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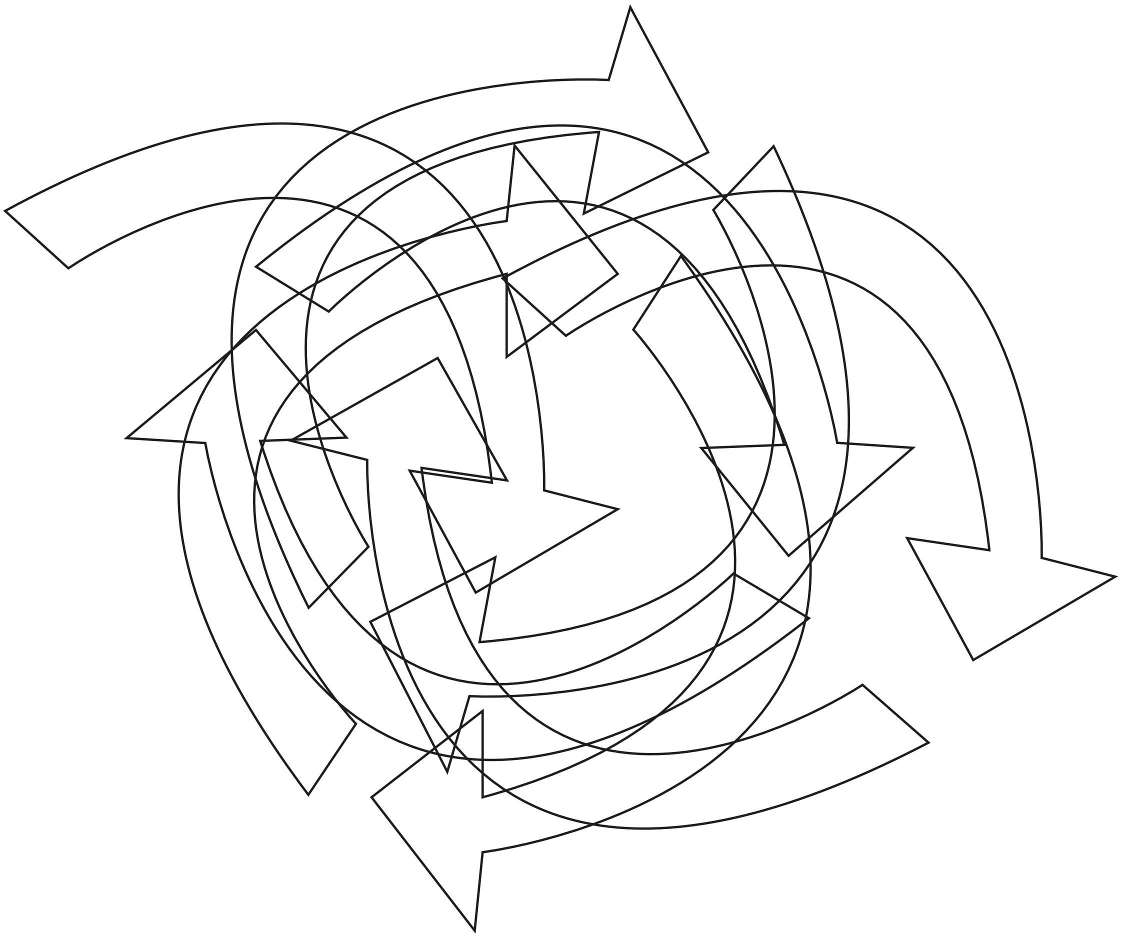

# Credit to Innovative Architecture

## A case study of circular design concepts and green building assessments

Master’s thesis in Industrial Ecology

YLVA WILDER

Department of Energy and Environment
Division of Environmental System Analysis
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2016
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# ABSTRACT

The purpose of this master's thesis is to explore innovative architecture and how it relates to environmental assessments methods for buildings. An increased awareness of the building sector's environmental impact is expressed through various innovative ideas and design concepts as well as a growing number of green building certifications. In this research, the link between these different pathways towards sustainable architecture is investigated. This is done through a review of innovation theory, design concepts related to circular resource use and green building assessment methods. It is further explored in a case study of the project Bråta Pavilion and the environmental assessment methods BREEAM SE, LEED and Miljöbyggnad. An analysis of the correlations between Bråta Pavilion and the performance based criteria in the methods provides an indication of how circular design is managed by the certification schemes. This study shows the benefits of an increased recognition of reused material and the complex relation between future and current reuse potential. The existing environmental assessments methods contribute to a future circular resource use which currently limits the implementation possibilities of reused material today. This study also highlights the importance of different pathways towards sustainable architecture but also a need for bringing them closer to each other.

Keywords: innovative architecture, innovation, design concept, cradle to cradle, C2C, regenerative design, environmental assessment methods, green building, certification, reuse

# PREFACE

This master's thesis of 30 credits was written within the master's programme Industrial Ecology at the Department of Energy and Environment, Division of Environmental System Analysis at Chalmers University of Technology, Sweden. It was carried out between September and December 2016 with associate professor Henrikke Baumann as supervisor and examiner.

This work originates from two different perspectives in my educational background, the creative design process within Architecture and the systemic approach to resource use and change within Industrial Ecology. To develop sustainable architecture is not an easy task nor a commonly defined concept. It involves exploration and innovation as well as diffusion of green building practices. I was curious of the concept innovative architecture and how it relates to our need for tools to assess environmental impact. Through bringing these fields closer to each other, I have learnt a lot and hopefully also contributed with some perspectives on the greening of architecture.

I would like to thank my supervisor and examiner Henrikke Baumann for inspiration and guidance which helped me to define and carry out this thesis. I would also like to thank Charlotte Farrouch who has been very helpful with the case project. Many other people have also influenced this work and I want to thank everyone who took their time for interviews, answering questions and interesting discussions. Lastly, a special thanks to my mother for a never ending encouragement and to Thobias Bågmark for always being there.

December 2016, Göteborg

Ylva Wilder

## ABBREVIATIONS

| | |
|---|---|
| BREEAM | Building Research Establishment Environmental Assessment Method |
| C2C | Cradle to Cradle |
| C2CPII | Cradle to Cradle Product Innovation Institute |
| GBAM(s) | Green Building Assessment Method(s) |
| KEMI | The Swedish Chemical Agency |
| LCA | Life Cycle Analysis |
| LCC | Life Cycle Cost |
| LEED | Leadership in Energy and Environmental Design |
| REACH | Registration, Evaluation, Authorisation and Restriction of Chemicals |
| SGBC | Sweden Green Building Council |
| USGBC | United States Green Building Council |

## TABLES & FIGURES

Tables and figures without source are illustrated by the author of the thesis.

# TABLE OF CONTENT

# 1

# INTRODUCTION

*This chapter includes a brief background which illustrates the relevance of the thesis. It is followed by the main purpose, aim and objectives, delimitations and short outline of the thesis.*

## 1.1 PATHWAYS TOWARDS SUSTAINABLE ARCHITECTURE

It is often discussed that innovation has an important or even fundamental role in the development of sustainable architecture - as it is necessary to find alternatives to the conventional way of doing things. Such development involves new design and construction processes, integration of technological solutions as well as contributions to lifestyle changes. Various innovative design concepts are being developed to explore alternatives for the future of sustainable architecture. This is noticed in various pilot projects, through new ideas and philosophies. In contrast, some argues that there is a need for standardisation of green building practices. To restructure the building sector, there is an increased establishment of new regulations, tools and environmental assessments. Voluntary (increasingly mandatory) green building certifications are influencing architecture projects as well as the concept of environmentally responsible design.

These different pathways have the same ambition – to develop sustainable architecture. Still, it seems to be a distance between the more innovative design concepts and the performance based tools. Are these approaches developing towards the same goal?

## 1.2 PURPOSE

The main purpose of this master's thesis is to explore innovative architecture and how it relates to Green Building Assessment Methods (GBAMs). Such knowledge can generate perspectives on the greening of architecture and the complex relationship between sustainability, innovation and standards. It can also create a discussion for further development of methods and mechanisms to enhance a more sustainable building sector.

## 1.3 AIM & OBJECTIVES

The aim is to investigate this relation through a case study of the innovative project Bråta Pavilion and the methods BREEAM SE, LEED and Miljöbyggnad. This is done through exploring how the circular design approach in the project relates to performance based criteria in the GBAMs. The two specific objectives that this study aims at answering are presented below.

- How is the design of Bråta Pavilion managed within the GBAMs ?
- In which way do the GBAMs enhance or limit architecture to involve a circular design approach ?

## 1.4 DELIMITATIONS

Due to a limited amount of time, the case study does not include a complete assessment but rather a qualitative evaluation of the relation between Bråta Pavilion and environmental performance criteria in the GBAMs. This study is also limited to focus on the material available to the researcher, which excludes an in-depth study of certain aspects of the GBAMs and some of the commercial databases.

## 1.5 OUTLINE OF THE THESIS

This master's thesis consists of total 9 chapters including this one. The next three chapters, 2 to 4, describes the theory and knowledge basis which the research is based upon - innovation, circular design concepts and green building assessments. In chapter 5, the method is presented which includes the research strategy and design, an explanation of the case study, how the data was collected and the analytic process. Chapter 6 provides a description of the case project Bråta Pavilion, including the process and the design. The findings from the case study are presented in chapter 7 which is followed by an analysis in chapter 8. The analysis aims at answering the objectives of the study through relating the findings to the theory presented in chapter 2 to 4. This is followed by a discussion about the main findings in relation to the purpose in chapter 9. Finally, chapter 10 provides a short summary and a conclusion in relation to the purpose of the thesis.

# 2

# INNOVATION

*This chapter provides a description of what innovation is, both generally and in the field of architecture and environmental sustainability.*

## 2.1 DEFINITION

Innovation is a widely diffused word, used in various context and for different purposes. The definition of innovation has also been described differently depending on theoretical discipline and focus area. According to Hansen & Wakonen (1997) the concept was coined by Joseph Schumpeter in the late 1920s. Schumpeter (1934) describes innovation as the application of something new – a product, process or method of production, market or source of supply or a new form of organisation. Many of the more recent definitions build upon Schumpeter's theory, often distinguishing between product and process innovation. In practice, there is not always a clear distinction between product and the process innovation (Rogers 2003). Another important categorization is the between radical and incremental innovation. According to the Oslo manual, radical innovations create big changes in the world while incremental innovations fill in the process of change continuously (Mortensen & Bloch 2005).

The development of innovation can be divided into three dimensions - invention, innovation and the diffusion of innovation (Hansen & Wakonen 1997). These Schumpeterian dimensions are shown in figure 1. Invention is described as the discovery of something new while innovation is the development and adoption of an invention. The further diffusion is the process by which the innovation is spreading, over time, in society. Rogers (2003) describes the spreading to happen through different 'communication channels', such as interpersonal contact or mass media.

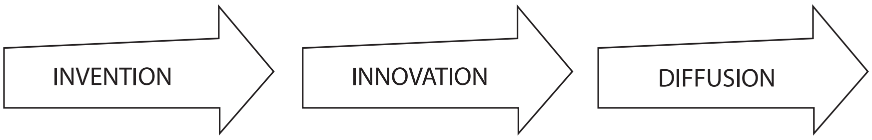


Figure 1: The three Schumpeterian dimensions

## 2.2 WITHIN ARCHITECTURE

The concept of innovation has been developed further and is today often used with the meaning of creativity, knowledge as well as change (Crossan & Apaydin 2010). It is often the case within architecture. To further clarify what innovative architecture is, the concept of architecture has to be defined. To put it simple, architecture is described as the art (or science) of designing and constructing buildings (Merriam Webster 2016a). Combined with the previously discussed concept of innovation, innovative architecture can simply be described as the art of designing and constructing buildings through a new process or by creating a new outcome. However, literature shows a broad spectrum of definitions and worth noting is the difference between architecture and construction focused research. According to Blayse & Manley (2004), a broadly accepted definition in construction considers the use of a nontrivial change and improvement of a process, product or system, which is new to the institution developing the change. There is a focus on the 'use of an innovation' and the novelty aspect is relative to the company or industry rather than to the world. In the field of architecture, Agenda Livsmiljö (2016) suggest that innovative architecture is to integrate new socio-cultural, technical, ecological and economical prerequisites into the build environment, including aesthetics and functions. Here the emphasise is on the new conditions, rather than that the actual architecture is new itself.

## 2.3 ECOLOGICAL INNOVATION

Another relatively new and increasingly used application of the term innovation is within environmental sustainability, often described as ecological innovation or eco-innovation. It is a broadly defined concept which is exemplified in the description by Rennings (2000, p. 322) as *"..all measures of relevant actors (firms, politicians, unions, associations, churches, private households) which develop new ideas, behavior, products and processes, apply or introduce them and which contribute to a reduction of environmental burdens or to ecologically specified sustainability targets."* The inclusive approach can also be seen in the European Commission project 'Measuring eco-innovation', where all new processes and products that are more resource efficient are considered to be eco-innovations (Kemp & Pearson 2007). These descriptions, among others, consists of two parts - the innovation aspect and the decreased environmental impact. By looking at the design framework in figure 2, the concept is expanded to involve both a decreased negative and an increased positive environmental impact. According to Könnölä (2008), the highest sustainability potential is for eco-innovations in the top right corner of the framework.

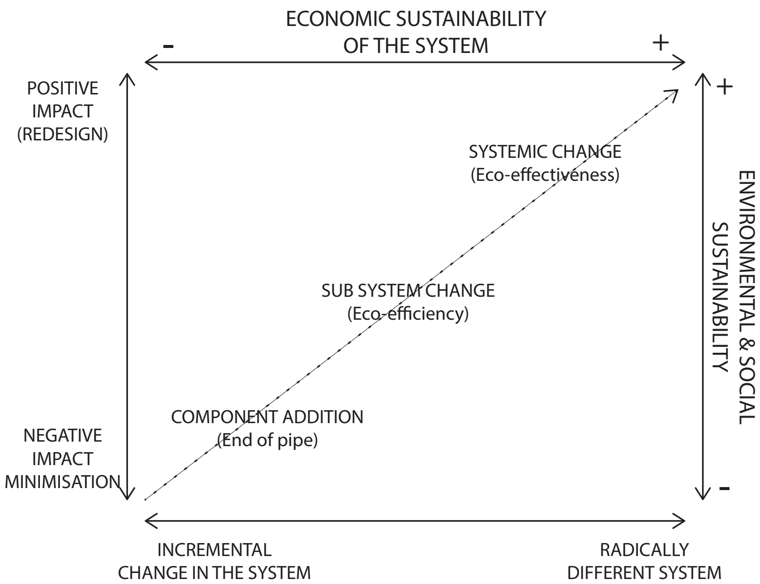


Figure 2: Design framework for eco-innovations (Könnölä et al. 2008)

According to Hellström (2007), the concept of eco-innovation does mainly emphasise innovations of incremental character and the concept seems to develop away from the type of innovations that actually have the potential of contributing to sustainable development. In relation to this, Brunklaus et al. (2013) highlights the risk of a 'rebound effect' of incremental innovations. It is a negative feedback which might results in that an eco-innovation does not contribute to a decreased environmental impact in the end.

## 2.4 SO TO CONCLUDE

The concept of innovation is commonly used in our society, with different meanings and purposes. In the field of architecture and construction, there is no clear definition of the concept or of what innovative design is. The innovation concept involves various types, such as process - product and incremental - radical. The difference between incremental and radical innovation is of importance in the field of environmental sustainability. Still, there is no common understanding of what distinguish an innovation from an improvement.

# 3

# WHAT IS CIRCULARITY?

*In this chapter, the concept of circular resource use is described as a basis for understanding the case study. The approaches of Cradle to Cradle and Regenerative design are also presented.*

## 3.1 A WIDESPREAD CONCEPT

The awareness of circular resource use is growing and various innovative concept have been developed both within architecture as well as other disciplines. These systemic approaches to resources have co-evolved within the fields of design, industrial ecology and economics. There is a high interrelatedness among the models and the main idea is to change the current linear resource system to a more resource efficient and closed loop system, see figure 3.

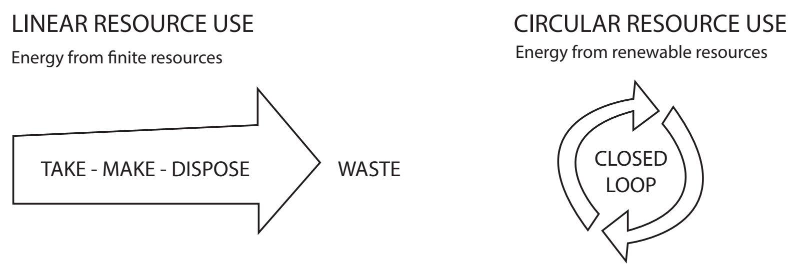


Figure 3: Model of the linear and circular resource concepts

An approach which have gain a lot of attention over the last years is Circular Economy - an economic model for a closed loop system through alternative business models (Ellen MacArthur Foundation 2015). The concept is increasingly discussed within governmental strategies as well as in the private sector (Preston 2012). The European Commission (2015) has developed an action plan for Circular Economy, which addresses the high resource use in the building sector and need for increased reuse and recycling. This development is supported by the Swedish Government (Regeringskansliet 2015) and a prioritisation of the resource use in the building industry can also be seen at a national level (Naturvårdsverket 2012). The increased interest in Circular Economy in the building sector (Åfreds 2016) can be seen as a response to this.

## 3.2 WITHIN DESIGN

The same idea of circularity is also present in more explorative design concepts within architecture - Biomimicry or biomimetic design (Biomimicry Institute 2016), Cradle to Cradle (McDonough & Braungart 2002) and Regenerative design (Lyle 1994). Some of the approaches have had an influence on the development of other models, as Circular Economy.

### 3.2.1 CRADLE TO CRADLE

Cradle to Cradle or C2C is a philosophy which involves both the design of products and material as well as whole systems. The concept was introduced in 1976 by Walter Stahel, often described as one of the first industrial ecologist (Preston 2012). The further development was initiated in 2002 by the the architect William McDonough and the chemist Michael Braungart through their book Cradle to Cradle: Remaking the way we do things. According to McDonough & Braungart (2002) the concept of Cradle to Cradle has three main principles; elimination of the concept of waste, the use of renewable energy and celebration of diversity (including social, technological and biological). The first of the principles is not seldom referred to as 'Waste=Food'.

By conceptualizing the idea of a closed loop systems, the building industry should be developed as an imitation of the ecosystems approach of circulation of material. This is done through separation of biological nutrients which can return to the ecosystem directly and and technical nutrients which should continue to circulate in a closed industrial system. (McDonough & Braungart 2002) At a material level, the biological nutrients can be exemplified with paper and technical nutrients with plastic (C2CPII 2016).

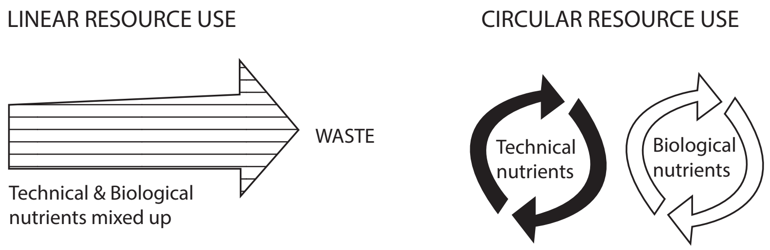


Figure 4: Separation of technical & biological nutrients

The concept is now a registered trademark and it has also been developed into a product certification scheme, which includes building material. This certification is based upon five criteria; avoidance of hazardous substances, recyclability or compostability, renewable energy, water use and social equity. Certified building material and products are rewarded by some of the GBAMs. (C2CPII 2016)

### 3.2.3 REGENERATIVE DESIGN

Regeneration in the meaning of 'renewal' or 'revival' (Merriam Webster 2016b) is increasingly discussed within both architecture and design. It can be seen as a reaction towards the static approach within environmental assessment methods (Cole 2012) and a need for a change view upon sustainability. According to Reed (2007), Regenerative design goes beyond the idea of decreased environmental impact. It is described as a co-evolution of natural ecosystem together with the human systems, sometimes through the terms of 'whole' or 'living' system.

The philosophy of Regenerative design goes back to John Tillman Lyle (1994) and his idea of a whole system approach to the design of buildings and cities. By contributing to restore ecological losses, the design focus is shifted towards a regeneration of the ecosystem. These thoughts have been developed further to incorporate more than the restorative approach, visualised through the conceptual model in figure 5, developed from Reed (2007).

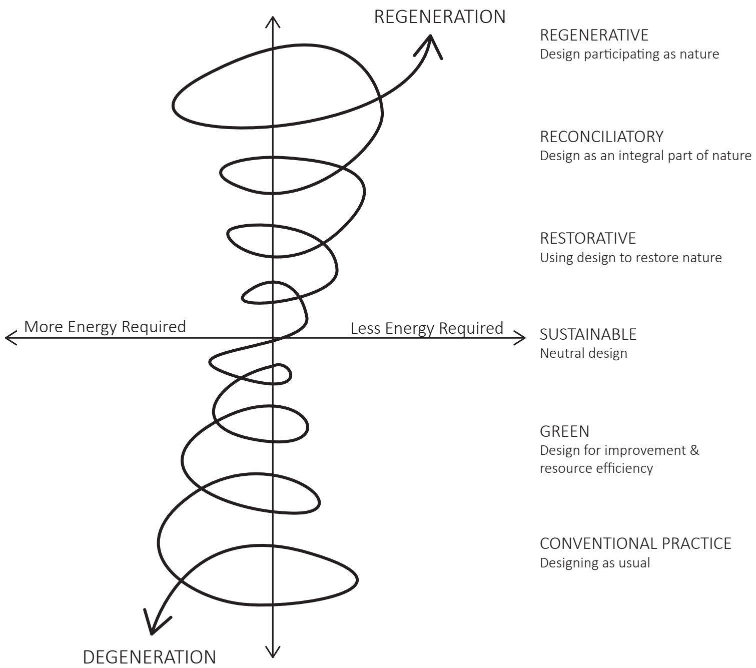


Figure 5: Conceptual model of Regenerative design, developed from Reed (2007)

Various other models and circular concepts relate to this ecological focus within regeneration. In architecture, the further development of Regenerative design has also incorporated socio-cultural aspects (du Plessis 2012). This involves the context and place of the building as a central part in the design process. According to Cole (2012), it is not the building itself that is regenerated but it should instead function as a catalyst for positive changes within the specific location of the project. This potential of the building is only realised through an integration of the surrounding ecosystem, infrastructure as well as community culture, economy and politics (Mang & Reed 2012).

## 3.3 SO TO CONCLUDE

Circularity is a concept which is present within various fields and aims at closing the resource loops. In architecture, the studied concepts of circular design emphasise a more radical type of innovations and a systemic change in our view upon material. There is a high focus on the process and vision rather than on how to implement the design in practice. Still, the concepts have also started to involve some performance based tools, such as the Cradle to Cradle material certification.

# 4

# GREEN BUILDING ASSESSMENTS

*This chapter provides a clarification of the green building concept, the role of assessments in a larger context, a description of the three studied GBAMs and relevant material assessments.*

## 4.1 GREEN AS A PART OF SUSTAINABLE

The GBAMs have contributed to a diffusion of the concepts of green and sustainable buildings (Ding 2008). However, the difference between 'green' and 'sustainable' has to be clarified as the terms are used interchangeably within both building practice and research. By looking at the widely accepted theory of sustainable development, it is reached through integration of the ecological or 'green' aspect together with the social and economic dimensions. Following that ideology, a green building should be discussed as an element in the concept of a sustainable building, see figure 6.

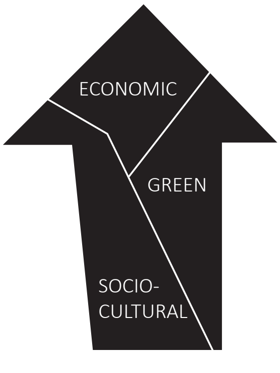


Figure 6: The three dimensions of a sustainable building

In the beginning, the frameworks of the GBAMs had an exclusionary focus on the ecological performance. A growing recognition of a need for balance between the three dimensions of sustainability in building design (Mateus & Bragança 2011) has resulted in a more holistic approach in the development of the methods. Today, the methodologies are increasingly including the economic and socio-cultural perspectives (Zuo & Zhao 2014) but the main focus is still on environmental sustainability and green buildings.

## 4.2 WE VALUE WHAT WE MEASURE

The need for environmental assessments in general, and for building specifically, can be described from different points of view. According to Meadows (1998), a simple explanation is that indicators and criteria create values. Through assessment criteria, the green building concept is operationalised (Schweber 2013), which leads to a value creation among architects as well as other actors in the building process. This is supported by research showing the value of green buildings in economic terms (Brown et al. 2016; Elchholtz et al. 2010). Some even argues that GBAMs are one of the most effective means to improve the environmental performance of a building (Cole & Jose Valdebenito 2013).

Yet, there are challenges which have to be managed within this approach to environmental sustainability. To make a complex system as a building measurable, the assessment methods simplify the context into certain criteria (du Plessis & Cole 2011). The GBAMs function as a decision platform in the design process (Schweber 2013) and the focus will therefore be relation to the criteria in the methods. As the criteria tend to privilege technical and physical aspects of the building (Cole 2005), a risk of ignorance of other aspects exist.

## 4.3 THE PROCESS

Even though green building certifications often are discussed as a final outcome, the assessment procedure is of importance for understanding the role of the GBAMs. According to Kaatz et al. (2006), the main contributions of the methods is through generating an increased awareness of buildings environmental impact and enhance the collaboration among actors in the building industry. This effect varies from project to project, depending on how the design team engage with the GBAMs (Schweber & Haroglu 2014). One way of approaching the often complex framework of the GBAMs is through a process aiming to achieve the highest credits for the least cost or effort. According to Cole (2005), this type of point-chasing create a focus on certain criteria rather than incorporate a holistic approach in the design. This might result in a gap between intended and actual environmental performance.

## 4.4 METHODS IN SWEDEN

In Sweden, the most common multi-criteria methods are BREEAM SE, LEED and Miljöbyggnad. They are offered by the Sweden Green Building Council (SGBC), a non-profit organisation working for a development towards a more sustainable building industry (SGBC 2016a). Over the last years, strategies to increase the acceptance of GBAMs in Sweden has been seen at both a company, municipal and national level (Malmqvist et al. 2011). This widespread adoption of the methods has resulted in an increased number of certified buildings (SGBC 2016b).

The frameworks of these voluntary systems vary but the main purpose is the same - to assess the environmental performance of a building within certain categories and criteria. The credits achieved within each criterion are assessed through verification of the design performance and/or measurements after the building is completed. Finally, the total credits get summarised according to certain weighting procedure into a final rating level.

### 4.4.1 BREEAM SE

As one of the first methods, BREEAM (Building Research Establishment Environmental Assessment Method) was established in 1990 in the United Kingdoms (Saunders 2008). In 2013, SGBC launched the Swedish version BREEAM SE for building certification of new construction and refurbishments. The framework is developed for public buildings as office, industrial and other commercial projects. The system consists of various criteria distributed in ten categories; Management, Health and Wellbeing, Energy, Transport, Water, Materials, Waste, Land use and Ecology, Pollution and Innovation. The achieved credits within the categories are summarised through a weighting procedure, resulting in a percentage of the maximum score. This number correlates to the final rating levels of Pass, Good, Very Good, Excellent or Outstanding. (SGBC 2013)

### 4.5.2 LEED

The globally widespread method LEED (Leadership in Energy and Environmental Design) was developed United States Green Building Council (USGBC) and launched in 2000. The framework is the same worldwide and the assessment is done by USGBC, even though support and education are offered by SGBC. The system can be used for certification of a range of projects - from new and existing buildings to whole districts. (SGBC 2000) The assessment for new construction projects is performed through a number of criteria within eight categories; Location and Transportation, Sustainable Sites, Water Efficiency, Energy and Atmosphere, Material and resources, Indoor Environmental Quality, Innovation and Regional Priority. The total credits achieved within each category are summarised into a final score which determines the rating level of Certified, Silver, Gold or Platinum. (USGBC 2013)

### 4.4.3 MILJÖBYGGNAD

Miljöbyggnad is a Swedish method, developed under the name 'Miljöklassad byggnad' by the building industry and universities in the ByggBo-dialogen. It was launched in 2009 and two years later when the system was transmitted to SGBC, the name was changed to Miljöbyggnad. (SGBC 2014b) It is the most widespread system in Sweden and can be used for certification of both new and existing buildings, including residential and public buildings. The system is less extensive than BREEAM and LEED and consists of three assessment categories; Energy, Indoor Environment and Material. In Miljöbyggnad, the final rating level is dependent on the lowest achieved level within one of the fifteen criteria. That level determines the final rating of the building which is Bronze, Silver or Gold. (SGBC 2014a)

## 4.5 INNOVATION CREDITS

Innovation credits is an approach used by some GBAMs to promote and award innovative design and new technical solutions. The design of the credits differs among the systems and far from all GBAMs have this type of criteria. Global examples of this type of criteria are; exemplary performance level (e.g. BREEAM SE, LEED), innovation application to be approved by a reviewing body (e.g. BREEAM UK), through approaching a predefined sustainability challenge (e.g. Green Star Australia) or through pilot credits for development of next method (e.g. LEED). Looking at the methods used in Sweden, BREEAM and LEED have innovation criteria. The credits are mainly awarded through exemplary performance within existing categories.

Described in the BREEAM SE manual, the purpose of the innovation credits is "*To provide additional recognition for a procurement strategy, design feature, management process or technological development that innovates in the field of sustainability, above and beyond the level that is currently recognised and rewarded within standard BREEAM issues.*" (SGBC 2013, p. 275). Innovation credits within BREEAM are achieved by reaching a predefined exemplary performance level within certain criteria (SGBC 2013). According to the LEED manual, the intent of innovation credits is to "*To encourage projects to achieve exceptional or innovative performance*" (USGBC 2016, p. 141). The credits are achieved by involving a LEED accredited professional, alternative innovation strategy, pilot credits for the development of new methods or an exemplary performance level within an existing criterion (USGBC 2016).

## 4.6 MATERIAL ASSESSMENTS

Different approaches are used in the GBAMs to evaluate the environmental impact of the building products and material. In the subsection, common tools used to assess the life cycle impact and to limit the risk for hazardous substances are described, as a basis for understanding the case study.

### 4.6.1 LIFE CYCLE ANALYSIS

Life Cycle Assessments or Analysis (LCA) is a holistic approach to the environmental impact of a product or and material. It is a method used for environmental evaluation within certain impact categories (e.g. emissions, energy use, water, resources) during the whole life cycle of a material. The life stages considered in a LCA are generally the raw material acquisition, production, manufacture, use phase, disposal as well as the transports in between (Baumann & Tillman 2004). According to Boverket (2015a), the interest in LCA for climate impact of buildings is increasing.

### 4.6.2 ENVIRONMENTAL PRODUCT DECLARATION

Environmental Product Declaration (EPD) is a global system for disclosure of information of the environmental impact of a product or material. It is based on the international standard ISO 14025 and the European standard EN 15804. An EPD consists of information about type of product, company information, content declaration and LCA performance. The LCA information includes use of resources, energy and different types of emissions. In addition, other environmental information such as use and end-of-life impact can be included. (EPD International 2014)

### 4.6.3 BASTA, BYGGVARUBEDÖMNINGEN, SUNDAHUS

The Swedish databases BASTA, Byggvarubedömningen and SundaHus are used for material evaluation and documentation of building material and products. BASTA is an open source database while Byggvarubedömningen and SundaHus are commercial systems. All three databases include the chemical content while the life cycle impact is only considered in Byggvarubedömningen and SundaHus. BASTA is dependent on the self-declaration from the product suppliers which is regularly audited by the organisation (BASTA 2016). Byggvarubedömningen and SundaHus evaluate both the chemical content and life cycle impact of material according to certain criteria (Byggvarubedömningen 2016; SundaHus 2016). Regarding the chemical content, the systems are based on the Swedish Chemical Agency's (KEMI) list which criteria corresponds to the high risk substances in the European regulation REACH (SGBC 2014a).

## 4.7 SO TO CONCLUDE

The use of GBAMs is increasing in Sweden and they are praised for contributing to a diffusion of green building practices. The methods are also criticised for various reasons, such as becoming a goal themselves rather than a tool for environmental sustainability. In relation to the concept innovation, the GBAMs can be described as contributing to incremental eco-innovations. Even the innovation credits are related to improved performance levels within the system. In contrast, research on the certification process shows a positive correlation between the GBAMs and the possibilities of collaboration and innovation. Any connection to innovative design concept such as circular design is not found in the methods or in research.

# 5

# METHOD

*In this chapter the research strategy and design is presented. The layout of the case study, a description of the data collection and the analytic strategy are also included.*

## 5.1 RESEARCH STRATEGY & DESIGN

The research strategy used in this thesis has been of qualitative character which according to Creswell (2014) was motivated by the holistic and explorative approach. The purpose of the research has been to develop new perspectives rather than to test existing theory. To gain a broad understanding of the studied phenomenon, the research has combined different theoretical disciplines. This multidisciplinary approach involved the fields of architecture, construction, innovation and sustainable development.

According to Bryman & Bell (2015), qualitative research likely to be of iterative character which also applies to this study. The research design was developed through an iterative process, starting by exploring innovative architecture and environmental assessment methods. Through the development of a case study, it was possible explore similarities and differences between the two approaches to sustainable architecture. Figure 7 present the research design in a schematic way.

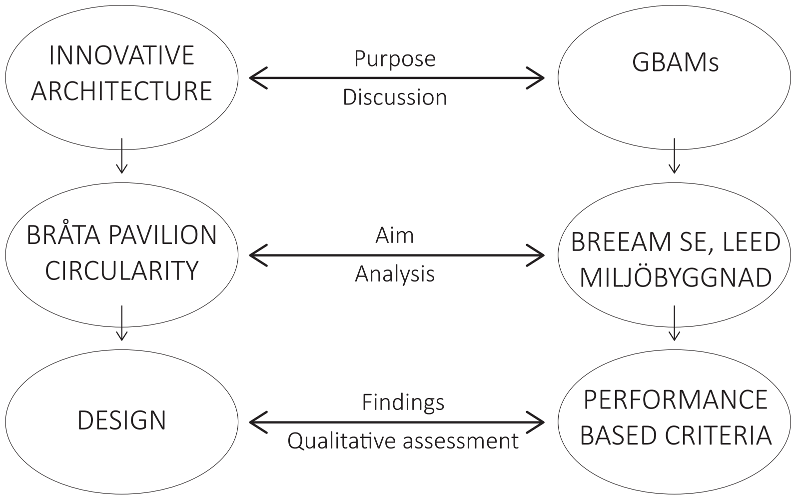


Figure 7: Schematic picture of the research design

## 5.2 CASE STUDY

The method used in this thesis was a case study of instrumental character, as a tool to explore the phenomenon of innovative architecture and the relation to environmental assessment methods. As Stake (1995) suggests, the selection of a case should be based on the opportunity to learn. It had an important influence on the choice of case. In this case study, innovative architecture represented by the project Bråta Pavilion/circularity and the three GBAMs demonstrate the approach of environmental assessments. Through a qualitative assessment, this relation was investigated. To explore a unique case project as Bråta Pavilion, can according to Eisenhardt & Graebner (2007) be seen as an opportunity for describing the existence of a phenomenon and the relating circumstances.

## 5.3 DATA COLLECTION

### 5.3.1 LITERATURE & THEORY

The review of literature and earlier research was done through various types of data sources - research journals, reports, books and various web sites. In addition, data that could not be gathered through the literature study was collected through semi-structured interviews and informal discussions. These where conducted with architects working with GBAMs, students and researcher at Chalmers as well as with some attendants at the World Green Building Conference in Stockholm.

### 5.3.2 CASE STUDY

Data for the case study was collected through documents, architectural sketches and drawings as well as interviews with one of the architects. The manuals of BREEAM SE, LEED and Miljöbyggnad was the main source for the qualitative assessment of Bråta Pavilion. It was used together with other material about GBAMs, interviews with assessors and email contact with the three material databases BASTA, Byggvarubedömningen and SundaHus.

## 5.4 ANALYTIC STRATEGY

An analytic strategy was developed to perform both the qualitative assessment and the further analysis. The strategy was divided into two parts; one to identify the correlations and one to analyse the findings in relation to the theory.

### 5.4.1 CORRELATIONS

To identify the correlations between the design of Bråta Pavilion and the performance based criteria, the manuals of the three GBAMs were examined. The criteria were classified as 'direct correlation', 'indirect correlation' or 'no correlation'. The correlations were evaluated by the author of the thesis and criteria with 'no correlation' were assumed to have no or insignificant relevance for the study. The direct and indirect correlations were further analysed and summarised into seven assessment areas. These assessment areas and the qualitative assessment of Bråta Pavilion is presented in chapter 6 - Findings.

### 5.4.2 PATTERNS

The second step of the analysis was to identify patterns within the findings on how the design of Bråta Pavilion was managed within the GBAMs. This part of the analysis tries to reveal patterns are related to how the GBAMs might enhance or limit architecture to involve a circular design approach. This was done by linking the findings to the theory in chapter 2,3 and 4. These observations are presented in chapter 8 - Analysis.

# 6

# BRÅTA PAVILION

*In this chapter, the case project Bråta Pavilion is presented.*

*It includes a description of the design process and final design.*

## 6.1 THE PROCESS

Bråta Pavilion project began in 2014 as an initiative from the municipality of Härryda. They had a wish for new ideas for the development of Bråta Waste Recycling Centre. Through contact with Chalmers University of Technology, the project became a part of a course called Sustainable Building at the master's programme Design for Sustainable Development in 2014. The further development of the project was done by the architecture practice JIG and in collaboration with a researcher at the department of architecture Chalmers University of Technology and Mistra Urban Futures. Today, two of the team members in JIG carry on the project's development at the architecture practice Helhetshus Arkitektstudio - currently finalising documents for the tendering process.

The design process has substantially differed from many other building projects through an involvement of different type of actors; Härryda Municipality, students, researchers and architects. The beginning of the design process involved the challenge from the municipality together with the course focus and criteria which included circular resource concepts as Regenerative design and Cradle to Cradle. The students worked with developing visions, strategies and goals for the further process as well as various design proposal. (Östlund et al. 2014)

After the course, the design process continued and the students' ideas were developed into a design proposal for the pavilion that was adapted to the municipality's budget and ambition. Some challenges were encountered, such as adapting the design to current building regulations and to different material procuration strategies. From the beginning, the material was supposed to be collected on site but it is still uncertain if that will be possible. [1]

## 6.2 THE DESIGN

The main function of the Pavilion is as a space for visitors to leave material to be reused. The material will be collected by two non-profit organisations, probably Emmaus and Alelyckan. There is no fulltime staff working in the pavilion and it will be open during the opening hours of the recycling centre. The pavilion consists of two rooms for material collection and one room for swopping of material, where the visitors are welcome to leave and take material at no cost.

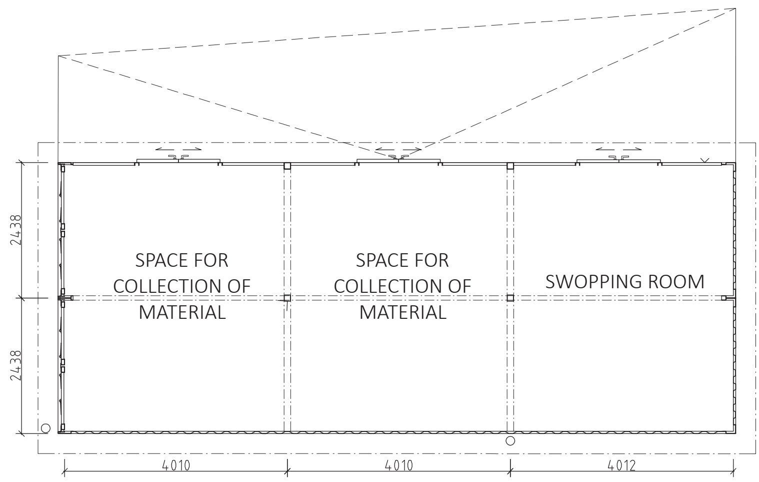


Figure 8: Plan of Bråta Pavilion (Helhetshus Arkitektstudio 2016)

[1] Personal contact with Charlotte Farrouch. Through interview, email and telephone, October and November 2016.

The design is developed to encourage the visitors to leave material and to inspire to reuse of material. This is done through implementing reused material in the design and through this visibility try to change the view upon material. The pavilion is design with reused and remanufactured material as well as some new material. The structure is made of old containers and the existing corrugate steel walls are partly removed and replaced with other reused material. On one side, a façade of sliding doors is built out of reused doors and wood panels. The glass facades between the containers and the roof is made from reused windows and glass. The new material in the pavilion is the concrete floor, the green roof and other minor building elements. The building is not isolated and will not be heated.

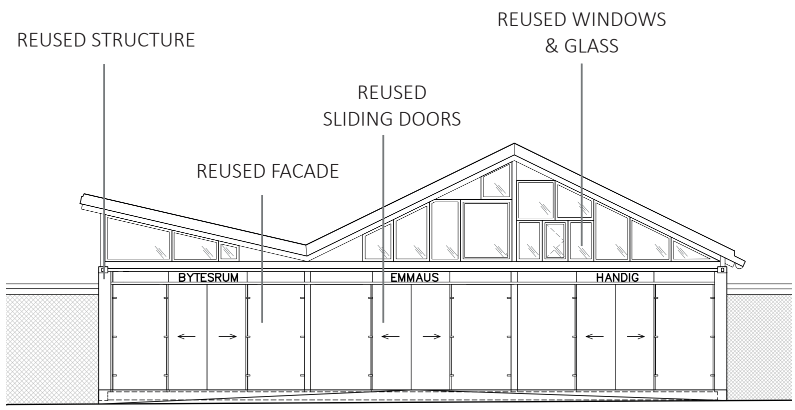


Figure 9: The north façade of Bråta Pavilion (Helhetshus Arkitektstudio 2016)

# 7

# FINDINGS

*This chapter provides the main findings – the correlations between the design of Bråta Pavilion and the performance based criteria in the GBAMs.*

## 7.1 CORRELATIONS

This section presents a description of the correlations between the actual design outcome of the case project and the studied GBAMs. In Bråta Pavilion, the circular design approach is visible through reused and remanufactured material, see table 1.

Table 1: Reused material in Bråta Pavilion

| COMPONENT | REUSED MATERIAL |
|---|---|
| Facade | Corrugated steel, wood panels etc. |
| Structure | Containers |
| Sliding doors | Doors  and wood panels |
| Windows | Windows, glass |

Correlations between the material in table 1 and the performance based criteria in BREEAM SE, LEED and Miljöbyggnad were identified (for a full summary, see Appendix I). These correlations were analysed and summarised into seven assessment areas which are presented in table 2. This overview shows which of the methods that has criteria within each of the assessment areas.

Table 2: Overview of assessment areas

| ASSESSMENT AREAS | BREEAM SE Version 2 - New Construction and Refurbishment | LEED Version 4 - Building Design and Construction | Miljöbyggnad Version 2- New Construction of buildings |
|---|---|---|---|
| 1. Reuse of material | X | X | |
| 2. Life Cycle Impact | X | X | (X)[2] |
| 3. Material documentation | X | X | X |
| 4. Hazardous substances | X | X | X |
| 5. Responsible Sourcing | X | X | |
| 6. Life Cycle Cost | X | | |
| 7. Modelling & Calculations | X | X | X |

## 7.2 QUALITATIVE ASSESSMENT

In this section, the findings from the qualitative assessment are described in each of the assessment areas. To achieve certain credits there is a demand for documentation, calculations, involvement of specific expertise and development of management plans. To make a relevant assessment of the relation between Bråta Pavilion and the GBAMs, it is assumed that those types of demands can be met.

### 7.2.1 REUSE OF MATERIAL

BREEAM SE and LEED have specific criteria for reused façades and structure. The criteria differ, LEED recognises reused material from off site while BREEAM SE only awards existing façades and structure. In Bråta Pavilion, the façades and structure are

[2] According to the hearing version for Miljöbyggnad 3.0, a new criterion will be included; LCA for façades and structure (Wahlström & Warfvinge 2016).

not existing on site. Thus, LEED is the only method that directly acknowledge the reuse of material in the project. The reuse of façades and structure is calculated as a percentage of the total surface.

Another recognition of reused material is within the criteria for site assessment in LEED. It involves assessing the potential of construction material on site, with existing recycle or reuse potential. In Bråta Pavilion, this would have recognised the potential of using construction material from the waste recycling centre. In BREEAM SE, the main contractors' material policy is another aspect related to reused material, either enhancing or limiting the implementation possibilities. Miljöbyggnad do not have criteria in direct connection to reused material. It is also noted that none of the systems have criteria for reuse of windows or external doors.

### 7.2.2 LIFE CYCLE IMPACT

In BREEAM SE and LEED, the life cycle impact of façades and windows respectively façades and structure are assessed. Through LCA of reused and recycled material, it can be concluded that the climate impact is low in comparison to new material (Moberg et al. 2015). Considering that the material in Bråta Pavilion require some renovation and remanufacturing, it is still assumed that the life cycle impact is low for the reused material. In BREEAM SE, the life cycle impact is evaluated either through their own tool Green Guide, a material assessment of embodied energy or through a nationally recognised LCA tool. In LEED, it is assessed through LCA, conducted to demonstrate a reduction compared to a similar standard building. A LCA demands advanced calculation which might need involvement of a LCA specialist (USGBC 2013). Worth noting is that LEED recognises the use of Cradle to Cradle certified material.

Today, Miljöbyggnad does not have criteria related to the life cycle impact of the building material. According to the hearing version of Miljöbyggnad 3.0, the next version will involve LCA and include the life cycle from raw material production to final building. The waste production will not be included and the criteria will not be in connection to any specific targets. (Wahlström & Warfvinge 2016)

### 7.2.3 MATERIAL DOCUMENTATION

All three methods involve criteria for material documentation through a demand for specifying the main building material and elements. These criteria are met differently within the systems and the demand for information differs. For the reused material in Bråta Pavilion, no written information is available regarding producer, material content or life cycle impact. The documentation in LEED is done by specifying EPD:s or other third party certifications for the material. In BREEAM SE and Miljöbyggnad, the three material databases BASTA, Byggvarubedömningen and SundaHus are recognised for documentation. Through email contact[3] it was confirmed that reused material can be documented in the log books in all three systems, without available information of chemical content or lifecycle impact. In Miljöbyggnad, the demand for a log book (including e.g. producer and material content) is mandatory for the lowest rating level. In BREEAM SE, the material documentation it is mainly to avoid hazardous substances which is described in the next subsection.

### 7.2.4 HAZARDOUS SUBSTANCES

Closely related to the demand for material documentation, the three GBAMs have criteria for phasing out hazardous substances and minimize the risk for material emission from the building material. In LEED, the options relevant to the Swedish context is to avoid substances in REACH. This relates to the KEMI list which is recognised by BREEAM SE and Miljöbyggnad. In BREEAM SE, there is a demand of using one of the systems BASTA, Byggvarubedömningen or SundaHus which is also recommended in Miljöbyggnad. As described above, it is possible to document the reused material in the three databases. In the case of Bråta Pavilion, written documentation of the chemical content in the material does not exist, therefore no such of evaluation can be done in the GBAMs or the databases. Even if that type of information was available, it would according to BASTA[4] be difficult to make sure that the material is not altered in any way.

[3] Personal contact with Sussie Wetterlin (BASTA), Lisa Elfström (SundaHus) and Johnny Hellman (Byggvarubedömningen). Through email, October 2016.

[4] Personal contact with Sussie Wetterlin. Through email, October 2016.

### 7.2.5 RESPONSIBLE SOURCING

The reused material in Bråta is evaluated as responsible sourced material in both BREEAM SE and LEED. Building elements of reused material contribute differently to the criteria in the two methods. BREEAM SE has its own weighting procedure while in LEED the reused material is calculated in relation to the total cost of all installed building products.

### 7.2.6 LIFE CYCLE COST

BREEAM SE has a criterion for Life Cycle Cost (LCC) analysis, which includes façades and structure. To achieve this credit, the best option has to be chosen considering different parameters, as cost for construction and maintenance. This assessment area is difficult to evaluate as the cost for construction is still uncertain in the project. Regarding maintenance, there might be an increased risk for future costs depending on the quality of the reused material. These uncertainties could affect the probability of reused material as the best choice in a LCC analysis.

### 7.2.7 CALCULATIONS AND MODELLING

In all three GBAMs, indirect correlations are found to criteria which include demand for different types of modelling and calculations. These criteria differ among the system but ta need for material data is recognised in criteria for energy, acoustics, moisture and thermal comfort. As Bråta Pavilion is a non-heated and non-isolated building this assessment area is hard to evaluate. However, there is no written data for these types of calculation (as U-value for windows or acoustic characteristics) for the material in Bråta Pavilion.

# 8

# ANALYSIS

*The purpose of this chapter is to present an analysis of*

*the findings based on the theory in chapter 2,3 and 4.*

## 8.1 DIFFERENCES

The empiric findings show the performance based correlations between the design of Bråta Pavilion and the criteria in the GBAMs. To be able to make a relevant analysis of these correlations, the differences between these approaches to environmental sustainability must also be considered. According to earlier research, there is a high focus on the criteria in the GBAMs which influences the design process. The environmental performance of the final certified building is considered in relation to the criteria. The criteria do also indirectly affect the concept of what environmentally responsible design is in the building sector.

In contrast, the process in Bråta Pavilion had a focus on developing visions in relation to the context and reach those through design. The environmental performance of the project is an outcome related to circular design concepts rather than specific criteria. As the case study shows, some challenges were encountered when the design were to be adapted to implementation, such as building regulations and strategies for material procuration. This has also affected the design of the project. The GBAMs have a more incremental focus within the system which is easier to implement in practice and in large scale. On the other hand, some research argues that a more radical approach, as in Bråta Pavilion, has a higher potential of contributing to sustainable architecture.

Observed in the empiric findings, these differences can be exemplified in the approach to Cradle to Cradle. In LEED, it is acknowledged through criteria which award Cradle to Cradle certified building material. In Bråta Pavilion, the same concept is visible through an implementation of reused material. The certified material is a more incremental approach to a circular resource use while reuse emphasises a more radical change. To only recognise Cradle to Cradle certified material might limit the perception of what closing the material loop means.

## 8.2 RECOGNITION OF REUSED MATERIAL

To some extent, the design of Bråta Pavilion is measurable through the performance based criteria. As the empiric findings show, some criteria within BREEAM SE and LEED recognise the reuse of material in the Bråta Pavilion. It is acknowledged through criteria for reused façades and structure, through a demand for LCA and by the criteria for responsible sourcing. Criteria which recognizes reused material contribute to an increased implementation potential in a certified project and indirectly through influencing the future development of environmentally sustainable architecture. The frameworks of the GBAMs are important for the perception of what a green building involves and a recognition of reused material increases the awareness in the building sector. The lack of criteria is on the other hand a limitation, which is the case for reuse of doors and windows. Currently, reused material is not considered in Miljöbyggnad. An implementation of a LCA criterion in the next version will change this.

## 8.3 UNKNOWN MATERIAL PROPERTIES

As the empiric result shows, most of the correlating criteria in the GBAMs limit the reuse of material in Bråta Pavilion. This is mainly related to the unknown properties of the reused material which complicate the certification process and directly impede design with reused material. In the GBAMs, this is both managed and hindered by the criteria for documentation of building material. This demand contributes to the future reuse and recycling of material through written information about the building content. As the empiric findings show, the criteria for material specification limit the implementation possibilities of reused material today. Thus, the GBAMs have a focus on the future reuse and recycling potential rather than an implementation of reused material today.

In relation to the unknown material properties of reused material, the EPD system and the material databases BASTA, Byggvarubedömningen and SundaHus were observed as important actors. Today, the systems do not have mechanisms which contributes to the implementation of reused material today. Even though the environmental impact of reused material can be considered low, it is not classified in the systems that involves life cycle impact.

Another aspect which is related to the unknown material properties was also found in the GBAMs. Various criteria in the GBAMs require calculations and modelling of energy, acoustics, thermal comfort and moisture. The amount and type of data needed varies but specific information is generally less available for reused material than new building products. This do not only complicate the process, the uncertainties of the material characteristics and quality do also create a risk for increased maintenance and for not reaching the criteria demands. This is especially relevant for energy, as it might be more difficult to meet high demands in a design with reused windows and doors.

## 8.4 FLEXIBILITY

Some design flexibility is a prerequisite to allow for innovative architecture as well as changed building practices. As the empiric findings shows, the design flexibility is larger through the approach of circular design concepts than through an environmental assessment process. The GBAMs have also different levels of flexibility which affects the possibility of reused material. In BREEAM SE and LEED, a larger flexibility between the credits might allow for more reused material in a project. On the other hand, the flexibility in the systems might also create a situation of point-chasing for easier credits rather than going for the relatively few credits related to reuse of material. The importance of criteria recognition decreases in relation to the flexibility.

In Miljöbyggnad however, the lowest achieved criteria determine the final rating level. In the current framework the material criteria for documentation and hazardous substances directly impede the reuse of material. Even if an LCA criterion will be included in the next version, to implement reused material in a certified project would be very complicated.

The actual design of the criteria might also influence the design flexibility and the possibilities of reusing material. As the empiric findings show, the criterion for on site reuse of façades and structure in BREEAM SE ignores the possibility of material from off site. In contrast, criteria which is designed to indirectly recognise reused material, as LCA or responsible sourcing, allow for a larger design flexibility.

# 9

# DISCUSSION

*This chapter provides a reflection about the scope of the thesis, the relation between innovative architecture and GBAMs, improvement areas and topics for further research.*

## 9.1 THE SCOPE

To explore innovative architecture and the relation to environmental assessment methods for buildings is complex. There is no common definition of what innovative architecture is and depending on how you perceive innovation, the GBAMs can also be discussed as highly innovative. The concept of innovative architecture involves much more aspects than this research includes. Through the case study, the scope was limited to circular resource use and the design of Bråta Pavilion. Even though reuse of material is nothing new in architecture, relative to current building practice and the existing environmental assessment methods it must be considered innovative.

Circular design involves various approaches to resources and material. In Bråta Pavilion, some of these approaches (implementation of reused material) are visible in the design while some are not (as design for dismantling). Thus, the scope was further limited to certain aspects of circularity. By analysing the reuse of material through the performance based criteria in studied GBAMs, the focus was directed to the possibilities and limitations of in the three methods. If the analytic strategy would have had another focus, the outcome would have been different.

## 9.2 A COMPLEX RELATION

This research started as a curiosity of the relation between innovative architecture and our (perceived) need to measure and assess environmental impact. By looking at the result of this thesis from a systemic perspective, both the more innovative approaches and performance based systems are contributing to a development of more sustainable architecture. Even though the innovative design concepts emphasise a more radical systemic change and the assessment methods have a more incremental focus within the system, they should not be seen as contrasts to each other. Explorative design is important for the development of sustainable architecture and assessment methods and other types of tools are means to apply the concepts further. GBAMs are important for an increased awareness of environmental sustainability and the diffusion of greener building practices. Still, environmental assessment methods will never be sufficient to achieve a sustainable development in the building sector. But neither will innovative pilot projects or concepts and ideas in their pure form be.

However, the methods and tools that we use to design sustainable architecture should enhance the possibility of innovation and exploration. At least, they should not limit the development and implementation of new types of sustainable architecture. As this case study shows, that is not the case within the three studied GBAMs in relation to circular resource use. Bråta Pavilion is a quite environmentally sustainable project and the environmental benefits of reused material are also possible to assess. This research shows that the environmental impact of a building developed through an innovative design procedure is, to some extent, possible to measure. Some of the studied GBAMs are recognising the environmental benefits but they are mainly limiting the reuse of material as in Bråta Pavilion. There is a need for mechanisms in the GBAMs to allow for other types of solutions as well as to inspire to innovative architecture. The current design of innovation credits within the GBAMs is not that mechanism, as the focus is on exemplary performance within other criteria. The innovation credits are rather limiting the perception of what innovative architecture might be.

While some argues that there is a need for standardisation of green building practice, this research shows a risk with less approaches to sustainable architecture. Different types of methods to develop (and certify) green buildings creates a broader knowledge diffusion among architects and other actors. This decreases the risk of lock-in to a specific standard and leads to a higher potential of more innovative and sustainable architecture.

## 9.3 WHAT WE MEASURE WE CAN IMPROVE

The GBAMs have an important role in the development and diffusion of the green building concept. The case study shows some areas of improvement in the methods to enhance the possibilities of more circular resource use. The environmental benefits of circular resource use are measurable through LCA or amount of reused or recycled material. Still, the recognition of reused material in the performance based criteria in the GBAMs is relatively low. As the findings shows, there are more criteria which limit than enhance the reuse of material. This result is supported by earlier research arguing the the reusability of building material is not discussed enough within GBAMs (Haapio & Viitaniemi 2008).

If an increased circular resource use is to be realised within the building sector, a focus has to be put on the actual implementation of reused and recycled material. The current green building practise is mainly preparing for the future rather than closing the resource loop today. This can also be seen in the investigation of a regulatory demand for documentation of building material made by Boverket (2015). The future possibilities for reuse and recycling was highlighted but how the material documentation might limit the implementation possibilities of reused material today was not considered. This focus on the future recyclability and reusability must be discussed in relation to the lifetime of the buildings. Considered that a buildings lifetime is at least 50 years (hopefully much longer), it is not enough to prepare for future circulation of material. It is necessary to also develop strategies for reuse of the material already in society.

Thus, there is a need for mechanisms to ensure that the demand for material documentation does not constrain the reuse possibilities. Without ignoring the importance of phasing out hazardous substance, the demand for documentation of building material has to developed further. The GBAMs and the material databases BASTA, Byggvarubedömningen and SundaHus have to develop mechanisms to deal with reused material. In the building sector, material certification of reused material could be one way to include reused material.

## 9.3 FURTHER RESEARCH

For further research, it would be interesting to investigate the possibilities of circular resource use in more standardised architecture projects. An increased implementation of reused and recycled material would affect the both the design and construction processes as well as the aesthetics and environmental impact of a building. To be able to increase the reuse and recycling rates, there is also a need for research for changed demolition practices.

Another topic future research is how to improve the link between innovative design processes and environmental assessments methods. Through involving visions and exploration into the assessment procedure, more sustainable architecture could be developed in practice.

# 10

# CONCLUSION

*This chapter provides a short conclusion of the case study and some final thoughts in relation to the purpose of this master's thesis.*

In this case study, the relation between the circular design approach in Bråta Pavilion and the performance based criteria in BREEAM SE, LEED and Miljöbyggnad was explored. The analysis of the findings shows a recognition within the GBAMs of the reused material in Bråta Pavilion. This was observed through criteria for LCA, responsible sourcing and specific criteria for reuse of façades and structure. Other criteria limit the reuse possibilities in the GBAMs, which to a large extent relates to unknown material properties. The current demands for material documentation, various types of calculations and phasing out of hazardous substances are not compatible with the uncertainty related to reuse of material. In can be concluded that the existing environmental assessment methods have a focus on the future reuse and recycling potential rather than on the implementation of reused material today. This creates a complex challenge for putting the concept of circularity into practise.

An even larger challenge is how to improve the understanding of the different pathways to sustainable architecture. It is necessary with exploration, ideas and innovative concepts as well as environmental assessment methods and other tools which contributes to the diffusion in the building sector. A holistic approach to sustainability is not only by integrating the ecological, social and economic dimension. It does also involve an understanding of the different pathways contributing to sustainable architecture.

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# I
# APPENDIX – CORRELATIONS

In Annex I, a summary of the identified correlations to the performance based criteria in the manuals of BREEAM SE (SGBC 2013), LEED (USGBC 2016) and Miljöbyggnad (SGBC 2014) is provided. These correlations are classified as 'direct', 'indirect' and 'no' and are presented according to the example below.

| | |
|---|---|
| CRITERIA<br>Description | Type of correlation |

### DIRECT CORRELATIONS

Criterion with direct connection to the reuse of façades, structure, windows and doors in Bråta Pavilion.

### INDIRECT CORRELATION

Criterion which indirectly is connected to the reuse of façades, structure, windows and doors in Bråta Pavilion.

### NO CORRELATION

Criterion which is assumed to have little or no connection to the reuse of façades, structure, windows and doors in Bråta Pavilion.

## 1 BREEAM SE

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|---|---|
| MAN 1 – COMMISSIONING<br>Criteria for coordinated building service commissioning | No correlation |
| MAN 2 - CONSTRUCTORS' ENVIRONMENTAL & SOCIAL CODE OF CONDUCT<br>Criteria for using a main contractor compliant with certain environmental & social demands | No correlation |
| MAN 3 - CONSTRUCTION SITE IMPACTS<br>Criteria for the  chose of main contractor with an Environmental Management System, Material policy & demonstrating certain specified environmental aspects for site activities. | Indirect correlation |

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| MAN 4 - BUILDING USER GUIDE<br>Criteria for development of a user guide for the operation phase | No correlation |
| MAN  12 – LIFE CYCLE COST ANALYSIS<br>Criteria for building products from Life Cycle Cost Analysis | Indirect correlation |
| MAN 14 – BREEAM-SE ACCREDITED PROFESSIONAL<br>Criteria for involving an accredited professional in the process | No correlation |
| MAN 15 - MOISTURE CONTROL<br>Criteria for securing moisture safe constructions | No correlation |
| HEA 1 – DAYLIGHT<br>Criteria for sufficient day light for the building users | No correlation |
| HEA 2 - VIEW OUT<br>Criteria for adequate view out from the building | No correlation |
| HEA 3 - GLARE CONTROL<br>Criteria for implementation of shading system | No correlation |
| HEA 4 - HIGH FREQUENCY LIGHTING<br>Criteria for using high frequency fluorescent lamps | No correlation |
| HEA 5 - INTERNAL & EXTERNAL LIGHTING LEVELS<br>Criteria for using sufficient lighting indoor & outdoor | No correlation |
| HEA 6 - LIGHTING ZONES & CONTROLS<br>Criteria for allowing occupant control of lighting | No correlation |
| HEA 7 - POTENTIAL FOR NATURAL VENTILATION<br>Criteria for implementation of natural ventilation | No correlation |
| HEA 8 - INDOOR AIR QUALITY<br>Criteria for management of pollution through ventilation | No correlation |
| HEA 9 - VOLATILE ORGANIC COMPOUNDS<br>Criteria for using paints, varnishes & certain building products tested for Volatile Organic Compounds | Indirect correlation |
| HEA 10 - THERMAL COMFORT<br>Criteria to secure the comfort through thermal modelling | Indirect correlation |
| HEA 11 - THERMAL ZONING<br>Criteria for allowing occupant control of heating & cooling | No correlation |

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| HEA 12 - MICROBIAL CONTAMINATION<br>Criteria for the water systems & for avoiding humidity systems | No correlation |
| HEA 13 - ACOUSTIC PERFORMANCE<br>Criteria for sound class B or C according to SS 25268:2007 | No correlation |
| HEA 14 - OFFICE SPACE<br>Criteria for good working environment in smaller office areas | No correlation |
| HEA 15 – RADON<br>Criteria for ground radon classification & measures | No correlation |
| ENE 1 - ENERGY EFFICIENCY<br>Criteria for energy efficient buildings | Indirect correlation |
| ENE 2 - SUB-METERING OF SUBSTANTIAL ENERGY USES<br>Criteria for sub-metering of different systems | No correlation |
| ENE 3 - SUB-METERING OF HIGH ENERGY LOAD & TENANCY AREAS<br>Criteria for sub-metering of energy consumption by users | No correlation |
| ENE 4 - EXTERNAL LIGHTING<br>Criteria for specifying energy-efficient external lighting | No correlation |
| ENE 5 - LOW OR ZERO CARBON TECHNOLOGIES<br>Criteria for using renewable energy sources | No correlation |
| ENE 6 - BUILDING FABRIC PERFORMANCE & AVOIDANCE OF AIR INFILTRATION<br>Criteria for minimizing heat loss & air infiltration | No correlation |
| ENE 7 - COLD STORAGE<br>Criteria for energy-efficient cold storage systems. | No correlation |
| ENE 8 – LIFTS<br>Criteria for energy-efficient lifts | No correlation |
| ENE 9 - ESCALATORS & TRAVELLING WALKWAYS<br>Criteria for energy-efficient transportation systems | No correlation |
| ENE 10 - INTERNAL LIGHTING<br>Criteria for energy-efficient internal lightning | No correlation |

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|---|---|
| TRA 1 - PROVISION OF PUBLIC TRANSPORT<br>Criteria for distance to & frequency of public transport | No correlation |
| TRA 2 - PROXIMITY TO AMENITIES<br>Criteria for closeness to different amenities | No correlation |
| TRA 3 - ALTERNATIVE MODES OF TRANSPORT<br>Criteria for biking possibilities, car pool & bus services | No correlation |
| TRA 4 - PEDESTRIAN & CYCLIST SAFETY<br>Criteria for implementation of secure pedestrian & cycle routes | No correlation |
| TRA 5 - TRAVEL PLAN<br>Criteria for development of a travel plan for the users | No correlation |
| TRA 6 - MAXIMUM CAR PARKING CAPACITY<br>Criteria for maximum of parking space provided | No correlation |
| TRA 7 - TRAVEL INFORMATION POINT<br>Criteria for real time information about public transportation | No correlation |
| TRA 8 – DELIVERIES & MANOEUVRING<br>Criteria for connection & space for delivery transports | No correlation |
| WAT 1 – WATER CONSUMPTION<br>Criteria for reduction of potable water per user | No correlation |
| WAT 2 – WATER METER<br>Criteria for monitoring of water consumption | No correlation |
| WAT 3 - MAJOR LEAK DETECTION<br>Criteria for implementation of a leak detection system | No correlation |
| WAT 4 - SANITARY SUPPLY SHUT OFF<br>Criteria for implementation of detectors for leakage in water supply to toilets | No correlation |
| WAT 6 - IRRIGATION SYSTEMS<br>Criteria for irrigation methods to reduce the potable water consumption | No correlation |
| WAT 7 - VEHICLE WASH<br>Criteria for collection of water in a vehicle wash facility | No correlation |
| WAT 8 - SUSTAINABLE ON-SITE WATER TREATMENT<br>Criteria for implementing treatment & reuse of waste water system on-site | No correlation |

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| MAT 1 - MATERIALS SPECIFICATION (MAJOR BUILDING ELEMENTS)<br>Criteria for specifying material in the BREEAM tool Green Book Live or through an nationally recognised LCA | Direct correlation |
| MAT 2 - HARD LANDSCAPING & BOUNDARY PROTECTION<br>Criteria for choosing external surfaces with low environmental impact during the full life-cycle | No correlation |
| MAT 3 - REUSE OF FACADE<br>Criteria for re-using existing façades on site | Direct correlation |
| MAT 4 - REUSE OF STRUCTURE<br>Criteria for re-using existing structure on site | Direct correlation |
| MAT 5 - RESPONSIBLE SOURCING OF MATERIALS<br>Criteria for choosing proofed responsibility sourced material in at least 80% in certain building elements | Direct correlation |
| MAT 6 - INSULATION<br>Criteria for choosing responsibly sourced thermal insulation with a low embodied environmental impact relative to its thermal properties | No correlation |
| MAT 7 - DESIGNING FOR ROBUSTNESS<br>Criteria for protection of exposed parts to vehicular, trolley & pedestrian movements | No correlation |
| MAT 8 – HAZARDOUS SUBSTANCES<br>Criteria for documentation of building products in BASTA, Byggvarubedömningen or SundaHus | Indirect correlation |
| WST 1 - CONSTRUCTION SITE WASTE MANAGEMENT<br>Criteria for reduction of construction waste | No correlation |
| WST 2 – RECYCLED AGGREGATES<br>Criteria for using 25% recycled & secondary aggregates | No correlation |
| WST 3 - RECYCLABLE WASTE STORAGE<br>Criteria for dedication of space for storage of recyclables | No correlation |
| WST 4 - COMPACTOR/BALER<br>Criteria for installation of a waste compactor or baler | No correlation |
| WST 5 – COMPOSTING & ANAEROBIC DIGESTION | No correlation |

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|---|---|
| Criteria for either installation of a vessel for on site composing or space for storage of food waste | |
| WST 6 - FLOOR FINISHES<br>Criteria for specification made by the users of the building | No correlation |
| LE 1 - REUSE OF LAND<br>Criteria for development on at 75% of land earlier used for industrial, commercial or domestic purposes | No correlation |
| LE 2 - CONTAMINATED LAND<br>Criteria for remediation of contaminated land | No correlation |
| LE 3 - ECOLOGICAL VALUE OF SITE & PROTECTION OF ECOLOGICAL FEATURES<br>Criteria to encourage construction on land of low ecological value & protect ecological value during construction | No correlation |
| LE 4 - MITIGATING ECOLOGICAL IMPACT<br>Criteria for involvement of an ecologist to limit the buildings ecological impact | No correlation |
| LE 6 - LONG TERM IMPACT ON BIODIVERSITY<br>Criteria for involvement of an ecologist to develop different long-term measures | No correlation |
| POL 1 - REFRIGERANT GWP – BUILDING SERVICES<br>Criteria for choosing refrigerant system with low Ozone Depletion Potential & Global Warming Potential | No correlation |
| POL 2 - PREVENTING REFRIGERANT LEAKS<br>Criteria for implementation of refrigerant leak detection | No correlation |
| POL 3 - REFRIGERANT GWP – COLD STORAGE<br>Criteria for choosing refrigerants & cold storage with low Ozone Depletion Potential & Global Warming Potential | No correlation |
| POL 4 - NOX EMISSIONS FROM HEATING SOURCE<br>Criteria for installing heat systems with low $NO_x$ emissions | No correlation |
| POL 5 - FLOOD RISK<br>Criteria for development in areas with low flooding risk or implementation of mitigation measures | No correlation |

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|---|---|
| POL 6 - MINIMISING WATERCOURSE POLLUTION<br>Criteria for management of pollution from surface water run-off from buildings & hard surfaces | No correlation |
| POL 7 - REDUCTION OF NIGHT TIME LIGHT POLLUTION<br>Criteria for avoiding unnecessary night time light | No correlation |
| POL 8 - NOISE ATTENUATION<br>Criteria for assessment & management of noise from the building to close by noise-sensitive areas | No correlation |
| INN 1 – INNOVATION<br>Exemplary performance level within 11 other criteria | Indirect correlation |

# 2 LEED

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|---|---|
| PREREQUISITE: INTEGRATIVE PROJECT PLANNING AND DESIGN | No correlation |
| CREDIT: INTEGRATIVE PROCESS | No correlation |
| LT CREDIT: LEED FOR NEIGHBORHOOD DEVELOPMENT LOCATION | No correlation |
| LT CREDIT: SENSITIVE LAND PROTECTION | No correlation |
| LT CREDIT: HIGH-PRIORITY SITE | No correlation |
| LT CREDIT: SURROUNDING DENSITY & DIVERSE USES | No correlation |
| LT CREDIT: ACCESS TO QUALITY TRANSIT | No correlation |
| LT CREDIT: BICYCLE FACILITIES | No correlation |
| LT CREDIT: REDUCED PARKING FOOTPRINT | No correlation |
| LT CREDIT: GREEN VEHICLES | No correlation |
| SS PREREQUISITE: CONSTRUCTION ACTIVITY POLLUTION PREVENTION | No correlation |
| SS PREREQUISITE: ENVIRONMENTAL SITE ASSESSMENT | No correlation |
| SS CREDIT: SITE ASSESSMENT | |
| SS CREDIT: SITE DEVELOPMENT—PROTECT OR RESTORE HABITAT | No correlation |
| SS CREDIT: OPEN SPACE | No correlation |
| SS CREDIT: RAINWATER MANAGEMENT | No correlation |

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|---|---|
| SS CREDIT: HEAT ISLAND REDUCTION | No correlation |
| SS CREDIT: LIGHT POLLUTION REDUCTION | No correlation |
| SS CREDIT: SITE MASTER PLAN | No correlation |
| SS CREDIT: TENANT DESIGN & CONSTRUCTION GUIDELINES | No correlation |
| SS CREDTI: PLACES OF RESPITE | No correlation |
| SS CREDIT: DIRECT EXTERIOR ACCESS | No correlation |
| SS CREDIT: JOINT USE OF FACILITIES | No correlation |
| WE PREREQUISITE: OUTDOOR WATER USE REDUCTION | No correlation |
| WE PREREQUISITE: INDOOR WATER USE REDUCTION | No correlation |
| WE PREREQUISITE: BUILDING-LEVEL WATER METERING | No correlation |
| WE CREDIT: COOLING TOWER WATER USE | No correlation |
| EA PREREQUISITE: FUNDAMENTAL COMMISSIONING & VERIFICATION | No correlation |
| EA PREREQUISITE: MINIMUM ENERGY PERFORMANCE | Indirect correlation |
| EA PREREQUISITE: BUILDING-LEVEL ENERGY METERING | No correlation |
| EA PREREQUISITE: FUNDAMENTAL REFRIGERANT MANAGEMENT | No correlation |
| EA CREDIT: ENHANCED COMMISSIONING | No correlation |
| EA CREDIT: OPTIMIZE ENERGY PERFORMANCE | Indirect correlation |
| EA CREDIT: ADVANCED ENERGY METERING | No correlation |
| EA CREDIT: DEM& RESPONSE | No correlation |
| EA CREDIT: RENEWABLE ENERGY PRODUCTION | No correlation |
| EA CREDIT: ENHANCED REFRIGERANT MANAGEMENT | No correlation |
| EA CREDIT: GREEN POWER & CARBON OFFSETS | No correlation |
| MR PREREQUISITE: STORAGE & COLLECTION OF RECYCLABLES | No correlation |
| MR PREREQUISITE: CONSTRUCTION & DEMOLITION WASTE MANAGEMENT | No correlation |
| MR PREREQUISITE: PBT SOURCE REDUCTION - MERCURY | No correlation |
| MR CREDIT: BUILDING LIFE-CYCLE IMPACT REDUCTION | Direct correlation |

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|---|---|
| MR CREDIT: BUILDING PRODUCT DISCLOSURE & OPTIMIZATION— ENVIRONMENTAL PRODUCT DECLARATIONS | Direct correlation |
| MR CREDIT: BUILDING PRODUCT DISCLOSURE & OPTIMIZATION – SOURCING OF RAW MATERIALS | Direct correlation |
| MR CREDIT: BUILDING PRODUCT DISCLOSURE & OPTIMIZATION – MATERIAL INGREDIENTS | Direct correlation |
| MR CREDIT: PBT SOURCE REDUCTION—LEAD, CADMIUM, & COPPER | No correlation |
| MR CREDIT: FURNITURE & MEDICAL FURNISHINGS | No correlation |
| MR CREDIT: DESIGN FOR FLEXIBILITY | No correlation |
| MR CREDIT: CONSTRUCTION & DEMOLITION WASTE MANAGEMENT | No correlation |
| EQ PREREQUISITE: MINIMUM INDOOR AIR QUALITY PERFORMANCE | No correlation |
| EQ PREREQUISITE: ENVIRONMENTAL TOBACCO SMOKE CONTROL | No correlation |
| EQ PREREQUISITE: MINIMUM ACOUSTIC PERFORMANCE | No correlation |
| EQ CREDIT: ENHANCED INDOOR AIR QUALITY STRATEGIES | No correlation |
| EQ CREDIT: LOW-EMITTING MATERIALS | Direct correlation |
| EQ CREDIT: CONSTRUCTION INDOOR AIR QUALITY MANAGEMENT PLAN | No correlation |
| EQ CREDIT: INDOOR AIR QUALITY ASSESSMENT | Indirect correlation |
| EQ CREDIT: THERMAL COMFORT | Indirect correlation |
| EQ CREDIT: INTERIOR LIGHTING | No correlation |
| EQ CREDIT: DAYLIGHT | No correlation |
| EQ CREDIT: QUALITY VIEWS | No correlation |
| EQ CREDIT: ACOUSTIC PERFORMANCE | No correlation |
| IN CREDIT: INNOVATION | Indirect correlation |
| IN CREDIT: LEED ACCREDITED PROFESSIONAL | No correlation |
| RP CREDIT: REGIONAL PRIORITY | No correlation |

# 3 MILJÖBYGGNAD

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|---|---|
| 1. ENERGY CONSUMPTION<br>Criteria for reduced yearly energy consumption | Indirect correlation |
| 2. HEAT EFFECT<br>Criteria for reduced need for heating | No correlation |
| 3. SOLAR HEAT LOAD<br>Criteria for reduced the solar heat load & minimise the need for cooling | No correlation |
| 4. ENERGY SOURCE<br>Criteria for choosing renewable energy sources | No correlation |
| 5. ACOUSTIC ENVIRONMENT<br>Criteria for sound class B- C according to SS 25268:2007 | Indirect correlation |
| 6. RADON<br>Criteria for indoor air radon levels | No correlation |
| 7. VENTILATION STANDARD<br>Criteria for implementation ventilation systems for air quality | No correlation |
| 8. NITROGEN DIOXIDE<br>Criteria for indoor air nitrogen dioxide levels | No correlation |
| 9. MOISTURE SAFETY<br>Criteria for securing moisture safe constructions | Indirect correlation |
| 10. THERMAL CLIMATE WINTER<br>Criteria for assessment of thermal climate through data modelling or transmission factor | Indirect correlation |
| 11. THERMAL CLIMATE SUMMER<br>Criteria for assessment of thermal climate through data modelling or solar heat factor | Indirect correlation<br>Available data, windows |
| 12. DAY LIGHT<br>Criteria for sufficient day light for the building users | No correlation |
| 13. LEGIONELLA<br>Criteria for the water systems | No correlation |
| 14. DOCUMENTATION OF BUILDING PRODUCTS<br>Criteria for specifying building material in a logbook | Direct correlation |
| 15. PHASING OUT HAZARDOUS SUBSTANCES<br>Criteria for hazardous substances according to KEMIs definition in the logbook | Direct correlation |

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