages to the environment, and increased emissions, as previously stated in Chapter 3.1, more and more construction companies are increasing their R&D budgets in order to come up with technological advancements that could help in counteracting such issues. In Denmark, such

a company that puts emphasis on advanced technology and digital tools is MT Højgaard. One of the company's highlights is the concept of VDC (Virtual Design Construction), where a building is designed, planned and even built digitally, before the actual real-life construction in undertaken. This helps with minimizing risks related to finances, operation & maintenance and even the environment. Another technological concept that is starting to catch wind, is that of smart buildings. With the aid of BIM, especially in the design phases, Smart buildings are designed to be as energy efficient as possible, without sacrificing quality or the user's comfort. However, the concept extends much more beyond just BIM, and therefore it will be explored in more detail later in Chapter 6.3 and Chapter 8.

6.1.5 Environmental (E)

Denmark is one of the global front-runners when it comes environmental matters. As mentioned in Chapter 6.1.4, it ranks very high in terms of renewable energy technology, as well as climate policies. According to SGI, *"Denmark falls into the top ranks worldwide (rank 5) with regard to environmental policies"* and *"Denmark is an environmental leader with very strong climate policy in particular."* (SGI, 2017) Denmark has also devised an Energy Strategy for 2050, which was described in Chapter 3.2. Some of the highlights of the strategy include phasing out coal by 2030, and producing fossil-fuel-free energy by 2050. (SGI, 2017)

The country ranks very high in different environmental and climate performance indexes; in the 2015 Climate Change Performance Index by the Climate Action Network Europe, Denmark was declared the most climate-friendly country in the world (SGI, 2017). Furthermore, according to Yale Centre for Environmental Law and Policy in their 2014 for Environmental Performance Index, Denmark ranked 13th from 178 countries (SGI, 2017). One of Denmark's most polluting industries continues to be agriculture, with ground and water pollution occurring from this industry being one of the reasons why the country does not rank higher in Yale's index. As previously mentioned, Denmark is a global leader in terms of renewable energy technology, and 23.4% of its energy consumption comes from renewable resources. This places Denmark in eighth place among OECD countries in terms of renewable energy (SGI, 2017).

If a comparison is drawn between Denmark and the EU average in terms of Environment and Global Environment protection, Denmark ranks higher, as seen in Figure 13 (the graph on the left). Furthermore, when it comes to Renewable Energy, Energy Productivity, and Waste Generation, Denmark again performs better if compared to the EU average, as seen in Figure 13 – graph on the right. However, Water Usage and Particulate Matter (sum of all solid and liquid particles suspended in air, with many being hazardous) is higher in Denmark that the EU average, as seen again in Figure 13 – graph on the right.

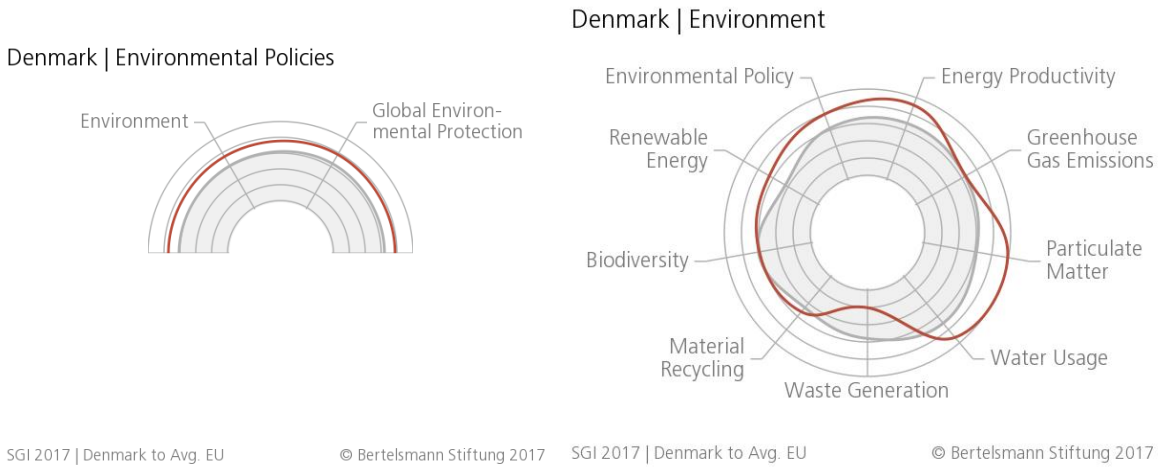


Figure 13 - Denmark compared to the EU average - Denmark represented with a red line (SGI, 2017)

In terms of Denmark's goals towards a more green and sustainable future, the goals and purpose of the 2050 Energy Strategy has already been explored in more depth in Chapter 3.2, so doing it again in this chapter would be redundant. In regard to the sub goals of the 2050 Energy Strategy, the aim to be coal-free by 2030 is moving along at a better pace than anticipated, so the date has been proposed to be moved to 2025 (SGI, 2017).

Denmark also actively engages in Global Environmental Protection throughout the European Union, relevant UN bodies and global conferences, including the Conference of the Parties (COP) under the Kyoto Protocol to the United Nations Framework Convention on Climate Change or UNFCCC (SGI, 2017). Current focus is directed to reducing CO_2 emissions, achieving higher energy efficiency and increased usage of renewable energies. In Denmark, being environmentally engaged is embedded into society, and more often than not, pressure is put on politicians and public entities by the population or non-governmental organizations which engage in environmental protection. The new government that came into power in 2015 has slightly reduced some environmental goals that the country set under the previous government. This included decreasing the objective of reducing CO_2 emissions by 40% between 1990 and 2020, to reducing CO_2 emissions by only 37% within the same time period (SGI, 2017). This has attracted some criticism from environmental NGO's, but the government rebuffed such criticism.

When it comes to the Danish construction industry, more and more efforts are being undertaken by companies to ensure that new projects are made according to the latest rules and regulations regarding energy. An increasing number of projects are also being designed as low-energy as possible; with some projects even applying to get certified by sustainability rating systems such as BREEAM, DGNB and LEED, which are analysed further in Chapter 6.2.

6.1.6 Legal (L)

Denmark is a Constitutional state that is ruled by law. The Danish legal system is based on the so-called two-tier principle, which means that the parties to a case generally have the option of appealing the ruling of one court to a higher instance (Danmarks Domstole, 2017). There are 24 district courts in Denmark, several high courts, the Supreme Court and also several special courts.

When focusing on legislature regarding the climate and environment, Denmark adopted in June 2014 the Danish Law on climate. According to the Danish Ministry of Energy, Utilities and Climate, *"The law establishes a general strategic framework for Denmark's climate policy in order to turning Denmark to a low emission society by 2050 - which means a resource efficient society with an energy supply based on renewable energy and significantly less emission of greenhouse gases from other sectors."* The contents of the law include the following:

1. Establishment of an independent, professionally based Climate Council;
2. Annual climate political report to the parliament and
3. Process of setting national climate targets (Danish Ministry of Energy, Utilities and Climate, 2017).

The latest report from the Climate Council, published in June 2017 is titled "Transition Towards 2030". In the same report, in chapter 3, called "Denmark's Climate Target", it is stated that *"Denmark meets Most of the 2020 Targets, but Lacks New Policy Towards 2030" and "For 2030, it is a different story. Many of the present climate initiatives will expire in a few years from now, and then, the projection shows, the green transition will come to a halt unless new climate and energy initiatives are implemented."* (Klimarådet, 2017, p. 16). In the opinion of the report team, it is quintessential that the Danish government starts thinking of initiatives, policies and legislature that is directed towards the climate and energy goals for 2030, sooner rather than later. The impressive progress that has been achieved thus far should not be wasted, and a period of standstill or regression must be out of the question.

In terms of construction and Danish law, buildings in Denmark must meet the Danish Building Regulations. These are updated every few years, and the current one in effect is Building Regulations 2015 (BR15). A building must meet the building regulations in terms of safety, structure, indoor climate, energy consumption and so on. If a project fails to meet the requirements it will most likely not get a building permit allowing the procurement/realization of a project, until the design is reviewed and corrected. The Contracts Act is important, as entering into agreements is partly governed by it. In construction, agreements are made between the different parties involved in a project. Lastly the Danish Tender Act 2007 and The Danish Procurement Act 2016 is also important to know, as they are relevant when procuring services such as consultancy in the design phase, supply of goods, and hiring of contractors.

As of yet, there is no specific law or regulations aimed solely at energy savings or sustainable buildings in Denmark. The Building Regulations 2015 has just one chapter that specifies

regulations regarding energy, and what requirements projects must meet. Therefore, it is currently up to the client and the parties involved in a project to determine if and in what way they want their buildings to be low-energy or "green", and push beyond the current regulations.

6.2 Criticism of the rating systems and initiatives

As Chapter 3.4 already presented, there are numerous systems developed in order to provide a means of substantializing the various efforts for sustainable constructions. These come in a vast array of types - rating systems, knowledge sharing initiatives, NGOs as well as government-funded organizations, independent companies on national or more global level. This section aims to categorize them into an overview, highlight what they have in common, challenge the weaknesses of the current setup and present good examples of successful experience in order to work out a potential future shape of these.

6.2.1 Assessment methods

This chapter stems from the fact there are almost countless such initiatives and it becomes extremely easy to get disoriented in them. To this day, there are nearly 100 official ones with new ones being constantly created and developed worldwide. (Bernardi, et al., 2017, p. 5) – see graph in Figure 14. The main source of inspiration was the report "*An analysis of the Most Adopted Rating Systems for Assessing the Environmental Impact of Buildings*", which used an argumentation for selecting the main initiatives with which the authors of this report identify - that these systems should be focused exclusively on buildings; be widely cited in scholarly articles (at least 20 in Elsevier's databases); have an adaptation of a minimum of 500 projects and have been in service for at least 5 years (Bernardi, et al., 2017, p. 6). Moreover, in order to underline the impact of variety, space will also be given to the smaller or newer initiatives, as well as to companies and organizations that pursue environmental impact research on their own. In order to perform this, the individual webpages of the respective initiatives were inspected. This provided the basis for most of the information, together with user manuals, if available.

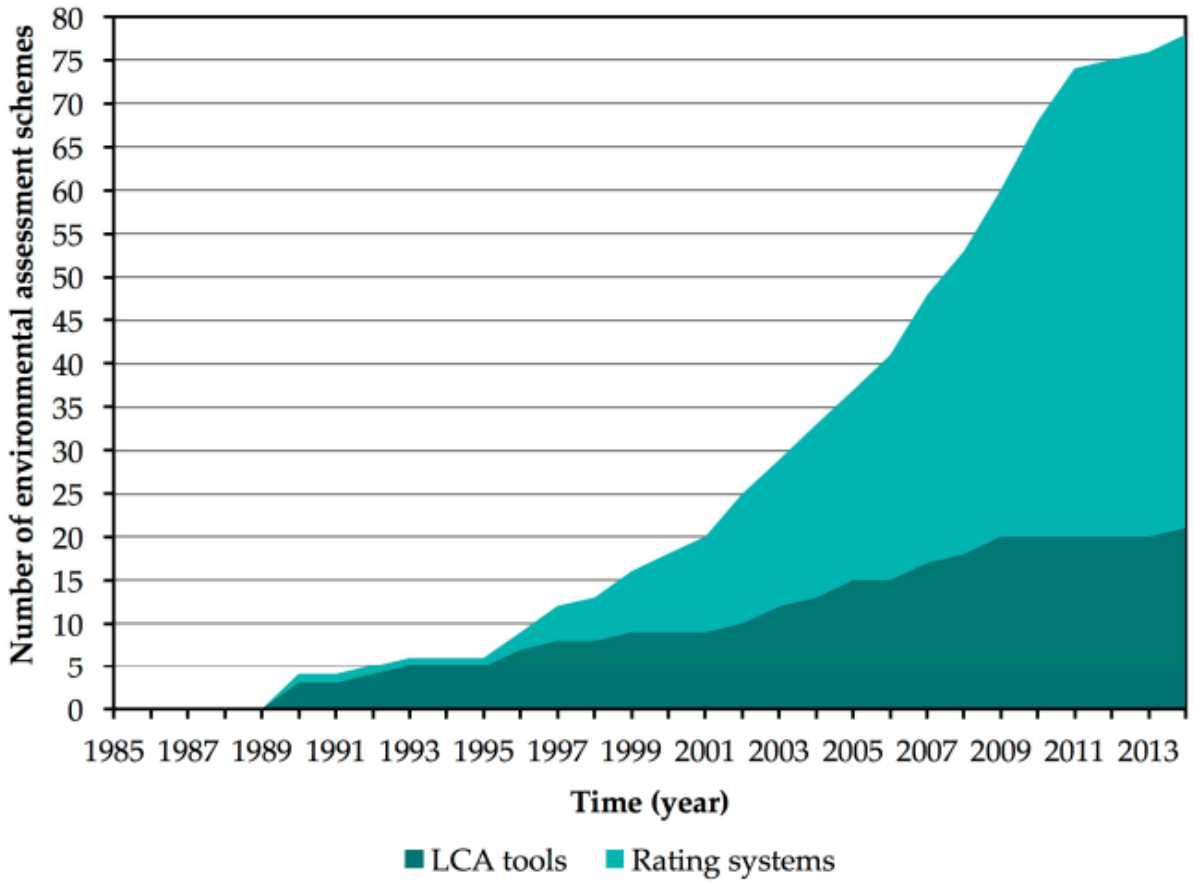


Figure 14 - Growing number of LCA tools and rating system over the past 3 decades (Bernardi, et al., 2017, p. 5)

The main motivation for the different assessment and rating systems to come to existence has been the arising need for change, along with the 2020 and 2050 energy initiatives and the inevitability of reducing the global greenhouse gas emissions. "*This has had a remarkable impact on the building and construction industry and, consequently, a wide array of rating schemes has been developed with different purposes and features to enhance buildings' sustainability.*" (Bernardi, et al., 2017, p. 21) Their main purpose is to measure the built environment's impact on society and the planet in a measurable, *consistent and comparable* manner, to enable building a basis for further knowledge expansion.

6.2.2 The big 6: the topics covered

To begin with, the six most extensive systems were assessed, namely DGNB, BREEAM, LEED, CASBEE, HQE and SBTool. Upon a more detailed examination of their scope, it was found that most of them take Life Cycle Assessment (LCA) as the common ground. The issue is that very commonly, different categories in various schemes often refer to the same measuring point; similarly, the other way around, categories with the same name sometimes assess slightly different characteristics. The most frequent aspects the rating systems investigate with the strongest emphasis were the following, in the respective order, as can be seen in the chart below (Figure 15 - taken from Bernardi, et al., p. 16). It shows nicely how

the different scopes/categories are distributed descending from the most common to the least featured ones. Not surprisingly, energy performance ranks the highest with around 40 systems including it, and the least covered area is resilience with less than 5 rating systems incorporating this measure.

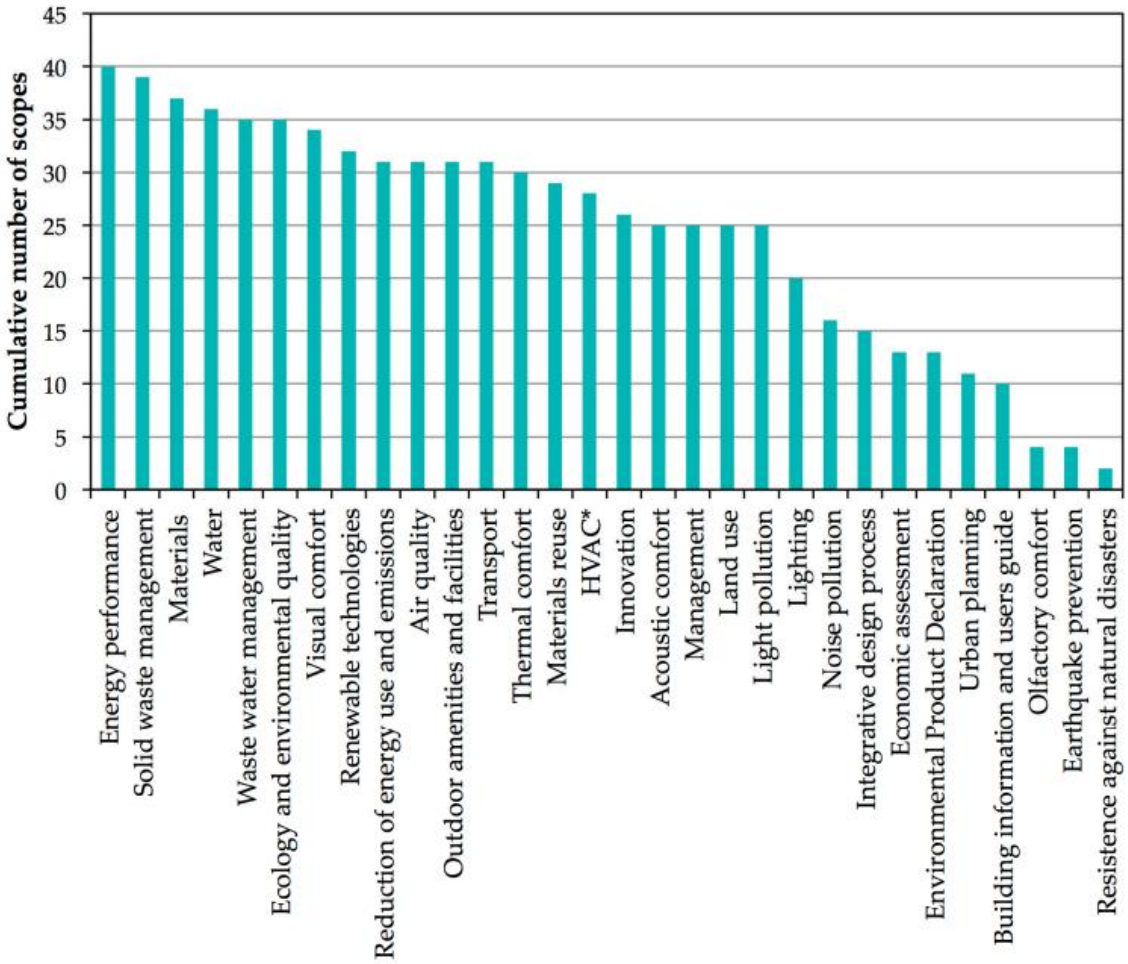


Figure 15 - scopes distribution among the selected rating schemes. (Bernardi, et al., 2017, p. 16)

Topics such as materials reuse, land use, light and noise pollution, building information and users guides and natural disaster resistance were not consistently found in each of the systems (Bernardi, et al., 2017, p. 16). Furthermore, often different categories of the same assessment system disregard individual scopes - for instance, BREEAM for commercial buildings from 2009 includes user guides, while the latest *International new construction 2016* code doesn't include it; similarly, its 2009 version looks into material reuse, but not all the newer versions for new construction and renovation do; and lastly, none of it looks into resistance against natural disasters.

Besides the areas already covered by the *Analysis…* report, other relevant criteria have been investigated. Unfortunately, not all of criteria can be applicable to all of the initiatives, simply due to the fact they do not focus on said area at all and thus no data is provided. The

questions below act as a summary of different kinds of criteria according to which the initiatives can be defined. The result of this comparison can be seen in Appendix B.

- What is the overall **aim** of the given system? (in terms of education, certification, knowledge sharing…)
- Through what **platforms** is the system spread?
- Does the initiative have a **national** version? Which country does the initiative **originate** in? Is it **mandatory**?
- What type of **weighing system** does it use? Is it based on different weighing factors? Are there any **minimum entry** level criteria?
- What type of **rating levels** are used?
- How many **criteria** and **categories** are there? Are any of these **prioritized** over others?
- How many **projects** have been through the system/initiative/association?
- What are the system's **constraints**/limits? (e.g. what does it not assess that other systems do?)
- Is the system **flexible**? Is it possible to be applied **internationally**? Does the system/platform have international **collaboration**?
- What type and status of buildings does this system cover? Does it include non-housing projects as well?
- Does it include operation and maintenance of the project/end user information?
- Does it involve the general public in any way (organizing workshops etc.)?
- Does the organization have its own software specialized on what they do?

An attempt has been made to summarize all the different initiatives together with their ranking system into one table, but as can be seen in Appendix B, this has proven impossible - as previously stated in this chapter, many of them are calling the same category a different name, or mean two various aspects using the same terminology. For this reason, the report team has concluded there is little value in filling in the whole table and left it as a demonstration of how impractical the fragmentation is. Furthermore, the problem with the current categories distribution is that they are way too scattered to provide a strong basis as well as easy orientation. A list of all categories for the "big 6" can be found in Appendix B, where they have been labelled according to which main sustainability category they fall into: economic, social or environmental. This can serve as a basis for proposing a new, unified categorizing system, which could benefit all the participants. Providing a single system to which anyone can refer back to with certainty what exactly they encompass can serve as a great tool to bring order in the chaos.

For this purpose, the criteria have been regrouped according to the outline as drafted by the Brundtland report, as the report team considers it to be a reasonable, simple yet efficient way of grouping the otherwise scattered and somewhat confusing categories (see Appendix A). As a conclusion, after having grouped the various criteria based on their focus points, it can be said that it summarizes the "best of the best" – in other words, criteria from the most used rating systems put together in one place. The report team suggests that what could be done is making an attempt to take a further step on this by representatives of all the systems, and

common goals could be discussed by narrowing down the rating categories further, making their purpose easy to understand, transparent and unified.

6.2.3 Smaller scale initiatives

Besides the main, widely recognizes evaluation systems that have already been introduced in the early stages of this report, there are also many middle- and small scaled initiatives, whose impact is nevertheless significant, therefore it is relevant to mention them. To a Danish reader, the Passive House Institute (PHI) from Germany will certainly be familiar. It refers to itself as an *independent research institute that has played an especially crucial role in the development of the Passive House concept - the only internationally recognised, performance-based energy standard in construction. (PHI, 2017)* Besides starting up the passive house standard movement, to which all buildings in Denmark are going to comply by 2020, they also perform expertise on new innovative projects and develop building materials. Keeping pace with technology, new software for dynamic building simulations is also being developed. PHPP (Passive House Planning Package) and designPH are further being taught on educational workshops for the general public and those who wish to acquire a passive house projecting certificate. Thanks to this combined with own component manufacturing, they are able to act as a provider of complex, in-depth consultancy services, as a great scale of insight is created this way. However, even in an organization which seems to cover all areas of sustainability can possibly mean, unexpected findings can occur. When taking a deeper look at what criteria it takes into consideration when evaluating a potential building material or component, the criteria list fully comprises of the physical attributes (airtightness, U-values, thermal conductivity, fire resistance, comfort). It becomes apparent that there is not a single mention of the building materials' environmental impact. This, along other misleading concepts already partially presented in chapter 5.1, creates common misconceptions about the extent of sustainability itself. Furthermore, it exposes the shortcomings of rating systems, and how they are not what one would anticipate and do not always automatically encompass all aspects that energy efficiency should mean.

Another category of assessment would be certification systems. In this category, EPD (Environmental Product Declaration) and FSC (Forest Stewardship Council) could be noteworthy as two most noticeable initiatives. EPD provides registration of a product according to the ISO 14025 standard about "type II environmental declarations" to be further used to communicate transparent life-cycle impact of products, used for instance in green public procurement - a useful tool for sourcing materials (EPD, 2017). Together with FSC, non-profit organization issuing certification of responsibly managed forests (both environmentally and socially) (FSC, 2017), they form a great basis for construction material selection, ensuring mindful and reliable sourcing.

Moving on to the smaller scale initiatives, it has to be noted first that it is practically impossible to cover all of them because of their large amount - around 80 worldwide (Bernardi, et al., 2017, p. 5) - although it is tricky to determine a specific number, as the initiatives constantly develop, merge and create and it is also troublesome to determine what

should be considered a measuring system. For this reason, only a selection of them will be presented here, with the main purpose to demonstrate the main differences and shortcomings they embody, so as to lay a foundation for further explanation of what issues these systems are encountering.

One of the best sources which gather the small initiatives into one place is the *Covenant of Mayors for Climate & Energy*, which is regarded as the world's biggest urban climate and energy initiative bringing together thousands of local governments and their inhabitants to pledge to decrease CO_2emissions and develop climate change adaptation plans (Covenant of Mayors for Climate & Energy, 2017). The Covenant makes a strong point of not being a stand-alone initiative, and hence provides a vast list of related movements (Covenant of Mayors for Climate & Energy, 2017), which makes it obvious upon the first sight that the amount of them is overwhelming.

To begin with, let's take ICLEI Europe - Local Governments for Sustainability. They act as an association of local governments of UN members. They act mostly as a resource centre with information, tools, networking opportunities, forums, training and consulting services in their key areas: low carbon development, resilient cities, resource efficiency, biodiversity, ecosystems management, with a major focus on globally relevant strategies. This starts off a list of minor initiatives with partial focuses. Some major interest groups have been identified as follows:

- **Connecting** professionals, authorities and citizens and **networking**
  (*BUILD UP, CIVITAS, EIP-SCC - EU Innovation Partnership of Smart Cities and Communities, CESMED)*
- **Trainings**, workshops, **events** etc.
  (*ManagEnergy, Sustainable Urban Mobility Camp)*
- **Knowledge sharing**, **information** gathering platforms
  (LAF - Local Administration Facility, CIVITAS, EU Smart Cities Info System, Green Growth Knowledge Platform, EU One-Stop-Shop for Cities, ELTIS)
- Providing **tools**, energy **technology**
  (RFSC - Reference Framework for Sustainable Cities, Green Digital Charter)
- Focusing on **transport**
  (ELTIS, Sustainable Urban Mobility Camp, CIVITAS, Mobilise your city)
  (Covenant of Mayors for Climate & Energy, 2017)

To demonstrate the overlaps of the above mentioned initiatives' focus areas, the research team developed an overview which attempts to summarize them in one space, depicting how scattered they are even better (see Appendix B). What stands out most clearly is that many of the initiatives are overlapping - in other words, they are attempting the same thing in different places. Although many of them promote knowledge sharing and experience exchange, doing so in such extremely segmented manner leads to the opposite effect. In today's information age, when there is nothing easier than establishing a common database that would enable participants from around the globe to contribute with their content and

experience, such fragmentation is practically equal to trying to reinvent the wheel 50 times, in different places, without communication. To a common user, the scope of initiatives and databases seems inescapably overwhelming - where to start looking? The odd part is also that these initiatives are almost exclusively created under large international organizations, such as the United Nations, European Committee or IEE (Intelligent Energy Europe). In light of this, it should become even easier to bring the initiatives together to create a united database of all the shared knowledge available for everyone to benefit from.

Therefore, as a proposal for the future development of environmentally friendly construction, the very first thing that can be done without much investment would be repairing the currently scattered data acquisition into a well-working, coherent database. Everybody would be free to both contribute and extract information from here, opening a door to worldwide best practices to virtually anyone. Despite the naturally occurring national differences stemming from regulation and varying climate, a common basis has the potential to make the data availability more complete and clear, which in return would aid the design and consultant teams with their decisions at the conception of each project. Moreover, it is no less important to seek improvement in other areas, such as improving the assessment systems to support the ideas of sustainability even further. As an instance, the previously mentioned lack of direction in defining materials' sourcing in the PHI specifications is something that should be further addressed. The European Insulation Manufacturers Association backs it up with claiming "*The World Business Council for Sustainable Development (WBCSD) found that sustainable construction is being held back by building sector professionals' overestimation of the real cost of green building. (...) Because the roll-out of sustainable construction is being inhibited by short-sighted views regarding construction costs, it means that we are constructing buildings which are less climate friendly and less cost-effective over the long term. (...) As policymakers seek answers to the big challenges ahead, it is clear that Europe's building sector professionals need to be encouraged to give greater consideration to the materials used in the construction process and to how buildings will consume energy.*" (Eurima, 2017)

Lastly, a factor that did appear throughout the initiatives somewhat scarcely was resilience - the ability of built areas to resist natural disasters. Although it might seem a bit of an exaggerated measure to take in the rather mild European countries, it needs to be considered that the climate is currently changing its behaviour quite violently (see Chapter 3.1). Since buildings are made to last many decades without having to make significant structural changes, it is only sound to take measures against the unpredictable weather swings already now and avoid high repair costs in the future.

6.3 Smart Technology in Construction - Overview & Analysis

Smart Technology, especially when used in the construction industry has the possibility to help buildings become more energy efficient, and environmentally friendly. The report team is of the opinion that by making widespread use of smart buildings within the Danish construction industry, the goals of the 2050 Energy Strategy in Denmark can be attained more easily. However, implementation of Smart Buildings cannot stand alone and hope to make a sufficient difference, but rather it is just one piece of the puzzle, a puzzle which will be brought whole in Chapter 8.

There is an abundant amount of literature available on popular subjects regarding smart buildings, such as a home energy management system (HEMS) by Bin Zhou (Zhou, et al., 2016, p. 1), Smart building energy management systems (BEMS) by Paula Rocha (Rocha, et al., 2014), and so on. Even though these subjects encompass just a small area of Smart Buildings, in terms of the aim of this report, to delve into such complex and technical matters would extend beyond the scope.

In light of this, it was therefore deemed interesting by the report team to see how BIM helps with Smart environments, especially in the design phases, because BIM is excellent at aiding collaboration in a project and also in bringing together the various concepts that have been explored in the report thus far, which can be seen in Figure 9 - Chapter 5.1. However, the interactions between these concepts and the core problem will be analysed later in Chapter 8. For this chapter, an overview of Smart Buildings will be given, together with a short analysis on how BIM can aid with designing and maintaining Smart environments.

Smart technology has seen great developments in the past decade, in many industries, including construction. In the construction industry, the terms *"Smart Homes"*, *"Smart Buildings"*, *"Smart Environments"* and *"Smart Cities"* are becoming more and more common, as companies involved in the industry are becoming familiar with the benefits these concepts bring about, which will be explored later in the chapter. One of the main drivers contributing towards Smart Buildings' popularity is the need for progressively energy efficient buildings and increased concerns for the environment, as stated in Chapter 3.1.

The concept of Smart Buildings is derived from Intelligent Buildings, with A. H. Buckman stating that: "*Smart Buildings are Intelligent Buildings but with additional, integrated aspects of adaptable control, enterprise and materials and construction*" (Buckman, et al., 2014, p. 6). Intelligent Buildings themselves are a concept that emerged in the 1980's, with numerous definitions being given since then. A more recent definition of an Intelligent Building is given by Clements-Croome in 2009; "*An Intelligent Building is one that is responsive to the requirements of occupants, organisations and society. It is sustainable in terms of energy and water consumptions*

besides being lowly polluting in terms of emissions and waste: healthy in terms of well-being for the people living and working within it; and functional according to the user needs" (Buckman, et al., 2014, p. 6)

There are also many definitions of Smart Buildings; however, very few actually manage to explain exactly what they are. The report team is of the opinion that one of the better definitions for Smart Buildings is given by A. H. Buckman, with the definition being as follows: "*Smart Buildings are buildings which integrate and account for intelligence, enterprise, control, and materials and construction as an entire building system, with adaptability, not reactivity, at the core, in order to meet the drivers for building progression: energy and efficiency, longevity, and comfort and satisfaction. The increased amount of information available from this wider range of sources will allow these systems to become adaptable, and enable a Smart Building to prepare itself for context and change over all timescales.*" (Buckman, et al., 2014, pp. 8-9) The features of a Smart Building according to the above-mentioned definition can be seen in Figure 16 as well.

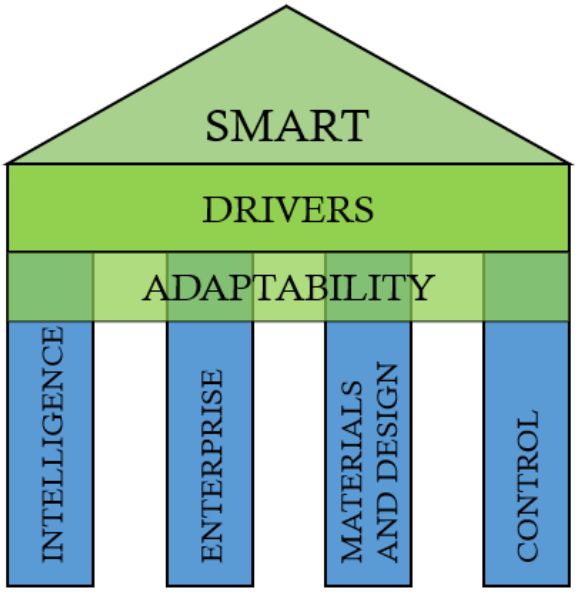


Figure 16 - Features of a Smart Building (Buckman, et al., 2014, p. 9)

Smart Buildings are also renowned for being able to maximize building performance and energy efficiency and add long-term sustainable value. According to *EnergyWorks*, the main benefits and capabilities of a Smart Building further include: tenant attraction and retention, reduced operating costs, energy metering, fast and effective service, simplified operations management, enhanced life safety and security, mobile security systems, added revenue streams and being environmentally friendly (EnergyWorks, 2013).

Buildings nowadays are very technically complex, when compared to even a decade or two ago. A lot of systems and subsystems ensure that buildings can function to their maximum potential, and provide adequate heating, ventilation, light and so on. These systems are used where it is needed depending on the use and occupants, without wasting energy. Smart Buildings push these boundaries even further and rely on adaptive automated systems to control the building. However, it is not only new buildings that should benefit from this increased technical complexity. Refurbishment projects that improve a building's envelope and energy efficiency are very important because a lot of buildings do not even meet current standards, let alone future standards. Paula Rocha states in regards to this matter that *"Especially in OECD countries, where the level of new builds is relatively low, improving the energy efficiency of buildings is likely to rely upon better operations of installed equipment and refurbishments."* (Rocha, et al., 2014, p. 1) It is therefore feasible to say that buildings both new and old, can be built or transformed into smart environments via various means and technologies. The technical complexity of a Smart Building and refurbishing an existing

building to become "Smart" brings about extra costs when compared to a regular building or typical refurbishment contract. Because of this increased investment cost, and a longer return-on-investment period, clients may be reluctant to opt for Smart Buildings projects. However, ESCO contracting provides a good solution for such projects, because of the strengths and opportunities that ESCO brings, as mentioned in Chapter 6.4.

Smart environments or buildings must have various smart objects (sensors, actuators, tags, meters, etc.) installed within them to aid with sensing and control. These smart objects need to be able to interact either amongst themselves, with the environment or the users, dependent on what their intended use is. The level of detail that has to be considered with such smart objects is at times overwhelming. Details can be as simple as whether communication is carried out wireless or wired, to more complex matters such as how the objects interact with the environment and if they are placed correctly and efficiently throughout the building. BIM can actually be seen as a solution when designing such smart environments, although not without further development first, as stated by Zhang et al. *"With the emergence of smart built environment technology, BIM should be further developed to be capable of seamlessly integrating smart objects in building design, verifying the SBE design and feeding smart objects with relevant building-related information."* (Zhang, et al., 2015, p. 4)

Based on the same study, designers working on projects concerning smart buildings can benefit from BIM by:

- Making use of BIM and the building knowledge within for efficient planning of layouts for sensors, actuators, tags, meters, etc. and obtaining an optimized layout for these smart objects in order to achieve maximum performance. By maximizing performance, it is feasible to assume that greater energy efficiency can be achieved.
- Using BIM as a data archive for *"physical information of smart objects"*. This means that the position of the smart objects within the building can be documented and viewed in 3D, as well as the hardware information of these smart objects can be stored. The data archive would be very useful for maintenance and facility management.
- Providing *"a perfect ontology database for smart objects"*, and profiling of each smart object with the help of BIM, through the "information exchange interface" of the object. Future projects can greatly benefit from profiling smart objects and adding them to a database, by possibly seeing reductions in both time to build and costs, because of a more streamlined system. (Zhang, et al., 2015, pp. 4-5)

As previously mentioned, energy management is vital for any smart building, and it can be enhanced via smart objects. Zhang et al. elaborate on this fact with the following statement: *"energy management can be enhanced through smart objects, such as temperature, occupancy and ambient light sensors, that provide data for estimating the building's energy requirements, understanding the building's energy usage patterns and decision-making by building control systems to achieve a balance between a building's energy efficiency and the comfort level of its occupants."* (Zhang, et al., 2015, p. 5) Energy management also has to take into account technologies such as DERs (distributed energy resources) such as solar cells, micro wind turbines, etc. These

can turn a building from a "pure energy consumer" to both an energy producer and consumer - a "prosumer". By turning a smart building into a "prosumer", the role it fulfils is also altered. Extra tasks that the smart building must cope with are added; such as monitoring energy generation from DERs, observing the energy load and distributing it accordingly and then deciding how to store any extra generated energy and sending it back to the grid. The main link to BIM is that smart meters and DERs can be viewed as smart objects that *"can be embedded in the BIM design of SBE, and the energy management system can benefit from the profiling capability of BIM."* (Zhang, et al., 2015, p. 5). This can also be seen in Figure 17 below, together with the extended role of BIM in a Smart Building.

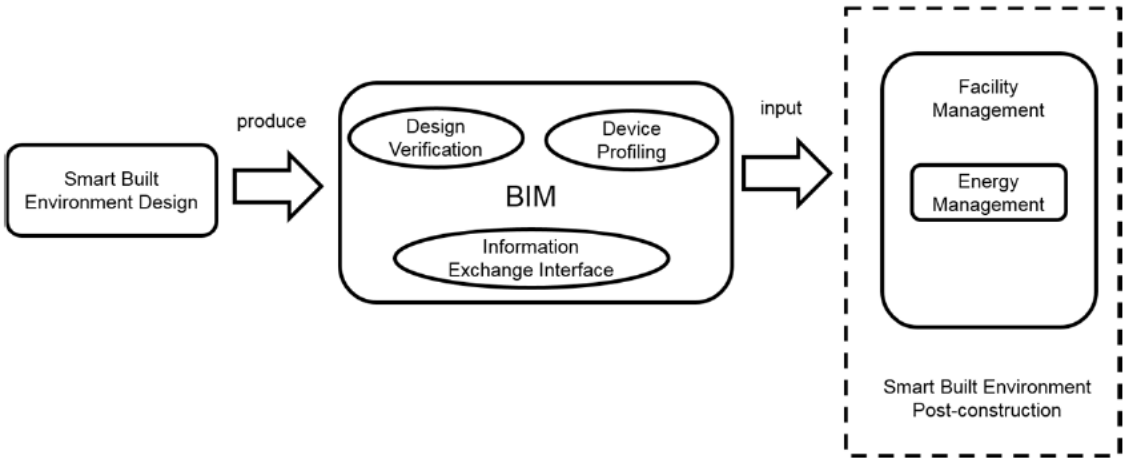


Figure 17- Role of BIM on smart built environments (Zhang, et al., 2015, p. 5)

To sum up, Smart Buildings maximize building performance and energy efficiency, and it is most likely that more and more buildings will be designed to be smart in order to help with lowering energy consumption and promote a "green" future. BIM can be used to aid the design of Smart Buildings, but technology still has to be developed in order to be able to fully link BIM with Smart Buildings, however prototypes are starting to emerge, such as the ones mentioned by Zhang, et al.: *"A basic, but functional, prototype of a smart house energy management system using Revit and the xBIM toolkit was also implemented and successfully demonstrated."* (Zhang, et al., 2015, p. 14)

Furthermore, in the opinion of the report team, Smart Buildings can help Denmark to better achieve their goals for the Energy Strategy for 2050, especially if paired up not only with BIM, as previously stated, but also with the other two concepts that are the central focus point of the report, namely ESCO contracting & environmental rating systems. Analysis on how these 3 concepts blend together and interact is done later in Chapter 8.

6.4 SWOT analysis of ESCO and rating systems

Up till this point, the report has been focusing on providing background information on the various incentives, energy contract forms and introducing the industry they are meant to be applied on. This chapter serves as a platform to analyse the energy contracts and incentives based on their strengths and weaknesses and assess their potential by means of looking at the threats and opportunities that they bring about.

Figure 18 - SWOT analysis scheme (Wikipedia, 2017)

As can be seen in the graph in Figure 18, the four categories of SWOT analysis can be grouped according to two viewpoints: internal and external (looking into attributes of the organization vs. its environment); moreover, they can be split into helpful or harmful in terms of achieving the system's perspective.

6.4.1 Strengths

As Chapter 3.3 has already presented, one of the main objectives of the ESCO initiative is to provide high energy saving solutions to complex building projects, as a framework contract that can be applied on any sort of building project, similar to a turnkey contract.

Currently, only 13% of energy used in Europe is being sourced from renewables (see Chapter 3.1). Taking into consideration the ambition to go fossil fuel free by 2050, it is about time to start increasing this number. Furthermore, the fact half of this energy is used by buildings (and even more taking into account the energy used up in their construction process) underlines the necessity to put real focus on the issue within the construction industry above all. One of the main strengths that ESCO contracts can build up on is the fact that they are providing a service which is in accordance with the current global focus on environmentally friendly solutions. Hence, energy contracts, especially in combination with using an environmental certificate such as DGNB, have great potential to be used as a means to achieve the objectives of the 2050 Energy Strategy on a global scale.

One of the strong sides of both ESCO and the rating systems is the knowledge base they provide, therefore saving their clients from having to invest time and money into doing their own research. Instead, they can provide tried and tested solutions. Thanks to their close to

turnkey contract nature, the responsibility for drafting out the necessary technological and logistic solutions can be forwarded to the ESCO body and/or the consultant responsible for the specific sustainable strategy for the given project. This way, well-functioning solutions can be achieved way more efficiently than in case the entire research was left to be the responsibility of a single, inexperienced person. Thus, a significant amount of risk is transferred from the client to the ESCO provider. Because currently, ESCO as well as rating systems are predominantly used by big companies and bigger scale projects (such as Schneider Electric, Eniig, NCC etc. - see chapter 3.3.3), the experience gained while working on these serves as a priceless basis for further (and smaller scaled) projects.

6.4.2 Weaknesses

On the other hand, besides the numerous strong sides of using energy contracts and rating systems, the research also shows drawbacks that cannot be ignored. The weaknesses can be identified easily from both independent research from different reports as well as based on interviews with industry experts.

First and foremost, one of the most frequently quoted problem that ESCO contracts come with is the extremely long payback time. Although it is natural that the return on investments in terms of energy precautions can only show in a long-term period, it is in the nature of consumers that they expect to see a tangible result immediately. More specifically, the 5-10 years standard payback time that is often stated as average often becomes prolonged due to the frequent need to renovate the entire building envelope, where this period easily becomes 25 years. Alex Røge Hermansen, an AAU employee who has experience with energy contracts over the past decade, agrees: "*the municipalities and regions can only have a loan admittance with 25 years' instalments compared to the loan's notice. This means people won't get their building fully renovated, but instead invest in renovation and optimization of the technical equipment. After a few years, you invest in subsequent building envelope renovation (due to leakages and similar) with extra insulation, which means that all of the sudden, you could have settled for less energy equipment, ventilation units etc. Summed up, the renovation becomes more expensive than if the whole project was handled and dimensioned at the same time.*" (See Appendix C.) The failure to incorporate the energy measures from the beginning of the project stems from lack of awareness and incentives to do so, therefore companies will often settle for complying to the mandatory values stated by the Building Regulations, without the motivation to take further initiative.

Moreover, there is a general lack of knowledge which affects efficient communication between different parties in the project. By words of Kurt Krogh Christensen, who works with ESCO projects for Aalborg Kommune, *"it has been rather resource demanding to implement an ESCO project, as an ESCO project shall be negotiated both regarding the price of the execution as well as the calculated savings. Especially for the calculated savings, there has been the need for savings calculations, which have been very time demanding; similarly, the following negotiations between the building owner and suppliers have been resource consuming."* (See the interview in Appendix D.) From this, it can be concluded that besides the long payback, the problem lies in difficulties

in the negotiations. This possibly stems from project managers not being well acquainted with the contractual framework, its content and scope; the same applies on the rating systems. Therefore, the communication between the energy consultant, the building owner and the contractors becomes complicated for them to assess whether the proposals and their scope are reasonable.

Lastly, as previously discussed in Chapter 4.3, it is most common that big scale companies and clients take up the vast majority of ESCO contracts. At the same time, they take up the most projects aspiring for an environmental rating. This puts SMEs in a disadvantage due to the lack of both manpower and financial resources they cannot afford to take part in such projects, unless they decided to make them the company's main focus and strength, rather than just a marginal part of their portfolio. Due to a weaker resource base, they naturally cannot afford to branch out as much as big companies; and without sufficient demand from the clients' side, the amount of companies that can survive while only focusing on environment-friendly certified projects is largely limited. This can put further growth of the number of companies with environmental focus to danger.

6.4.3 Opportunities

This section puts together the strengths with external potentials which have the capacity to enhance the usage of energy contracts and rating systems. Simultaneously, it builds up on the weaknesses and provides suggestions for avoiding them.

In light of the growing global tendency to increase focus on green energy, together with the 2050 ambition, the market is ready for creating an ideal background for "green" movements of any kind to grow and prosper. The first key for this to come true is creating awareness among common people and professionals both inside and outside of the building industry, so that they become well-informed of the scale of the environmental issue. Even more importantly, it is crucial to educate them about the options they have as individuals to make a difference. This will be further enhanced on in the following chapters, providing specific examples of how to make the change happen - the next chapter elaborates on the concept of Smart buildings, which provides a great base for creating more value on top of energy contracts.

After having been acquainted with the options of what impact a building can make on the environment, it becomes clear that incorporating the green options is vital from the very beginning of the project (also see the quote by A. R. Hermansen in the previous subchapter) - this would apply for creating the new buildings in the most ideal way available, in order to save money on future retrofitting and "future-proof" buildings already from the earliest project stages (see Chapter 3.2). However, since new buildings only account for ~1% of the current building stock, a significant amount of attention should be directed at retrofitting the existing ones and making this as efficient as possible. Spreading awareness by working out two simultaneous long-term budgets - one showing the development of operation & maintenance costs if only the equipment is refurbished and the second one showing the long-

term costs when the complete building envelope is changed - can be immensely helpful in depicting how useful it becomes in the long run to make a thorough investment now to save for the future.

6.4.4 Threats

The threats deal with factor that can be potentially dangerous to the development and spreading of the environmental initiatives in question, mainly of external origin - caused by outside circumstances, but also on the self-induced ones.

One of the possible threats is focusing too narrowly only on energy consumption during the operation and maintenance phase by the building owners. This is likely to happen, because the numbers are rather easy to predict and they are also getting advertised the most. By doing so, the importance of embodied energy of building materials, energy used during construction and transportation - and thus the environmental footprint of the building gets neglected and thus undermines the goal of lowering the impact on this planet.

Furthermore, since Denmark has not clarified the exact reduction obligations for 2030 yet (Danish Energy Agency, 2017), it can get rather troublesome to predict the future development of the policies and future proof the building according to them. Indeed, the design team is still able to make estimations, but without having a clear number to hold as a target, they can easily underestimate it - or even worse, get discouraged completely and only comply to the current building regulations.

Building on top of that, the most devastating external threat is the overall mentality of both the general public and the professional community. The majority does not see the importance of environmental protection at the moment, or underestimates it. This is due to the lack of the sense of urgency - since it is not yet a legal requirement to implement any kind of energy contract or achieve a sustainability certificate, while fossil fuel prices remain low and comparable to prices of green sourced energy, the initiative would have to come from the users themselves. In other words, it must be a conscious client, company or public body who deliberately wants to create a long-term investment because of their own interest in the cause.

Additionally, a really strong threat is created by the ESCO contracts and rating system themselves, or at least its origin can be blamed on their shortcomings. Namely, the problem lies in the extremely long-term return on investment, which combined with the lack of awareness comes about as rather unappealing to the users. The lack of information is another topic supporting this claim, because the users cannot really be blamed for not being smarter than the law-givers unless they have been educated on the matter thoroughly. Lastly, due to the large amount of environmental rating initiatives and their scattered focus (as discussed in Chapter 6.2.2), it is easy to become disoriented in which one of them is appropriate to choose for the given project and in which ways it would benefit it.

The entirety of Chapter 6 was focused on analysing both external factors that affect the Danish construction industry, as well as the three main concepts linked to the core problem.

All the conducted analysis done so far is aimed to strengthen the views of the report team and show that indeed the chosen concepts have a great chance of aiding Denmark with its 2050 Energy Strategy. Furthermore, this analysis also has the role of providing information that is relevant and linked to the next chapters of the report. The next chapter will investigate the barriers that are holding back the three main concepts of the report.

7. Barriers

This chapter will analyse the barriers that prevent the concepts explored thus far into the report (ESCO, Smart buildings, Sustainability rating systems), to be more used than they currently are. These concepts are being specifically analysed, because as previously mentioned in Chapter 5, the report team believes that they would have a positive impact and be influential on achieving the goals stated in the 2050 Energy Strategy, and therefore the decision to give them more focus than other concepts, was taken. Barriers might also possibly hinder the future progress that these concepts could experience, such as improved versions, better public perceptions and acceptance and limiting the potential to become helpful tools in achieving a more sustainable construction, both in the operation and maintenance of buildings, as well as the design and construction phases.

7.1 Barriers for ESCO

The concept of ESCO has been introduced in Chapter 3.3, and the strength and weaknesses of ESCO were analysed in Chapter 6.4. In this subchapter, the barriers towards an extensive implementation of ESCO, with a focus on Denmark, will be scrutinized.

In Denmark, ESCO has seen more use on public projects that are conducted by the municipalities, rather than private projects. Therefore, the barriers are from the perspective of the municipalities, consultants, politicians and non-governmental organisations involved in these public projects.

One of the biggest barriers towards ESCO is that many municipalities believe that making energy related projects in-house rather than through ESCO-contracting is more cost efficient and profitable, and also gives full control on what solutions to implement. Competences also stay in house, rather than being outsourced, meaning that experience is gained by the people from the municipalities involved in energy-retrofit projects, and this experience gain can be carried over to the next project, instead of always having to hire an external ESCO-contractor. The sense of self-growth, accomplishment and control could also be diminished if the responsibilities of the municipality in retrofit projects is greatly reduced, by leaving the majority of the work to the ESCO-contractor. This is very much linked to human behaviour, motivation and mentality, especially with the needs for esteem and self-actualization from Maslow's hierarchy of needs, as seen in Annex A.

There is also a misconception that ESCO's are inclined to use expensive and standard solutions (like CTS technology), but the case is actually different. According to Jensen et al., *"the typical approach in most ESCO-contracts is that the municipalities chooses the solutions from a catalogue presented by the ESCO-provider, where each solution has a guarantee of a certain energy saving."* (Jensen, et al., 2013, p. 13) Based on the statement, the municipalities have no reason to believe that they will always pay for the expensive solutions, when it is actually at their

liberty what to pick from the catalogues. It all comes down to how much energy savings they want to get from the ESCO projects, and it is reasonable to assume that the more energy savings the project will receive, the more expensive the solutions from this catalogue will be.

Transaction costs are also one of the main barriers for ESCO-contracting. It is expected that by using ESCO, lower production costs can be achieved, but the overall transaction costs are increased (Jensen, et al., 2013, p. 13). By increasing the complexity of an ESCO-contract, it will in turn make the transaction costs increase and negotiating contract terms may become difficult with complex contracts, because of disagreements concerning if the reduced productions costs would be sufficient to account for the increased transaction costs. The possible solutions of this issue will be looked at closer in the next chapter.

Besides the cost issues, negotiating an ESCO-contract is generally perceived to be more difficult and complex than a traditional turnkey contract. It is hard to negotiate the baseline of the contract, and the amount of energy savings. Another barrier emerges because of this complexity; in addition to that, it is believed that more resources are necessary to negotiate ESCO contracts. A project manager for Aalborg Kommune, in an interview with the report team stated that: "*For us, it has been rather resource demanding to implement an ESCO project, as an ESCO project shall be negotiated both regarding the price of the execution as well as the calculated savings. Especially for the calculated savings, there has been the need for savings calculations, which have been very time demanding; similarly, the following negotiations between the building owner and suppliers have been resource consuming.*" (Appendix D)

There is another barrier related to the risk of transaction costs increasing due to a lack of experience with tendering, PPP-collaboration and so on. However, in the opinion of the report team, **experience cannot be increased by avoiding something we are inexperienced in**. Therefore, it might happen that for early ESCO-projects, transaction costs will be higher than they should, but in time, with gained experience and knowledge, negotiating and delivering such contracts will become easier, and in turn, transaction costs will decrease.

Several studies (Jensen et al., 2013 & Bertoldi, 2017) have revealed a questionable usability of ESCO-contracting in integrated energy and building renovations. This would mean that ESCO might not be suitable for deep renovations (building shell – façades, roofs, windows etc.). Jensen et al. states an argument for this with *"ESCO-suppliers are only interested in energy savings with short pay-back time (the low-hanging fruits)"* (Jensen, et al., 2013, p. 14). The head of Division for Construction and Operation at Aalborg University also states in an interview that *"ESCO concept is facing the challenge that the suppliers are typically only interested in the renovation of installations with a low payback time period of 5-10 years"* (Appendix C). Deep renovations with ESCO-contracts have a 15-25 years payback period compared to the 5-10 years payback period with simpler renovations (usually just for the interior of the building). Municipalities are, however, slowly starting to accept a longer payback period, up until 25 years, because the importance of energy savings are starting to get more attention, thus opening the gates for more extensive ESCO-projects. The integrated approach for ESCO-projects is seen as more of a future trend, instead of being usable now in the moment, since

with ESCO projects a payback period is locked-in, in most cases for a period of at least 5 to 10 years. This could lead to delays in better optimized ESCO-contracts, if the project is still within the payback period, but better energy solutions have become available on the market. To account for this issue, the contract can be devised in such a way to offer some degree of flexibility for future refurbishments, if national energy goals change over time and better energy efficiency is required.
Internal collaboration in integrated ESCO projects is important. The client's internal organization should closely collaborate with the ESCO-providers, and therefore *"As a consequence, ESCO-providers and consultants advocate for partnerships instead of guarantees, and see barriers as being more cultural than technical"* and *"it is necessary to see the ESCO-project as a partnership, instead of an outsourcing."* (Jensen, et al., 2013, p. 15). The cultural barriers of ESCO could be related to the fact that sometimes the internal organization views the ESCO-provider as a competitor, instead of a partner, that was brought into the project because of the inability of the internal organization to deliver a successful project.

ESCO as a concept cannot evolve and become more efficient by avoiding its problems forever, but instead the problems must be acknowledged, and viable solutions to combat the barriers are needed. In Denmark, ESCO-providers and consultants are of the opinion that barriers are more related to culture rather than technical matters, yet the fact remains that most clients and contractors are still reluctant to enter into a project with a long return on investment period cannot be ignored. Furthermore, there are still many people within the construction industry that have not yet heard of ESCO, let alone be involved in an ESCO-project.

7.2 Barriers for Smart Buildings

The concept of Smart Buildings has been mentioned in previous parts of the report, and an analysis was conducted in Chapter 6.3. In this subchapter, barriers that prevent the concept of Smart Buildings from seeing even more increased use will be explored. A lot of the barriers in the upcoming paragraphs are related to both technological as well as social aspects, which are more related to the user's and consumer's perception of Smart Buildings.
The learning curve involving Smart Buildings is one of the main barriers towards its expansion. The simple fact is that not everyone is aware that the technology exists, and some that know of it believe it is far too complex, without even having tried it themselves first. Some users also reported experiencing difficulties while using smart technology.

Another barrier is the cost of Smart technology. A Smart Building compared to a regular building is still seen as expensive by most clients and the upfront costs of retrofitting smart technology into a project is still not considered to be cost efficient. The scepticism and reluctance of clients, related to the extra costs a Smart Building project involves, is also amplified by the fact that there is a distinct lack of tax incentives to cover the initial investment. This particularly affects building owners of small to medium sized buildings, because the upfront cost of turning them into Smart Buildings is quite high.

There are clear problems with interoperability between smart devices. This is because there is no single standard protocol to connect all devices, with a lot of devices being made by different manufacturers that use various communication protocols. Open communications protocols such as BACnet and Lonworks aid with this problem to some degree, but not enough. This is due to the fact that the companies that manufacture the smart devices aren't required to make sure their devices can communicate using these open protocols. The problem of interoperability makes integrating all the devices inside a Smart Building a bigger challenge than it should be, and even adding other devices or replacing existing ones in a Smart Building is quite complex and difficult to do. In the opinion of the report team, a solution to the problem of interoperability between smart devices is greatly needed and perhaps the industry could take a look at the BIM industry and take inspiration from the IFC data model that that helped solved some of the interoperability issues within BIM.

Reliability of interconnected smart device within Smart Buildings is an ongoing issue. There is a risk that the smart system is not dependable or robust enough, because of the complex interconnectivity between these devices and also the problems with interoperability mentioned above. An example is given in an article on social barriers towards smart homes adoption, which states that *"boiler designers and home computer developers work under different assumptions about the appropriate tolerance level for crashes. Combining the two different products introduces room for complications: otherwise insignificant malfunctions in the home computer could potentially cause malfunctions in the boiler it is networked up to."* (Balta-Ozkan, et al., 2013, p. 4) At times it is almost impossible to determine what impact a simple malfunction could have on the entire system, but with time and better experience with Smart Building construction such issues will surely decrease. Another reliability related issue is that the ability of Smart Buildings to predict human behaviour is still limited, and most often than not the systems will misinterpret the activities and actions of the user.

In current times, cybersecurity is a big concern related to any smart technology, Smart Buildings not being an exception. Buildings that rely more and more on complex technologies, with management devices that are connected to the internet, are prone to being breached. Sensitive data about the users can be stolen, or even worse the systems within the Smart Buildings could be compromised and use for malicious intents. IT and operational technology industries, for example Cybersecurity companies, must start developing strategies and devise better protection protocols, especially when Smart Buildings will become more common. According to Balta-Ozkan et al., *"security concerns will differentiate preferences for the different smart home technologies available."* (Balta-Ozkan, et al., 2013, p. 4) This means that even though certain technologies would be suitable to use in a Smart Building, it may be decided to not adopt these technologies because they may not be secure enough. Furthermore, the users' apprehension in regard to security, and the level of security in current Smart Buildings and how this security will evolve in the future, will be one of the determining factors that will contribute to the increase in Smart Building construction, in the opinion of the report team.

System maintenance and a**dministration** of Smart Buildings is also a challenge. Who is responsible for **maintenance**? Can the user be expected to be able to install, upgrade and maintain the building's software or in some cases even the hardware. "*The operational and management needs of a smart home cannot be fully dealt with by a third-party developer or service provider. This is because there are some devices and services for which the required configuration may be highly subjective. In other words, it may not be feasible for a third party to fully grasp or anticipate the specifics of a particular individual's needs or how they interact with certain devices.*" (Balta-Ozkan, et al., 2013, p. 4)

The subjectivity regarding configuration and user preferences could lead to maintenance that is deemed satisfactory by the service provider, but not the actual user. The smart system also need to be able to evolve and be adjusted over time, in order to meet a user's ever shifting needs and demands. The system should also be able to receive upgrades, via either hardware or software, depending on the case to keep up with ever growing technological advancements. As an example, a Smart Building constructed in 2017 may become obsolete in 2030, because of technology evolution, if upgrades cannot be installed.

Apart from technological barriers, social barriers also exist for Smart Buildings. For one, the impact of converting more and more buildings to be Smart is unpredictable, and the interaction between Smart Building technology and society is often neglected. Poorly integrated Smart Building technologies may become redundant or not used at all, if the user considers that the smart system is too much of a bother and it makes his life harder rather than easier.

Consumer perceptions on Smart Buildings also constitute a barrier towards expansive use. Not all consumers are open to the idea of automation in their homes. From these, most even lack knowledge about the electricity markets, and exactly how a Smart Building might help them save energy, and at the same time increase the indoor comfort. Balta-Ozkan et al. highlight some more consumer barriers, such as *"response fatigue; availability, financing and cost of demands response technologies; transaction costs involved in seeking out price and consumption information; relative share of saving compared to total expenditures and satisficing behaviour in switching patterns; and difficult user interfaces"* (Balta-Ozkan, et al., 2013, p. 5). Furthermore, consumers don't trust utility companies very much, and somehow the industry must change this perception, in order to reassure customers that Smart Buildings and Smart grids are actually beneficial to them.

A final barrier that will be mentioned is the reluctance of individual companies to keep up the pace with technology. As an example, in the Danish construction industry, it is mostly the big companies, such as MT Højgaard, NCC, COWI etc. that are willing to spend extra funds for research, and to include advanced technologies in the buildings they are delivering. In most construction projects the clients themselves don't want to opt for advanced and expensive technologies, and because of this, the market demand simply is not there yet. The report team hopes that in accordance to current trends, Smart technology prices will go down over the next few years, and thus become more affordable to the average client. This would

increase the market demand for Smart Buildings, and construction companies would take an increased interest as well to an expanded market.
The barriers that prevent Smart Buildings from seeing increased implementation are indeed crucial. These barriers must be overcome, with some being easier to cross than others. In terms of cost, it seems that with time, the costs for Smart Buildings will decrease, and government incentives could indeed help as well. From the technological side, interoperability and reliability of smart devices must increase. Regarding the social barriers, it is up to the consultants, service providers and even governmental agencies to offer knowledge to clients and users, and also raise the awareness and consumer perceptions towards Smart Buildings.

7.3 Barriers for sustainability rating systems

The concept of Sustainability rating systems was previously described in Chapter 3.4 The overview in Chapter 6.2 compared six of the most popular rating systems, and analysed what they have in common, but also what the differences are between them. Smaller scale initiates such as the Passive House concept were looked into. In this subchapter, the barriers that limit these rating systems shall be highlighted.

The first barrier that comes to mind is the fragmentation of the certification initiatives and rating systems. There is a tremendous number of different initiatives that are being used by various countries around the world. Some initiatives, such as DGNB, which started in Germany, have national adaptations for several other countries, such as Denmark. CASBEE, for example, is predominantly being used exclusively in Japan, with only a pilot version being published for international use. LEED and BREEAM could be considered as one of the few initiatives that have seen global adoption.

The fact that all the initiatives have their own criteria and rating levels, albeit these being very similar to each other, can confuse potential clients on which initiative is better to get certified in. This factor adds on top of the problem that only few clients are currently willing to explore new innovative concepts and actually try to construct a building that will meet the certification requirements. A lot of clients perceive buildings that are energy efficient and innovative in other aspects as well, as highly risky, because there is no guarantee that the larger initial investment will pay off in time.

False perceptions in regard to sustainability and misleading concepts within sustainability, contribute to a public image that is at times subject to criticism. This constitutes a barrier because sustainability is often viewed as not being that useful as people make it out to be. As presented in Chapter 5, companies that harm the environment with their businesses are included in lists of the most sustainable companies in the world. The triple bottom line of sustainability (social, environmental and economic) is also, at most times, not in balance.

These issues create a misleading view on sustainability, and to some degree delimit its credibility. This situation is often referred to as "greenwashing".

Another, more local, barrier to the initiatives is that Denmark has yet to set any clearly defined energy goals towards 2030. The energy goals for 2020 are on their way to be met in the allocated timeframe; however, the Danish government has yet to push out any further goals beyond that. In turn, it is unknown at this time how much of a positive impact a more widespread implementation of the most commonly used rating system in Denmark, which is DGNB, could have on the goals of 2030 and beyond. If even more energy savings are required, and the usage of non-renewable energies is going to be lowered again, making buildings according to the DGNB standards could help in both achieving lower energy buildings, and ensuring that such buildings rely on "green" energies more and more, such as solar and wind power.

The next possible barrier for certain sustainability rating systems could be the certification fees. For example, with DGNB a fee must be paid in order to get precertification or certification. For DGNB members certification starts from 3,250 € (for projects up to 5000 m^2) and goes until 30,000 € (for buildings up to 130,000 m^2. The entire list of prices can be seen at DGNB's website under the section "*Zertificierungskosten*" (DGNB System, 2018). While the fee might not seem like much when compared to the cost of certain construction projects, not all clients, especially the ones that have a small to medium sized project in mind, will be open to paying these extra fees.

The barriers that sustainability ratings systems face must be acknowledged. Even though BREEAM and LEED have been around for a long time, when one considers the enormous amount of buildings that exist worldwide, and compare it to the number of buildings that have received certification in any of the rating systems that currently exist, it seems that things could indeed be better. Whether it is from the client's side that they are unwilling to make a bigger initial investment in their building projects, or from the side of the governments, because they are not making new legislation and setting more demanding goals in related to energy, something will have to change in the future, if humanity has a desire for a better and sustainable future.

7.4 Summing up the barriers

The chapter analysed various barriers that could prevent the three main concepts (ESCO, Smart Buildings and Sustainability rating systems), the report has a focus on, to be implemented on a large scale. In table in Figure 19 below, the barriers analysed throughout this chapter can be seen.

Barriers		
Concepts		
ESCO	Smart Buildings	Sustainability rating systems
• Various misconceptions • Lack of knowledge • Lack of experience • Higher transaction costs • Difficulty in negotiating • Usability in integrated projects • Long payback period	• Learning curve • Lack of knowledge • Cost of SMART Technology • Interoperability • Reliability • Security and privacy • System Maintenance & Administration • Social & Consumer Perceptions	• Fragmentation of the certification initiatives and rating systems • Clients unwilling to invest in new innovation concepts because of the risks •False perception and misleading views on sustainability • Not clearly defined energy goals for 2030 (Denmark)

Figure 19 - Barriers towards larger implementation of the three concepts

If the barriers these concepts face, together with other barriers that have not been analysed by this report, do not get acknowledged, and solutions towards limiting these barriers are not implemented/used/put into practice, then the degree of contribution to the 2050 Energy Strategy will be lessened. As previously stated, the report team believes that the three concepts, coupled with other sustainable concepts beyond the scope of this report, would be of great help to the goals that are set out by the 2050 Energy Strategy, and even the energy goals of 2030, when they will be drafted out. The next chapter sets out to analyse how the same concepts can be seen as enablers to the 2050 Energy Strategy in Denmark.

8. Enablers

After having looked into what obstacles are standing in the way of implementing ESCO, Smart buildings and sustainability rating systems into common practice, this chapter provides an insight on the drivers and possible strategies which have the potential to help this. Whereas the previous chapter looked at barriers specific to each of the three main areas, due to the holistic nature of the issue, the enablers are likely to influence each other on a fundamental interconnected level, hence it is not necessary to split them into categories (see Figure 22 at the end of this chapter).

One issue to be addressed is the fact that in Denmark, the 2020 Energy Strategy goals are expected to be achieved, even though **not all existing buildings have been renovated** yet to meet the demands of the 2020 strategy. Furthermore, **even new buildings aren't all built in order to meet 2020 energy demands**. For 2030, the goals are yet to be set, as stated in Chapter 6.1.6. It is reasonable to assume that the goals for 2030 will be more difficult to achieve than those for 2020. The concepts explored thus far in this report (ESCO, Smart buildings, sustainability rating systems) could aid in achieving the future goals of 2030 and even 2050 strategies. Moreover, formulating a clear strategy for 2030 energy targets including specific goals and criteria that new buildings will have to fulfil will help developers and building owners form a clear idea about what is required - without having the demands clearly stated and anchored, it becomes rather discouraging for any company or private person to venture into the unknown. On top of that, a crucial area that must not be neglected is retrofitting the existing buildings. As previously stated in chapter 3.2, new buildings only account for approximately 1% of all construction, while the existing ones are expected to operate for decades. In light of this, it is reasonable to put a greater focus on retrofitting existing developments to comply to future standards, and that new buildings are created as "futureproof" should be something taken for granted. Currently, no legislation or regulation demands building owners to renovate their buildings with a due date and an energy consumption target; establishing such legislation in the near future to ensure that by 2050, all buildings are able to make the transition to fossil-free fuel is inevitable.

With the use of ESCO contracting, more low-energy or sustainable buildings can be built. These buildings can include smart technologies (sensors, actuators, meters, etc.). Furthermore, such buildings would meet most of the criteria for sustainability rating system, such as DGNB, and therefore get certified. **This in turn would increase the public knowledge and opinion, and possibly make these concepts more popular**. In Chapter 4.3, the principle of a "vicious circle" was explained - unawareness leads to low demand from the consumers' side, and since the market is demand-driven, it decreases the enterprises'

motivation to improve their own skills, in the long run leading back to low quality qualifications.

Figure 20 - The loop after implementing enablers

On the contrary, the chart in Figure 20 depicts how the previously vicious circle can become its exact opposite thanks to the simple step of making consumers aware of the importance of green and sustainable solutions. Creating this awareness is therefore the first necessary step to make the implementation of ESCO, Smart systems and rating systems more widespread.

1. Awareness is raised in the consumers, who come to realize the urgency of changing their habits and perception of how buildings affect our daily lives;
2. The increased interest has an immediate effect on the demand, which increases;
3. In a demand-driven economy/market, the motivation for the enterprises to improve their competencies rises arithmetically with the increased demand;
4. As a result, the company invests more resources into improving their services;

5. Consequently, its skill range is affected: the newest technology and knowledge about how this can be best incorporated is introduced, and its experience expands;

Finally, these factors combined create overall improving performance of the company in environmental terms - which is leading back to supporting spreading the awareness about such options among the consumers and increasing demand, slowly creating grounds for making the shift global.

At the same time, because of reduced energy consumption of such buildings, the goals of the 2050 Energy Strategy could be attained more easily. 2050 is still some time away, but it is not that far into the future. Therefore, it is important that buildings start becoming more efficient in terms of energy savings as soon as possible. It also plays an important role that just like Rome was not built in a day, no company or person can perform great on the first few tries - thus, gaining experience and perfecting the performance is bound to take some time. It is therefore sensible to assume that in the beginning there will be problems with smart buildings, but in time, with the technology being improved, and contractors and consultants gaining experience with such technologies, it can only get better and better, and efficiency will increase even further.

The previous chapter introduced the issue of high transaction costs in ESCO contracts acting as a discouraging factor. In theory, there is a rather simple solution to reduce transaction costs, and that is by "bundling". "Bundling" can be defined as taking a larger number of buildings that are similar, and preparing a tender for all of them. This should make the net transaction costs decrease. According to Jensen et al., *"To avoid too high transaction costs, the minimum volume for an ESCO-project in the Danish context is assessed to 10-15 million Danish Kroner"*, however *"the average ESCO-project is approximately 5.5 million €* [cca 41 mio DKK] *in volume, and therefore well beyond the critical limit."* (Jensen, et al., 2013) It seems that at least Danish municipalities make good use of the "bundling" feature, and this is partly because of the 2007 'Kommunalreformen', where the number of Danish municipalities was reduced, and this in turn made each municipality be responsible for a larger amount of buildings. However, not every client has the possibility to bundle a large amount of buildings into a single contract, especially private clients. It would seem that the barriers related to transaction costs are still quite big, especially for private clients and smaller clients, but at least the municipalities have found out a workaround.

A more specific concept which can have a positive stimulating effect on implementing ESCO contracts in particular are PPP and Partnering contracts. These can play a key role to help companies adapt the initiatives and make both the public and private sector more aware. For instance, having people working for the municipality who would act as specialists on energy contracting, Smart buildings or rating systems respectively, who would collaborate with companies in public projects and would also be available as consultants for private enterprise projects and development. At the same time, early involvement of the client in combination with IPD are a great tool helping all participants to keep pace with the project's progress at all stages. This in turn makes it more approachable for everyone to understand the

procedures and reasons behind the decisions made, making them able to contribute to decision-making in the future. Moreover, involving the building owner early in the project bears the benefit of making the communication about all possibilities and implementation consequences much more efficient.

Facility management is a topic that has already been touched in Chapter 4.4, which could have a great influence over implementation of the Smart building concept, as well as energy efficient buildings. Compared to "mainstream" buildings, these demand a much greater care when it comes to their operation and maintenance in order to function as intended, and the users must be informed about the purpose of each of the building's features, how to use it so that desired results in energy efficiency and pleasant indoor climate are achieved and, most importantly, so that they do not end up having the exact opposite effect and cause more harm than good. Ergo, producing a good quality building user manual is essential; on top of that, in particular in public, special use or large-scale buildings it provides an opportunity to use Facility management companies, which would take care of the operation and maintenance of the increasingly complex buildings. It is a relatively old-fashioned, but no less efficient tool which can help this take up; from the rating systems, CASBEE already has creating manuals embedded in their rating criteria. Already nowadays, buildings include many systems that need regular check-ups - and with Smart systems implemented, making a contract with a trustworthy company who would be responsible for all the facilities and components running smooth and in good condition would take a huge burden from the users' shoulders, while also ensuring professional quality treatment of the facilities, thus preventing accidental mistreatment.

Regarding Smart technology and BIM implementation, it is also reasonable to mention that this is an ideal era for incorporating such concepts into everyday use. The youngest generation grows up with smartphones and nearly-AI technology at such ease it seems to be almost an extension of their own hands, hence the integration is logically more approachable for them than for the more traditional oriented experts with many years of experience in the field. A truly high-quality result can therefore be achieved through their close collaboration - the experienced ones sharing their best practice and knowledge and the technology-oriented ones creating means of implementing it as effectively as possible. If a good standard protocol would be built up to enable all the different (and segmented) BIM tools operate on an equal level and make interoperability something granted, it would make their integration an easy task, thanks to a well-functioning platform it can lean on. The type of company that is most likely to initiate changes are the "prospector" companies, who invest a large part of their resources into innovation and investigating new possibilities - make a move and help the change happen.

A condition that contributes to creating a stimulating environment for introducing new concepts is the fact that Denmark can be considered an ideal country for establishing these concepts, since it has a stable government and economy with low corruption levels, hence providing a good environment in the long term. The presence of an actual written strategy

for 2050 is also a helping aspect, because it provides an anchor encompassing all the ideas in one place, thus acting as a referring point for the public.

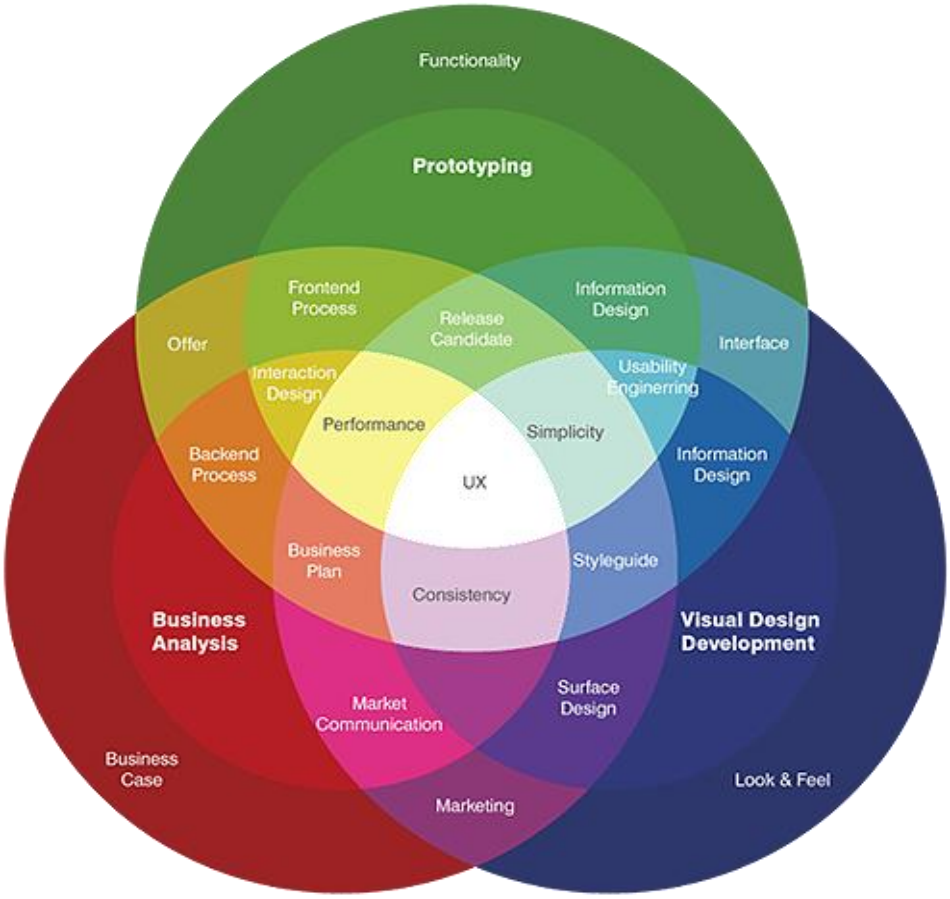


Figure 21 - User experience (UX) important factors (StudioAum, 2015)

Chapter 6.2.3 together with Appendices A and B have already provided Creating a common database or a rating/certification system with a knowledge sharing base would be a great aid in enabling everyone to have equal access to information. Defragmentation of the now scattered rating criteria would make orientation in the entire system a whole lot easier, thus motivating experts to use them more - just like with any other platforms, user experience is where one can make it or break it. If the design seems inaccessible, the user is way more likely to not even give it a try - while a simple, easy to structure that is attractive to the user is often the key to success. Apple operating systems are a shining example of an extremely intuitive UX, as even a child can work with their products after only a few minutes of figuring out how it works. Same can apply to the potential database: The easier to navigate, user-friendly and interoperable it would be made, the more chances it stands to succeed - as the Figure 21 above shows, it encompasses many factors and should therefore be treated with all due professionality: it merges functionality, usability engineering, information design, the overall look & feel with interaction design and simplicity to create the overall user experience. Moreover, the lack of awareness and the difficulty in use could be tackled by offering training

and documentation. This could help in raising awareness and give greater understanding to both clients that would like to incorporate such a technology into their buildings, as well as the users that have to make use of the building.

Finally, the **authorities** play an important part in aiding these enablers. They have the power to promote it across the public. The stance the government should take, and the measures they should look into regarding promotion of smart technologies, rating systems and energy contracts will be analysed in Chapter 9.

Enablers		
ESCO	**Smart Buildings**	**Sustainability rating systems**
Raising awareness – making the concepts more popular Increasing demand Work out specific demands and a strategy for 2030 Creating a demand for retrofitting existing buildings (anchored by law) Future-proofing new constructions PPP, Partnering contracts, IPD Early client involvement Good communication Facility management Increase users' trust in Smart buildings Developing standard protocols to aid Smart concepts and BIM Creating a common database of rating & certification systems Involving the authorities: promotion, laws		

Figure 22 - Summary of the enablers

9. Incentives for change

This chapter intends to summarize the content of the findings of the previous chapters to find a feasible way to solve the issues this report is addressing. It takes the majority of its background information from the SWOT analysis, enablers and barriers, working with the strengths and opportunities to use their full potential, and taking the weaknesses and threats so as to avoid them in the future. Keeping the holistic nature of these issues in mind, the main obstacles that stand in the way of change are considered here and at the same time, realistic scenarios for the course of action are drafted out. It keeps the focus on the three main areas, as established by the problem formulation (see Figure 23).

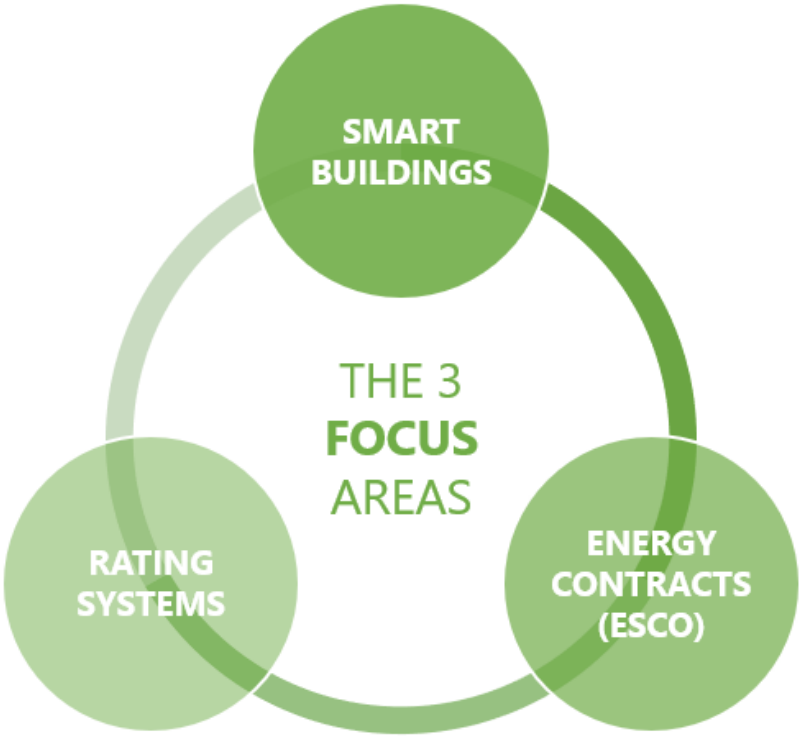


Figure 23 - The three main focus areas

"The holistic nature of the sustainable construction agenda and the fact that the built environment affects the quality of our lives so fundamentally, and in so many diverse ways, means that the built environment has the potential to be a focus for a wide range of policy. (…) they [sustainable features] are fast becoming a requirement on construction projects and are increasingly used to raise standards beyond a legislative requirement. (…) clients have the opportunity to look at models of best practice and recognise the benefits that can accrue from it. Governments need to take a more forthright role in raising the policy commitments and the legislative requirements, linking policy and legislation to the available knowledge at an ambitious pace commensurate with delivering much needed changes." (Halliday, 2008, p. 32)

This chapter takes a closer look at the issues mentioned in this quote - mainly to answer the following question: How can governments, public bodies as well as companies and common people collaborate together and put the principles into a course of action?

9.1 Government's and authorities' role

The Danish authorities will play a key role in ensuring that the Energy Strategy for 2050, as set out in 2011, will be successfully met. As mentioned throughout this report, the goals for 2020 are on their way to being fulfilled, so the efforts are on the right track, so far. The lack of an extensive climate policy going towards 2030 is a slight concern, as mentioned by the Danish Council on Climate Change (Klimarådet), where it is stated that *"political action is required if we are to meet the EU reduction target for non-ETS sector by 2030 and the government's own target of 50 per cent renewables within energy supply"* (Klimarådet, 2017, p. 16). As seen in the statement, the Government has so far set a goal for 50% renewables by 2030, and that is at least the minimum that should be met.

The main initiative must come from the Government, even though in Denmark, the municipalities have a good amount of independence. A municipality can decide to be more ambitious than any goals set by the Government, via national legislation, but they cannot go below the set threshold. As an example, if the Government passes a bill that requires 25% of all future public projects to be designed as Smart Buildings, then a municipality may decide to make 50% of all public projects within their jurisdiction as Smart Buildings. However, they cannot decide to reduce the number from 25% to 20%.

In Denmark, proposals for an Act can come from many different sources such as: ordinary citizens, interested groups such as NGOs, Green Building Council Denmark, etc., Members of Parliament or the Government's ministers. However, only Members of Parliament and the Government's ministers can introduce new bills and propose amendments. In Denmark, 200 to 300 bills are introduced each year. This means organizations that can't introduce bills and propose amendments, have to look at what the current focus of the Government is, and give proposals at opportune moments, in order for these proposals to have a bigger chance of being heard and acknowledged. A Minister can decide to set up an expert committee or commission to look into the need for legislation in a given area. As a rule, the results of the committee are published in a report. In terms of climate goals, if the agenda of the ruling Government or the Ministers doesn't focus on the environment and climate, then bills concerning these issues will be less likely to pass, when put up against the issues currently being focused on. As an example, if the current agenda involves making tax reforms, climate related issues will only be given secondary attention.

However, if the Government doesn't currently focus on climate issues that much, but the population of Denmark is engaged and wishes the subject would be given more attention,

then it is in the power of the general populace that in the next elections, they choose the parties and representatives that show more engagement in environmental and climate policies. That underlines the importance of raising public awareness, because the first initiative can just as well come from the general public. "*Although public building accounts for only 5% of all buildings, municipalities are increasingly becoming central actors in achieving carbon neutral cities, and ESCO-contracting holds many potential lessons for the municipalities to perform "Urban Climate Governance"* (Jensen, et al., 2013, p. 3)

The current Danish Government has shown in the past that they are not as driven as the previous one in terms of increasing climate goals. As previously mentioned in the PESTEL Analysis conducted in this report (see Chapter 6.1), the current government decreased the objective of reducing CO_2 emissions by 40% to 37 % between 1990 and 2020. Furthermore, the budget for research and development (R&D) was also reduced from 3% of the GDP to 1% of the GDP, since the new Government took office (OECD, 2016). The report team considers these actions are a setback, when it comes to meeting the long-term goals of the 2050 Energy Strategy, and one can only hope that the goals for 2030 will somehow compensate for these reductions.

9.1.1 Incentives and initiatives related to ESCO, Smart Buildings & Sustainability rating systems

Taking a look at incentives that can be applied by the government, it can be said that better tailored strategies are necessary in order to persuade clients in the construction industry to invest more in low energy buildings. As previously mentioned in the report, most clients have little to no motivation to invest in low energy buildings, that need a greater amount of initial investment, and then have a longer payback period of at least several years. It is pure and simple not attractive for clients to have their money "locked-up" for several years. An incentive that could combat this issue would be some sort of government subsidies. ESCO can also help tackle this problem, and persuade clients to opt for such low energy buildings.

The Government could help promote the concept of ESCO and work more closely with the Danish municipalities that have already been using ESCO, to promote its use even more amongst the other municipalities. Because of its increased usage within public projects, it is feasible to assume that the ESCO concept would become more appealing to private projects over time. ESCO-contracting could eventually see its way in an updated version of the GC92 & GC93, and with collaborative input and development from professionals and experts from the trade, to give even further validity to the concept. Thus, it could reach a similar level of utilization as the more traditional forms of contracting. ESCO could also be made mandatory for any public projects that involve energy retrofits and new low-energy construction, in a similar fashion to how BIM was made mandatory for public projects back in 2007.

Regarding Smart Buildings, the first incentive would again be to offer subsidies to clients that opt for such a solution. A similar case can be observed in Norway, where the government

introduced tax subsidies for electric cars: electric car owners save up to 8860 DKK/year on taxes (according to a study by Statistics Norway analyst Bjart Holtsmark); moreover, the same amount is subsidies for road tolls, free parking of about 31000 DKK and avoiding other charges, together adding up to as much as 52,000 DKK per year per a car (Doyle & Adomaitis, 2013). As of today, there are over 100,000 electric cars in Norway, according to Statistics Norway (Statistics Norway, 2017). Norstart predicts that by 2030, there will be 269,300 electric cars in the country, accounting for almost 10% of its total car amount (Kvisle, 2010) – see Figure 24.

Salgsvolum ladbare biler – hentet fra Klimakur

	2010	2015	2020	2025	2030
Salg biler totalt alle teknologier					
Antall lette personbiler (M1) totalt	2 180 000	2 337 000	2 505 000	2 686 000	2 879 000
Antall førstegangsregistrerte det året	137 600	147 500	158 100	169 500	181 700
Salg elbiler					
Elbiler totalt	2 049	20 800	67 900	147 800	269 300
Andel av markedet	*0,1%*	*0,9%*	*2,7%*	*5,5%*	*9,4%*
Antall elbiler førstegangsregistrert	1 376	5 900	11 600	20 000	34 500
Andel av førstegangsregistrerte det året	*1,0%*	*4,0%*	*7,3%*	*11,8%*	*19,0%*
Salg ladbare hybridbiler					
Ladbare hybrider totalt	138	12 500	59 300	160 200	365 700
Andel av markedet	*0,0%*	*0,5%*	*2,4%*	*6,0%*	*12,7%*
Antall ladbare hybrider førstegangsregistrert	138	5 200	12 400	26 800	57 900
Andel av førstegangsregistrerte det året	*0,1%*	*3,5%*	*7,8%*	*15,8%*	*31,9%*
Totalt salg ladbare biler (el og hybrid)					
Totalt antall ladbare biler	2 187	33 300	127 200	308 000	635 000
Andel av markedet	*0,1%*	*1,4%*	*5,1%*	*11,5%*	*22,1%*
Antall ladbare biler førstegangsregistrert	1 514	11 100	24 000	46 800	92 400
Andel av førstegangsregistrerte det året	*1,1%*	*7,5%*	*15,2%*	*27,6%*	*50,9%*
Salg hydrogenbiler					
Hydrogenbiler totalt	0	0	6 500	42 000	124 200
Andel av markedet	*0,0%*	*0,0%*	*0,3%*	*1,6%*	*4,3%*
Antall hydrogenbiler førstegangsregistrert	0	0	2 500	10 100	21 900
Andel av førstegangsregistrerte det året	*0,0%*	*0,0%*	*1,6%*	*6,0%*	*12,1%*

Figure 24 - Sales volume of cars (Kvisle, 2010)

These numbers certainly prove that governmental subsidies do change the way people consider their investments into green power - simply because compared to the long-term ROI in energy contracts, this deal brings an immediate reward. Thus, Norway became the first country with a Tesla supercharger network. However, according to Bloomberg, "*Sales in Denmark of Electrically Chargeable Vehicles (ECV), which include plug-in hybrids, plunged 60.5 percent in the first quarter of the year, compared with the first three months of 2016, according to latest data from the European Automobile Manufacturers Association (ACEA). That contrasts with an increase of nearly 80 percent in neighbouring Sweden and an average rise of 30 percent in the European Union.*" (Levring, 2017)

The reason behind this are likely the Government's recent efforts to phase out the tax breaks, which spared consumers from the rocket high 180% import tax. Such initiatives are clearly in discord with the otherwise environmentally progressive Denmark, and should be re-evaluated.

At the same time, legislation, preferably at EU level, should be introduced that would require smart device manufacturers oriented at the construction industry, to enable their devices to be interoperable with each other, and work with the same protocols. Just like a couple of years ago, it was impossible to charge your phone unless you had the specific charger for the exact brand and model you owned, until they finally became standardized and now it is possible to use them interoperably, saving a lot of frustration. This, as an analogous situation, would solve some of the interoperability problems currently existing within Smart Buildings. There would be some obstacles that would most likely have to be crossed first, such as the companies probably not agreeing at first, because that would require them to invest more; it will take time for such an initiative to take root because of bureaucracy and other factors; it may seem simple in theory, especially when compared to the problems BIM faced in the past with interoperability, that were partly fixed by introducing IFC. However, IFC was devised by the organization buildingSMART, with the backing of many companies within the field of BIM and digital design. Again, promoting Smart Buildings via various campaigns and informative actions would help in making the concept more well-known as well as reducing confusion to what exactly Smart Buildings are and how they can help and enhance our day-to-day lives.

Furthermore, provided that the government starts funding sustainably sourced energy, Smart buildings and environmental efforts more extensively, it can bring even further improvements by acting as a first-mover in different areas. It should start going as the example - the government has quite a lot of respect in Denmark and because public projects always receive a lot of media attention, it would provide the public with instant access to up-to-date information from a powerful tool the media certainly is.

Moving on, in terms of the sustainability rating systems, in Denmark, there are several currently being used. Out of all of them, only DGNB has a national adaptation, therefore it would make more sense to support the growth of DGNB. The Danish Government could again offer subsidies for clients that decide to have their building certified. Ideally, a singular system should be devised, that would then be used worldwide, but until then, DGNB could be the main supported system, serving as a basis. Denmark could also actively engage in the creation of such a singular sustainability rating system, considering that in terms of sustainability, climate friendliness, renewable energies and environmental issues, Denmark is one of the leading countries worldwide, and has many experts within these domains. Another incentive to promote usage of the DGNB certificate, especially among small to medium sized clients, would be to lower the fee for certifications, which were previously explained in Chapter 7. One possible solution could be that the EU introduces some form of legislation that would reduce or eliminate the fee. However, if this would be the case, it is most likely that payment would come out of European funds, considering that the fees are

not primarily meant to generate profit, but to pay the experts who carry out the certification process, and covering all of the other expenses related to certification.

9.1.2 Legislation

All the above-mentioned initiatives will be most efficient when they are possible to be enforced by law. Overall, a stricter legislation on a national (ideally global) level should be introduced taking effect as soon as possible that would address the 2050 strategy in a more inclusive manner, starting with creating a specific strategy for 2030 including precise numbers.

A topic that seems unrelated but in fact is extremely relevant is the way electric power is distributed. Power delivery is outdated, wasteful and unreliable. Currently, ⅔ of fuel that is used to generate power in a plant never actual reaches its destination as electricity (Mainster, et al., 2017), which is an alarming number. A solution might be to make it more efficient by introducing on site energy generation, which would abolish dependence on external energy suppliers; it is independent, responsive and sustainable. It can be created by renewable technologies (photovoltaics, anaerobic digestion, distributed steam, co-generation technology/CHP - combined heat & power). The major hurdle here is the cost, which is naturally higher at the beginning of implementing this procedure. To play the first-runners role, schools, hospitals and public institutions could receive funding for trying the method out and this way go by the example. A way to make the implementation process more efficient and acquire as much knowledge at a point as possible could be **teaming up the following parties:** utilities + developers + tech providers + environmental agencies + governments, in order to create a simple solution together. The end users do have to be prepared and willing to pay a little extra - perhaps by making them aware that if the development described in Chapter 3.1 will continue on the trend it does now, it will only make matters worse in the long run regarding climate change, fossil fuel depletion etc. It is therefore also important to set realistic expectations, not unattainable; execute the shift one step at a time, but efficiently so it doesn't take until after the apocalypse. Ensure transparency, as it helps increase public trust significantly, and **lead the change** by further incentive requirements by the government - as Gandhi's famous quote goes, *"Be the change you wish to see in the world".*

Further on, the legislation should include the following topics:

- Enhancing biodiversity by requiring to use natural and locally sourced materials; supporting communities with interest in building naturally; using resources effectively with as little waste as possible, minimising pollution, creating healthy environments;
- Introducing stricter management of the building process, especially during the crucial handover points where responsibilities change, so that it is less convenient to pass the responsibility on to the next manager/party;

- Use case studies as educational tools highlighting experience and encourage their implementation. Then they can be included as an educational tool as well; they could be included as a part of the knowledge sharing resource base.
- Holistic views should be paid more attention to: combining traditions with modernity could be a viable solution. However, this is rather troublesome to anchor in legislation.
- PPP should become a preferred form of contracting, because it enables collaboration of all parties involved from the very start, early involvement of the client and everyone being well-informed from the very beginning. Considering life cycle costs and replacement value should also become mandatory.

9.2 Knowledge sharing & raising awareness

As has already been heavily promoted throughout this report, one of the most crucial tools for implementation is establishing a wide sense of awareness of the concepts this thesis deals with: energy contracting, rating systems and smart buildings. It is obvious that in the present, the common public's mentality is not in the right place - the majority of people do not see the importance of environment protection at the moment enough to make it a priority. Introducing new legislation presented in the previous section is not the biggest issue - that is just a set of rules that needs to be followed and does not support creativity nor improvements. What really needs to be changed is the mindset of the enterprises within the industry, so that they will be encouraged to seek development themselves. This implies a fundamental need for innovation and education. Sandy Halliday, a consultee on a wide range of initiatives including BS7750, ISO14000 and BREEAM and a member of the Gaia group, agrees: "*However, legislation can only ever be a lowest common denominator. It is the actions of industry leaders, responsive to and seeking out contemporary knowledge, that are at the forefront of change. Businesses and individuals are driving components in the sustainability performance of mainstream construction practice, not the other way around.* " (Halliday, 2008, p. 3) Although there is no denying that the government will have to have an imperative role in the process and without a doubt it should play the role of the first-runner, the action has to come from other places as well to be truly effective. This subchapter takes a closer look at the specifics of how this can be achieved.

9.2.1 Education

Education is a broad term which includes many different means and platforms. Naturally, it includes schools and universities, as well as other institutions, for instance companies organizing workshops etc. However, in the opinion of this report's authors, schools remain one of the most important places for spreading awareness about sustainability, for one simple reason - the earlier in life one's education begins, the deeper the values get embedded in one's value system, and the more likely the individual is to practice them throughout their lives. Education is the core of personal development, and where a lot of attitudes are formed;

therefore, it is vital to strengthen the continuing education of construction workers, architects, engineers, managers and consultants alike - share knowledge through centres and campaigns. For example, even though the report team's members have spent 5 years within construction academic environment (UCN and AAU), not even once throughout this period have concepts such as ESCO been mentioned, and sustainability or smart buildings are subjects that are only touched marginally. If even the courses specifically focused on the building industry have not looked deeper into these topics, then where else is the general public supposed to get deeper information? This draws an accurate picture about the gaps in the education system, since these topics are crucial for the future global development, hence being aware of them should not even be a matter of discussion, but something naturally included in the curriculum from the very beginning and thus shaping a green construction-minded mindset. The first step to take here is to simply start including green strategies as a part of the curriculum from early on, together with engaging the students in extracurricular activities, case competitions and collaboration with other institutions in order to engage the students to the highest degree possible. **Supporting interdisciplinary cooperation already during education** is the vital step to take here - but at the same time, great attention should be paid towards explaining the purpose behind it and thus create the proverbial "sense of urgency" that an action is really needed, otherwise it could end up feeling like just another of the forced initiatives that exist simply to hide some sort of a lobby behind them.

Since ESCO contracts have been successfully implemented mostly in public tenders (Jensen, et al., 2013, p. 1), chances are that schools are to be one of the first public institutions to be built in accordance with many of the propositions discussed in this thesis. This would provide an exceptional environment for students to learn about sustainable and green concepts first-hand, given that the building itself would become used as an interactive learning tool.

Similarly, companies would benefit in various means of continuing education. These could include engaging employees in further courses, organizing workshops both internally and for the public and collaborating with other companies on a deeper level than just working on the same project. The companies (namely the design teams, contractors and suppliers - described in more detail in chapters 4.2 and 4.3) can start being more proactive as the starting point, instead of passively waiting for the clients to make the first move. Perhaps if the companies took it as their own personal challenge to start educating the users and suggest sustainable alternatives to the building owners, presenting them the long-term benefits, they could have the potential to grow the public ability to distinguish the importance of these concepts. The clients (see chapter 4.1) need to be aware of the long-term implications of the built environment's qualities; therefore, new buildings should be built exclusively with higher standards in order to future proof them. Similarly, in 2015, there were still buildings being constructed that complied only to the 2010 standard, because at the time of attaining the building permit, the old Building Regulations still applied. Unless the building owners recognize this urgency and take it as an inevitable part of corporate social responsibility, its

chances to catch up are poor. To quote Mrs Halliday again, *"Increasing focus on the corporate responsibilities of businesses, leading to greater emphasis on good business practice and fair trade."* (Halliday, 2008, p. 31) Moreover, if there is no demand, the market has no incentive to expand and take its qualities to a higher level.

9.2.2 Knowledge sharing platforms

As discussed in Chapter 6.2.2, what the industry clearly suffers from is lack of communication as well as fragmentation of the different platforms attempting to make a change, such as the green building rating systems. In order to unify these and make the acquired knowledge available across the industry, creating a universally accessible database of "green knowledge" serving as a common sharing space for this knowledge is the key logical step.
A good example of a knowledge-sharing platform is BUILD UP Skills. It was established by the European Commission in 2009 with the purpose to support EU Member States in implementing the Energy Performance of Buildings Directive (EPBD) (European Commission, 2009). It is also a part of IEE - Intelligent Energy Europe. The intention is to *"reap the benefits of Europe's collective intelligence on energy reduction in buildings for all relevant audiences. It will bring together new practitioners and professional associations while motivating them to exchange best working practices and knowledge and to transfer tools and resources"* (Rømø, 2013). This initiative has national branches in 30 European countries, which received funding up to 90% in order to educate their workforce and achieve the 2020 goals more efficiently. The national projects were supplemented by international meetings of project coordinators twice per year at "EU Exchange Meetings", the latest of which was held in Rotterdam in May 2017, and were aimed to support knowledge sharing.

The local branch, Build Up Skills Denmark, in which AAU was also involved, was mainly focusing on educating construction workers on the topics of energy optimisation and renewable energy. Among other goals, it mapped all relevant education programme offers targeted on construction sector craftsmen, thus creating a national roadmap of skills which could together act as a platform to refer to when working towards the 2020 energy goals. Among other activities, it also focused on involving stakeholders in the process, energy strategies, green skills and demand for technical measure and energy efficiency - all of these being concepts that have been proposed in this thesis. Results showed that out of the 140,000 workers in the building sector, 20-27,000 require further training (mainly bricklayers, carpenters, VVS/HVAC and electricity specialists). It concluded that there is a great need for increased vocational recruitment (AMU = *arbejdssmarkedssuddannelse*) as continuous education for these craftsmen, which will only be purposeful if the awareness about its value from the workers' side increases as well. Furthermore, more attention shall be paid to interdisciplinary topics by introducing more joint competences, which will become invaluable in the future, as all areas become interconnected in the world dominated by technology and BIM. To achieve this, great emphasis needs to be placed on continuing

education for specialist teachers and creating more collaborative initiatives across professions.

The outcome of the Danish Build Up Skill initiative proved that it is more complicated to endorse its ambitions than anticipated. Nevertheless, the participants reached the same conclusion as this report, that early involvement is crucial for the project's efficiency: *"In order to get a high level of understanding and positive commitment from the stakeholders we learned about the importance of starting up the endorsement process very early in the project."* The conclusion is that it is needed to get more people to attend the continuing education courses (which do exist, just aren't used to their full potential). (Danish Energy Agency, 2014)

The lesson Build Up Skills can teach us is the great potential, which setting up a knowledge sharing platform for both would provide. Just like in any other relationship, the professional sphere also has a great amount to learn by improving their communication on a multidisciplinary level. First and foremost, the more information professionals share on a regular basis, the more aware of the issues other businesses encounter they can become. If acted upon, it can provide a priceless resource basin for all parties involved, which in the long run can improve the collaboration experience for every party involved. As already mentioned in Chapter 6.2.3, this kind of collaboration can prevent the industry from the pointless fragmentation, causing businesses to do the equivalent of attempting to reinvent the wheel, many places at the same time, with no communication. We live in an age of technology, and sharing virtually anything has never in history been easier - so there is no point in making life harder with a whole arsenal of useful tools at hand.

This chapter shows different means that can create a bridge between plans and implementation into real life, by proposing a governmental action in the form of introducing new legislation and participating more actively in the process of raising awareness; furthermore, it stresses how supporting interdisciplinary cooperation already during education can contribute in the cause. It concludes that creation and promotion of knowledge sharing platforms is vital for successful implementation, showing positive experience from the Build Up Skills initiative. The next chapter provides a summary of the whole report.

10. Conclusion

This chapter will serve as a brief summary of the issues discussed throughout the whole report as well as their implementation's outcomes. The reader will also be reminded of the problem statement and assess how the report team managed to address the core problem. This report focuses predominantly on how the 2050 Energy Strategy can be led to success through an assortment of three main concepts:

- ESCO contracting
- Sustainability rating systems
- Smart buildings

The report itself starts out with outlining the current main issues that led to its conception and thus laying a factual foundation for the analysis performed in its second part. First of all, it presents the current environmental issues the Earth is facing and stresses why they inevitably need to be addressed. It presents the scope and content of the Danish 2050 Energy Strategy and further describes the status quo of energy contracting. It provides a brief summary of the local currently most used environmental performance rating systems, namely BREEAM, LEED and DGNB.

After having set up the circumstances, the design and construction process participants are introduced in order to investigate how much influence each of these has on the process of enabling said sustainable practices; it helps the reader understand links between their collaboration as well as how these parties affect each other. In connection with project managers, the concept of Facility Management was also briefly assessed. This chapter strongly underlines the importance of tight collaboration from the early project stages between all parties including the end users, in accordance with the concept of Integrated Project Delivery, while taking a closer look at the more specific ways how each of them can contribute to making the process more efficient.

The problem statement is built upon the baseline the information collected in the first chapters and it provides and narrows down the report's further focus and direction to find out how to overcome the challenges Denmark needs to tackle in order to successfully implement the 2050 Energy Strategy by making use of the three abovementioned concepts (Figure 9/23).

In order to strengthen the argumentation and to find out what factors contribute most to the implementation process, a PESTEL analysis was drafted out as a means to collect the external influences that affect the industry. Its main function is to provide an information source for the rest of the analysis part, which proceeds with a critical evaluation of the existing rating systems, taking a closer look at their weaknesses, mainly their mutual incompatibility, as well as outlining a possible solution. Further on, Smart buildings were looked into and concluded that for their successful implementation, a more functional link with BIM is

needed. Taking advantage of the information gathered in these three chapters, a SWOT analysis follows to scrutinize energy contracts, Smart buildings and environmental rating systems internally and point out the main threats and opportunities embodied in them.

The SWOT analysis provides ground for the most extensive analytical chapters: the Barriers and Enablers to the three concepts, which inspect in deeper detail what the hindrances for their implementation are, and correspondingly, which strategies can act as the most powerful drivers towards success. Whilst the barriers were investigated individually for each of the three concepts, the enablers were taken in one package due to the holistic nature of the issue. The most crucial barriers identified were mainly lack of communication, missing environmental awareness among the general and professional public, as well as not clearly defined goals for 2030 (see details in the table in Figure 19); on the other hand, the main drivers towards fruitful implementation were raising the awareness via founding knowledge sharing platforms, introducing IPD and involving the authorities to a greater extent (see Figure 22).

Eventually, the Incentives for Change provides a detailed description of the report team's suggestions for what strategies shall be used to tackle the core problem and act as strong catalysts towards making a change in a positive and feasible way. It highlights the crucial role the government and authorities will need to play in order for the changes to gain a solid ground, makes suggestions for legislation to be implemented and underlines the overall necessity for a paradigm shift to take place in people's mentality. Further on, it proposes how knowledge sharing platforms together with improved education could positively affect the progress of embedding these concepts into the public's mindset.

To conclude, this report is a problem-oriented work, based prevalently on investigation of the report team rather than external collaboration. Therefore, its outcome is also mainly based on the information gathered. Since the addressed issue has a global scope, applying the strategy only in Denmark would not be solving it sufficiently enough to make a change on a global scale, but the report team considers it a good starting line, because the country is one of the front runners in the field of progressive environmental activities and green energy sourcing. Thus, it can act as a more reliable authority for other countries to follow its example. The most vital concepts the team believes should be implemented are introducing more detailed and strict legislation, which should be put into effect by tighter collaboration between all building process participants rather than merely enforcing it "on paper"; creating a positive environment by introducing efficient knowledge sharing platforms; make the environmental rating systems more unified and their systems interoperable; and all in all, facilitate a shift in the general mentality towards concepts, techniques and management styles promoting a greener future.

11. Perspectives

The report focused on investigating three concepts (see Figure 9) that could aid Denmark with the Energy Strategy for 2050. The concepts were chosen because in the report team's opinion they could have the best impact. However, as mentioned in Chapter 5.1 and Chapter 5.2, many other concepts that could be of use, are either currently available on the market or just now emerging. In Chapter 9, the report team gave suggestions and steps on how these three concepts could be implemented or given more attention, with the help of the government and local authorities. In this chapter, some of the ideas that were left out of the report, but could be expanded in the future shall be mentioned in short. Each of the bullet points presents a perspective that could be further analysed in a different report, followed by a brief description of what it might include.

- **How will increased development of solar and wind energy in Denmark help in achieving the 2050 Energy Strategy?**

Solar and wind energy have been mentioned several times throughout the report, mostly with the aim of supporting the main ideas discussed throughout the report. Both solar and wind power are concept that have seen increased use in Denmark in the past years. As mentioned in Chapter 6.3, DERs could become one of the more common sources of energy within in the near future, especially if Smart Buildings start becoming more common. Denmark as a country, has the advantage of being open to innovation and investments related to green energy, so it is not too far-fetched to assume that various forms of green energy will continue to be developed and improved within the country. There is no doubt that with improvements to these areas, the impact on the Energy Strategy will be visible.

- **How could developments in other construction technologies (robotics, VR, augmented reality, etc.) aid with ensuring a "greener" future for construction?**

In terms of technology, the report looked primarily at Smart Buildings and how they could help enhance sustainable construction. Other technological advancements have been seen in construction in recent years; however, because of the delimitation linked to --the report, they could not be explored in depth. One such advancement is augmented reality and VR in connection to BIM. A BIM model can now be viewed in VR, and it can even be "explored" either by clients or the specialists that created the model. This can aid in identifying problems, as well as ensuring the building is to the liking of the client. Advanced simulations can also be carried out; however, these are not entirely dependent on augmented reality and VR. As an example, with the aid of simulations, it can be determined from early on, if the building will meet the criteria and requirements for a sustainability rating system (DGNB, LEED, BREEAM, etc.). In the opinion of the report team, a lot of the new technologies that are emerging in construction, have the possibility to contribute to a more sustainable construction industry, if properly adopted and used.

- **Lastly, how would implementing this report's proposals alter the amount of ESCO contracts as well as energy certified buildings; evaluate how governmental subsidies would help achieve the proposals and whether an increase in interest has been noted.**

As a concluding statement to this chapter, the report team is aware that it is not feasible to assume that covering all the interesting ideas that were generated for the duration of the writing period can be included into a single report. At the same time, the team is satisfied with the three concepts that were chosen as the focus point, and with the outcome that was delivered in the report. The next chapter will deal with the methods and source criticism.

12. Methods & source criticism

In Chapter 2 – Methodology, the report research method was given, and explained how it best fits the report team's needs. The chapters within the report rely extensively on various sources of literature, from where data, theories, facts, etc. are extracted. This is done in order to support the claims the report team is making. However, as with most sources of information, the reliability and validity of these sources is debatable. Therefore, in the following paragraphs, a criticism regarding reliability and validity will be made.

12.1 Reliability

Most of the report, relies a lot on the data gathered by the report teams from various databases, journals, webpages, and so on, which were explained in Chapter 2. There is a risk that some of the sources might be out of date, especially if it involves technological advancements, even though newer literature was used (from the past 5 to 10 years). Reliability was somewhat boosted by the fact that the report teamed aimed, in most cases, at having sources that had a high number of citations. However, some brand-new articles were used, which had a release date in late 2017, which had no citations. This was a risk the report team was willing to take, in order to ensure that the information within the report was the most up-to-date.

When looking at webpages that were used as sources of information, the aim was to use webpages from either institutions that have a respectable and reliable reputation, as well as governmental organisation that can be considered reliable, such as the OECD or Klimarådet. Another source of information came from interviews that the report team conducted. People that have experience with ESCO in Denmark were interviewed, which offer a higher degree of reliability towards the responses received.

One last thing to consider when thinking about the reliability is the fact that the report team itself has a great impact on the report. The team consists of two students, which even though are on the verge of finishing their studies, are still in the process of learning, and have yet much to learn, and a lot of experience still to gain. Therefore, the report will not rival that of an expert within the field of construction management and even energy. Furthermore, the report team had been bound by a set deadline, by which the report had to be finished, and because of this a limited scope had to be set in terms of how big and ambition the report could be in order to be able to deliver it by the deadline.

12.2 Validity

In relation to questioning the validity of the solution given in Chapter 9, it must be considered that the report team looked only into three concepts (Energy Contracts, Smart Buildings, Rating Systems) that could aid in achieving the 2050 Energy Strategy. These are just one fraction of the possible management, technology and energy solutions that could help in achieving a better and more sustainable construction in Denmark. Furthermore, the report team has no educational background related to politics and general legislation, but it has good knowledge of legislation within construction. Taking these factors into account, it could be said that the validity of the solutions is slightly questionable, however the report team is confident that it provided feasible and achievable solutions as best they could.

Taking into account the validity of the literature used, the report team used both Danish and global literature. However, it must be mentioned that the use of Danish literature was lower, because the team members do not speak the Danish language fluently, and it would have taken a longer time to translate Danish literature, and ensure no mistranslations or misinterpretation occurred. Because of this, global literature written in English was preferred, even though the team is aware that solutions that apply to a specific country, might not necessarily apply to Denmark. To make sure this did not become an issue, the report team presented their findings to the assigned supervisor throughout the writing period of this report, and constant feedback was received.

When taking into consideration both the reliability and validity of the report, it can be concluded that some factors could have been better, if given more time, or if the sources would be more related to Denmark. This would have helped achieve a more enhanced report, and perhaps even deliver a better outcome. However, considering the limitations the report team had to cope with, as well as the scope that was set out, it is by the opinion of the report team that the final outcome of the report was achieved, and the team is quite pleased with it.

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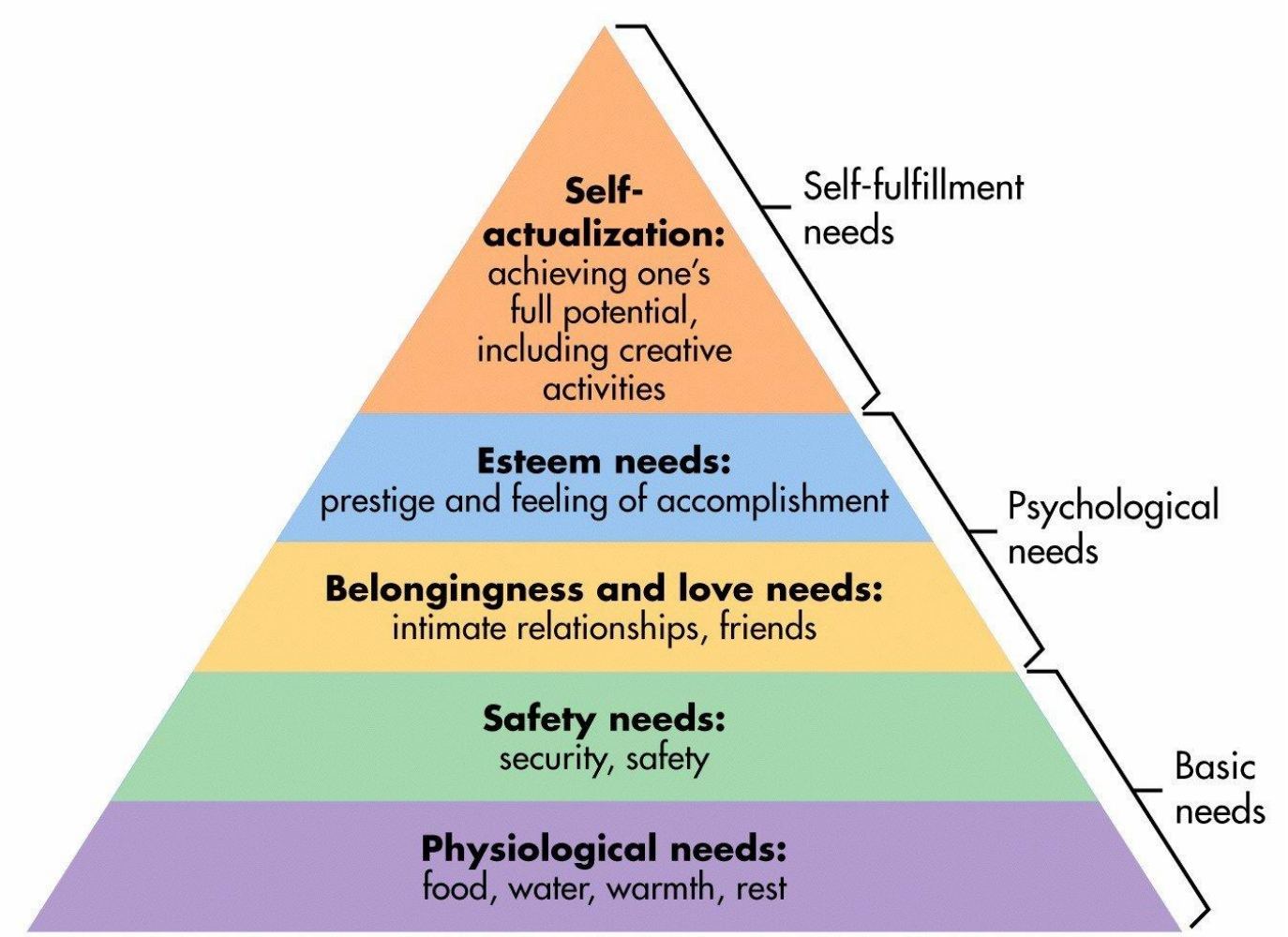
List of figures

ANNEX 1

Maslow's hierarchy of needs



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ANNEX 2

Level of development for each national ESCO market within the EU

Table 1
National ESCO market characteristics.

	Number of ESCOs[a] in 2010 in 2013		Market size[a] in 2010 in 2013		Market potential estimated in 2012–13[a]	ESCO association (year of establishment if known)
EU						
Austria	5–14	over 50	€10–15 million	€15–20 million	n/a	yes (2005)
Belgium	10–15	10–15	n/a	€5 million	between €500 million and several billion	yes, two
Bulgaria	20	7–12	€6 million	€33 million (?)	€500–900 million	no
Croatia	2	10	€10 million	€100 million	n/a	no
Cyprus	0	0	0	0	n/a	no
Czech Republic	8–10	20	€2–4 million	€10–20 million	€100–500 million	yes (2011)
Denmark	10	15–20	€8–25 million	€140–150 million	€1 billion	no
Estonia	2	2 (3?)	n/a	n/a	€100 million (only renovation of buildings)	no
Finland	8	5–8	€4 million	€10 million	€200 million	no
France	10 large and 100 small	350	€4–5 billion	€3.2 billion/a	€250–500 m for EPC and €5 billion for all ESCO projects	yes, several
Germany	250–500	500–550	€1,7–2,4 billion/a	€3–4 billion/a	€20–30 billion	yes, several
Greece	2	5	n/a	0	€5 million	no
Hungary	20–30	10	n/a	n/a	n/a	no
Ireland	15	30	n/a	n/a	n/a	no
Italy	100–150	50–100	€275 million in 2008; €387 million in 2009	€500 million	€1–10 billion	yes, several
Latvia	5	8	€1–1.5 million	> €2–3 million/a	€100 million-€10 billion	no
Lithuania	6	3–5	n/a	n/a	n/a	no
Luxembourg	3–4	3–6	0	0	€5.1–6–2 million	no
Malta	0	0	0	n/a	n/a	no
Netherlands	50	50	n/a	n/a	€30 million/year	yes
Poland	3–10	30–50	€5–€10 million/year	€ 10–25 million (2011) (annual turnover)	€25–75 million/year (economic potential)	no
Portugal	10–12	n/a	€10–30 million	n/a	€100–200 million	yes (2011)
Romania	14	15–20	ca. €50 million	n/a	n/a	yes (2013)
Slovakia	5	6–8	€10–12 million	n/a	n/a	no (under discussion)
Slovenia	2–3	5–6	n/a	€3million	€15 million	no
Spain	> 15	20–60	> €100 million	€300–400 million/a	€1.5–2–6 b	yes, several
Sweden	5–10	n/a	€60–80 million	€60–80 million	€300 million/yr	yes (2006)
United Kingdom	20	30–50	€400 million/a	n/a	n/a	yes
Other European countries						
Norway	5	10	€25 million	n/a	n/a	no
Switzerland	76 (7–10?)	6	€170–350 m/year	n/a	n/a	yes
Southeastern Europe						
Albania	0	0	n/a	n/a	n/a	no
BiH	n/a	5	n/a	n/a	n/a	no
FYR Macedonia	1	0	n/a	n/a	n/a	no
Kosovo	0	0	n/a	n/a	n/a	no
Montenegro	0	0	n/a	n/a	n/a	no
Serbia	10	3–5	n/a	n/a	n/a	no
Turkey	n/a	30 (?)	n/a	n/a	n/a	plans
Eastern Europe and Transcaucasia						
Armenia	n/a	11	n/a	n/a	n/a	yes (2006)
Belorussia	n/a		n/a	n/a	n/a	no
Georgia	0	0	n/a	n/a	n/a	no
Moldova	0	0	n/a	n/a	n/a	no
Russia	n/a	up to 100	n/a	€100 million/year	€2.8–7 billion	no
Ukraine	n/a	ca. 30	n/a	€100 million/year	n/a	yes (1999, recreated 2013)

Notes: (?): uncertain data, disagreement between experts.

[a] These values are robust and originate from expert interviews and experts surveys based on precise definitions given during the communication. Nevertheless the comparison of country indicators should be tackled with care. Differences may be due to the interpretation of the ESCO company definition in the given context, while in the case of the market sizes, sources include different parts of the value chain and/or calculate or estimate these in a variety of ways.

APPENDIX A

Rating systems criteria

This appendix summarizes the 6 most common rating systems and their criteria in the state as they are at the moment.

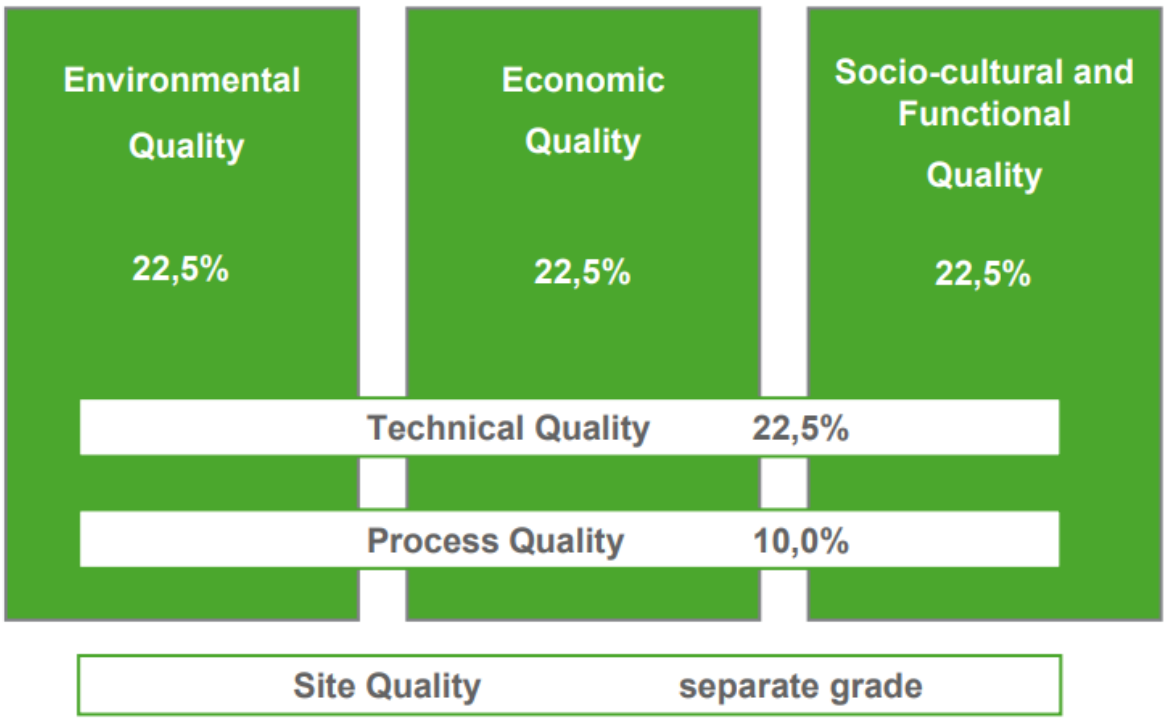
For the purpose of further analysis, the criteria were given a colour scheme as follows:

1. Environmental Quality (**green**)
2. Economic Quality (**red**)
3. Socio-cultural Quality (**blue**)

The leftover categories that the team was unable to put into a category were left in the end in **black**. These either belong to categories 4, 5 or 6, or are too vague to be decided upon for sure.

1.1 DGNB

Consists of **61 criteria** (48 active) with different weighting



(http://www.eic.cat/gfe/docs/7991.pdf by DGNB, p. 15)

Awards:

Gold	> 80%
Silver	65% - 80%
Bronze	50% - 65%

1. Environmental quality

Global warming potential (GWP)
Ozone depletion potential (ODP)
Photochemical ozone creation potential (POCP)
Acidification potential (AP)
Eutrophication potential (EP)
Local environmental impact
Sustainable use of resources / wood
Non-renewable primary energy demand
Total primary energy demand and proportion of renewable primary energy
Drinking water demand and waste water volume
Land use

2. Economic quality

Building related life-cycle costs
Suitability for third-party use

3. Sociocultural and Functional Quality

3.1 Health, comfort and user well-being

Thermal comfort in the winter
Thermal comfort in the summer
Indoor air quality
Acoustic comfort
Visual comfort
User influence on building operation
Quality of outdoor spaces
Safety and security

3.2 Functionality

Handicapped accessibility
Efficient use of floor area
Suitability for conversion
Public access
Cycling convenience

3.3 Aesthetic Quality

Design and urban planning quality trough competition

Integration of public art

4. Technical Quality

Fire prevention

Noise protection, emission controls

Building envelope quality

Ease of cleaning and maintenance

Ease of dismantling and recycling

5. Process Quality

Comprehensive project definition

Integrated planning

Comprehensive building design

Sustainable aspects in tender phase

Documentation for facility management

Environmental impact of construction site / construction process

Prequalification of contractors

Construction quality assurance

Systematic commissioning

6. Site Quality

Site location risks

Site location conditions

Public image and social conditions

Access to transportation

Access to specific-use facilities

Connections to utilities

1.2 LEED

1. **Location and Transportation**
   - LEED for Neighbourhood Development Location
   - Sensitive Land Protection
   - High Priority Site
   - Surrounding Density and Diverse Uses
   - Access to Quality Transit
   - Bicycle Facilities
   - Reduced Parking Footprint
   - Green Vehicles

2. **Sustainable Sites**
   - Construction Activity Pollution Prevention
   - Site Assessment
   - Site Development - Protect or Restore Habitat
   - Open Space
   - Rainwater Management
   - Heat Island Reduction
   - Light Pollution Reduction

3. **Water Efficiency**
   - Outdoor Water Use Reduction
   - Indoor Water Use Reduction
   - Building-Level Water Metering
   - Outdoor Water Use Reduction
   - Indoor Water Use Reduction
   - Cooling Tower Water Use
   - Water Metering

4. **Energy and Atmosphere**
   - Fundamental Commissioning and Verification
   - Minimum Energy Performance
   - Building-Level Energy Metering
   - Fundamental Refrigerant Management
   - Enhanced Commissioning
   - Optimize Energy Performance

- Advanced Energy Metering
- Demand Response
- Renewable Energy Production

Enhanced Refrigerant Management
Green Power and Carbon Offsets

5. Materials and Resources

Storage and Collection of Recyclables
Construction and Demolition Waste Management Planning
Building Life-Cycle Impact Reduction
Building Product Disclosure and Optimization - Environmental Product Declarations
Building Product Disclosure and Optimization - Sourcing of Raw Materials
Building Product Disclosure and Optimization - Material Ingredients
Construction and Demolition Waste Management

6. Indoor Environmental Quality

Minimum Indoor Air Quality Performance
Environmental Tobacco Smoke Control
Enhanced Indoor Air Quality Strategies
Low-Emitting Materials
Construction Indoor Air Quality Management Plan
Indoor Air Quality Assessment
Thermal Comfort
Interior Lighting
Daylight
Quality Views
Acoustic Performance

7. Innovation

Innovation
LEED Accredited Professional

8. Regional Priority

Regional Priority: Specific Credit

1.3 SB Tool

1. **Location, Services and Site Characteristics**
   Site Location and Context
   Off-site services available
   Site Characteristics

2. **Site Regeneration and Development, Urban Design and Infrastructure**
   Site Regeneration and Development
   Urban Design
   Project Infrastructure and Services

3. **Energy and Resource Consumption**
   Total Life Cycle Non-Renewable Energy
   Electrical peak demand
   Use of Materials
   Use of potable water, storm water and greywater

4. **Environmental Loadings**
   Greenhouse Gas Emissions
   Other Atmospheric Emissions
   Solid and Liquid Wastes
   Impacts on Project Site
   Other Local and Regional Impacts

5. **Indoor Environmental Quality**
   Indoor Air Quality and Ventilation
   Air Temperature and Relative Humidity
   Daylighting and Illumination
   Noise and Acoustics

6. **Service Quality**
   Safety and Security
   Functionality and efficiency
   Controllability
   Flexibility and Adaptability
   Optimization and Maintenance of Operating Performance

7. Social, Cultural and Perceptual Aspects

Social Aspects

Culture and Heritage

Perceptual

8. Cost and Economic Aspects

Cost and Economics

The system is shown with Generic content and for Design Phase assessments for a location in Any place, any country, suited to any or all of the following project or occupancy types: New construction with, and/or Offices, and/or Resto / cafeteria.

http://www.iisbe.org/node/140

1.4 CASBEE

The four main categories are as follows:

1. Energy efficiency
2. Resource efficiency
3. Local environment
4. Indoor environment

Which are further recategorized into the following two:

Q: Built environment quality

- **Indoor environment**
  - **Sonic environment**
    - Noise
      - Background noise level
      - Equipment noise
    - Sound insulation
      - ~ of openings
      - ~ of partition walls
      - ~ performance of fixed slabs (lightweight)
      - ~ performance of fixed slabs (heavyweight)
    - Sound absorption
  - **Thermal comfort**
    - Room temperature control
      - Room temp. setting
      - Variable loads and following-up Control
      - Perimeter Performance
      - Zoned control
      - Temperature and humidity control
      - Individual control
      - Allowance for after-hours air conditioning
      - Monitoring systems
    - Humidity control
    - Type of air conditioning system
  - **Lighting and Illumination**
    - Daylighting
      - Daylight factor
      - Openings by orientation
      - Daylight devices
    - Anti-glare measures
      - Glare from light fixtures
      - Daylight control
      - Reflection control

        - Illuminance level
        - Lighting controllability
    - **Air quality**
        - Source control
            - Chemical pollutants
            - Asbestos
            - Mites, mould etc
            - Legionella
        - Ventilation
            - Ventilation rate
            - Natural ventilation performance
            - Consideration for outside air intake
            - Air supply planning
        - Operation plan
            - CO2 monitoring
            - Control of smoking

- **Quality of services**
    - **Service ability**
        - Functionality and usability
            - Provision of space & storage
            - Use of advanced information system
            - Barrier-free planning
        - Amenity
            - Perceived spaciousness & access to view
            - Space for refreshment
            - Décor planning
        - Maintenance management
            - Design which considers maintenance management
            - Securing maintenance management functions
    - **Durability and reliability**
        - Earthquake resistance
            - Earthquake resistance
            - Seismic isolation & vibration damping systems
        - Service life of components
            - ~ of structural frame materials
            - Necessary refurbishment interval for exterior finishes
            - Necessary renewal interval for main interior finishes
            - Necessary replacement interval for air conditioning and ventilation ducts
            - Necessary renewal interval for HVAC and Water Supply and Drainage Pipes
            - Necessary renewal interval for Major Equipment and services

        - Reliability
            - HVAC system
            - Water supply & drainage
            - Electrical equipment
            - Support method of machines and ducts
            - Communications & IT equipment
    - **Flexibility & adaptability**
        - Spatial margin
            - Allowance for floor-to-floor height
            - Adaptability of floor layout
        - Floor load margin
        - System renewability
            - Ease of air conditioning duct renewal
            - Ease of water supply and drain pipe renewal
            - Ease of electrical wiring renewal
            - Ease of communications cable renewal
            - Ease of equipment renewal
            - Provision of backup space

- **Outdoor environment on site**
    - Conservation & creation of biotope
    - Townscape and landscape
    - Local characteristics & outdoor amenity
        - Attention to local character & improvement of comfort
        - Improvement of the thermal environment on site

L: Built environment load

- **Energy**
    - Building thermal load
    - Natural energy utilization
        - Direct use of natural energy
        - Converted use of renewable energy
    - Efficiency in building service system
    - Efficient operation
        - Monitoring
        - Operation & management system

- **Resources & Materials**
    - Water resources
        - Water saving
        - Rainwater & grey water
            - Rainwater use system

        - Grey water use system
    - Reducing usage of non-renewable resources
        - Reducing usage of materials
        - Continuing use of existing structural frame etc.
        - Use of recycled materials as structural frame materials
        - Use of recycled materials as non-structural frame materials
        - Timber from sustainable forestry
        - Efforts to enhance the reusability of components and materials
    - Avoiding the use of materials with pollutant content
        - Use of materials without harmful substances
        - Elimination of CFCs and Halons
            - Fire Retardant
            - Foaming Agents (Insulation Materials etc)
            - Refrigerants

- **Off-site Environment**
    - Consideration of global warming
    - Consideration of local environment
        - Air pollution
        - Heat island effect
        - Load on local infrastructure
            - Reduction of rainwater discharge loads
            - Sewage load suppression
            - Traffic load control
            - Waste treatment loads
    - Consideration of surrounding environment
        - Noise, vibration & odor
            - Noise
            - Vibration
            - Odor
        - Wind damage & daylight obstruction
            - Restriction of wind damage
            - Sand and dust
            - Restriction of daylight obstruction
        - Light pollution
            - Outdoor illumination and lights that splits from interiors
            - Measures for reflected solar glare from building walls

BEE (Building Environmental Efficiency) = Q/L

http://www.ibec.or.jp/CASBEE/english/softwareE.htm

1.5 BREEAM

1. **Management**
    - Project brief and design
    - Life cycle cost and service life planning
    - Responsible construction practices
    - Commissioning and handover
    - Aftercare

2. **Energy**
    - Reduction of energy use and carbon emissions
    - Energy monitoring
    - External lighting
    - Low-carbon design
    - Energy efficient cold storage
    - Energy efficient transport systems
    - Energy efficient laboratory systems
    - Energy efficient equipment

3. **Water**
    - Water consumption
    - Water monitoring
    - Water leak detection
    - Water efficient equipment

4. **Waste**
    - Construction waste management
    - Low impact aggregates in the construction process
    - Operational waste
    - Speculative floor and ceiling finishes
    - Adaptation to climate change
    - Design for disassembly and functional adaptability

5. **Pollution**
    - Impact of refrigerants
    - Local air quality
    - Surface water run-off
    - Reduction of night time light pollution
    - Reduction of noise pollution

6. **Health & Wellbeing**

- Visual comfort
- Indoor air quality
- Safe containment in laboratories
- Thermal comfort
- Acoustic performance
- Safety and security
- Safe and healthy surroundings

7. Transport – subject to consultation

- Public transport accessibility
- Proximity to amenities
- Cyclist facilities
- Maximum car parking capacity
- Travel plan

8. Materials

- Building life cycle assessment
- Environmental Product Declarations
- Responsible sourcing of materials
- Designing for durability and resilience
- Material efficiency

9. Land use and ecology – subject to consultation

- Site selection

10. Innovation

- Innovation

https://tools.breeam.com/filelibrary/Consultations/SD5078_DRAFT-UK_nondom_NC_2018-manual.pdf

1.6 HQE

ECO-CONSTRUCTION

- Physical relationship of the buildings with their immediate environment
- Integrated choice of construction processes and products
- Low-pollution site

ECO-MANAGEMENT

- Energy management
- Water management
- Business waste management
- Upkeep and maintenance

COMFORT

- Hygrothermic comfort
- Acoustic comfort
- Visual comfort
- Olfactory comfort

HEALTH

- Health conditions
- Air quality
- Water quality

https://www.victaulic.com/assets/uploads/literature/White%20Paper/WP-10.pdf

(the more detailed categorization not available)

APPENDIX B

Rating systems, categorized

This appendix summarizes the 6 most common rating systems, giving them a better structure. The categories follow those outlined by the Brundtland Report or Our Common Future, published by the United Nations World Commission on Environment and Development in 1987. It has been referred to ever since, as the division of sustainability which it proposes is three simple categories groups:

1. Environmental Quality
2. Economic Quality
3. Socio-cultural Quality

Furthermore, in addition to that, the authors of this report deemed it relevant to also include a few points included later by other systems, namely DGNB. Here, three extra categories groups are intro:

4. Technical Quality
5. Process Quality

These two overlap the three main ones to ensure and supervise the technical and process quality, as their stretch of influence goes across more than just one area.

6. Site quality

This category stands outside of all the others and is disputable, because it encompasses all the other categories in itself at the same time. Therefore, it serves more as a reminder to keep site quality in mind as an important part of the design process.

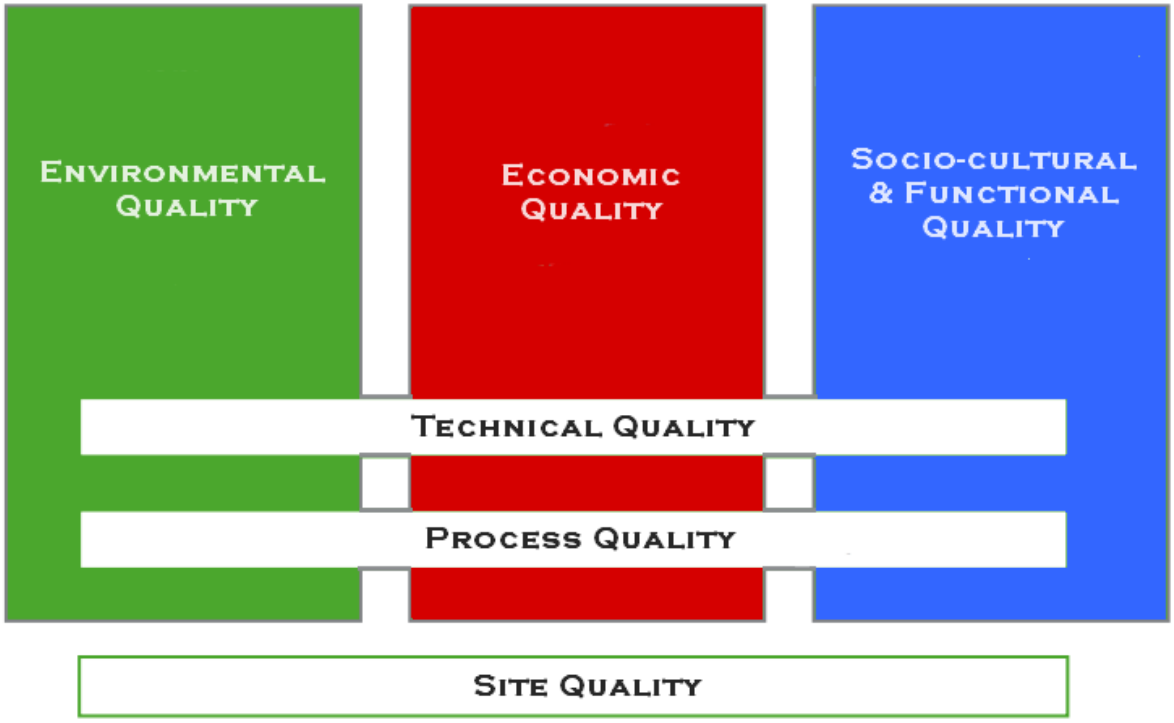
After having gathered all criteria from the six main rating systems, the team has put them all together regardless of which system they originate from and assigned a colour scheme to each of them as follows:

4. Environmental Quality (**green**)
5. Economic Quality (**red**)
6. Socio-cultural Quality (**blue**)

The leftover categories that the team was unable to put into a category were left in the end in **black**. These either belong to categories 4, 5 or 6, or are too vague to be decided upon for sure.

As a conclusion, after having grouped the various criteria based on their focus points, it can be said that it summarizes the "best of the best" – in other words, criteria from the most used rating systems put together in one place. The report team suggests that what could be done

is making an attempt to take a further step on this by representatives of all the systems, and common goals could be discussed by narrowing down the rating categories further, making their purpose easy to understand, transparent and unified.



Environmental quality

Global warming potential (GWP)

Ozone depletion potential (ODP)

Photochemical ozone creation potential (POCP)

Acidification potential (AP)

Eutrophication potential (EP)

Local environmental impact

Sustainable use of resources / wood

Non-renewable primary energy demand

Total primary energy demand and proportion of renewable primary energy

Drinking water demand and waste water volume

Land use

LEED for Neighbourhood Development Location

Sensitive Land Protection

Reduced Parking Footprint

Green Vehicles

Sustainable Sites
Construction Activity Pollution Prevention
Site Assessment
Site Development - Protect or Restore Habitat
Open Space
Rainwater Management
Heat Island Reduction
Light Pollution Reduction

Water Efficiency
Outdoor Water Use Reduction
Indoor Water Use Reduction
Building-Level Water Metering
Outdoor Water Use Reduction
Indoor Water Use Reduction
Cooling Tower Water Use
Water Metering

Energy and Atmosphere
Fundamental Commissioning and Verification
Minimum Energy Performance
Building-Level Energy Metering
Fundamental Refrigerant Management
Enhanced Commissioning
Optimize Energy Performance
Advanced Energy Metering
Demand Response
Renewable Energy Production
Enhanced Refrigerant Management
Green Power and Carbon Offsets

Materials and Resources
Storage and Collection of Recyclables
Construction and Demolition Waste Management Planning
Building Life-Cycle Impact Reduction
Building Product Disclosure and Optimization - Environmental Product Declarations
Building Product Disclosure and Optimization - Sourcing of Raw Materials
Building Product Disclosure and Optimization - Material Ingredients
Construction and Demolition Waste Management

Outdoor environment on site
Conservation & creation of biotope
Townscape and landscape
Local characteristics & outdoor amenity
Attention to local character & improvement of comfort
Improvement of the thermal environment on site

Energy
Building thermal load
Natural energy utilization
Direct use of natural energy
Converted use of renewable energy
Efficiency in building service system
Efficient operation
Monitoring
Operation & management system

Resources & Materials
Water resources
Water saving
Rainwater & grey water
Rainwater use system
Grey water use system
Reducing usage of non-renewable resources
Reducing usage of materials
Continuing use of existing structural frame etc.
Use of recycled materials as structural frame materials
Use of recycled materials as non-structural frame materials
Timber from sustainable forestry
Efforts to enhance the reusability of components and materials
Avoiding the use of materials with pollutant content
Use of materials without harmful substances
Elimination of CFCs and Halons
Fire Retardant
Foaming Agents (Insulation Materials etc)
Refrigerants

Off-site Environment
Consideration of global warming

Consideration of local environment
Air pollution
Heat island effect
Load on local infrastructure
Reduction of rainwater discharge loads
Sewage load suppression
Traffic load control
Waste treatment loads
Consideration of surrounding environment
Noise, vibration & odour
Noise
Vibration
Odour
Wind damage & daylight obstruction
Restriction of wind damage
Sand and dust
Restriction of daylight obstruction
Light pollution
Outdoor illumination and lights that splits from interiors
Measures for reflected solar glare from building walls

Energy
Reduction of energy use and carbon emissions
Energy monitoring
External lighting
Low-carbon design
Energy efficient cold storage
Energy efficient transport systems
Energy efficient laboratory systems
Energy efficient equipment

Water
Water consumption
Water monitoring
Water leak detection
Water efficient equipment

Waste
Construction waste management

Low impact aggregates in the construction process
Operational waste
Speculative floor and ceiling finishes
Adaptation to climate change
Design for disassembly and functional adaptability

Pollution
Impact of refrigerants
Local air quality
Surface water run-off
Reduction of night time light pollution
Reduction of noise pollution

Materials
Building life cycle assessment
Environmental Product Declarations
Responsible sourcing of materials
Designing for durability and resilience
Material efficiency

Land use and ecology – subject to consultation
Site selection

ECO-CONSTRUCTION
Physical relationship of the buildings with their immediate environment
Integrated choice of construction processes and products
Low-pollution site

ECO-MANAGEMENT
Energy management
Water management
Business waste management
Upkeep and maintenance

Environmental Loadings
Greenhouse Gas Emissions
Other Atmospheric Emissions
Solid and Liquid Wastes
Impacts on Project Site; Other Local and Regional Impacts

Economic quality
Building related life-cycle costs
Suitability for third-party use

Cost and Economic Aspects
Cost and Economics

Innovation
LEED Accredited Professional

Management
Project brief and design
Life cycle cost and service life planning
Responsible construction practices
Commissioning and handover
Aftercare

Sociocultural and Functional Quality
Health, comfort and user well-being
Thermal comfort in the winter
Thermal comfort in the summer
Indoor air quality
Acoustic comfort
Visual comfort
User influence on building operation
Quality of outdoor spaces
Safety and security
Functionality
Handicapped accessibility
Efficient use of floor area
Suitability for conversion
Public access
Cycling convenience
Aesthetic Quality
Design and urban planning quality trough competition
Integration of public art
Indoor Environmental Quality
Minimum Indoor Air Quality Performance
Environmental Tobacco Smoke Control
Enhanced Indoor Air Quality Strategies
Low-Emitting Materials
Construction Indoor Air Quality Management Plan
Indoor Air Quality Assessment
Thermal Comfort
Interior Lighting
Daylight
Quality Views
Acoustic Performance
Indoor Environmental Quality
Indoor Air Quality and Ventilation
Air Temperature and Relative Humidity
Daylighting and Illumination
Noise and Acoustics

Service Quality

Safety and Security

Functionality and efficiency

Controllability

Flexibility and Adaptability

Optimization and Maintenance of Operating Performance

Social, Cultural and Perceptual Aspects

Social Aspects

Culture and Heritage

Perceptual

- **Indoor environment**
  - **Sonic environment**
    - Noise
      - Background noise level
      - Equipment noise
    - Sound insulation
      - ~ of openings
      - ~ of partition walls
      - ~ performance of fixed slabs (lightweight)
      - ~ performance of fixed slabs (heavyweight)
    - Sound absorption
  - **Thermal comfort**
    - Room temperature control
      - Room temp. setting
      - Variable loads and following-up Control
      - Perimeter Performance
      - Zoned control
      - Temperature and humidity control
      - Individual control
      - Allowance for after-hours air conditioning
      - Monitoring systems
    - Humidity control
    - Type of air conditioning system
  - **Lighting and Illumination**
    - Daylighting
      - Daylight factor
      - Openings by orientation
      - Daylight devices
    - Anti-glare measures
      - Glare from light fixtures
      - Daylight control

- Reflection control
- Illuminance level
- Lighting controllability

- **Air quality**
  - Source control
    - Chemical pollutants
    - Asbestos
    - Mites, mould etc
    - Legionella
  - Ventilation
    - Ventilation rate
    - Natural ventilation performance
    - Consideration for outside air intake
    - Air supply planning
  - Operation plan
    - CO2 monitoring
    - Control of smoking

Quality of services

- **Service ability**
  - Functionality and usability
    - Provision of space & storage
    - Use of advanced information system
    - Barrier-free planning
  - Amenity
    - Perceived spaciousness & access to view
    - Space for refreshment
    - Décor planning
  - Maintenance management
    - Design which considers maintenance management
    - Securing maintenance management functions

11. Health & Wellbeing

- Visual comfort
- Indoor air quality
- Safe containment in laboratories
- Thermal comfort
- Acoustic performance
- Safety and security
- Safe and healthy surroundings

COMFORT

- Hygrothermic comfort
- Acoustic comfort
- Visual comfort
- Olfactory comfort

HEALTH

- Health conditions
- Air quality
- Water quality

- **Flexibility & adaptability**
  - Spatial margin
    - Allowance for floor-to-floor height
    - Adaptability of floor layout
  - Floor load margin
  - System renewability
    - Ease of air conditioning duct renewal
    - Ease of water supply and drain pipe renewal
    - Ease of electrical wiring renewal
    - Ease of communications cable renewal
    - Ease of equipment renewal
    - Provision of backup space

- **Transport – subject to consultation**
- Public transport accessibility
- Proximity to amenities
- Cyclist facilities
- Maximum car parking capacity
- Travel plan
- **Location and Transportation**
- High Priority Site
- Surrounding Density and Diverse Uses
- Access to Quality Transit
- Bicycle Facilities
- Public image and social conditions

  Access to transportation

  Access to specific-use facilities

  Connections to utilities

Technical Quality
Fire prevention
Noise protection, emission controls
Building envelope quality
Ease of cleaning and maintenance
Ease of dismantling and recycling

Process Quality
Comprehensive project definition
Integrated planning
Comprehensive building design
Sustainable aspects in tender phase
Documentation for facility management
Environmental impact of construction site / construction process
Prequalification of contractors
Construction quality assurance
Systematic commissioning
Innovation
Regional Priority
Regional Priority: Specific Credit
Location, Services and Site Characteristics
Site Location and Context
Off-site services available
Site Characteristics
Site Regeneration and Development, Urban Design and Infrastructure
Site Regeneration and Development
Urban Design
Project Infrastructure and Services
Site Quality
Site location risks
Site location conditions

Energy and Resource Consumption

Total Life Cycle Non-Renewable Energy

Electrical peak demand

Use of Materials

Use of potable water, storm water and greywater

Q: Built environment quality
Durability and reliability
Earthquake resistance
Earthquake resistance
Seismic isolation & vibration damping systems
Service life of components
~ of structural frame materials
Necessary refurbishment interval for exterior finishes
Necessary renewal interval for main interior finishes
Necessary replacement interval for air conditioning and ventilation ducts
Necessary renewal interval for HVAC and Water Supply and Drainage Pipes
Necessary renewal interval for Major Equipment and services
Reliability
HVAC system
Water supply & drainage
Electrical equipment
Support method of machines and ducts
Communications & IT equipment

Appendix C

Questions - ESCO and energy contracting

Alex Røge Hermansen

❖ Do you have any experience with ESCO contracting and ESCO companies?

Jeg har erfaring fra mit tidligere job som teamleder for byggeri i Hjørring Kommune, hvor jeg sammen med ekstern rådgiver forestod et udbud af en ESCO-renovering af en sportshal med ambition om at energirenovere klimaskærm og installationer.

I have experience from my previous job as a teamleader for construction in Hjørring Kommune, where I was together with an external consultant in charge of an ESCO renovation contract of a sportshall with the ambition to renovate its building envelope and installations.

❖ If yes, for how long have you known about the concept?

Jeg har vel kendt til ESCO-konceptet siden 2008/2009.

I have been familiar with the ESCO concept since 2008/2009.

❖ Has your company been engaged in any ESCO projects recently? If yes, what kind of client have you worked for? Was it a private or public client?

Min nuværende arbejdsgiver AAU (siden november 2015) har ikke været enggageret i ESCO-projekter.

My current employer AAU (since November 2015) has not been engaged in ESCO projects.

❖ Is there demand from the clients for ESCO projects, or it's more that you propose such an option to the client?

Vi forestår i Campus Service ved egen energiansvarlig medarbejder energirenoveringsprojekter. Som offentlig institution er vi underlagt et direktiv omkring 14 % energibesparelser i undervisningssektoren målt i forhold til sektorens energiforbrug i 2006. AAU har ekspanderet voldsomt i perioden og vores energiforbrug er derfor i absolutte tal vokset markant i perioden. Måler man på energiforbruget pr. m² eller pr. bruger er vi imidlertid ret godt med. Der afsættes årligt en pulje på 3,5 mio. kr. i investeringsbudgettet til energibesparende foranstaltninger.

We are in charge of the Campus Service with our own employee responsible for energy renovation projects. As a public institution, we are subjected to a directive of achieving cca 14% energy savings in the education sector, measured compared to the sector's consumption in 2006. During this period, AAU has expanded massively; therefore, in absolute figures, the energy consumption rose markantly as well. If you measure the energy consumption per m² or per user, we are doing quite well. A pool of 3.5 mio kr is deposited yearly in the investment budget for energy saving arrangements.

❖ What is your opinion on the 2050 Danish Energy Strategy? Is it looking too far ahead into the future? Should it be shorter term?

Jeg tænker at strategien har et passende sigte. Det er en enorm omstillingsproces med de ambitioner der lægges op til, og det tager tid. Samtidig hjælper den teknologiske udvikling os, ligesom eks. fornyelse af bolig- og bygningsmassen vil sikre et lavere og mere energineutralt forbrug over en årrække, idet man allerede med det nuværende bygningsreglement bygger og renoverer til langt mere energieffektive bygninger. Over en 30 års periode må ca. en tredjedel af bygningsmassen forventes erstattet af nybyggeri eller renoverede bygninger og en række andre vil være effektiviseret som følge af billigere VEløsninger.

I think that the strategy has appropriate aims. It is an enormous conversion process with the ambitions which it initiates, and that takes some time. At the same time the technological development is helping us, just like for example renovation of housing- and building bodies will ensure lower and more energy neutral consumption over a few years' period, just like the much more energy efficient buildings that are already being built/renovated these days according to the current building regulations. Over the following 30 years' period, it is expected that cca. a third of all buildings will be replaced by new buildings or renovated ones, while many others will be made more effective as a consequence of cheaper renewable energy solutions. (VE = vedværende energi)

❖ Speaking of shorter term, what is your opinion of the 2020 Energy strategy? Are the demands feasible and attainable?

Det har jeg ikke et bud på.

I don't have an estimation about that.

❖ What is your opinion on sustainability in construction? Do you think the concept of sustainability is being used to its full extent, or companies use it more to gain publicity (positive publicity), to gain more customers and to generally look good?

Jeg tror på bæredygtighed i byggeriet, særligt i forhold til energi- og materialevalg, da der er en god totaløkonomi for bygherre heri. De blødere værdier som indgår i bæredygtighedsstrategier, herunder social bæredygtighed m.v. er måske mest et udtryk for at man godt vil sikre sig at byggeriet også på et mere etisk niveau er forsvarligt.

I believe in sustainability in the construction industry, especially in terms of energy and material choice, as there is good total economy for the building owners. The "soft" values which form the sustainable strategies, such as social sustainability and so forth, are perhaps more of an expression that one wants to ensure that construction is justifiable also on a more ethical level.

❖ In general, how open are clients to investing more initially in the building so it is lower energy, and "greener", but having a longer return on investment for the clients (circa 10-15 or even 20 years)?

Det er mit indtryk, at der er vilje til at se på bæredygtighed, men at det helst ikke må koste for meget på bundlinjen. Så længe der er fokus på en sund totaløkonomi vil bygherre typisk godt betale for grønne løsninger. Generelt koster det ikke meget mere at tænke energieffektivitet ind fra starten af et byggeri, mens det kan koste meget hvis man først projekterer et hus efter normale standarder, og derefter klistrer grønne løsninger på. Der bør være mere fokus på passive energibesparelsestiltag tidligt i projektforløb, herunder særligt fokus på solens påvirkning (solindfald som varmekilde om vinteren, og passende skyggevirkning om sommeren for at undgå energiforbrug til køl)

My impression is that there is the will to consider the concept of sustainability, but that it should ideally not cost too much as the bottom line. As long as there is focus on healthy total economy, the building owner will typically pay for the green solutions. In general, it doesn't cost much more to think about energy efficiency from the beginning of the building process, while it can cost a lot when the house is first drafted out according to the normal standards and only afterwards, the green solutions are glued on that. There should be more focus on passive energy saving initiatives early in the process, comprising especially of focusing on the sun's impact (solar radiation as a heat source during winter and appropriate shading during summer in order to avoid using energy for cooling)

❖ What would you identify as the main difference in process between a standard and an energy project? (as a contractor/architect/building owner/…)

Energiprojekter er i vores terminologi fokuseret på at opnå energibesparelser i det eksisterende byggeri, mens standardprojekter omhandler øvrige ombygningsopgaver eller nye projekter. For sidstnævnte indtænkes energieffektivitet fra starten.

In our terminology, energy projects are focused on achieving energy savings in the existing buildings, while standard projects deal with the remaining projects or new projects. For the last mentioned, energy efficiency is being incorporated from the start.

❖ Where does the initiative to perform an ESCO/sustainability certified project usually come from, is it mostly the client? If so, what kind of clients are those? (public, big companies, private...)

På AAU opføres den nye bygning til Science & Innovation Hub formodentlig efter DGNB-standarden for at sikre en bæredygtig tilgang tidligt i projektforløbet efter ønske fra universitetet som bygningsejer/lejer. Både fordi bygningen skal være state of the art indenfor tværvidenskabelig forskning, hvor netop bæredygtighed er en af de globale udfordinger som kun kan løses tværvidenskabeligt, men også fordi vi ønsker et fremtidssikret hus, med en god totaløkonomi, som kommer automatisk med DGNBcertifikat. AAU har i øvrigt ikke en bæredygtighedsstrategi.

At AAU the new building for Science & Innovation Hub is being built presumably according to the DGNB-standard in order to ensure a sustainable approach early in the project process, as after the university's wish as the building owner/renter. Also, because the building should be in the state of the art within interdisciplinary research, where sustainability is particularly one of the global challenges that can only be solved in an interdisciplinary manner – but also because we wish to have built a "future-safeguarded" house with good total economy, which comes automatically with a DGNB certificate. AAU has no further specific sustainability strategy.

❖ What would you identify as the biggest weakness of ESCO contracting and/or sustainable construction?

ESCO konceptet udfordres af at leverandørerne typisk kun interesserer sig for renoveringer af installationer med lav tilbagebetalingstid på 5-10 år. Som offentlig bygherre har man ofte behov for at renovere hele bygningen, herunder oftest hele klimaskærmen, som typisk omfatter langt dyrere tiltag med langt dårligere tilbagebetalingstider – måske over 25 år, hvor eksempelvis kommuner og regioner kun har låneadgang med op 25 års afdragsmulighed jf. lånebekendtgørelsen. Det betyder at man ikke får totalrenoveret sin bygning, men i stedet investerer i renovering og optimering af tekniske anlæg. Efter nogle år investerer man så efterfølgende i renovering af klimaskærmen (pga. utætheder og lignende) med efterisolering, hvilket betyder at man pludselig kunne have nøjedes med mindre energianlæg, ventilationsanlæg m.v. Samlet set bliver renoveringen derfor dyrere end hvis hele projektet blev håndteret og dimensioneret samtidigt.

ESCO concept is facing the challenge that the suppliers are typically only interested in the renovation of installations with a low payback time period of 5-10 years. As a public building owner (client) often has the need to renovate the whole building, most commonly the whole building envelope, typically including a lot more expensive initiative with much worse payback periods – perhaps over 25 years, where f. ex. the municipalities and regions can only have a loan admittance with 25 years' instalments compared to the loan's notice. This means people won't get their building fully renovated, but instead invest in renovation and optimization of the technical equipment. After a few years, you invest in subsequent building envelope renovation (due to leakages and similar) with extra insulation, which means that all of the sudden, you could have settled for less energy equipment, ventilation

units etc. Summed up, the renovation becomes more expensive than if the whole project was handled and dimensioned at the same time.

❖ What would you identify as the most significant obstacle towards building more sustainably/achieving the 2050 strategy?

Lave energipriser på fossile brændsler og stigende renteniveau vil være største risiko for at strategien mislykkes.

Low energy prices on fossil fuels and the rising interest rates levels will become a huge risk for the strategy's failure.

❖ What technology do you see having the greatest impact in the near future and how?

I forhold til energieffektivt byggeri vil større anvendelse af certificeringsordninger såsom DGNB og lignende koblet med krav om energieffektivt nybyggeri og renovering i bygningsreglementerne have størst virkning. Krav om totaløkonomibetragtninger kunne sikre mere systematisk anvendelse af passive tiltag.

In terms of energy efficient construction, wider use of certification schemes such as DGNB and the like tied with a requirement on energy efficient newly built structures and renovations in the building regulations would have the biggest effect. A requirement about total economy considerations could ensure more systematic use of passive initiatives.

❖ Do you think the government should have more initiatives when it comes to low-energy buildings? (more subsidies, tax reductions etc.)

Jf. ovenstående vil krav om totaløkonomi kunne bidrage til hurtigere omstilling. Fradragsordninger for grøn omstilling ift. energiforbrug kan også bidrage.

Compared to the above mentioned, a demand on total economy could contribute to faster conversion. Tax deduction for green conversions in regards to energy use can also contribute.

❖ Have you ever been involved in a project that was meant to deliver a smart built environment? (smart building/smart home)

Nej ikke direkte, men jeg har været med til at implementere enkeltkomponenter og smart styring.

Not directly, but I have been involved in implementation of single components and smart control equipment.

❖ Do you think that low-energy and energy efficient buildings are more popular in Denmark also due to public perception, and in general how people feel about the environment and climate?

Lavenergibyggeri er populært pga. lave omkostninger og sundt indeklima. Jeg tænker ikke at folk generelt er villige til at betale meget mere for bæredygtighed.

Low energy construction is popular because of the low living costs and healthy indoor climate. I don't think that people are generally willing to pay much more for sustainable solutions.

❖ Where do you see the Danish construction industry in 15-20 years?

Jeg håber at der kommer mere fokus på passive tiltag og smarte energiløsninger som kan sikre et godt og sundt indeklima uden miljøbelastning. Jeg ser gerne øget genanvendelse af byggematerialer samt større fokus på totaløkonomi i det offentlige byggeri.

I hope that more focus on passive initiatives will come about as well as smart energy solutions that can guarantee good and healthy indoor climate without burdening the environment. I would like to see increased reusing of building materials, as well as bigger focus on total economy in the public-sector construction.

❖ Do you think that companies that do not adapt to recent technological improvements in construction will have a hard time surviving? What about companies that fail to adapt to the increase in demand of energy efficient buildings?

Der vil altid være plads til traditionelle byggefirmaer som ikke fokuserer på bæredygtighed men bygger til de lavest mulige omkostninger og deraf følgende billigste løsninger, men jeg tror at befolkningen generelt (jo rigere vi også bliver) ønsker mere bæredygtige løsninger, da det er en generel trend i samfundet.

There will always be space for the traditional construction companies that do not focus on sustainability but keep building to fulfil the lowest possible costs and therefore the cheapest solutions, but I think that people in general (also as we become richer) wish to own more sustainable solutions, as it is a general trend in society.

Med venlig hilsen

Alex Røge Hermansen

Appendix D

Questions - ESCO and energy contracting

Kurt Krogh Christensen

❖ Do you have any experience with ESCO contracting and ESCO companies?

Ja/*Yes*

❖ If yes, for how long have you known about the concept?

Siden 2010/*Since 2010*

❖ Has your company been engaged in any ESCO projects recently? If yes, what kind of client have you worked for? Was it a private or public client**?**

Jeg er ansat i Aalborg Kommune, vi har et ESCO projekt på 2 skoler, hvor Eniig er totalentreprenør.

I am employed at Aalborg Kommune, we have ESCO projects at two schools, where Eniig is the total contractor.

❖ Is there demand from the clients for ESCO projects, or it's more that you propose such an option to the client?

Jeg kan ikke anbefale ESCO.

I cannot recommend ESCO.

❖ What is your opinion on the 2050 Danish Energy Strategy? Is it looking too far ahead into the future? Should it be shorter term?

Der burde nok ske en hurtigere afvikling af fossible brændsler.

A much faster replacement of fossil fuels should take place.

❖ Speaking of shorter term, what is your opinion of the 2020 Energy strategy? Are the demands feasible and attainable?

De opsatte mål kan sagtens opnås, det er blot et spørgsmål om viljen er til stede.

The determined goal can definitely be achieved, it is merely a question of whether the will to do so is present.

❖ What is your opinion on sustainability in construction? Do you think the concept of sustainability is being used to its full extent, or companies use it more to gain publicity (positive publicity), to gain more customers and to generally look good?
Der kan helt klart opnås mere. Men motivationen er for de fleste byggefirmaer nok primært at skaffe kunder og få en god forretning.
It is completely clear that a lot more can be achieved. But the motivation of most of the construction companies is primarily to obtain customers and get good business.

❖ In general, how open are clients to investing more initially in the building so it is lower energy, and "greener", but having a longer return on investment for the clients (circa 10-15 or even 20 years)?
For langt de fleste bygherrer og bygningsejere er økonomien den vigtigste parameter, så hvis der er god økonomi I at være bæredygtig, så er det let. Nogle bygherrer kan godt acceptere en relativ lang tilbagebetalingstid på energibesparelser.
For by far the most building owners, the economy of their project is the most important aspect, so if it happens to be a good deal to be sustainable, it is easy. Some of the building owners can also accept a relatively long payback time on energy savings.

❖ What would you identify as the main difference in process between a standard and an energy project? (as a contractor/architect/building owner/…)
Den største forskel ligger i at der foruden prisen også er fokus på energibesparelsen.
The biggest difference lies in the fact that besides the price, there is also focus on energy savings.

❖ Where does the initiative to perform an ESCO/sustainability certified project usually come from, is it mostly the client? If so, what kind of clients are those? (public, big companies, private…)
Det kommer primært fra ESCO firmaerne.
It comes primarily from the ESCO companies.

❖ What would you identify as the biggest weakness of ESCO contracting and/or sustainable construction?
For os har det været ret resourcekrævende at gennemføre et ESCO project, idet der I et ESCOprojekt både skal forhandles om prisen på udførelsen og så også om den beregnede besparelse. Specielt for den beregnede besparelse har der været brug for besparelsesberegninger, som har været meget tidskrævende, ligesom den efterfølgende

forhandling mellem bygherre og levereandør har været resourcekrævende.
For us, it has been rather resource demanding to implement an ESCO project, as an ESCO project shall be negotiated both regarding the price of the execution as well as the calculated savings. Especially for the calculated savings, there has been the need for savings calculations, which have been very time demanding; similarly, the following negotiations between the building owner and suppliers have been resource consuming.

❖ What would you identify as the most significant obstacle towards building more sustainably/achieving the 2050 strategy?
Højere energipriser og økonomiske incitamenter fra staten.
Higher energy prices and economic incentives/stimuli from the state.

❖ What technology do you see having the greatest impact in the near future and how?
LED, varmepumper og vedvarende energikilder.
Hvis vi ser på et længere perspektiv, vil også efterisolering af ældre Bygninger være væsentligt.
Looking at it from a long-term perspective, also additional insulation of older buildings will become a substantial contribution.

❖ Do you think the government should have more initiatives when it comes to low-energy buildings? (more subsidies, tax reductions etc.) **Ja. / *Yes.***

❖ Have you ever been involved in a project that was meant to deliver a smart built environment? (smart building/smart home)
Vi har installeret cts i mange bygninger og også smart lysstyring.
We have installed CTS (a smart control system by Siemens) in many buildings as well as smart light installations.

❖ Do you think that low-energy and energy efficient buildings are more popular in Denmark also due to public perception, and in general how people feel about the environment and climate?
Det kommer an på hvem der sammenlignes med, men jeg tror Danmark er et af de lande hvor der er mest focus på lavenergibyggeri.
That depends on who we are comparing Denmark to, but I think that Denmark is one of the countries with the biggest focus on low energy construction.

❖ Where do you see the Danish construction industry in 15-20 years?

Svært at sige, da udenlandske byggefirmaer I mange tilfælde kan arbejde med en lavere lønudgift. Så måske vil den danske byggesektor få det svært på store projekter.

Hard to tell, because the foreign construction companies can in many cases work with much lower labour costs. So maybe the Danish building sector will have a hard time on the big projects.

❖ Do you think that companies that do not adapt to recent technological improvements in construction will have a hard time surviving? What about companies that fail to adapt to the increase in demand of energy efficient buildings?

For større entreprenørfirmaer vil det være vigtigt at følge med I den teknologiske udvikling, da de ellers ikke vil overleve. Mange små håndværksvirksomheder vil nok fortsat kunne eksistere uden den helt store teknologiske udvikling, dog vil der være nogle teknologier de vil være nødt til at kunne håndtere.

For the big contractor companies, it will be important to keep pace with the technological development, as otherwise they won't survive. Many small labour firms will be able to continue even without the whole huge technological development, although there will be some technologies which will become necessary to have the ability to handle.

THE END.

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2018