# Environmental Assessment Tools for Neighbourhoods and Buildings in relation to Environment, Architecture, and Architects

**MARITA WALLHAGEN**

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**Author:** Marita Wallhagen

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Department of Sustainable development, Environmental science and Engineering
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*To my family – past, present, and future generations*

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# ABSTRACT

This thesis explores Neighbourhood and Building Environmental Assessment Tools (NBEATs) and their relations to the environment, architecture, and architects. To better understand NBEATs' function as assessment tools, as decision support, and their possible influence on the environment, architecture and architects, knowledge has been gained through studies analysing and testing a number of tools (LEED-NC, Code for Sustainable Homes, EcoEffect, LEED-ND, BREEAM-C, and the ENSLIC-tool), their manuals and their use. Moreover, professionals' (architects') self-rated opinions regarding use and knowledge of assessment tools and environmental aspects have been surveyed.

The studies show that there are similarities and considerable differences between the studied NBEATs regarding, content, structure, weighting and indicators used. Even when the environmental issues seem to be the same, they use different kinds of indicators for assessment. The indicators can be distinguished as procedure, performance and feature indicators, and measure social, environmental and technical aspects. If the aim is to assess the environmental dimension of sustainability — recognising ecological limitations — there are areas that can be improved such as transparency, tradability of indicators, relative measures, low criteria levels, limited life cycle perspective, and exclusion of relevant environmental aspects, such as embedded toxic substances, nutrient cycles, land use change, and ecosystem services.

The NBEATs, their different criteria, criteria levels and indicators influence architecture in varying ways, and can result in different environmental ratings of buildings or neighbourhoods. Higher criteria levels could increase the impact on architectural design. To bring knowledge of the environmental impacts of architecture closer to architectural design and its aesthetics, NBEATs could be more closely linked to architectural theory and practice. The aesthetic influence of NBEATs and their connection to architectural theory are fields open for further research.

There is limited use of NBEATs as decision support in early design phases, such as in an architectural competition, and few architects self-rate their skill in handling environmental aspects high. Nevertheless, the importance of environmental aspects is rated high. These results call for increasing the knowledge and know-how of environmental strategies and solutions among architects. Environmental aspects and NBEATs' criteria and goals could be better integrated into architectural projects and NBEATs more adapted to the creative and innovative early design process.

As NBEATs' content, indicators and weightings aim at influencing how architecture should be designed and built, they ultimately operationalise ethical positions, which can influence what codes of conduct are used when designing architecture. Therefore, a continuous discussion regarding the environmental ethics in NBEATs is needed to make it clear what values NBEATs and related buildings codes reflect and what values we want them to create.

Furthermore, this thesis highlights that NBEATs are related to the environment (ecological systems), which is interlinked with architecture (technological systems), and with architects, people and process surrounding architecture (sociological systems). This calls for an increased socio-eco-technological system perspective in NBEATs, in architecture and among architects. If NBEATs are to assess, drive and guide architects and architecture towards environmental sustainability, they need further development and both practical and philosophical (i.e. ethical) considerations are of importance to complement the economic aspects that dominate today. NBEATs help to accommodate change. However, as they are constituted and used today, other measures as well, through policy, governance, regulation, or paradigm changes, seem to be needed in order to influence architects and other stakeholders towards designing and constructing an 'environmental' architecture with limited negative environmental impacts, which answer the environmental sciences' urgent call for action.

**Keywords:** architects, architecture, buildings, environment,
environmental assessment tools, environmental sustainability, neighbourhoods

# SUMMARY IN SWEDISH (SAMMANFATTNING)

Denna avhandling undersöker miljöbedömningsmetoder för stadsdelar och byggnader, Neighbourhood and Building Environmental Assessment Tools (NBEATs), samt deras relationer till miljön, arkitektur och arkitekter. Detta är viktiga frågor som påverkar NBEATs samlade effekt på både den byggda och naturliga miljön. För att bättre förstå hur NBEATs fungerar som miljöbedömningsverktyg, beslutsstöd, och dess eventuella påverkan på miljön, arkitektur och arkitekter, har kunskap erhållits genom studier som analyserar och testar ett antal NBEATs (LEED-NC, CSH, EcoEffect, LEED-ND, BREEAM-C och ENSLIC-tool), deras manualer och deras användning. Dessutom har yrkesverksamma arkitekter tillfrågats angående deras självskattade användning och kunskap om bedömningsmetoder och miljöaspekter.

Studierna påvisar likheter men också skillnader mellan NBEATs gällande innehåll, struktur, viktning och använda indikatorer. Även när miljöfrågorna är desamma, används olika typer av indikatorer för bedömning. Dessa indikatorer kan delas in process-, prestanda-, och egenskapsindikatorer, vilka mäter sociala, miljömässiga respektive tekniska aspekter. När NBEATs syftar till att utvärdera miljödimensionen av hållbar utveckling där ekologiska gränser erkänns, så finns det saker i metoderna som kan förbättras: transparens, utbytbarhet av indikatorer, relativa kriterier, låga kriterienivåer, begränsat livscykelperspektiv och uteslutning av relevanta miljöaspekter såsom inbyggda farliga ämnen, näringsämnens kretslopp, förändrad markanvändning och ekosystemtjänster.

Olika NBEATs, deras kriterier, kriterienivåerna och dess indikatorer påverkar arkitektonisk formgivning på olika sätt och resulterar i att byggnader eller stadsdelar kan få olika miljöbetyg. Högre kriterienivåer skulle förmodligen öka påverkan på arkitekturen. För att föra kunskap om arkitekturens miljöeffekter närmare arkitekturfrågorna och deras estetiska frågor, skulle en väg framåt kunna vara att koppla NBEATs närmare arkitekturteori och praktik. NBEATs inflytande på estetik samt deras koppling till arkitekturteori och praktik är områden som lämpar sig för ytterligare forskning.

Användningen av NBEATs som beslutsstöd i tidiga designfaser, såsom i en arkitekttävling, är begränsad och få arkitekter självskattar sin förmåga att hantera miljöaspekter som hög. Samtidigt anser de att miljöaspekter är viktiga. Dessa resultat talar för att öka kunskapen och kompetensen bland arkitekter angående miljöanpassade lösningar och strategier. Vidare kan miljöaspekter, NBEAT-miljökriterier samt miljömål integreras bättre i arkitekturprojekt och NBEATs kan bättre anpassas till den kreativa och innovativa designprocessen. NBEATs, dess innehåll, indikatorer och viktning, syftar till att påverka hur arkitektur ska utformas och byggas, därför operationaliserar de etiska ställningstaganden och kan därmed påverka uppförandekoder vid utformning av arkitektur. En kontinuerlig diskussion om miljöetik i NBEATs behövs därför för att klargöra vilka värden NBEATs och inkluderade byggnadsregler representerar och vilka värden vi vill att de ska skapa.

Denna avhandling understryker att NBEATs är relaterade till miljön (ekologiska system), som är sammanlänkad med arkitektur (tekniska system), samt med arkitekter, människor och processer kring arkitektur (sociologiska system). Detta synsätt, betonar behovet av ett socio-eko-tekniskt systemperspektiv i NBEATs, i arkitektur och bland arkitekter. Om NBEATs ska bedöma, driva och leda arkitekter och arkitektur mot miljömässig hållbarhet, behöver de vidareutvecklas. Då är både praktiska och filosofiska (d.v.s. etiska) överväganden av betydelse för att komplettera de idag dominerande ekonomiska aspekterna. NBEATs bidrar till förändringsarbetet, men om de ska påverka arkitekter och andra intressenter till att utforma och skapa miljöanpassad arkitektur med begränsad negativ miljöpåverkan, när NBEATs är utformade och används som idag verkar även andra åtgärder och förändringar genom exempelvis politik, styrning, reglering eller paradigmskiften krävas för att svara mot miljövetenskapernas brådskande uppmaning till handling.

# PREFACE

### *An interest in environment, architecture and research*

This thesis is about Neighbourhood and Building Environmental Assessment Tools (NBEATs), and how they assess environmental aspects on different scales of architecture, influence architects decisions and ultimately affect the environment. Now as this PhD period draws to a close, I begin to wonder how and when this interest in environment, architecture and research all started.

Many consider Rachel Carson's book Silent Spring as a starting point for the environmental movement, and this haunting title has influenced my own environmental interest. A silent spring is scary because I have always loved birds, animals, flowers, plants, and insects. It became evident when I as a child was living in Bangladesh with my family and it made me appreciate Nordic nature and the Swedish Right of Public Access. That experience made me aware of the differences and challenges with regard to climate, population density, land use, built environments, social codes, women rights, and our connection to nature.

My first close contact with research and environmental issues was my final project in high school. Then, my study about how changes in the transportation network could influence CO2 emissions, brought me to the final in the Young Scientist competition, culminating with an exhibition at the National Museum of Science and Technology in Stockholm. Later, my architectural studies continued to inspire me not only in the field of architecture but also in environmental issues. Studies at Southern Illinois University, brought me closer to the work of Buckminster Fuller, an architect with great concern for the environment. Through a project in collaboration with NASA, insight into the difficulties with space travel and earth's vulnerability gave me a new perspective on sustainability issues. An internship at The National Board of Housing, Building and Planning (Boverket), and work with Maria Petersson and Ingrid Hernsell taught me about policy and building codes connected to justice for the disabled. In the end I got the chance to combine my interest in architecture together with my interest in environmental aspects, in my master thesis in architecture, 'More with less', where I got great input from my supervisors and opponents, Christer Wiberg, Maria Nyström, Lars Reuterswärd, Thorbjörn Laijke, and Rikard Küller.

In 2005, winning the MEM scholarship made it possible for me to go to San Francisco where the renowned architect Eric Corey Freed opened up opportunities and insights within the emerging field of sustainable building in California. It also took me to Cathy Stewarts and Alex Kirkwood at Pascall + Watson in London, who were working with environmental assessment tools in their architectural company. By then I had been working at Arkitektgruppen in Gävle for a few years and was the Chair of the Swedish Association of Architects Gävle-Dala (SAGDA). At one of our meetings I came across Mauritz Glaumann who asked if I knew anybody who was interested in research in the field of sustainability. It turned out to be me!

### *A broader perspective*

My PhD studies, with this cover essay, have in many ways influenced me and been influenced by my interest in architecture however small or large. The spaces created by walls, roofs, floors, and where they meet and interact are fascinating. As are the underlying processes, from early design sketches, to drawings, specifications, and construction, to use, maintenance, refurbishments, and destruction — all entailing multiple choices and numerous decisions. My interest lies in how details create larger structures and spaces which eventually become the environment in which we live our lives.

Apart from man-made artefacts, another interest of mine is natural settings, forests, meadows, archipelagos, and especially mountains. I love to climb, reach the top and enjoy the fantastic and dramatic view from the summit. From there you get a wider and deeper perspective on the world and yourself as a human being; a perspective which stretches across time and space. All this has influenced this thesis on environmental assessment tools, which focuses on neighbourhood and building environmental assessment tools (NBEATs) and their use as assessment, and decision support tools in architectural projects. Even if it is a defined and concentrated area of research, it links up to many other areas and gives this thesis a wider scope.

After studying some of the many existing environmental assessment tools for buildings and neighbourhoods, I want to be able to tell the story of the assessment tools. To explain for everyone, including my children, what they include, how they want us to build sustainable architecture, and what the result would be if we followed their advice. I know that many people who have been involved in creating these assessment tools, like some of my supervisors, have put great effort, time and energy into these tools. They deserve special recognition. They have good intentions, have used existing knowledge in the field and have been struggling to make them valid, reliable and usable, and there have been many different stakeholder and strong views on the agenda. Some of the content in this cover essay can be interpreted as a critical examination of environmental assessment tools, without giving much clear advice on what exactly the perfect assessment tools should look like. Answering that question is beyond the scope of this thesis and a field for future research.

My hope is that anyone reading this thesis will be interested in learning more about ‘environmental’ architecture and how it can be assessed with NBEATs. This work has increased my knowledge, expertise and skills in this area, and can possibly do the same for others. An increased interest in these things will hopefully have an impact on several issues: increasing demand for ‘environmental’ architecture; ensuring the further development of environmental assessment tools for buildings and neighbourhoods: broadening the perspective on architecture towards a socio-eco-technological system perspective, and being the basis for new innovations and environmental transformation of the built environment and current architectural theory and practice. Issues, which I hope I can continue working on now when my PhD studies are coming to an end.

### *Outline of the thesis*

The thesis with its focus on NBEATs, consists of five studies described in five appended Papers (Papers I, II, III, IV, and V), and a cover essay which provides a summary of the five papers. This cover essay describes how they are linked together and discusses the results in relation to the environment, architecture and architects. First, a background of the research including terminology used, is presented in Chapter 1. It is followed by the aims in Chapter 2. Then Chapter 3 describes the research context in which the studies have been carried out and the methods used. Chapter 4 contains a presentation of the research findings from the Papers that are connected to environment, architecture and architects. In Chapter 5, the results from the Papers regarding assessment tool framework (Paper I), tool analysis (Paper II and IV), simplified Life Cycle Assessment study (Paper III), and the survey (Paper V) are discussed in relation to environmental sustainability, architecture and architects. It also elaborates on suggestions regarding future research. The last section, Chapter 6, presents the main conclusions.

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My doctoral studies in Environmental Strategic Analysis have been possible though a collaboration between University of Gävle and KTH Royal Institute of Technology. There are many people I would like to thank for making this journey possible. To name everyone who has inspired and supported me is an overwhelming task. Nevertheless, I would like to start with thanking my wise supervisors, Göran Finnveden, Ola Eriksson, Tove Malmqvist, Josefin Wangel and my former supervisor Mauritz Glaumann for guiding and inspiring me through my work. Thank you, Mauritz for giving me the opportunity to start this PhD work, and Göran for enabling the collaboration between the universities. Mauritz, your interest and knowledge in sustainable building, endless curiosity and open mind will always inspire me. Göran, you have supported, complemented, and supervised me from the start until this final PhD thesis. Your sharp mind, vast experience and clear vision have been invaluable to me. After my Licentiate thesis, Ola, together with Göran and Tove, found a solution to allow me to continue to a PhD. I am very thankful for that. Ola, you are a well-organised, intelligent, fair and percipient person who has taught me a lot. I want to thank Tove, who has co-supervised me since the last months of my licentiate work. Thanks for guiding and supporting my work with constructive feedback, insightful knowledge, and relevant questions. Many thanks also to Josefin Wangel, for your quick-witted thoughts, broad knowledge about sustainability issues, and positive energy which you always bring and spread around you. Furthermore, I would like to thank the co-authors who I had the opportunity to work with. Thank you, Ulla Westerberg, for all your intelligent suggestions, language skills, and reflective thoughts, and many thanks to Enrico Mazzucchelli and Patrik Sörqvist for our fruitful collaboration. Thanks also to Mary McAfee and Anne Thompson-Ashby for improving the language in the papers and the thesis.

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Finally, to my loved ones, my dear husband, Peter Magnusson, and our lovely sons Lukas, five years old, and Melvin, two years old. I would like to thank you, Peter, because you are the one who has meant the most in my life and during this journey. You always stand by me, give me generous support, countless advice, positive encouragement and exciting moments. I will forever be thankful for that. You are my soulmate and I love you. My adorable Lukas, you are a miracle, with your golden hair that shines almost as much as your beautiful smile — you have enriched my life. Thank you for making me enjoy the small things in life. My sweet Melvin, you are one of the wonders in this world, with your joyful character, and carefree and cheerful ways of dealing with things. Thank you for making me see and enjoy every beautiful moment. Together your constant smiles, daily presence and energy have lit up my days and nights. Thank you, you are my favourites. You have a special place in my heart. I will always love you.

# LIST OF PAPERS

This thesis is based on the following articles, which are referred to in the text by their Roman numerals:

**Paper I** Wallhagen M., Glaumann M., Eriksson O., Westerberg U. (2013). Framework for Detailed Comparison of Building Environmental Assessment Tools. *Buildings*, Volume 3, Issue 1, Pages 39-60.

**Paper II** Wallhagen M., Glaumann M. (2011). Design consequences of differences in building assessment tools: a case study. *Building Research & Information*, Volume 39, Issue 1, Pages 16-33.

**Paper III** Wallhagen M., Glaumann M., Malmqvist T. (2011). Basic building life cycle calculations as decision support to decrease contribution to climate change. *Building and Environment*, Volume 46, Issue 10, Pages 1863-1871.

**Paper IV** Wangel J., Wallhagen M., Malmqvist T., Finnveden G. (2016). Certification systems for sustainable neighbourhoods: What do they really certify? *Environmental Impact Assessment Review*, Volume 56, Pages 200-213.

**Paper V** Wallhagen M., Malmqvist T., Eriksson O. (2016). Professionals' knowledge and use of environmental assessment in an architectural competition. *Building Research & Information*, Pages 1-17. Published online: 9 March 2016.

### *My contributions to the papers*

**Paper I.** I contributed by: being involved in the design of the study, developing the framework, analysing the environmental assessment tools, making figures and tables, writing most of the paper, and being the corresponding author.

**Paper II.** I contributed by: planning the study, testing three environmental assessment tools on a residential building, gathering data, writing most of the paper, and being the corresponding author.

**Paper III**. I contributed by: designing part of the study, planning the outline of the article, testing the ENSLIC-tool, performing the study and the analysis, drawing up figures and tables, writing the majority of the paper, and being the corresponding author.

**Paper IV.** I contributed by: being involved in the study design, performing text and data analysis of BREEAM-C and LEED-ND, drawing up figures and tables, interpreting the data-analysis, writing a large proportion of the article mainly with Josefin Wangel (with whom I share the first authorship).

**Paper V.** I contributed by: being responsible for, and performed the; idea of the study, study design, questionnaire, pilot study, data-collection, statistical analyses, follow-up, interpretation, outline of the paper, writing of the article, and was the corresponding author.

# LIST OF ABBREVIATIONS

| | |
|---|---|
| AIA | The American Institute of Architects |
| ASHRAE | American Society of Heating, Refrigerating and Air-Conditioning Engineers |
| BEAT | Building Environmental Assessment Tool |
| BIM | Building Information Modeling |
| BRE | Building Research Establishment Ltd. |
| BREEAM | Building Research Establishment Assessment Method |
| BREEAM-C | Building Research Establishment Assessment Method for Communities |
| CASBEE | Comprehensive Assessment System for Built Environment Efficiency |
| CSH | Code for Sustainable Homes |
| $CO_2eq$ | Carbon Dioxide Equivalent |
| DCLG | Department for Communities and Local Government |
| DGNB | Deutsche Gesellschaft für Nachhaltiges Bauen |
| ELN | Environmental Load Numbers |
| EMS | Environmental Management System |
| FSC | Forest Stewardship Council |
| GHG | Green House Gas |
| GW | Global Warming |
| GWP | Global Warming Potential |
| IPCC | Intergovernmental Panel on Climate Change |
| ISO | International Organization for Standardization |
| JSBC | Japan Sustainable Building Consortium |
| LCA | Life Cycle Assessment |
| LCC | Life Cycle Costing |
| LCIA | Life Cycle Impact Assessment |
| LEED | Leadership in Energy and Environmental Design |
| LEED-ND | Leadership in Energy and Environmental Design for Neighbourhood Development |
| LEED-NC | Leadership in Energy and Environmental Design for New Construction and Major Renovations |
| NBEAT | Neighbourhood and Building Environmental Assessment Tool |
| $NO_x$ | Nitrogen oxide |
| RIBA | Royal Institute of British Architects |
| SBS | Sick Building Syndrome |
| SETS | Socio-Eco-Technological Systems |
| SGBC | Sweden Green Building Council |
| SPSS | Statistical Package for the Social Sciences |
| USGBC | United States Green Building Council |
| VOC | Volatile Organic Compounds |

# 1. BACKGROUND

## 1.1. Environmental problems and the built environment

We live in an Anthropocene period where humans are the largest environmental force on the planet influencing both our local and global environment (Crutzen, 2002). Humans are making dangerous transgressions on our planet's boundaries and the population growth is continuing (Rockström et al., 2009; Steffen et al., 2015). Probabilistic projections of population growth estimate that there will be around 10,9 billion people on this planet in year 2100 (Gerland et al., 2014; Institute, 2015). In the year 2008 half of the earth's population lived in cities and urbanisation and population growth is continuously increasing (UN-Habitat, 2008). This creates an increased demand for houses and other built environments.

The *built environment*, here referred to as 'architecture', includes structures that are made by humans for their use and activity. This includes buildings, urban, suburban and rural structures, such as infrastructure, roads, parks etc. Built environments provide the basic necessities for modern life and therefore must be sound, functional and healthy (Scientific Research Publishing Inc., 2015), but they are responsible for a large proportion of global environmental impacts. New buildings are being built at an enormous rate and the built environment has become a major force of change on this planet (Hong et al., 2015). In China the existing floor area of commercial buildings (approximately 7.1 billion $m^2$, in 2012) is increasing by almost 2 billion $m^2$ per year (Diamond et al., 2013). The corresponding number for the US is 7.6 billion $m^2$ existing commercial buildings with an annual increase of 100 million $m^2$ (Diamond et al., 2013). Production of building materials, such as cement, used in concrete, has increased to an annual global production of 3600 billion ton, relating roughly to 510kg/person per year (Komiyama, 2014).

Built environments are responsible for a large proportion of the energy use, raw material consumption, timber harvest and deforestation, hazardous and non-hazardous waste sent to landfills, radioactive waste, and use of toxic chemicals (Roodman et al., 1995; Toller et al., 2013). All major environmental impacts affect the earth, the ecosystems, nature as we know it, and ultimately our wellbeing and quality of life. It can lead to a transgression of planetary boundaries, which could threaten the ecological systems that people's daily lives depend upon (Lucht, 2010; Rockström et al., 2009). Construction and operation of buildings is estimated to be responsible for 40% of the global energy-related greenhouse gas (GHG) emissions (Metz et al., 2007; Omer, 2008). Rising levels of carbon dioxide ($CO_2$) emissions increase global temperature and lead to global effects on climate, sea levels, ecosystems, and ultimately public health (Srinivasan et al., 2003). Tackling this climate change is a huge challenge but could at the same time be regarded as the greatest global health opportunity for the 21st century according to the Lancet commission on Health and Climate Change; because according to future projections, climate change represents an 'unacceptably high and potentially catastrophic risk to human health' (Watts et al., 2015).

Despite efforts to reduce unsustainability and an increased awareness of sustainability issues, global resource consumption continues to grow (Fiksel, 2006). To change this trend, and to address strategic action to limit negative environmental impacts, it is important to have a deep understanding of the impacts associated with the built environment and put in place strategies for more sustainable urban environments.

## 1.2. The built environment — architecture

Our environment on earth consists of a heterogeneous range of both spontaneously occurring '*natural* environments' and humanly intentionally organised and constructed '*built* environments', which creates the setting for people's daily lives (Fox, 2000). In this thesis, this built environment will be termed architecture. Architecture is the art or science of the process and the production of planning, designing and constructing buildings, structures, objects and outdoor spaces (Learner's Dictionary, 2016; Oxford English Dictionary, 2016; Wasserman et al., 2000). It includes the internal space, the space around, above and in-between the building and hence embraces landscape architecture and urban planning.

Historically the term architecture has focused on monumental architecture and the history of architecture has to a large extent been the history of great architects and great buildings (Conway & Roenisch, 2005). In this thesis a broader definition of architecture is used, to describe edifices of any kind for human use (Oxford English Dictionary, 2016). It encompasses all types of built environments and other physical structures: historic, monumental, prestigious, traditional, vernacular, non-formal, non-classified, utilitarian building, civic engineering work, cottages and barns (Conway & Roenisch, 2005) and architecture made without architects (Rudofsky, 1964).

Further, architecture not only includes built structures, but also non-built models, drawings and specifications. It can have an aesthetical dimension, a symbolic purpose, structure and articulate existential space, and focus on creating space with meaning (Ching, 2014). Architecture is not only an technological issues, but it can also be seen as a highly efficient and complex social ecological system (Fisher et al., 2015) because it is interrelated with social-economical-political-cultural circumstances (Wasserman et al., 2000). Therefore, architecture can become a physical manifestation reflecting the prevailing mores of the time in which it is built. Hence it can bear a testimony of its era (Wasserman et al., 2000).

For convenience, and to distinguish the physical structure from the design process, this thesis uses the term *architecture* and *architectural design* for the physical structures, and *design of architecture* and *designing architecture* for the process of designing physical structures. If the architecture has features and characteristics that makes it notable or historically identifiable, it is said to have an *architectural style*.

## 1.3. Changed prerequisites for architecture

The architecture surrounding us today is the result of human aspiration, technological development, economic power, culture and the use of vast natural resources. Its form reflecting the way we live our lives, has developed over a long period of time, but has changed greatly during the last century. It has been influenced by historic buildings, modern design, material and technological breakthroughs. Significant buildings were designed and constructed to last for decades (Bedoire, 2015), and construction took many years. Historically, most buildings used local construction materials, as transportation of material was difficult. In addition, knowledge about the impact on the surrounding ecosystems was not as great as today, and environmental impacts were less extensive and seldom visible.

The last decade has changed the time horizon and the speed of construction. Today architecture has a profound effect on the state of the world, the availability of natural resources for future generations and the health of the geobiosphere. Never has the rate of transformation of the built and natural environment on earth been as fast or with as many opportunities and decision options as now. Still, existing architecture is by many viewed as a rather static artefact that is difficult to change (Harrison 2013).

Global environmental impact from the built environment has seldom been the subject of public battles, like pollution from cars or factories, or public concern over food, medical or pollution issues (Woolley, 2000), even though local problems with buildings have been recognised such as sick building syndrome (Apter et al., 1994; Redlich et al., 1997). Market demand for environmental buildings has not increased as much as the growing demand for ecological food. In Sweden 130 multi-residential buildings were certified with the environmental assessment tool Miljöbyggnad in 2015 (Sweden Green Building Council, 2016b), which comprise a small portion of the 35800 apartments in multi-residential building projects that were started in Sweden the same year (SCB Statistics Sweden, 2016). Ecological food, on the other hand, represented 7.7% of the total food market in Sweden in 2015, and increased by 39% compared to the previous year (Ecoweb, 2016).

The harm caused by buildings has largely escaped scrutiny (Fenner & Ryce, 2008), even though the environmental cost of building has been emphasised in research, for example in various Life Cycle Assessment (LCA) studies (Chau et al., 2015; Kats et al., 2003; Seinre et al., 2014). Furthermore, it has also been concluded that a more sustainable design of buildings and neighbourhoods could improve building quality without increasing economic costs (Kats et al., 2003), it can increase market value (Eichholtz et al., 2010), and at the same time benefit both human health and the environment (Azhar et al., 2011). However, political agreements, such as the Paris Climate Change Agreement 2015 and Agenda 21, have been made, and environmental and sustainable buildings and urbanisation are requested. Therefore, global and local environmental impacts on ecosystems, and on people's health – both directly and indirectly, is now a growing concern for the building and property sector, architecture and architects.

In parallel, academics and practitioners are discussing two main issues: what a sustainable built environment is and how to measure it (Berardi, 2011).

The next question, how to design this environmentally sustainable built environment, is an additional and separate discussion, closely linked to architecture. The first two, are traditional research questions dealing with describing how things are at the moment, and the development of methods. The third, the design question, deals with how things can be, could be, or ought to be. This includes design thinking, that not only is adding a beautiful wrapper around an idea, but is tactical and innovative and can lead to dramatic new forms of value (Brown, 2008).

Taken altogether, the environmental and health aspects, research results, and political goals place environmental demands on both present and future architecture. Today, architecture has to live up to high expectations regarding design, functionality, indoor environment, social aspects, environmental performance, health, and resilience; it has to combine flexibility, adaptability, and foresight with the capacity to anticipate and accommodate change (Fiksel, 2006, 2015). This implies that the basic prerequisite for design, construction and use of buildings is changing and consequently architecture has to change to meet these new demands. To make that possible there is a need for knowledge on the consequences of design choices. Using Neighbourhood and Building Environmental Assessment Tool (NBEATs) is one possible way to get closer to solving how present and future environmentally benign architecture should be designed.

## 1.4. Architects and decision-making

The environmental impact from architecture is influenced by its design, the design process and the decision-making within it. Behind the architectural design and decisions are the people involved in the planning, programming, design and construction of the architecture. In the end it is not the buildings that are responsible for the environmental impacts they cause, it is the people designing, constructing and using the buildings (Janda, 2011). These decision-makers consist of multiple stakeholders and the decision-making and design of the urban environment can be performed by different stakeholders on different levels, from legislation (e.g. building regulations), to policies and politics (e.g. from municipal and local governments, and institutions), to private sector influence and from users and professionals as groups and individuals (Fisher et al., 2015). All these different stakeholders influence the complex decision and design process and how the architecture is finally designed, built and managed. Therefore, the design varies with each project and country. Even when a project is carried out by individual architects, it is often within a team, working with other stakeholders from other disciplines – real estate owners, local governments, developers, contractors, engineers, other consultants and builders. All these individuals affect the built environment and have an important role in designing, creating, operating, refurbishing, human structures into a more sustainable built environment (Kibert, 2007).

In the early design phases, the programming, planning and design of buildings and neighbourhoods are carried out and decision-making is crucial for sustainable architecture (Hawken et al., 2013). Then, decision-makers, such as architects and other urban design professionals (landscape architects, urban planners and urban designers), are key actors, who influence the design and are the stakeholders most involved in the whole process (Elforgani & Rahmat, 2010).

They operationalise goals, ideas and programmes into physical form by communicating and working together with all the other stakeholders involved. Therefore, these key actors are influential and important driving forward the future design and planning of more environmentally sustainable architecture.

The focus in this thesis will be on the architects, because their design and decision-making is important from an environmental perspective. The term *architect*, which derives from the Greek *archos* meaning *chief* and *tekton* meaning *builder* (Conway & Roenisch, 2005), will be used here to represent people designing buildings, architecture, and urban landscapes, i.e. including architects, landscape architects, urban designers and urban planners. An architect can be the chief designer involved in the building project from the beginning to the final construction and use phase, or have a role that includes supplying drawings, being a developer or acting as a manager of building projects (Conway & Roenisch, 2005).

There are cost-effective ways to minimise much of the damage that buildings create and at the same time meet people's expectations of modern buildings (Fenner & Ryce, 2008). The main barrier for improved environmental and sustainable architecture and urban environments is therefore neither technological nor economic issues, but rather social and psychological factors (Hoffman & Henn, 2008), organisational and procedural difficulties (Häkkinen & Belloni, 2011), and an issue of education, of information dissemination and better use of technologies (Girardet, 2000). Therefore, research regarding decision-making and decision-makers, such as architects, that influence architectural design and environmental issues in the planning and building sector is important.

## 1.5. Architecture and the environment

The role of architecture in a sustainable society is discussed in the field of architecture and urban design, but less in the public media. The importance of the environmental impact from architecture is gradually receiving wider recognition by political agendas and protocols. But, architecture that considers environmental sustainability aspects is not completely new. Climate, comfort and material choices have been part of building design since Vitruvius's Ten books on architecture' (Edwards, 2004; Rowland & Howe, 2001; Vitruvius, 2015) written between 80 B.C. and A.D. 15, and first printed in Latin in 1486 (Cavallo & Storey, 2013). Architecture, called environmental, organic or ecological has been a subject since the 1970s (Williamson et al., 2003), and during the 1960's, environmental design became a coherent theme of education in the construction industry (Edwards, 2004). Environmental design has been recognised by, for example, Buckminster Fuller (1969), Frank Lloyd Wright (1939), Olgyay (Olgyay & Olgyay, 1963), Ian McHarg (1969), Reyner Banham (Edwards, 2004), and Ralph Erskine (Erskine, 1968; Pressman, 1996).

The American Institute of Architects (AIA) funded AIA Committee on the Environment (AIA/COTE) in 1990 (Gould, 2016). Principles for environmental sustainability in architecture has been endorsed by The Union of International Architects at their World Congress 1993 in their *'Declaration of Interdependence for a Sustainable Future'* as a comittment for the profession of architecture as a whole. It states that architects should 'place environmental and

social sustainability at the core of our practice and professional responsibility' (The Union of International Architects, 1993, p.1). Environmental and sustainable design of buildings has been primarily concerned with energy efficiency issues, but today the subject includes multiple topics with a wider definition of sustainability that frames the process of sustainable design and includes the full range of human settlement and ecological issues (Gould, 2016).

Architecture taking into account environmental considerations has been called by numerous names and with different main concerns, from 'green' building, sustainable architecture (Williamson et al., 2003), resilient planning and cities (Jabareen, 2013; Pickett et al., 2004), regenerative design (Cole, 2012a), ecological design (Van der Ryn & Cowan, 1996) and organic architecture (Pearson, 2001). The rhetoric, terminology and the dominant concerns have been changing. Williamson, Radford, and Bennetts (2003) present three contrasting images of architectural sustainability which they call: the natural image, the cultural image, and the technical image. In summary, the natural image mainly concerns the environment, ecosystems, health, balance and sensitivity to local natural systems. The cultural image focuses on cultural place, people, genuis loci (i.e. the special atmosphere and spirit of a particular place (Norberg-Schulz, 1980; The Free Dictionary by Farlex, 2016)), with emphasis on local culture and local involvement. While the last, the technical image's dominant concern is global environmental impacts, technologies, cost-benefit analysis, and risk management, supported by studies in natural science, economics and technology. Common factors for the environmental, sustainable or 'green' architecture are the links to issues of sustainability, which concerns human intra-generational justice, human inter-generational justice, the ethics of the human-non-human relationship — including the preservation of global biodiversity — and, ultimately, questions concerning the richness, beauty, and even survival of life on earth (Fox, 2000).

In this thesis '*environmental*' architecture is defined as architecture which takes into account its relationship and impact on the local and global environment from the whole life cycle of the architecture. It aims at minimising negative environmental impacts and maximising the positive environmental impacts on the earth's ecological systems, and human quality of life. To assess, stimulate and market environmental design and the construction of buildings and neighbourhoods, i.e. architecture, building environmental assessment tools (BEATs) and neighbourhood environmental assessment tools have been developed. In many ways they also function as decision-making tools.

## 1.6. Neighbourhood and Building Environmental Assessment Tools

Neighbourhood and building 'environmental', or 'sustainability', assessment 'tools', or 'systems', 'rating systems', 'certification systems', 'schemes', 'instruments', 'processes', 'methods', or 'methodologies' (Poveda & Lipsett, 2014), have been designed to evaluate how environmentally benign a building or a neighbourhood is. Additionally, they often aim at stimulating and marketing 'environmental', 'sustainable', or 'green' architecture with the overall purpose of mitigating the negative environmental impact from buildings (BRE, 2012).

Since the 1990's, when the first environmental assessment tool for buildings, BREEAM was launched (BRE Global, 2011), assessment tools have been developed and launched globally. More recently, in the beginning of the 21st century, these have been followed by assessment tools for neighbourhoods (Sharifi & Murayama, 2015). For the purpose of this thesis, they are here together termed neighbourhood and/or building environmental assessment tools (NBEATs) and include the tools/methods/guides/ calculation tools/certification systems/rating systems that assess environmental and sometimes also social and economic sustainability issues for neighbourhoods and/or buildings and includes the tools studied in this thesis: BREEAM-C, CSH, EcoEffect, LEED-NC, LEED-ND, and ENSLIC-tool.

The NBEATs assess issues relating to environmental impacts, such as: energy use, water use, material use, waste generation, ecology, indoor environment, transport, and infrastructure (Malmqvist, 2008b; Reith & Orova, 2015), and offer different types of structured and systematic sets of criteria for a project to work with and towards. By doing this, they try to encourage sustainable building and urbanisation by enabling decision-makers, companies, governments and institutions to make more deliberate environmental decisions (Cole, 1999). Decisions, which ultimately often influence design choices. They can also be of importance in the decision-making process for internal management, as design guidelines and for market and stakeholder communication (Crawley & Aho, 1999), which also influence the choices.

Even though NBEATs are still rather a new subject, the tools have been studied in academic papers. Studies have involved comparing and testing various environmental assessment tools for buildings (Cole, 1999; Ding, 2008; Gu et al., 2006; Haapio & Viitaniemi, 2008; Lewandowska et al., 2015; Schwartz & Raslan, 2013; Todd et al., 2001; Todd et al., 2013; Wallhagen et al., 2013) and more recently, assessment tools for neighbourhoods, communities and districts (Haapio, 2012; Kyrkou & Karthaus, 2011; Nguyen & Altan, 2011; Sharifi & Murayama, 2013, 2014, 2015; Zeinal Hamedani & Huber, 2012; Zhou et al., 2011). Comparisons have been made on a general level including, cost, background, type of system (Forsberg & von Malmborg, 2004; Reijnders & van Roekel, 1999; Todd et al., 2001), analysing their use (Todd et al., 2013), discussing the possibility to export assessment systems to other countries (Chew & Das, 2008), possible use in non-developed countries (Ali & Al Nsairat, 2009), regional differences (Sev, 2011), and how they may work as policy instruments (Schweber, 2013). The used environmental indicators have been discussed (Dammann, 2004; Malmqvist, 2008a), new tools and methodologies have been presented (Assefa et al., 2007; Shamseldin, 2016), and existing tools have been critiqued (Schweber, 2013). The methods, their criteria, and indicators have incorporated both scientific and practical considerations and have the potential to make environmental impacts and benefits visible according to Dammann and Elle (2006). In reality practical considerations are generally given greater emphasis when balancing environmentally relevant content, systematic and trustworthy assessment procedures and practical considerations (Malmqvist, 2008b).

The various assessment tools can be categorised depending on their form. Fenner and Ryce (2008) distinguish between: Knowledge based tools (manuals and information sources); Performance based tools (life cycle assessment

(LCA), calculation, simulation and optimisation tools) and Building rating tools (design checklists and credit rating calculators, also including certification systems, with a third-party evaluation against a pre-defined set of environmental or sustainability indicators). They all use specific processes, criteria and indicators, to assess and provide guidance for building and urban developments.

In doing that, they aim to: 1) provide guidance for urban development projects on how to work with environmental and sustainability issues in planning and development activities; 2) assess a baseline of current status; 3) assess a building in advance by identifying, predicting and evaluating significant environmental changes resulting from a proposed activity and 4) identify progress and promote desirable behaviour. Moreover, they have become voluntary market drivers, with the potential to benchmark and market urban development projects as 'environmental', 'green' or 'sustainable', and companies spend a great deal of money on certification fees (Fuerst & McAllister, 2011; Miller et al., 2010). The tools may simplify the process of setting environmental goals, help with procurement and create a common set of environmental aspects to work with and collaborate around (Brown et al., 2015). Therefore it becomes important that the assessments are relevant, reliable and not subjective. If the environmental aspects included in the evaluation are not relevant and lead to a decrease in environmental impact, the marketed effect can be questioned.
Compared to many other products, buildings are difficult to evaluate because of the following reasons: they are large in scale, complex in materials and function and temporally dynamic due to the limited service life of building components and changing user requirements (Asdrubali et al., 2013). Moreover, their production processes are much less standardised than most manufactured goods because of the unique character of each building (Cabeza et al., 2014). Thus, assessing the broad impacts of policy and technology choices in the built environment can be considered a formidable challenge (Fiksel, 2006) and the high expectations for NBEATs can be hard to achieve, even if many stakeholders have been involved in the process of developing and updating the tools.

The measuring of environmental and sustainability aspects for the built environment has provided explanatory tools which try to translate sustainable development into practical terms (AlWaer et al., 2008). Often a predefined set of criteria and assessable indicators is used. In addition, these criteria and indicators provide quite a precise definition of what 'environmental' architecture is according to the tools. The NBEATs let us know which environmental aspects they consider important. With their criteria they specify what environmental considerations should be included in the architecture; which processes to consider and what design features or technical equipment to use, and what levels of emissions to have as thresholds. In one way their criteria directly or indirectly provide their definition of environmental or 'green' architecture. Directly, specific technical features can be demanded (e.g. laundry drying spaces, bicycle parking, energy-efficient white goods), and the way to do things can be specified (e.g. ventilation system commissioning, democratic planning processes, use of accredited assessors). Indirectly, environmental criteria, benchmarks, and performance targets can push the design in certain directions (e.g. on-site renewable energy, daylight demands). In this sense, NBEATs can provide a sense of direction for decision-makers (e.g. architects, urban planners, developers), policies, regulation systems, and can determine

how successful specific efforts are in meeting sustainable development targets and objectives. It also inspires research, to question and analyse NBEATs, environmental assessment, design and management of architecture in more detail. If a perfect environmental assessment tool existed, it would make it possible to adjust the proposed architecture accordingly and to avoid unnecessary and unexpected environmental consequences.

Every year, the number of certified buildings is increasing (Cidell, 2009; Sweden Green Building Council, 2016b), reflecting that the tools in one way have gained attention and credibility (Eichholtz et al., 2010; Poveda & Lipsett, 2014). Benefits with certified buildings compared to custom building are marketed by the tool developers, and the efficiency of NBEATs, such as BREEAM, has been studied (Aspinal et al., 2012). Their actual effect, however, has been debated (Newsham et al., 2009; Scofield, 2009). Use of environmental assessment tools for buildings and neighbourhoods has been put forward as one driver of sustainable architecture (Ahn et al., 2013), but the environmental effect of the tool is seldom discussed in relation to the ecological limitation of sustainability.

There has been no consensus on how different NBEATs should be compared. The analyses of NBEATs and their content have often been at a general level. A few studies have gone into detail in to what issues and indicators the tools contain, but the tools content has seldom been analysed regarding the connection to and possible effect on architecture. Further research regarding how the tools may influence architecture is therefore required. Moreover, the studies of the implementation and use of NBEATs among different stakeholders has been limited. The importance of implementing environmental aspect into the early design stages has been highlighted (Basbagill et al., 2013; Kohler & Moffatt, 2003; Malmqvist et al., 2011a; Russell-Smith et al., 2015) and others have put forward architects and urban planners as key actors in this decision-making process in the early design phases (Chen et al., 2008; Elforgani & Rahmat, 2010). The use, knowledge, or the possible effect the tools may have for architects and urban planners has only been investigated to a limited extent.

## 1.7. Scope

Even though the environmental impacts from architecture are real, there is an interpretative flexibility attached to it; meaning that the concept of an architecture that is more environmental is at the same time a social construct (Guy & Farmer, 2000). Guy and Farmer recognise that to understand 'green' buildings' (including 'environmental' architecture), more fully, we have to consider '*the social structuring of both the identification of the environmental problems, and their resulting embodiment in built forms*.' Moreover, they highlight that there exist widely different perceptions of what environmental innovation is among different individuals, groups and institutions. In this thesis, NBEATs are regarded as a socially constructed link between the environment, architecture, and architects (Figure 1). When it assesses the architecture's environmental impacts, and when it demands certain criteria, or generates environmental information, that influences the architecture, it is a link between the architecture (involving buildings and neighbourhoods) and its impact on the environment.

When the NBEATs function as a tool for decision-making, it works as a constructed link between the architects and the architecture, and between the architect and the environment. This is because; it highlights, describes, and filters environmental and architectural information to the architects (the decision-makers). Therefore, NBEATs criteria, may influence architects' processes and design outcomes.

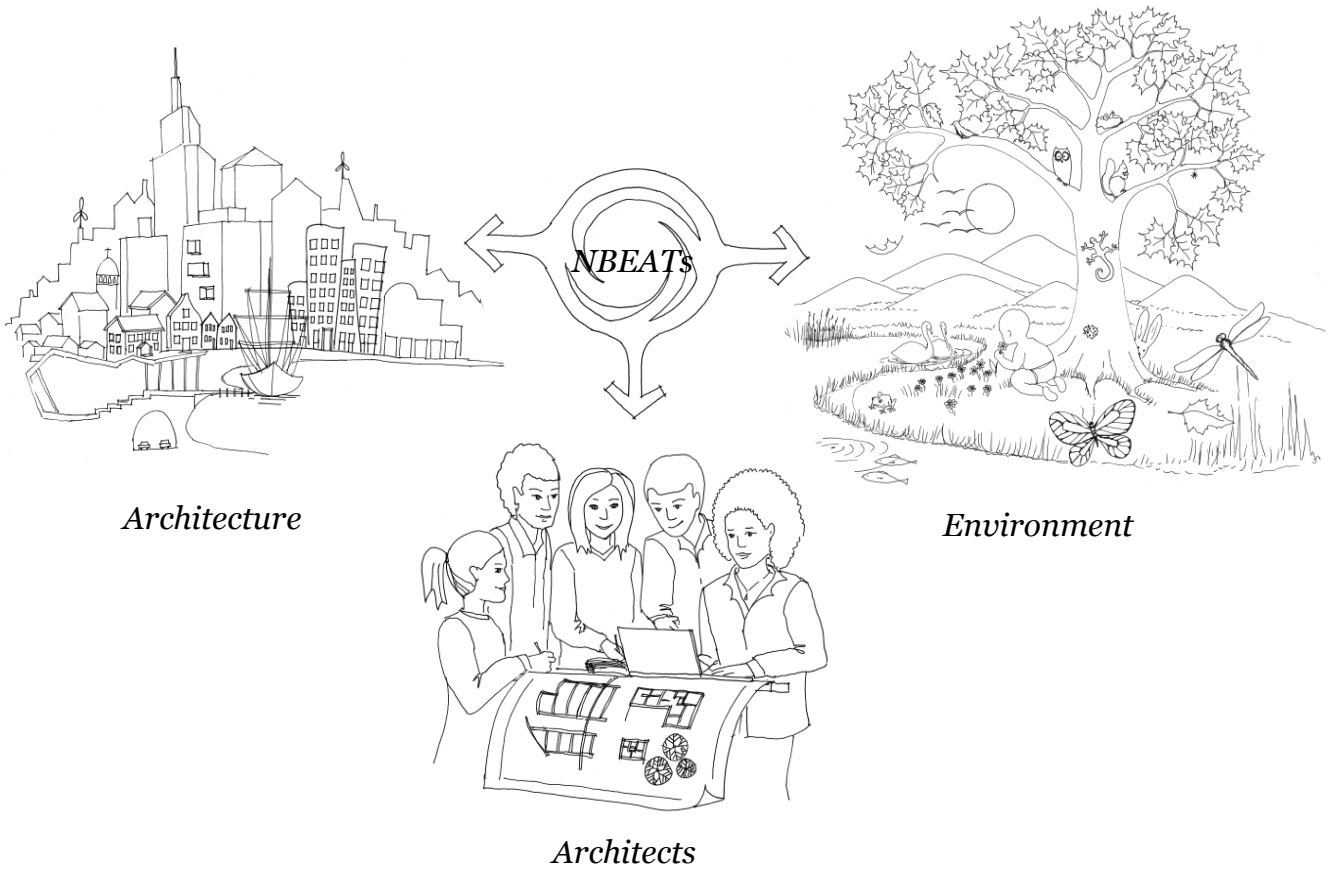


***Figure 1.*** *Environmental assessment tools for buildings and neighbourhoods function as a socially constructed link between the environment, architecture and architects.*

Together, NBEATs incorporate a broad architectural perspective, which encompasses the building and its connected systems and features, and the surrounding neighbourhood, including the site, infrastructure, transportations system, and the natural environment. However, this is not on a city scale or a regional level.

The broad scope of this thesis concern NBEATs, environmental issues, architecture, but also includes architectural design and professional decision-makers, who make many of the decisions in planning and design projects. Thus, the perspective has been widened from the licentiate thesis (Wallhagen, 2010) where predominantly building environmental assessment tools were studied. Here mainly six NBEATs have been studied, which are presented in the next chapter.

## 1.8. The analysed Environmental Assessment Tools

The backgrounds of the NBEATs analysed and tested in case studies in this thesis are briefly presented here, starting with the building tools and followed by the neighbourhood tools. For more information regarding tool content, see Appendix A-F.

***LEED-NC v3, Leadership in Energy and Environmental Design for New Construction and Major Renovations, version 3***

LEED-NC is a criteria-based tool and building certification system, which provides third-party verification that strategies aimed at improving the environmental performance across a number of measurables are met when the building is designed and built. The tool is the most used one in the world and has been exported to several countries (United States Green Building Council, 2008).

***CSH, Code for Sustainable Homes***

CSH is the national standard for the sustainable design and construction of new homes in the UK. The Code aims to reduce carbon emissions and create more sustainable homes. It measures and communicates the sustainability performance of a new home against categories of sustainable design with minimum standards for energy and water use at each level. It is criteria-based but includes the use of LCA for evaluating materials (Planning Portal, 2010).

***EcoEffect***

EcoEffect is an assessment tool based on both criteria and LCA analysis. It assesses energy use, material use, and indoor and outdoor environment. The magnitude of the environmental impact in different environmental categories is calculated and the building assessed on the basis of that information. The tool has been used for academic purposes and some of its content and ideas have been passed on to the Swedish environmental assessment tool Miljöbyggnad (Malmqvist et al., 2011b; Sweden Green Building Council, 2016a) and the ENSLIC-tool (Assefa et al., 2010; Assefa et al., 2007; Glaumann, 1999, 2016; Glaumann et al., 1999).

***ENSLIC-tool, Energy Saving through Promotion of Life Cycle Assessment in Buildings-Tool***

The ENSLIC-tool is a basic LCA tool developed by Mauritz Glaumann in the European Union project ENSLIC. It is meant to be used for quick feedback in early design phases. The tool can be used for performing simplified LCA calculations based on data about use of building materials and energy. The programme calculates related environmental impacts, carbon dioxide equivalent ($CO_2$eq) emissions and rough estimates of annual energy use. It can also test a number of building improvements and their potential environmental impact. The tool has continued to be developed into the tool BECE (Basic Energy and Climate Estimations for Buildings) (Intelligent Energy Europe, 2009; Malmqvist et al., 2011a) and BECEREN tool for renovation (Olsson et al., 2016).

LCA used in the ENSLIC-tool is a methodology for evaluating the environmental load of products and process (goods and services) during their life cycle from cradle to grave (or cradle to cradle) (Hauschild, 2005; Ortiz et al., 2009; Reap et al., 2008). A number of International standards regarding principles, framework, requirements and guidelines (ISO 14040-44) have been developed by the International Standard Organisation (ISO) (Klöpffer, 2012) and standards for calculating environmental impacts from buildings (EN-15978) (CEN/TC 350, 2011).

### *LEED-ND v4, Leadership in Energy and Environmental Design for Neighbourhood Development, version 4*

LEED-ND is the scheme for assessing the environmental performance of neighbourhoods and larger districts. It has been jointly developed by the U.S. Green Building Council, Natural Resources Defence Council, and the Congress for the New Urbanism, and is administered by the U.S. Green Building Council. Included in the tool are key aspects and concepts regarding where to build, what to build and how to manage environmental impacts, that can provide guidance when working with neighbourhoods and communities. (Welch et al., 2010). LEED-ND has been engineered to inspire and help create better, more sustainable, well-connected neighbourhoods and consider entire communities (United States Green Building Council, 2016). Both environmental and community criteria is included in the tool (United States Green Building Council, 2014).

BREEAM®

### *BREEAM-C, Building Research Establishment Assessment Method for Communities*

BREEAM Communities is a third-party assessment certification standard that is based on the established BREEAM methodology (Sharifi & Murayama, 2013). It is designed to provide a framework to support planners and local authorities, developers and investors to measure and certify the sustainability of large-scale development plans through the master-planning process (BRE, 2016). It was developed by BRE Global (the Building Research Establishment Ltd. Global) in 2009 to support planners and developers take account of the full range of issues that must be considered from the earliest stages of the development process. It is designed to measure and independently certify the sustainability of project proposals at the planning stage of the development process (BRE, 2012; BRE Global, 2011).

# 2. AIMS

The purpose of this thesis is to contribute to a deeper understanding of environmental assessment tools for buildings and neighbourhoods, their use and their possible impacts. More specifically, the aim has been to gain knowledge about the studied NBEATs in relation to: architecture, architects, and ultimately the potential effects on the environment and human wellbeing. To achieve this, the research investigates three of the environmental assessment tools main functions:

- Their function as an assessment tool that evaluates the real and potential, local and global environmental impacts from buildings and neighbourhoods. (Papers I, II, III, and IV).
- Their function as a tool connected to the operationalising and physical design of architecture (Papers I, II, III, and IV).
- Their function as a decision support tool that influences and guides architects towards decisions that are environmentally sustainable (Papers V and I, II, III, and IV).

To summarise, the NBEATs' relation to the *Environment*, *Architecture* and *Architects* is investigated. By studying in detail the numerous ways the tools measure the environmental aspects of buildings and neighbourhoods, information is gained about both the strengths and limitations, and the possibilities of the tools. Such knowledge is useful for the continual improvement and development of environmental assessment tools, and how they can influence architecture, architects and the work connected to environmental sustainability, sustainable development and environmental protection. In addition, the study can contribute to increased understanding about how assessment tools should be designed. First, to ensure that architecture is designed to minimise impact on nature and maximize human wellbeing during its whole life cycle, and, second, to help architects and other professionals involved in the building process to make informed decisions for a more environmentally sustainable society.

The studies in Papers I-V contribute to the aims of the thesis in different ways (Table 1) but also have their own objectives. The specific objectives for each Paper are described below.

### *Developing a framework to compare tools (Paper I)*

In Paper I the main objective is to develop a framework for examining environmental assessment tools for buildings and neighbourhoods on a detailed level in a way that could be applicable for analysis of other tools. The framework then forms the basis for further analysis and discussion of tool content, tool structure and tool development in the three selected tools for environmental assessment of buildings: LEED-NC, CSH, and EcoEffect.

### *Influence on assessment result and design (Paper II)*

The study in Paper II examines how the differences between assessment tools, as reported in Paper I, can influence the assessment results, and the design of architecture, improvement measures, and technical solutions in a residential building project.

### *Life cycle calculation tools as decision support (Paper III)*

The objective of Paper III is to test an interactive basic life cycle calculation tool, the ENSLIC-tool, as decision support; examine how various building improvements can reduce greenhouse gas emissions ($CO_2$eq) from an office building's material production and energy use; examine which improvements are advocated; and estimate the relative importance of different improvements related to *material production* and *energy use* for an office building in Sweden. The ENSLIC-tool is an interactive assessment tool without defined criteria and rating levels, which is designed to be used as LCA-decision support in early design phases.

### *Analyse and discuss certification systems for neighbourhoods (Paper IV)*

In Paper IV the objective is to analyse and discuss two environmental assessment tools for neighbourhoods (BREEAM-C and LEED-ND) and their detailed content, structure and type of indicators in relation to how sustainable development is defined. The following was studied: what limitations and biases in the tools can be identified regarding the sustainability issues included; if these certification systems focus on the procedures of the development process, on certain features or on the actual performance of urban development projects; and to what extent the certification process can be expected to lead to more sustainable outcomes, based on the design of these systems.

### *Knowledge and use of NBEATs among professionals (Paper V)*

The objective of the study in Paper V is to investigate knowledge and use of NBEATs among professionals involved in design and planning in the architectural competition *A New City Centre for Kiruna*, which represents an early design phase. Further, the potential connection between using NBEATs and self-rating of environmental knowledge, the inclusion of environmental aspects in the competition programme, and environmental importance is investigated. Aspects that the participants believed could have improved the competition proposals from an environmental point of view are also examined.

***Table 1.*** *The articles and their contribution to the thesis and how they relate to Environment, Architecture, and Architects.*

| Paper | Contribution to the main thesis | Relation to: Environment Architecture Architects |
|---|---|---|
| **Paper I** | Knowledge about BEATs different content, structure, scope and parameters. | Environment<br>Architecture<br>Architects* |
| **Paper II** | Differences between BEATs and their influence on architectural design. | Environment<br>Architecture<br>Architects* |
| **Paper III** | Test of simplified assessment tool and knowledge of the environmental impacts from buildings and building improvements. | Environment<br>Architecture<br>Architects* |
| **Paper IV** | Knowledge about NBEATs different content, structure, types of indicators, their simplicity and their validity in measuring sustainability. | Environment<br>Architecture<br>Architects* |
| **Paper V** | Information about professionals self-rated use of NBEATs in early design phases and their knowledge about environmental aspects. | Architects<br>Architecture<br>Environment** |

** The papers cover which procedures are effected by the tools and therefore indirectly involve architects.*
*** This paper relates to knowledge about environmental aspects and only indirect effects on the environment.*

# 3. METHODS

## 3.1. Scientific context

In this cover essay investigations are undertaken by critically examining the knowledge gained from the results in the studies made in Papers I-V of NBEATs and their use, and the content of the studied environmental assessment tools manuals. This is followed by further discussion on how these results relate to the environmental aspects, architecture, and architects.

The studies and the tools themselves belong within several different research fields. All five studies fit into the framework of *Environmental Strategic Analysis,* are a form of *architectural research,* and belong to the field of *technological science,* which is further explained below. The tools have been developed by using knowledge from environmental and health sciences, and decision methods, and concern our built environment. The survey in Paper V touches upon environmental psychology and behavioural research and uses statistical methods to analyse the data. Common to all five studies is that they are mainly *empirically based*, studying existing documents, buildings and professionals, using case study methodology, surveys, comparisons, and structured analysis.

### *Research in Planning and Decision Analysis, and Environmental Strategic Analysis*

The thesis is carried out in the doctoral programme Planning and Decision Analysis with a specialisation in Environmental Strategic Analysis. Here research is included that aims to improve and critically examine the basis for planning and decisions focusing on strategic environmental problems, i.e. environmental problems that are important (globally, for a country, for a sector, for a company or an agency) and require long-term solutions. Research examples in this field investigate: how sustainable development can be achieved, how environmental impacts from products, services or other systems can be measured, or how environmental assessment tools can be developed. It also includes carrying out environmental impacts assessments with different methods, for example by using LCA. Further, the aim is to develop solutions, knowledge and debate concerning strategic environmental problems (Environmental Strategies Research, 2016). The research in the five Papers examines environmental assessment tools and their use in decision-making. Therefore, the research is a type of Environmental Strategic Analysis research, which interconnects environmental, technological, and societal issues.

Furthermore, the assessment tools studied are problem-orientated, with the aim of being functional tools to assist in the process of solving problems (i.e. decrease the environmental impacts from buildings). Studying man-made objects and their design is one of the characteristics of technological sciences (Hansson, 2007). The studies in Papers I-IV correspond well with the characteristics of technological science (Wallhagen, 2010) where man-made objects and the practice of engineering design is studied; less far-reaching idealisations than those of natural sciences are employed and approximations are used.

### *Architectural research and architectural design research*

Architectural research is research in, or about, architecture or architects. It covers research focused on both the physical outcome of the design, the process of design and the practice of architectural firms (Groat & Wang, 2002). As well as being connected with art and building research, de Jong and Van der Voordt (2002) bring together architectural research with research in the area of urban and technical design.

Therefore, this thesis can also be considered architectural research, because it explores: the environmental aspects of architecture addressed by NBEATs, the possible effects on the architecture, and the connection to the architects and their design processes. The studies in Papers I and IV are about the content of assessment tools which, if used, may influence the process of design, the practice and the final outcome. The case studies in Papers II and III involve assessment tools, and can also be considered architectural design research, as they are studies of architectural projects. The results reveal the environmental impacts that can be caused by current conventional architectural design, but they also identify possible building improvements to decrease these impacts. Paper V studies architects and other professionals behind architecture and can likewise be considered as architectural research.

### *Interdisciplinary research*

The research conducted and methodologies used, have a theoretical base in several research fields, such as survey methodology or statistical research. The environmental assessment tools' content, criteria, indicators, and ways to aggregate the results are connected to knowledge, data and theory from many disciplines. Therefore, the research can be categorised as holistic and interdisciplinary, meaning that it integrates knowledge and methods from different disciplines. Interdisciplinary research is a form of research that uses multiple disciplinary approaches. It is sometimes used interchangeably with the terms multi-, cross-, and transdisciplinary as they are ambiguously defined. The objectives of multiple disciplinary approaches according to Choi and Pak (2006) are to resolve real-world or complex problems, to provide different perspectives on problems, to create comprehensive research questions, to develop consensus, definitions, guidelines, and provide comprehensive services.

This research combines knowledge from many disciplines and transgresses traditional boundaries between academic disciplines. This is typical of architectural research, which often is interdisciplinary in the sense that it encompasses and engages with many different disciplines, and harnesses strategies and tactics from other disciplines to achieve its end, which is to gain knowledge about how built environments could enhance human life (Wang et al., 2002).

This type of research can also be called an issue driven interdisciplinary research, which also holds for other research in the field of sustainability or sustainable development, being inherently complex, multi-faceted and problem based, and focused on multiple 'knowledge realms' (Robinson, 2008).

### *Empirically based case study research*

The five studies are empirically based — the tools manuals are analysed, the architectural projects (including the physical buildings and building processes) are assessed, and professionals (including architects, landscape architects, urban planners and other urban designers) are surveyed. Then based on the results, NBEATs' relation to the environment, architecture and architects is discussed. Moreover, all the Papers can be considered case studies. 'A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context…' (Yin, 2003, p.13). The case study approach is sometimes criticised because there is little basis for generalising from one case to another. However, its strength is its capacity to go from analytical generalisation to theory, by comparing the results of a case study to a previously developed theory, which in turn can be tested through other experiments. The theory grounded in one single case can therefore become the vehicle for examining other cases (Yin, 2003).

The method of reasoning used in the thesis is mainly induction. Specific observations and measures of empirical data are studied to detect patterns, regularities and irregularities that provide the basis for construction of frameworks, discussion and to formulate conclusions. Inductive reasoning is essentially exploratory. Abductive reasoning is also used when inductive and deductive methods are combined to create frameworks, surveys, and research questions.

## 3.2. Research methods used in the Papers

In the studies, different methods have been used to gain more knowledge about environmental assessment tools, their difference, the possible impact from using them, how they can be compared, and more information about the use and knowledge about the tools and the environmental aspects they contain. The five Papers examine environmental assessment tools and their use; they include the framework for analysing assessment tools in Paper I, the test of assessment tools in Paper II, the test of an LCA-tool in Paper III, the analysis of assessment tools for neighbourhoods in Paper IV, and the survey among potential and actual tool users in Paper V. The used methods include structured analysis, comparison, development of framework, test of assessment tools, simplified LCA, questionnaire, and statistical data analysis (Table 2). More details are given in the appended Papers.

### *Structured analysis and comparison (Papers I and IV)*

Paper I is based on a combination of the development of a framework by using structured analysis and comparing three assessment tools: LEED-NC v3, Code for Sustainable Homes, and EcoEffect. The comparison exemplifies how information regarding the content, structure and weighting method of the tools can be analysed when comparing other tools in a similar way.

Tool documents, especially the manuals, are studied, and NBEATs' content is structured into: Assessment Object, Assessment Tool, and Assessed Environmental Impacts. Their content (defined as categories, issues, assessment criteria, and parameters) are compared separately, and the weighting and aggregation used in the tools are studied.

An important part of the analysis is an illustration of the hierarchical structure of the tools. These are inspired by rich picture diagrams (Sutrisna & Barrett, 2007), which visually presents the often complex, uncertain and dynamic process of an architectural project (Nguyen et al., 2004). By making a hierarchical diagram of the tools' structures, it becomes possible to grasp the richness of their structure all at once (Figure 4). This gives an overview and is a basis for further analysis and understanding of the tools. Different types of issues/indicators are further defined: performance, procedures and features. Parts of this developed framework are also the basis for the analysis of BREEAM-C and LEED-ND in Paper IV.

***Table 2.*** *Research methods used in the Papers.*

| Paper | Methods |
|---|---|
| **Paper I** | Structured analysis<br>Comparison<br>Development of framework |
| **Paper II** | Case study<br>Structured analysis<br>Test of assessment tools |
| **Paper III** | Case study<br>Test of assessment tool<br>Simplified LCA |
| **Paper IV** | Structured analysis |
| **Paper V** | Questionnaire<br>Case study<br>Data analysis/Statistical data analysis |

In Paper IV, two tools for sustainable assessment of neighbourhoods, BREEAM-C and LEED-ND manuals, are studied through structured analysis aiming to organise, quantify and visualise the tools' contents to give an overview, make a comparison, and discuss if they may lead to sustainable neighbourhoods. The tools' contents and structures are compared, focusing on two methodological considerations for assessment tools – simplicity and validity. The material is analysed in both a qualitative and a quantitative way. The number of, and types of, indicators (procedures, features and performance) that are used, and their limitations regarding sustainability are identified and discussed.

### *Case study (Papers II, III, and V)*

In Papers II, III and V, a case study methodology is used to analyse differences and compare tools. The tools analysed in Paper I (LEED-NC, CSH, and EcoEffect) are used to assess an architectural project in Paper II. The project is a product-based industrialised eight storey multi-family house in Stockholm, Sweden, developed by SKANSKA (Figure 2).

Differences between test results and the improvements the tools demand to receive higher results are examined. Based on information from drawings, specification documents and through interviews with the SKANSKA project manager and environmental consultant assessment results were calculated and

estimated. The comparative analysis of the results also includes rearrangement of the indicators into common categories. Differences between the tools are identified and their potential influences on future sustainable architectural projects discussed.

Paper III, is a case study of a four storey office building in Gävle (Figure 3) and study how an assessment tool can propose possible building improvements. The $CO_2$eq emissions from the production of building materials and energy use during the occupancy phase are studied by using a basic life cycle calculation tool, the ENSLIC-tool (Malmqvist et al., 2011a). This tool contains data regarding $CO_2$eq emissions from a number of materials and energy sources, and a set of predefined options for building improvement measures. The reductions in $CO_2$eq in a 50-year life cycle perspective is retrieved by inserting data from: drawings, specifications, and energy calculations performed with Enorm (Byggtjänst, 1996), into an Excel program and then testing a number of relevant building changes and changes in energy sources.

***Figure 2.*** *Left, the residential building Grönskär in Stockholm, Sweden.*
***Figure 3.*** *Right, the office building in Gävle, Sweden.*

### *Case study and Survey with questionnaire (Paper V)*

Paper V is an observational cross-sectional survey with a questionnaire (Appendix B in Paper V) distributed to professionals involved as competitors or jury group in the international architectural competition *A New City Centre for Kiruna* (Appendix A in Paper V). It is retrospective and measures their self-rated opinions about use and knowledge of environmental aspects and NBEATs in the competition. Analyses of frequencies, means and percentages are used to describe data and statistical analyses using SPSS (Statistical Package for the Social Sciences) version 22 are made for making t-test, Fisher's exact test, Pearson's chi-squared test, Cramers V, and correlation analysis. Some of the questions were developed based on theories regarding pro-environmental behaviour in psychology and environmental psychology.

# 4. RESULTS

Different tools relate differently to the environment, the architectural design, and tool-users. They can promote different measures, by demanding different procedures, features, or performances. The implemented measures will influence architects, their designed architecture, and eventually have an impact on the local and/or global environment. The results from Papers I-V which have a relation to the three interlinked subjects: the environment, the architecture, and the architects, will be presented in this section.

These subjects are specified as the:

- **Environment:** local and global, present and future environment, including environmental aspects effecting humans and the geobiosphere.
- **Architecture:** the built environment including physical buildings, the surrounding modified environment and the integrated and connected systems. The influence can be on the general design (i.e. design principles, processes, technology, concepts, and the making or production of artefacts), architectural and urban design that is recognisable with the senses, or as an influence on external, off-site, distant design and technology.
- **Architects:** including architects, landscape architects, urban planners and urban designers that the tools affect either by influencing their work tasks, individual psychological factors, or work processes, such as: the design processes, construction, management, refurbishment, reuse, and destruction processes.

## 4.1. Results related to the Environment

Results concerning properties of NBEATs that relate to real and potential environmental impacts from buildings and neighbourhoods will be presented in this chapter. The framework for comparison of tools presented in Paper I show some aspects to consider in a systematic comparison of NBEATs. Important aspects can be information regarding both details and the tools as a whole, including the content, structure, aggregation and scope. Differences in any of these can influence assessments and the relation to environmental aspects.

### 4.1.1. Visualising the structure (Papers I and IV)

NBEATs are complex and therefore it is valuable to acquire an overview. One way to understand them better and how they assess the environmental performance of buildings and neighbourhoods is to create a hierarchical diagram with the structure, content and aggregation of the tools (Figure 4).

The structures of NBEATs vary. They can have a different number of hierarchical levels, weighting, categories, indicators, credits, and labels. LEED has a flatter hierarchy with the weighting of issues integrated in the number of credits given to each issue. EcoEffect also includes normalisation, and concludes with two final results related to architectural quality and environmental loads respectively. Having two final results makes it clearer which issues in the system the final result comes from and the sometimes conflicting goals between internal quality (indoor and site specific) and external environmental loads aspects becomes apparent. In the other tools, all the credits have been aggregated into one single, final result, which is easier to use from a marketing perspective.

Differences in the studied NBEATs are located on all hierarchical levels (final result-, category-, issue-, and point-level) in the tool structure and the methodology for scoring and weighting differs between all five – LEED-NC, CSH, EcoEffect, LEED-ND and BREEAM-C.

### 4.1.2. Assessed environmental aspects (Papers I, II, and IV)

The following comparison involves deconstructing the tool components into smaller parts (final result, categories, issues, parameters, weights), and comparing them separately. In the studied building environmental assessment tools (BEATs) there were both common and unique environmental categories. Energy & Pollution, Material & Waste and Indoor Environment were common and the unique categories were: Water, Design & Innovation, Sustainable Site and Regional Priority (in LEED-NC); Water, Management and Ecology (in CSH); and Site Assessment and calculation of Life Cycle Costs (LCC) (in EcoEffect).

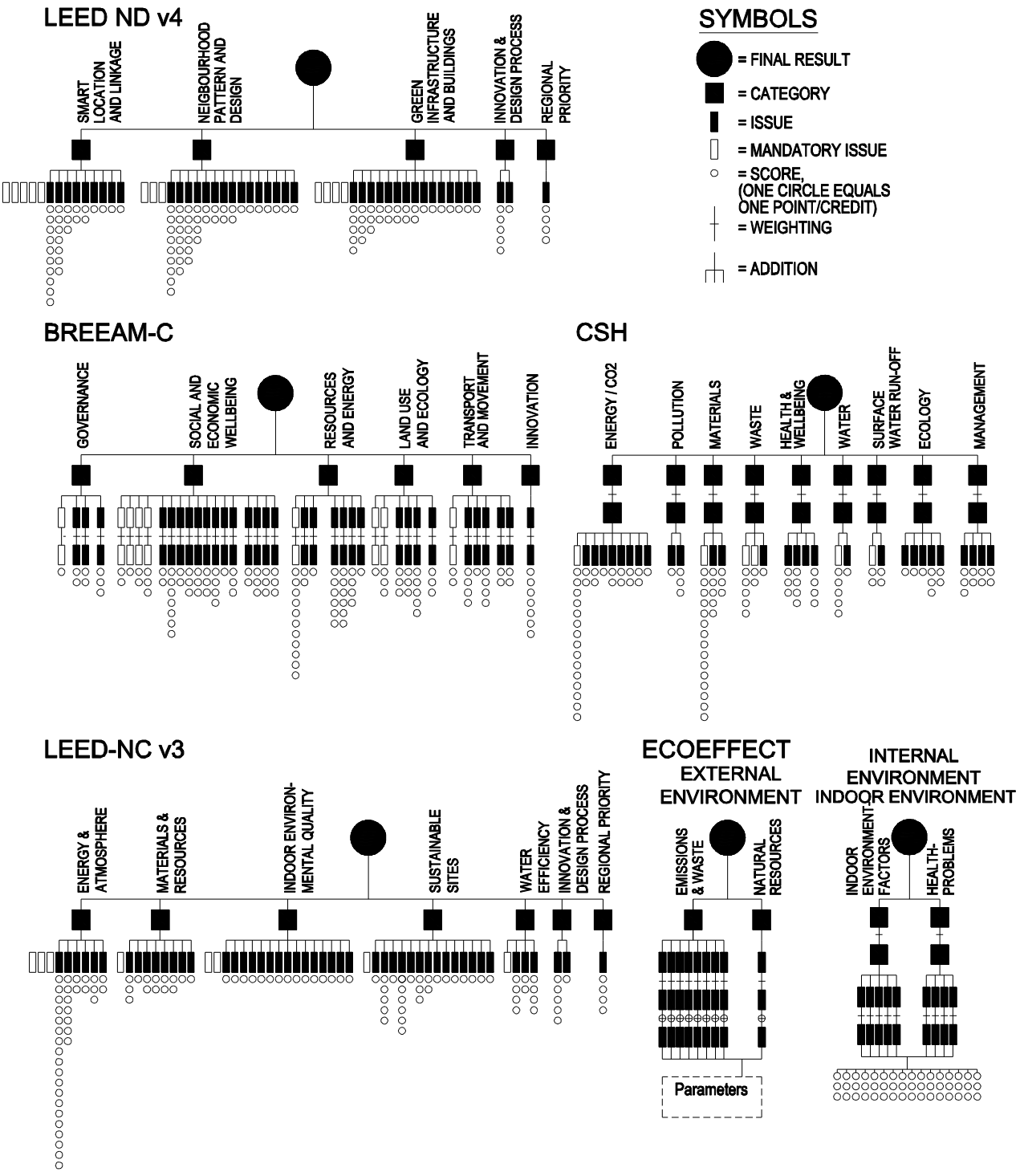


***Figure 4.*** *Hierarchical diagrams illustrating how LEED-NC, CSH, EcoEffect, BREEAM-C and LEED-ND aggregate the large number of building environmental issues addressed into one, two or three final results though a structured hierarchy, containing: final results, categories, issues, points, parameters, weighting and aggregation. In EcoEffect under External environment, each issue can contain a number of parameters, which are not included in the diagram. The Outdoor Environment category in EcoEffect is not presented (Paper I and IV).*

In LEED-ND and BREEAM-C the names of the tool-categories varied, but when reorganising the issues into common framework categories, most tools contained the environmental categories energy, material & waste, site & ecology, water, and transport.

The similarity is lesser than the diagrams in Figure 4 indicate because the issues and parameters under each category vary between tools. As an example, energy use during the building operation phase is indirectly measured in all three tools, but the focus varies from decreasing energy costs (LEED-NC) to decreasing $CO_2$ emissions (CSH) or decreasing environmental impact from a number of different impact categories (EcoEffect).

Another example is that for a certain issue there can be a cluster of indicators, and some indicators contain a cluster of sub-indicators (e.g. LEED-ND, Certified green buildings GIB C1.). Moreover, under some issues and indicators 'nested indicators' are found. The tools, for example, can refer to ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) standards, or another system or tool that is needed in order to measure the indicator.

In order to measure environmental impact, it is not always the environmental impact itself that is measured. Instead, indicators are used for indicating the environmental impacts. The studies in Papers I, II and IV identify differences in what the indicators (in Paper I also called *issues)* assess and they distinguish three different types of *indicators*:

• **Procedures** – Specific procedures, activities or processes are assessed (e.g. commissioning of a ventilation system (LEED-NC C3), use of an accredited assessor (LEED-NC ID C2), delivering a home user guide (CSH), making a consultation plan, using consultation to engage members of the community (e.g. BREEAM-C, GO 01), a flood risk assessment (e.g. BREEAM-C, SE03) or a noise impact assessment (e.g. BREEAM-C, SE04).

• **Features** – Specific physical or social measures, solutions or equipment are assessed, e.g. technical solutions or specific equipment such as laundry drying spaces, bicycle parking, high efficiency lighting or specific lighting device requirements (LEED-NC, GIB C17 Light pollution reduction), or specific project procedures that measure social features that will exist in the built environment, e.g. the distance to public transport hubs (LEED-ND, SLL P1) and provision of cycle storage (BREEAM-C, TM05), or social features coming into play after the development work has finished, e.g. establishing funding schemes, subsidies, and training initiatives (BREEAM-C, SE17), or subsidised public transport services (BREEAM-C, TM01).

• **Performance** – Results and performance of technical solutions or designs are assessed, measuring how well the development area actually performs in terms of environmental and social pressure or impacts (e.g. lowered energy requirement, lowered $CO_2$eq emissions). Performance indicators also include requirements on and commitments to achieving a certain level of performance such as ambient noise levels in buildings (BREEAM SE 04) or on-site renewable energy sources (LEED-ND GIB C11).

Performance issues are used in all three tools. Features and procedures are mainly found in LEED-NC and CSH, while EcoEffect concentrates more on performance issues (Table 2 in Paper I). In the tools for neighbourhoods, LEED-NC focuses on features and BREEAM-C contains more procedure indicators (Figure 6 in Paper IV). For building tools the procedures assessed in the design and building process are particularly those relating to the design, construction and management phases. Neighbourhood tools mainly include procedures connected to the programming and early planning phase. Some issues are assessed by using a combination of feature, procedure and performance indicators. One example is the issue Water Strategy (RE03) in BREEAM-C. It includes a consumption target in relation to local water availability (performance indicator); the development of a strategy for water management (procedure), and last, the implementation of specific landscape design features for reduced water demand (feature).

### 4.1.3. Aggregation and weighting (Papers I, II, and IV)

The tools use a procedure called aggregation to aggregate results from many different issues and indicators into one, two or three final results. For example, when aggregating indoor environmental issues and energy issues into one result, it is common to use a point or credit system (e.g. LEED, BREEAM). EcoEffect has a different method for the external environmental aspects where the environmental emissions are normalised, and the measured emissions are expressed as a percentage/ relative number of the national or global emission of that substance.

Apart from aggregation, NBEATs often use some kind of weighting, either direct (with a weighting number awarded to specific issues) or indirect (through a different amount of credits/points given to issues). Weighting is used to give different degrees of emphasis to categories and issues. For the building tools the main emphasis is on the categories connected to Energy & Pollution (Papers I and II). Approximately one-third of the scores available in LEED-NC and CSH are located in this field (Figure 5). For the neighbourhood tools the relocated weighted credits give the highest scores to Local Economy & Vitality, Transport and Other. The environmental issues are weighted higher than the social and economic ones. The final result is based on a full score when all the issues have been included. For certification most issues are tradable and less than half of the criteria need to be reached.

It is difficult to compare the weighting in the building tools with the weighting in the neighbourhood tools as more social and economic aspects are included in the latter. For instance, if only comparing the weighting within the environmental categories, water is given higher priority in LEED-ND and Ecology & Biodiversity is given higher priority in BREEAM-C. Energy issues are not weighted high in neighbourhood tools according to the figures, but energy connected to transport is hidden in the transport category, and energy issues that are embedded in issues of assessing and certifying the buildings are included in the category ‘Other’.

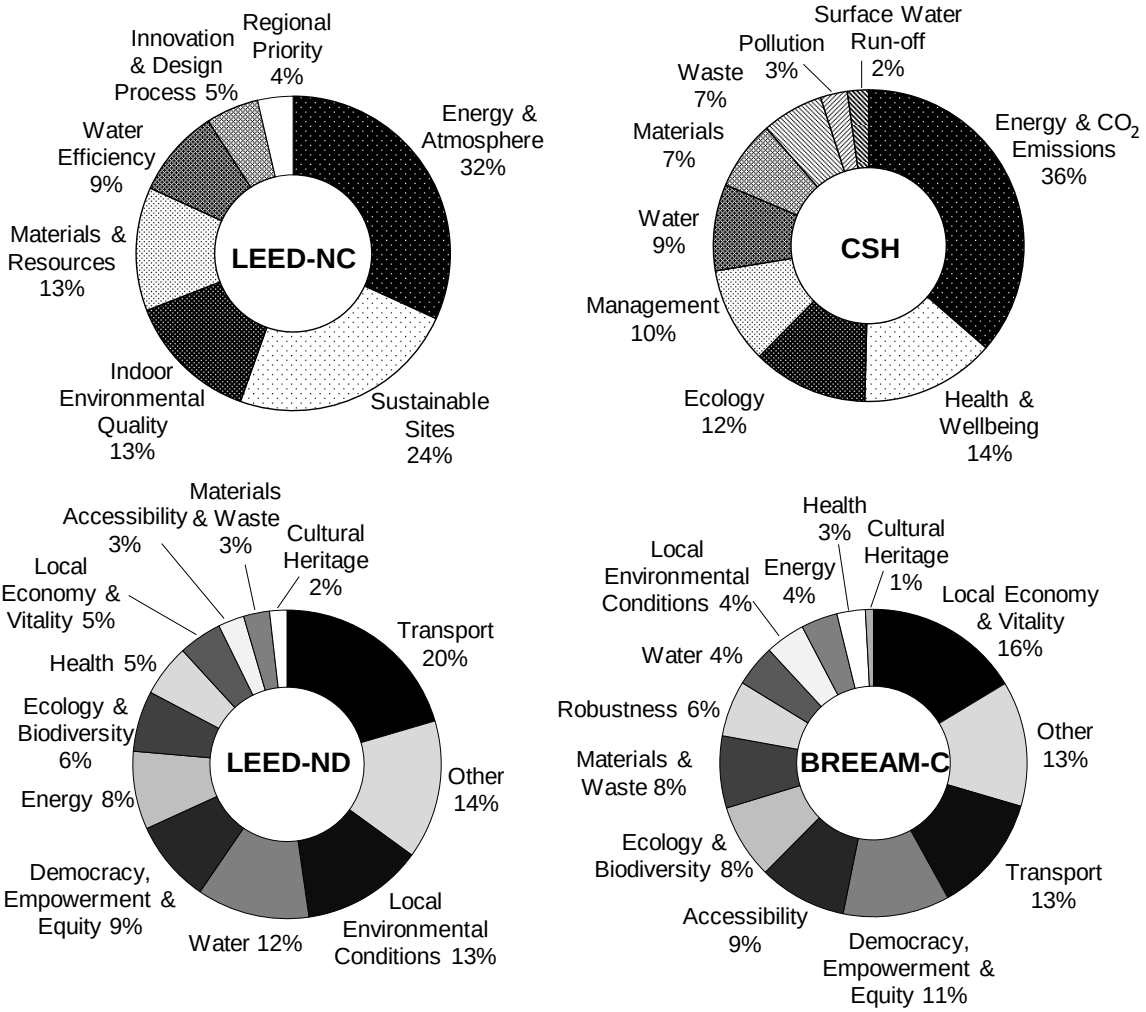


***Figure 5.*** *Distribution and relative importance (%) in relation to total score of weighted credits among categories in the building tools LEED-NC v3 and CSH (Paper I) and the neighbourhood tools LEED-ND and BREEAM-C (Paper IV).*

### 4.1.4. Scope – assessed object and environmental considerations

By studying the content of the tools and their indicators, it becomes clearer what parts of an architectural project are assessed. Thus, the assessment object can be defined. This influences the assessment as it can influence the result, just as which assessed environmental aspects are included (section 5.1.2.) can influence the result. For example, it is important to know how areas are defined if energy use per square metre per year is measured. The result can vary depending on whether areas with low temperature, inner walls, and the inside or outside of the walls are included.

The aspects assessed are either parts of the physical building, such as: a) the constructed building, b) the indoor environment, c) the site and its surrounding d) the neighbourhood, e) the environmental impacts; or, the assessed aspect can be part of a process connected to: f) the building, g) the neighbourhood, h) the users, or, i) the design of the project. These assessed aspects, (objects and/or processes), can be specified depending on in what stage of the building's life cycle they occur: at manufacturing, building construction, use and management, refurbishment, or the end-of-life stage; or, in what phase in the project process life cycle they occur: at planning, early design, design, construction, or management stage. The building stages and phases examined by the tools analysed in this thesis assess aspects in: planning, early design, design, manufacturing, construction and use of the building. The end-of-life stage is only indirectly included in the tools.

When a process is assessed, the person performing the process is indirectly included in the assessment. The users of the buildings and neighbourhoods are rarely included in the assessment. Energy calculations include the users' behaviour to some extent, but indicators in the tools do not measure the users' behaviour, procedures or other aspects such as energy use per user, waste amount per user, or material amount per user.

## 4.2. Results connected to Architecture

In the following section, results relating to the connection between environmental assessment tools and architectural and urban design will be presented focusing on how the tools are connected to and may influence architectural design.

### 4.2.1. Environmental criteria for high rating (Paper II)

The tools content, categories, criteria, indicators and weighting influence the total assessment result which reflects how environmental benign the building is. When testing LEED-NC, CSH and EcoEffect on the Grönskär building in Paper II, the project assessed receives a rather low total score with all three tools. In both LEED-NC and CSH, it obtained a similar percentage of total scores 44% (48 points) and 49% (49.4 points) respectively. It is given the label certified in LEED, 2 stars with CSH and with EcoEffect 9.6 ELN (Environmental Load Number) (4 stars) for External Environmental Impact and 3.3 ELN (3 stars) for Internal Environmental Impact, which can be considered a medium to good score. Here the tools show similar results, but study of the category scores, show great variations between the tools. In the same category, the building obtains a high score in one tool and a low score in another. The tools send varying signals regarding the strong and weak environmental properties of the assessed building and what constitutes 'environmental' architecture, by giving high and low scores. Similarly, the tools give the highest and lowest score to Grönskär in different categories, as presented in Table 3. Thus, the tools assess the project differently and/or value different environmental issues differently.

***Table 3.*** *Tool categories in which the Grönskär project receives the highest and lowest scores in relation to maximum scores (LEED-NC and CSH) and in relation to reference building scores (EcoEffect) (data from Table 3, Paper II).*

| NBEAT | Category with the highest score | Category with the lowest score |
|---|---|---|
| **LEED-NC v3** | Indoor Environmental Quality (80%) | Material & Resources (21%) |
| **CSH** | Waste (86%) | Water (17%) |
| **EcoEffect** | Energy Emissions (45% compared with reference building scores) | Material emissions (-8% compared with reference building scores) |

When reorganising the results under a set of common new categories, the variations become clearer (Figure 6). In the category Material & Waste and in Indoor Environment, the variations between the assessment results ranges from almost 80% of maximum scores in LEED-NC to less than 20% in EcoEffect.

The reason behind the variation in tool results is mainly the large variation in the issues, indicators and parameters used. This is apparent when studying the detailed assessment results in the common categories Energy & Pollution, Material & Waste and Indoor Environment (Table 5 in Paper II). The issues are not the same and even the sole common issue in all three tools — Daylight — is assessed with different parameters. Therefore the Grönskär project scores differently with high ones in LEED-NC but not in CSH and EcoEffect.

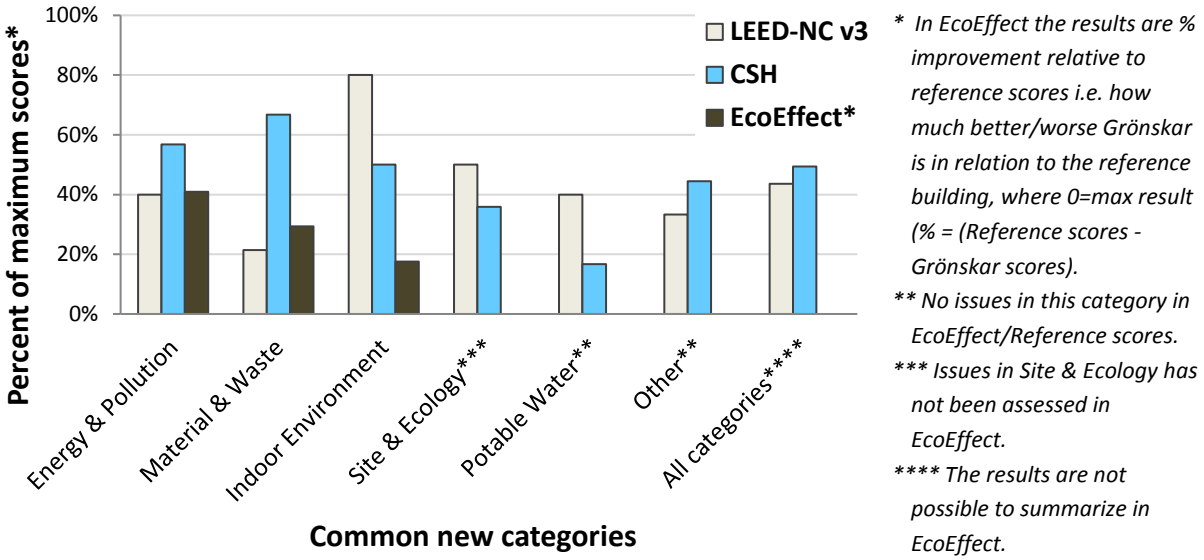


***Figure 6.*** *Assessment results for Grönskär in the tools LEED-NC, CSH and EcoEffect; presented for LEED-NC and CSH as the result in % of the maximum scores available in the tool in the new common categories; and for EcoEffect as the result in % of the scores for a reference building (data from Table 4 in Paper II).*

It is difficult to predict exactly how the different criteria and indicators used in the assessment tools can influence architectural design in general or in a specific building and neighbourhood. Usually the effect on design of a feature (or procedure) indicator is clearer than the effect a performance indicator will have. Predominantly feature indicators will influence the design or the architectural design in the project. The effect of performance indicators is not as clear, for example EcoEffect measures regarding external indicators are not defined in advance. Instead, the size of the reduction in environmental impact is assessed and compared to a reference building. Then the environmental improvement is credited and not the measure itself.

### 4.2.2. Tools for buildings – influence on architectural design

Differences between the tools in the categories Energy & Pollution, Material & Waste and Indoor Environment have been studied (Table 4). The tools criteria reward a number of different improvements. Using that as a basis, potential influences on the architectural design can be discussed. In the case study, Grönskär, it is shown how the tools can guide a project in different directions (Table 6, Paper II). When using the ENSLIC-tool (Paper III) a number of voluntary measures to decrease $CO_2$eq emissions from energy and material use are put forward and tested on an office building, which in turn may steer a project in a certain direction.

#### *Measures regarding Energy & Pollution*

In the Energy & Pollution category, all four tools (LEED-NC, CSH, EcoEffect, and ENSLIC-tool) require several energy-related improvement measures. Indirectly, all tools favour reduced energy use for heating, hot water and operation (e.g. lighting, pumps, ventilation) but the emphasis is on different aspects, Energy Cost (LEED-NC), $CO_2$ emissions (CSH), Environmental Impact (EcoEffect), which may result in different solutions.

One way to achieve higher results in all the tools is by having sufficient thermal insulation. This affects the design and construction of walls, slabs, roof, doors and windows and thus also the architectural design. With the ENSLIC-tool a number of measures are tested and the result shows that each measure gives a limited effect on the buildings total $CO_2$ emissions. Consequently, to decrease emissions substantially, all measures are needed and thus the impact on the design will be greater.

Other measures included in all tools are renewable energy and low carbon energy sources, but only LEED-NC demands on-site renewable energy, such as thermal solar panels, photovoltaic cells or windmills on the building site. These will be visible, influence the architectural and urban design, building orientation and may also influence the building form, for example by affecting the roof angle.

CSH, Ecoeffect and the ENSLIC-tool also highlight the importance of using energy-saving technical appliances (feature indicators) in addition to lighting which is included in all tools. These features will probably be easy to see as well. Other specific features that influence the architectural design are low-tech building facilities such as spaces for drying laundry (CSH) and storing bicycles (LEED-NC includes bicycle storage, under the category Sustainable Site), which may influence the design of floor plans.

By using systems for heating and ventilation with high efficiency and/or systems with heat recovery from air and/or water reduction in energy cost (LEED-NC), $NO_x$ emissions (CSH) and savings on environmental impact via energy use (CSH, EcoEffect and ENLIC) can be made. As these systems are integrated within the building they will most likely influence the building design, and often make visible impacts on the architecture. For example, in the case study office building in Gävle (Paper III) the ventilation system (with an air-to-air heat exchanger) required a raised attic to accommodate all the equipment.

Not only may the specific indicators influence the architectural design. The available technology, the choice of technology and technical appliances and the

criteria levels are also important. For example, the tools criteria referring to energy savings are set at various levels; 46% energy cost improvement (LEED-NC), zero carbon dioxide (CSH), or zero environmental impact (EcoEffect). Achieving a zero carbon dioxide or zero environmental impact will place greater demands on the energy system in the building than the requirement to decrease the energy cost by 46%. This makes it difficult to exactly predict the effect on the architectural design based on these studies.

### *Measures regarding Material & Waste*

In the Material & Waste category, the tools demand different changes for the Grönskär case study, mainly regarding the materials (Table 7, Paper II). LEED-NC credits the use of reused and recycled material, and of rapidly renewable materials (e.g. hemp, straw, bamboo), even if only a limited quantity of the materials are needed to meet the criteria. These features influence the architectural design the most if the materials are exposed. However, recycled or low-emitting material (e.g. steel, aluminium, low Volatile Organic Compounds (VOC) paint) does not always look different, and materials hidden in the construction (e.g. hemp insulation) don't have to influence the architecture design.

Criteria in CSH for instance, demanding larger composting facilities, or the use of responsibly sourced materials may influence design. But when using responsibly sourced wood — for example Forest Stewardship Council (FSC) certified wood — it will be difficult to distinguish it from non-certified wood. However, not all materials are available as responsibly sourced, and exclusion of some materials can have an influence on the architectural design. Responsible sourcing of materials is not considered in LEED-NC and EcoEffect, which can result in the use of different building materials.

Because CSH and EcoEffect demand materials with low environmental impact there are many possible building material combinations that can be made so it is difficult to predict the influence. Still, in these cases the requirements may limit the design choices, which in turn can influence the architectural design. The rating of materials in the *Green Guide to Specification* limits the choices if high ratings are demanded (Anderson & Shiers, 2009).

To define differences in architectural design based on the environmental impacts from materials more exactly, a closer examination of all the materials and constructions in the CSH Green Guide to Specification would be required. The materials in EcoEffect, on the other hand, would need to be tested in the assessment programme or emission data would have to be calculated. Any material changes would in general alter the architectural design, since materials are of great importance for the architectural quality of buildings (Nygaard, 2002; Rönn, 2010). Material innovation such as steel, carbon fibre, or low thermal emissivity glass has sometimes changed the architectural expression of buildings and in that sense driven architectural design forward. Information regarding the materials used would become clearer if a declaration of content was available for all buildings.

***Table 4.*** *Measures included in the assessment tools for buildings, in the environmental categories Energy & Pollution, Material & Waste, and Indoor Environment.*

| NBEAT | Measure included in each category for an improved rating |
|---|---|
| **Energy & Pollution** | |
| **LEED-NC** | Lower energy costs, on-site renewable energy, and green electrical power |
| **CSH** | Low or zero carbon technology, lower dwelling emission rate ($CO_2$), lower $NO_x$ emissions from space heating and hot water, better building fabric, energy-efficient external lighting, energy-labelled white goods, laundry drying space, and bicycle storage |
| **EcoEffect** | Lower environmental impact from energy use such as acidification, nitrification, greenhouse impact, radioactivity, ozone depletion, ozone formation, toxic substances, deposited waste, depletion of natural resources (for example through renewable energy sources, thermal insulation, reduced energy use by low energy technology (lights, white goods, water use appliances), heat recovery, building automatisation) |
| **LCA ENSLIC-tool** | Energy-saving measures: extra insulation in walls, roof, basement/slab, Low U-value in windows, decreasing window area/façade area ratio, waste water heat exchanger, low energy lighting and white goods 20% better, building automatisation, solar cells, $CO_2$-free electricity, and wooden slab |
| **Material & Waste** | |
| **LEED-NC** | Building reuse, material reuse, recycled material 20%, certified wood, regional materials, and rapidly renewable materials |
| **CSH** | Larger waste composting facilities, responsible sourcing of materials, and lower environmental impact of materials according to the Green Guide to Specification |
| **EcoEffect** | Lower environmental impact from materials (using less material/$m^2$ and/or materials with lower impact (e.g. renewable materials by replacing polystyrene insulation with 'eco-fibre' (wood, linen or hemp) and/or reused or recycled material). |
| **LCA ENSLIC-tool** | Using materials which create low $CO_2$eq emissions during extraction, production, and maintenance |
| **Indoor environment** | |
| **LEED-NC** | Low emitting materials (adhesives, sealants, paints and coatings) and Construction Indoor Air Quality Management plan |
| **CSH** | Daylight, sound insulation, views and sunlight, home user guide, life time home, and security |
| **EcoEffect** | Light conditions (sun hours in kitchen, living room and balcony, window area, number of light fittings, and low flickering light)<br>Air quality (limited sources of exhaust fumes outside the building from traffic, separable kitchen area, covered electrical wires, easy to clean service facilities, and service and technical instructions for users and facility management personnel)<br>Thermal comfort (no cold bridges, use thermograph to identify cold bridges, and low air velocity for fresh air distribution)<br>Sound quality (low sound levels for refrigerator, freezer and other installations)<br>Electromagnetic fields (sufficient distance around mains electrical cables and conduits and use of five-wire electricity distribution system) |
| **LCA ENSLIC-tool** | *Not assessed* |

#### *Measures regarding Indoor Environment*

The issues for which the Grönskär project does not receive scores in the Indoor Environment category reveal which improvements the tools demand to obtain maximum scores and get the highest rating, and that they vary widely (Table 8 in Paper II).

Different actions are demanded. To meet the criteria regarding improvement of daylight in LEED-NC and EcoEffect, the design of window placements and floor plans will be affected. Low emitting materials (LEED-NC), sound insulation (CSH) and thermal comfort (EcoEffect) will affect the construction of the walls in different ways, but will not necessarily be visible. However, sound insulation will affect the acoustic conditions in the building, which is an important aspect affecting the impression and experience of a space or architecture (Sällström, 2000). Thermal comfort (EcoEffect) may put certain demands on the temperature of the walls, floors and ceilings, which in turn will also influence the architectural design experience. The other changes in equipment, walls, doors, etc. demanded by EcoEffect and CSH will affect the design. Building users occupying the building for longer periods will probably notice the details regarding e.g. low flickering light and limited exhaust fumes from traffic, or adjustments for the disabled, but these architectural details might not be very obvious to the layperson visiting the building for a short period. Finally, the Home User Guide for building users (CSH) and Construction Indoor Quality Management Plan (LEED-NC) are the only issues that will not have a distinct impact on the architectural design.

### 4.2.3. Tools for neighbourhoods – influence on urban design

For the neighbourhood tools LEED-ND and BREEAM-C tests were not conducted, but the indicators analysed in the tools give us a clue regarding what would be measured and thus could be influenced in the architectural design. Here four common categories will be presented: Energy & Pollution; Material & Waste; Transport; and Ecology, Biodiversity and Local Environmental Conditions, to exemplify the tools differences and the possible impact of the indicators (Table 5).

#### *Measures regarding Energy & Pollution*

The Energy & Pollution category in BREEAM-C has one indicator with the big task of making an energy strategy, including energy and carbon emission calculations/predictions. LEED-ND on the other hand separates the different energy aspects into separate indicators and assesses the buildings' energy use and orientation to the sun. Furthermore, renewable energy on-site and district heating and cooling are encouraged in the tools. Infrastructure energy as low energy lighting fixtures, water and waste pumps are also included. Thus, LEED-ND includes more features and will therefore influence the architectural design in a more obvious way.

### *Measures regarding Material & Waste*

Regarding Material & Waste, both NBEATs consider reuse of existing structures on-site. Regarding the materials used, LEED-ND demand the use of recycled material, while BREEAM-C demand low impact materials and resource efficiency. The possible impact might be the exclusion of some types of materials and the favouring of others. More importantly, the total amount of material is not assessed, even though often the most environmental choice of material is to limit the use of materials, i.e. to minimise the use of materials, dematerialisation (Ljungberg, 2007).

***Table 5.*** *Measures included in the assessment tools for neighbourhoods, in the environmental categories Energy & Pollution, Material & Waste, Transport, and Ecology, Biodiversity & Local Environmental Conditions. Category- and indicator numbers in parentheses (Appendix E and F).*

| NBEAT | Measure included in each category for an improved rating |
|---|---|
| | **Energy & Pollution** |
| **LEED-ND** | Building energy efficiency (GIB P2, GIB C2), Solar orientation (GIB C10), On-site renewable energy sources (GIB C11), District heating and cooling (GIB C12), Infrastructure energy efficiency (GIB C13) |
| **BREEAM-C** | Energy strategy (RE 01) |
| | **Material & Waste** |
| **LEED-ND** | Existing building use (GIB C5), Recycled content in infrastructure (GIB C15), Solid waste management infrastructure (GIB C16), |
| **BREEAM-C** | Existing buildings and infrastructure (RE 02), Low impact materials (RE 05), Resource efficiency (RE 06) |
| | **Transport** |
| **LEED-ND** | Smart location (SLL P1), Access to quality transit (LT C1), Bicycle facilities (LT C2), Walkable streets (NPD P1, NPD C1), Compact development (NPD P2, NPD C2), Mixed-use neighbourhoods (NPD C3), Transit facilities (NPD C7), Transportation demand management (NPD C8) |
| **BREEAM-C** | Transport carbon emissions (RE 07), Transport assessment (TM 01), Cycling network (TM 03), Access to public transport (TM 04), Cycling facilities (TM 05), Public transport facilities |
| | **Ecology, Biodiversity & Local Environmental Conditions** |
| **LEED-ND** | Imperilled species and ecological communities (SLL P2), Wetland and water body conservation (SLL P3), Agricultural land conservation (SLL P4), Preferred locations (SLL P4), Brownfield remediation (SLL C2), Tree-lined and shaded streets (NPD C14), Construction activity pollution prevention (GIB P4), Minimized site disturbance in design and construction (GIB C7), Heat island prevention (GIB C9), Light pollution reduction (GIB C17) |
| **BREEAM-C** | Ecology strategy (LE 01), Land use (LE 02), Enhancement of ecological value (LE 04), Landscape (LE 05), Noise pollution (SE 04), Microclimate (SE 08), Light pollution (SE 16) |

### *Measures regarding Transport*

Transportation is a large category in both BREEAM-C and LEED-ND. As mentioned in Paper IV, there seems to be a larger focus on pedestrian walkability in LEED-ND and a stronger focus on bicycling and bicycle networks in BREEAM-C. Access to public transport and public transport facilities are assessed in both tools. The walkability of streets through having pavements, bicycle networks and public transportation facilities are all things that will be visible in the urban environment, however, there is room for great variation.

### *Measures regarding Ecology, Biodiversity & Local Environmental Conditions*

In the ecology, biodiversity and local environmental conditions category LEED-ND obviously contains a number of specific environmental measures and features that are important (Table 5). Some of them deal with the choice of site, and do not have a strong connection with the design of buildings or infrastructure. Other aspects will be visible on-site, such as Imperilled species and Ecological communities (LEED-ND, SLL P2), Tree-lined and shaded streets (LEED-ND, NPD C14), Light pollution reduction (LEED-ND, GIB C17). Two aspects consider the impact only during the construction and therefore their impact will be limited over time. BREEAM-C on the other hand has more loosely defined issues that are more open to multiple design solutions. It incorporates more local outdoor aspects than LEED-ND, such as noise pollution and microclimate which will influence the design and the experience of the site. Moreover, it does not include water bodies as clearly into the assessment compared with LEED-ND, which is likely to make the design of neighbourhoods certified with different tools different in character.

## 4.2.4. Context and life cycle perspective influence the design

The results from the tests of the ENSLIC life cycle assessment tool on an office building in Gävle show that this type of tool also can be used as decision support. The ENSLIC-tool can be used to test the impact of possible building improvements by giving rough estimates regarding the $CO_2$eq emissions from material production and energy use during occupation. However, in comparison to LEED-NC and CSH's weighting of issues the results from the tested measures guide the architecture towards a stronger focus on the importance of renewable fossil- and carbon-free electricity and of materials. This is because, the greatest $CO_2$eq reduction is obtained by changing to $CO_2$-free electricity, and the second greatest is obtained by changing slab construction from concrete to wood. The large quantity of concrete is responsible for more than 70% of the $CO_2$eq emissions from materials in the project when having a 50-year life cycle perspective. Changing the construction to wooden slabs would decrease the emissions by approximately 1 kg $CO_2$eq/m$^2$/year. $CO_2$eq emission calculations of the office building in Gävle shows that the tested suggested improvements result in a total emission reduction of approximately 2.8 kg $CO_2$eq/m$^2$/yr. during production and use (Figure 7).

For this specific building, material production has a significant impact on the emissions over a 50-year life cycle, both before and after improvements are made. Before improvements, material production is responsible for 54% of total emissions (amounting to 5.9 kg $CO_2$eq/m$^2$/year).

After improvements, 74% of the $CO_2$eq emissions relate to material production, total emissions amount to 3.1 kg $CO_2$eq/m²/year (Figure 7).

The results also highlight the importance of what life cycle perspective is used. Depending on short or long life cycle perspectives, the relation between the material and energy use change, since the emissions from material production occurs in the beginning of the building's life cycle (Figure 8). If the goal is to reduce the emissions in a ten-year perspective, the importance of the emissions from the materials becomes even more important.

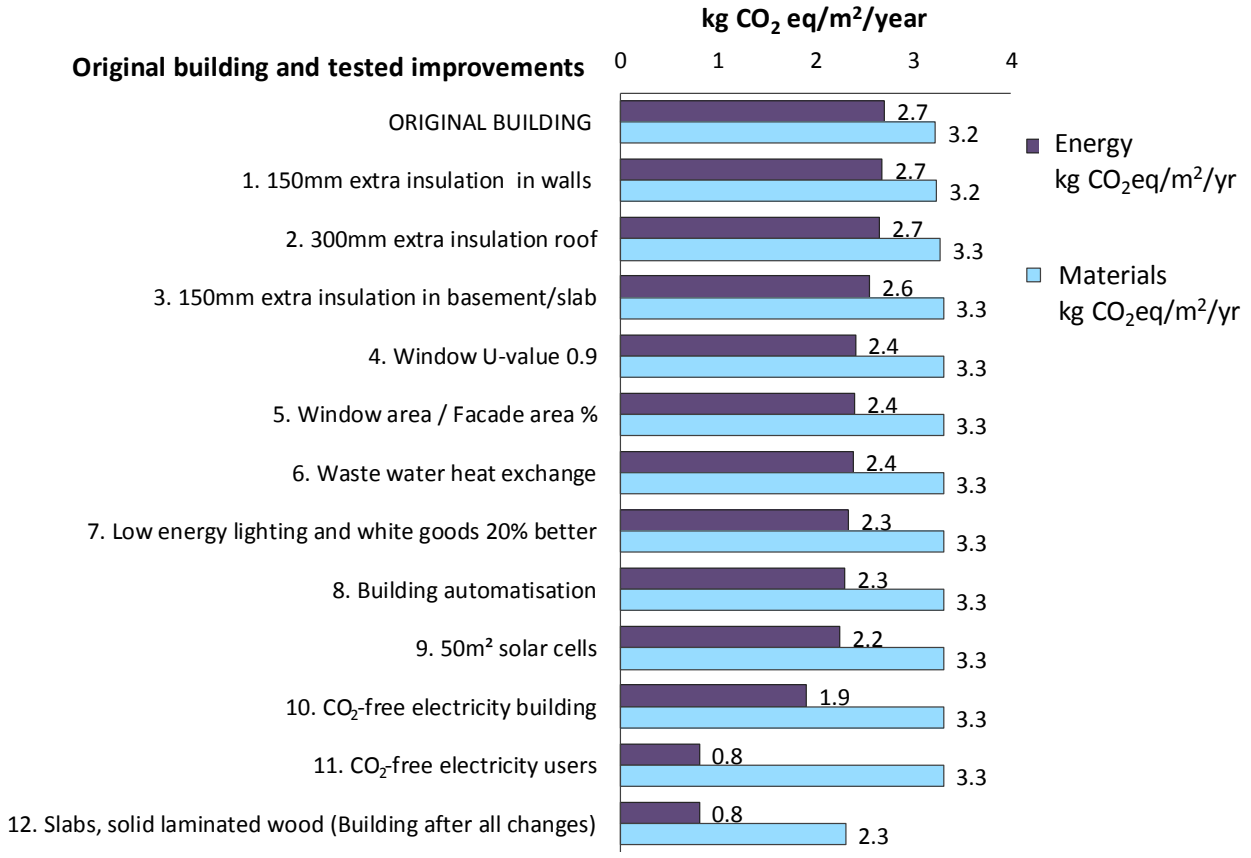


***Figure 7.*** *Accumulated results in kg $CO_2$eq/m²/yr for the 12 tested building changes in the order they were examined (Paper III).*

The main reasons behind these results were found to be because of the use of low carbon dioxide energy sources, such as Swedish electricity mix and Gävle district heating, with rather low $CO_2$ emissions from energy use. In many ways this is linked to the context of the building as other countries have other energy and electricity sources with a different mix. If the energy sources had been electricity and energy from coal, the result would have been different, as emissions from energy use would have increased approximately by a factor of 20.

The second reason was the low energy use of the building. After the improvements, which resulted in a 50% reduction of energy use compared with the original building, the building had an energy use comparable to a passive house. In this case, the ENSLIC-tool advices greater focus on material choices if $CO_2$eq emissions are to be decreased over a 50-year perspective or less.

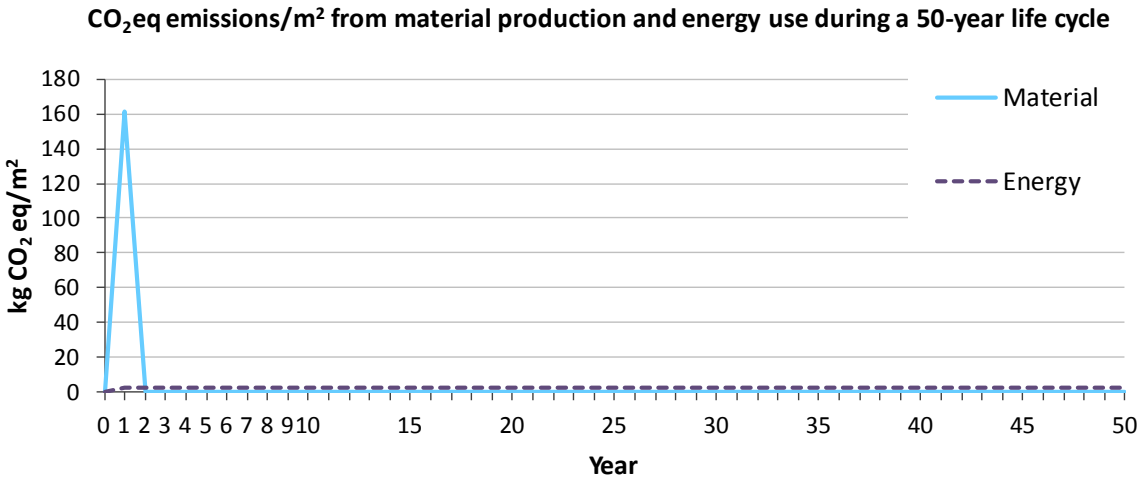


***Figure 8.*** *$CO_2$eq emissions from material manufacture and operational energy use over a 50-year life cycle (Paper III).*

### 4.2.5. Summary of the observations

After this review of the NBEAT indicators, the overall conclusion is that architectural design features will be influenced by the tools. The NBEATs wide variety of indicators and proposed measures will have visible consequences on the architectural design, but as there are so many optional ways to meet the criteria, combined with the fact that not all indicators are mandatory, it will probably be difficult to distinguish a certified building or neighbourhood from a non-certified without the tool manual or without an awareness of the many indicators in the tools. There is still room for different types of architectural styles. Life cycle perspective and contextual aspects, such as climate, culture, energy sources and national legislation may influence the design as well and other studies have also shown that they may have some impact on which environmental criteria are met in a project (Faulconbridge, 2015; Wu et al., 2016).

## 4.3. Results connected to architects

### 4.3.1. Use of NBEATs among architects

NBEATs are designed to be used as decision support. Just as mentioned in section 4.1.2., the assessment tools do influence the design process, where the building design is planned and decided. Therefore, professionals are affected by the tools in a direct way, as tools require these processes are performed by architects, consultants, engineers, developer, designers, construction workers, or facility managers. It is also probable that professionals can be influenced by assessment tools directly when using them, learning about them, knowing about them, and indirectly when colleagues and other stakeholders use the tools and integrate them into daily practise. However, to influence professionals, architects, landscape architects and other urban designers directly it is important that they know about assessment tools and somehow get in contact with them.

The results in the survey in Paper V show that there is a limited use of NBEATs in the early design phase of the architectural competition *A New City Centre for Kiruna*. Eight competitors and one jury group member, in total 9 of the 68 participants (13%), used one or more of the NBEATs or environmental management systems (EMS) listed. They used BREEAM (n=3), LEED (n=2) and Minergie (n=2) and then DGNB (n=1), Miljöbyggnad ('Environmental Building') (n=1). A larger number of participants, in total 35 (51%), had used 1-6 of the NBEATs and/or environmental management system before and/or in the competition.

The tools that were familiar to most participants were LEED and Green Building. However, the tool that had been most often used was BREEAM (n=18, 26%). Two participants knew about several tools and mentioned other tools as well. However, in total, six of the 17 tools listed had not been used by any participant, and four participants (6%) did not know any of the NBEATs or EMS listed. Knowledge about LCA and the international standard ISO 14001 was limited; 19% knew about or had used LCA and 56% knew about or had used ISO 14001.

### 4.3.2. Knowledge about handling environmental aspects

Results in Paper V show that the participants' self-reported knowledge about handling environmental aspects vary between different environmental issues, and is rather low. No matter whether the concerns were energy issues, material, ecology or indoor environment, the participants score low on a three step graded scale. On the other hand, the importance of environmental impacts is rated high independent of NBEAT use.

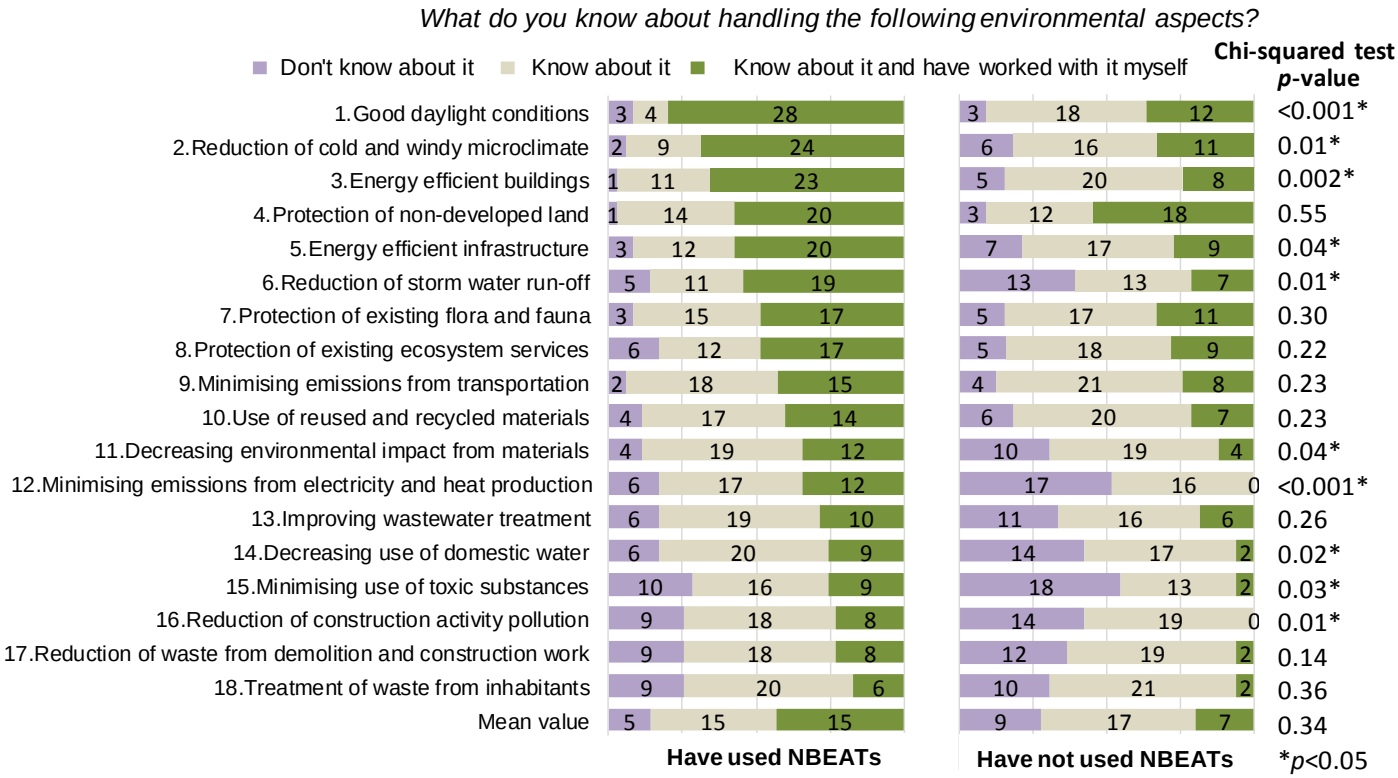


***Figure 9.*** *Self-reported knowledge by NBEAT users (n=35), non-NBEAT users (n=33) about handling environmental aspects and chi-squared test results showing if the difference is statistically significant (p<0.05) (Paper V).*

Significant differences were found between NBEAT users and non-NBEAT users in self-reported knowledge about handling environmental aspects in 10 of the 18 environmental aspects (Figure 9), where the Pearson's chi-squared test showed a *p*-value <0.05. This indicates that perhaps use of NBEATs can increase knowledge about how to handle most environmental aspects, but the effect is limited. Even so, the ratings of knowledge regarding how to handle environmental impacts are rather low for all participants, except for the environmental aspects: good daylight conditions, reduction of cold and windy microclimate, energy efficient buildings, protection of non-developed land, and energy efficient infrastructure. Among participants that had not used NBEATs, knowledge was rated highest regarding the aspect 'Protection of non-developed land' (Figure 9).

The smallest difference between NBEAT users and non-NBEAT users was found regarding 'Protection of non-developed land' (mean 0.1), and the largest difference was found regarding 'Minimising emissions from electricity and heat production' (mean 0.7). None of the non-NBEAT users reported working with this aspect themselves. Further, both groups self-rated their knowledge lowest for the environmental aspect 'Minimising use of toxic substances'. Ten NBEAT users and 18 non-NBEAT users answered 'Don't know about it'. Among NBEAT users, knowledge of the impacts related to waste was self-rated lowest.

### 4.3.3. Perceived importance of environmental impacts

Even though the rating of knowledge of handling the environmental impacts was not high, the perceived importance of environmental impacts from the *A New City Centre for Kiruna* project was high among all participants. Mean values were around 4 on a 5-point Likert scale ranging from 1 = 'Not at all important', to 5= 'Extremely important'. Most environmental impacts were rated slightly higher among the participants who had been using NBEATs in the competition or at another time, (n=35), but the difference was statistically significant for only four environmental impacts: 'Emissions from electricity and heat production' ($p$=0.013), 'Destruction of existing ecosystem services' ($p$=0.038), 'Polluted storm water run-off' ($p$=0.005), and 'Waste from inhabitants' ($p$=0.024).

Many of the environmental aspects that were rated high (Cold and windy microclimate, Emissions from buildings' energy use, Emissions from transport, and Lack of daylight) were also rated as the ones that had been addressed to the greatest extent in the competition programme according to the participants. Correlation tests revealed correlation ($p$<0.05) between competition programme and rated importance for: 'Emissions from electricity and heat production', 'Reduction of cold and windy microclimate' and 'Daylight conditions'. The competition programme was in general perceived as addressing different environmental aspects to a moderate level. The mean value for competition NBEATs users was 3.3, compared with 2.9 for non-NBEATs users on a scale from very little (1), to very much (5). The environmental issues included in the competition programme to the greatest extent according to the participants were: 'Cold and windy microclimate' and 'Lack of daylight'. These were also the aspects which the participants reported most knowledge on how to handle. Moreover, when comparing the rating of perceived importance of the environmental impacts and knowledge about how to handle the impacts, a substantial gap was found Even among NBEAT users, knowledge was low even though the importance was rated high.

### 4.3.4. Measures for improving the competition proposals

In Paper V, the drivers of environmental design were investigated by asking the participants whether a number of different aspects could make their competition proposals better from an environmental point of view (Paper V, Figure 4.). Economic aspects were given high scores, 'Larger budget for the competition proposal' and 'Larger budget for the whole project'. but among the other top five rankings were aspects that in many ways are linked to the functions of assessment tools: 'Higher environmental goals in the competition programme', 'If you had been able to analyse and evaluate different design proposals from an environmental point of view', and 'More measurable environmental requirements in the competition programme'. If assessment tools can be used for setting targets, having measurable indicators and benchmarks, and objective evaluation, are functions that are sought after by the participants, and which they self-rate as important for improving environmental design.

### 4.3.5. Procedures and design processes

Depending on when during the design process the NBEATs come into the project, their influence on the architects and the design of the project varies. It has been highlighted by others that the earlier in the process environmental issues are recognised, the larger the possibility to influence the outcome in an environmental way (Basbagill et al., 2013; Kohler & Moffatt, 2003; Malmqvist et al., 2011a; Russell-Smith et al., 2015). The analysis of neighbourhood assessment tools in Paper IV shows that the issues in BREEAM-C are divided into three parts: Part I Establishing the principle of development, Part II, Determining the layout of the development, and Part III, Designing the details. This kind of differentiation of the issue is not as clear in the building tools studied in Paper I, and II, but some issues can be clearly linked to a certain phase of a project, such as site analysis performed by an ecologist (CSH Ecological value of site, and BREEAM-C, LE 01. Ecology strategy), which has to be done prior to construction and, in the best case scenario, completed before the design.

When the tools are applied in an early phase, they may influence the planning and design. When they are used during the use of the building, it is facility managers and real estate owners that are more affected by the criteria. Depending on what issue the indicators demand, the influence on the professionals also varies. The procedure indicators presented in Paper I, II, and IV, state what needs to be done to receive the credits. These are clearly defined criteria that will affect what is done, as long as the work that is demanded is not already standard practice. Then the additional effects of the tools will be non-existent.

When the indicators demand specific features, which might involve extra work by the architects or other professionals, the design process is affected. In the neighbourhood tools, a guarantee for public transport is demanded and that will result in the need for contracts with public transport companies. When good daylight conditions are specified it will imply either simulation of daylight conditions or calculations. Including renewable energy would also require simulations and calculations.

The performance indicators which do not specify procedures or features offer many solutions to reach the target. However, in this case it is important how the calculations of the performances are made and how input data is retrieved. Energy performance is, for example, dependent on a number of input data about the construction of the house, thermal bridges, the inhabitants' behaviour, room temperature etc. Besides, other studies show that another effect of use of NBEATs is that the tools can serve as a platform for collaboration between different stakeholders in the building process (Brown et al., 2015). This has an added value and can benefit the project in general and not only the environmental aspects.

The exact relation and possible impact on the architect by studying the NBEATs manuals is not possible to define. However, it is clear that all the tools demand documentation to a varying extent. When the certification is done prior to construction, when only the model of the building exists, it results in the need for extended detailed specification of materials, technical aspects, fittings etc. (information which often does not exist during these early stages).

NBEATs then demand all these decisions to be made at the design phase. As a result, more time for design and environmental evaluations of design choices in early phases is needed and the possibility of changing the specifications later in the process is decreased, because changes might influence the final assessment result.

# 5. DISCUSSION

## 5.1. NBEATs in relation to environmental sustainability

### 5.1.1. Limitations regarding environmental sustainability

When investigating to what extent NBEATs can be expected to lead to more environmentally sustainable outcomes, their content, (based on the results in previous chapters and the content in their technical manuals) has to be compared with environmental sustainability criteria in mind. The environmental dimension of sustainability, 'environmental sustainability', can be defined in different ways as it contains normative considerations of what we value and how much we value it (Beemsterboer & Kemp, 2016). The concept of sustainability is broad. Even if the Brundtland report (Brundtland et al., 1987) defines sustainable development, a consensus on the exact definition of sustainability is lacking (Aspinal et al., 2012; Fainstein, 2012), and no clear operationalised, concrete, and generalisable example exists. However, a number of criteria that sustainable development incorporates have been suggested. Five of them are presented in Paper IV. Here, two of them, the most important from an environmental point of view, are used as a basis when defining environmental sustainability and when discussing NBEATs' relation to environmental sustainability. These criteria for environmental sustainability are:

- **Social and natural capital are not exchangeable**
  Social and natural capital, on a large scale, need to be sustainable in their own right, meaning that losses in one type of capital cannot be replaced by a gain in another type of capital. Then, degrading one type of capital (e.g. natural) in order to increase another (e.g. economic or social) cannot be seen as compatible with sustainability (Berkes & Folke, 1992; Hopwood et al., 2005).
- **Ecological limitations exists**
  There are ecological limitations, earth has a limited carrying capacity and humanity already is imposing unsustainable levels of resource use and pollution on the environment (Steffen et al., 2015). This creates a growing demand for net-zero, net-positive or regenerative interpretations of sustainability (Robinson and Cole 2015) especially in new developments. Therefore, to achieve sustainable development, there is a need to decrease resource use and pollution in absolute terms (Rockström et al., 2009; Steffen et al., 2015). Then sustainability cannot be seen as a relative concept; achievable through harm reduction and with little concern given to what pressures the ecosystems can actually stand.

With these two criteria as a basis, a number of limitations have been identified in Paper IV regarding the sustainability issues included in the BREEAM-C and LEED-ND certification systems. These limitations concerning environmental issues are also mostly valid for the building tools LEED-ND and CSH, and, but only to some extent, also for EcoEffect and the ENSLIC-tool, because tools like EcoEffect and ENSLIC have different ways of assessing the building by

measuring and calculating the environmental emissions instead of having predefined criteria. Therefore, just some of the points in this list are valid for them. Key limitations found in the studied NBEATs are:

a) **Important indicators are sometimes missing.** Indicators do not exist for one or several environmental impacts that are important for a safe environment and environmental sustainability (e.g. embodied toxic substances, land use change, loss of biodiversity, biogeochemical flows for phosphorus (P) and nitrogen (N), freshwater, ecosystem services).

b) **Important indicators are not mandatory**. The project does not have to meet the criteria to become rated, (i.e. there is no guarantee that the indicator will be measured and the criteria met). This concerns LEED, CSH and BREEAM, and not tools like EcoEffect and The Swedish assessment tool Miljöbyggnad, where all the indicators are mandatory.

c) **Indicators can be ignored.** To receive the highest rating one does not have to meet all the indicators. This means that a best practice environmental building or neighbourhood does not have to meet best practice levels on all subjects. For example, a neighbourhood can become certified with only one building (LEED-ND GIB C1 Certified green buildings), or zero buildings meeting environmental criteria (BREEAM-C RE04 Sustainable buildings). Projects have been certified without receiving credits from the Energy category or Material category in LEED v2.2. (Wu et al., 2016).

d) **Many indicators are tradable**. For example, environmental aspects can be traded to meet social or economic aspects, e.g. meeting a criterion for social sustainability can be traded with a criteria regarding biodiversity worth as many credits.

e) **Often, the procedure and not the outcome or the performance is measured.** The link to the environmental impact can be weak and not guaranteed when an indicator measures the procedure and not the performance, which dominates in BREEAM-C and LEED-ND (Paper IV) and in CSH and LEED-NC (Paper I), (e.g. consultation of an ecologist, use of accredited professional, commissioning of the ventilation system).

f) **The indicator does not measure the specific environmental impact.** There is an indicator measuring an aspect that is related to environmental aspects, but is not explicitly stated in the manual, (e.g. use of rapidly renewable materials instead of decreased environmental impact from material use).

g) **Relative measures are used.** Most indicators are based on a relative measurement (e.g. demanding a percentage water use reduction) instead of absolute indicators and measures (e.g. calculating water use reduction in litres). This makes it difficult to compare the environmental impact from different buildings, and can hide the project's total environmental impact. Further, when the assessment results are a percentage number it becomes difficult to compare the environmental impacts from buildings or neighbourhoods with other products and services. Here the 'conventional building' sets the standard to measure from and it is not the environmental limits that set the baselines.

h) **The criteria levels and benchmarks are not high enough**. The tools measure environmental issues but it is done at a level that is questionable from an environmental sustainability perspective. The ecological limitations are not considered sufficiently as there is no limit in the use of material or energy per project and function. It is therefore probable that the environmental impact from a certified building or neighbourhood is far from net-zero, plus or regenerative.

i) **The interpretation of the criteria and indicators can be subjective.** When doing the studies, some indicators were open to different interpretations. Other studies have revealed this ambiguity in the BREEAM process, where according to a study by Aspinal et al. (2012) a majority of the assessment criteria are down to the interpretation of how a sentence or paragraph could be read by the individual.

Limitations regarding what environmental aspects are being addressed by the tools, low criteria levels and benchmarks, together with the notion that not all criteria are mandatory, makes it clear that a high rated and certified building or neighbourhood only means than it is more environmental than a conventional building for some of the environmental aspects included in the tools, but not for all aspects. It is therefore not certain that they are creating a built environment that leads to environmental sustainability. Having relative measures can also have negative environmental consequences. Olgyay and Herdt (2004), stress the importance of measuring the environmental impact from buildings against criteria that are based on the ecological carrying capacity. If environmental sustainability is the goal, that is more relevant than quantifying the assumed relative negative impacts of man-made interventions on the natural environment compared to a code compliant reference building, which is used as a standard to improve upon, like in many NBEATs. Finding exact benchmarks can be difficult when variations in performance among buildings are large. For example, the life cycle primary energy requirement of conventional residential buildings can be in the range of 150–400 kWh/m² per year and that of office buildings in the range of 250–550 kWh/m² per year (Ramesh et al., 2010). These variations in energy source and material production can result in a wide variety of environmental impacts. Moreover, even though the environmental impact from energy and materials is large and important for environmental sustainability, studies of LEED v2.2 certified projects conclude that energy-related and material-related points are the most difficult to obtain and the ones that are reached the least (Wu et al., 2016).

It has been found that energy performances in certified buildings can even be higher than in non-certified buildings. Studies regarding LEEDs influence on energy use in buildings showed that LEED projects on average used 18–39% less energy per floor area than their conventional counterparts, but, 28–35% of LEED building projects used more energy (Newsham et al., 2009). This analysis was based on energy use per project with equal weighting for each building. If calculating with the energy use per square metre, the total energy saving was smaller, 10-17% (Scofield, 2009); an indicator, which perhaps, is a more relevant measure when evaluating the NBEATs' influence on the reduction of environmental impacts.

As these tools set the standard for what an environmental building is, make developers pay high costs for certification, and market buildings as

environmental, it is important that their criteria lead to architecture that moves towards environmental sustainability. An architecture that will minimise the environmental impacts a building or neighbourhood causes or even result in mainly positive environmental impacts. This is difficult to accomplish as most technologies have aspects that can be problematic from an environmental point of view.

The tools limitations regarding incorporating environmental sustainability and having criteria linked to ecological limits can be explained by the fact that the environmental assessment tools have never declared to be based on the notions of ecological limitations, and they are not solely based on scientific data. During development, the toolmakers have many aspects to consider, such as practical issues, available data, cost of the assessment, time, available techniques, human resources, availability of tools, and economic aspects (Malmqvist, 2008b). Based on the results there seems to be a focus on the market's economic demands and that the buildings and neighbourhoods should be better than any others on the market.

### 5.1.2. The tools' environmental concerns

The environmental issues included in the assessment tools show what environmental aspects the tools are concerned with. If different aspects are included it reflects different environmental concerns and it will result in different environmental impacts. The idea that we measure what we care about and we care about what we measure has been emphasised by Meadows (1998). That concept shows that values play a fundamental role in defining indicators and that those indicators can influence and create values. Therefore, it is important that the indicators used in the tools are relevant and reliable and cover fundamental aspects of environmental sustainability.

The main differences between tools are differences regarding what environmental aspects they assess, how they assess these aspects, what parts of the building/neighbourhood or building/neighbourhood process they assess, and finally how they weight the assessed aspects (Papers I, II, III, and IV). In the neighbourhood tools environmental aspects dominate social and economic aspects. Common to both neighbourhood tools and building tools is to assess Energy, Material & Waste, and Land & Ecology. Building tools also assess Indoor environmental aspects, and neighbourhood tools also have Transport and Water as commonly assessed environmental aspects. A wide range of environmental aspects are considered. The number of indicators in the neighbourhood tools is very large (Paper IV), but still the studied tools seldom use similar indicators, but rather measure different things. The results in Papers I, II, and IV identify three types of indicators and issues: procedure, feature and performance. Therefore, the link between the indicators measuring an environmental impact and the resulting environmental impact is not always very clear, e.g. for the indicator LEED Accredited professional. Performance indicators are often more closely linked to the environmental impact.

The number of indicators per category can also vary. One indicator can cover a large number of environmental aspects as there can be nested indicators within it. A closer examination shows that there are some environmental aspects that are important for environmental sustainability that are only covered to a limited extent, e.g. embedded toxic substances, biogeochemical flows for phosphorus

and nitrogen, land use change, and ecosystem services. Here, ecosystem services, lands use and biodiversity will be discussed more in detail below.

The importance of local ecosystems is often forgotten in urban planning, perhaps because cities often rely on vast external land. However, ecosystem services are increasingly in the spotlight in research and policy (Maes et al., 2012; Millennium Ecosystem Assessment, 2005). Ecosystem services include environmental impacts that are closely connected to changes in land cover, i.e. the biophysical attributes of the earth's surface, and land use, i.e. human purpose or intent applied to these attributes. Land cover change and land use change, can be considered as 'spatio-temporal change patterns', and can be used to analyse ecosystem services and landscape metrics (Haas, 2016). Land cover change has also been pointed out as being among the most important environmental issues (Turner et al., 1990) and can influence how vulnerable and resilient a place is to climatic or socio-political disruptions (Lambin et al., 2001). Urbanisation, rangeland modifications, agricultural intensification and deforestation which are changing the land use have such a large impact that they, when aggregated globally, significantly affect key aspects of earth system functioning (Lambin et al., 2001), and effect environmental issues such as: biotic diversity (Sala et al., 2000); local and global climate change (Chase et al., 2000; Houghton et al., 1999); soil degradation (Tolba & El-Kholy, 1992); and by altering ecosystem services, affect the ability of biological systems to support human needs (Vitousek et al., 1997).

Buildings and their connected infrastructure are not possible to disconnect from land use change and are also linked to biodiversity issues. When conventional building converts productive natural systems into less productive ones, the resulting habitat destruction causes our current decay of ecological diversity and contributes to the extinction crisis. Ecological considerations are brought into NBEATs which include the site, i.e. LEED-NC, LEED-ND, CSH, BREEAM-C, and EcoEffect, through consideration of use of non-developed land, permeable surfaces, storm water reduction, use of native plants and greenery. But, the biodiversity on the development site before construction and after is included to a limited extent. Therefore, a certified architecture might be green, but the diversity is not safe-guarded. Biodiversity is about much more than protecting rare species. The loss of genetically distinct populations within species is, at the moment, at least as important a problem as the loss of entire species. Protecting diversity within species is also important, since global environmental impacts are affecting protected separated natural preserves. Acid rain and climate change do not respect any boundaries.

### 5.1.3. Weighting reflects the environmental importance

The environmental issues that are addressed by the tools and how they are weighted reflect the environmental importance the tools give to the issues. As a consequence, missing or undervalued environmental aspects have a very low importance. That the tools consider different environmental issues can be due to cultural difference. Noise is an issue that not is assessed in the American tool LEED, but is considered in BREEAM-C and also in the Swedish Miljöbyggnad (Sweden Green Building Council, 2016a). Another difference is that LEED-NC has minimum car parking levels as criteria, while Code for Sustainable Homes has maximum limits. This could reflect a different view between the United

States and Great Britain on the importance of the car and its role from an environmental perspective.

The different weightings of environmental aspects have been based on both practical and environmental considerations (Malmqvist, 2008b). Cultural aspects have probably been included and the tool developers' values are likely to have had some impact. Regional differences can also be responsible for why different environmental aspects are considered important in one specific context and not in another. Water is one such issue, where LEED and CSH include this aspect, while EcoEffect and Miljöbyggnad do not. Water shortage has not been considered a crucial issue in Sweden, which probably is the reason behind these differences. This is a direct example where tool-developers have probably made deliberate decisions.

The LCA study of the Teknikparken office building in Gävle (Paper III) shows that context and regional aspects can play an important role when determining the relative environmental impact from materials versus energy use during occupancy. These results may influence the weighting. In the Gävle context, with district heating from industrial rest heat and combustion of biomass, and electricity based on the Swedish electricity-mix, the relative importance of the materials' environmental impact is higher than in a context where heat and electricity is generated from fossil fuels. This highlights the drawbacks with making the weighting in the assessment tools at too high a hierarchical level. In most tools the energy issues are weighted higher, i.e. considered more important, than the material issues. This weighting remains even though the context changes or if the building design includes a building designed with very high embodied energy and environmental impacts from materials. Thus, the weighting is disconnected from the ecological limitations as it is not based on the assessed architectural project's environmental impacts. Another aspect that can influence the weighting and the assessment is which environmental impacts are included in the NBEATs. The ENSLIC-tool LCA study only consider climate change ($CO_2$eq emissions). If other impacts had been included, the environmental importance of materials in relation to energy use could have been different.

### 5.1.4. A life cycle perspective

BREEAM, LEED, and CSH have incorporated criteria from different parts of the building's life cycle, but many of them do not include LCA with a whole life cycle perspective from cradle to cradle. This influences the credibility of the results as important environmental impacts might not be considered. If not the whole life cycle is considered, there is a high risk of sub-optimisation. To capture the total environmental impact from a project, both upstream and downstream environmental effects should be considered, and direct and indirect impacts should be reduced and not transferred in time, space or between problems.

Here, the LCA study in Paper III reminds us that a life cycle perspective can influence what environmental aspects are considered most important and relevant and it can vary with context and time perspective. Materials were shown to have the largest environmental impact on climate change in comparison to the impact from energy use during operation. This was because the energy came from low emitting district heat and Swedish electricity mix, and production of the materials, especially concrete and steel, resulted in high

$CO_2$eq emissions. The importance of construction materials has been highlighted in other studies as well, especially in studies of low energy buildings (passive houses, zero-energy houses, zero emission houses) (Blengini & Di Carlo, 2010; Bribián et al., 2009; Chau et al., 2015; Din & Brotas, 2016; Karimpour et al., 2014; Stephan et al., 2013).

Because of the environmental impacts' connection with context (Paper III) it is difficult for NBEATs simultaneously to have predefined, comprehensive criteria, indicators and weighting that represents the environmental impact, and yet adapt to different countries, regions, and cultures. The level of detailing the LCA tools have also influences the result. In the German assessment tool DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen), LCA according to ISO 14040 and 14044 is used as an established method to determine environmental impacts and ecological sustainability of buildings. However, use of the simplified method of LCA dominates use of the complete LCA procedure. This can induce a systematic assessment error of the environmental impacts of buildings (Graubner & Pohl, 2015).

The benefits of having a life cycle perspective when assessing buildings is that the total emissions from the whole life cycle are considered. However, one difficulty is how to aggregate the results of different emissions and impacts into a single result — a difficulty shared with most assessment tools. This aggregation is performed in the life cycle impact assessment (LCIA). One limitation with LCA that has been highlighted is that results presented as emission or impact parameters, such as $CO_2$ emissions, are 'too distant from the design world' (Millet et al., 2007) and are not presented in a way that clearly provides valuable information for the architect (John & Habert, 2013). On the other hand, LCA parameters do make it possible to compare environmental impacts from architecture with environmental impacts from other products and services, such as transport or food production. In Paper III the studied office building emits 3.1kg$CO_2$eq/m$^2$/year in a 50-year life cycle perspective on material production and operation. This can be compared to the emissions from a car, meeting the Swedish 'supermiljöbil' standard (0.050kg $CO_2$eq/km) (The Swedish Transport Agency, 2016). This gives some perspective, and can be of use to policy-makers, individual customers and during early strategic decision-making. Defining criteria levels and benchmarks is, however, not easy as mentioned earlier.

Other critical problems with LCA, which most NBEATs share, is that it does not consider spatial variation and local environmental uniqueness (Reap et al., 2008). Further, data availability and data quality are identified as critical problems (Reap et al., 2008) affecting both the outcome and how easy it is to use LCA as an assessment tool. Data availability is especially crucial in early design phases when choices have not been made and data is unavailable. Another problem is that not always all impact categories are considered. Impact categories such as land use, habitat alteration, impacts on biodiversity, human toxicity and ecotoxicity (Finnveden et al., 2009), non-toxicological human impacts, and impacts in the work environment typically escape consideration (Finnveden, 2000). This is also seen in the NBEATs, maybe because of significant data gaps. Impacts that are not connected with quantifiable emissions can be more difficult to measure.

Indicators are lacking for endpoint impact categories, such as damage to the abiotic natural environment (degrading of landscape, glaciers, waterfalls, including destruction or dissipation of non-renewable natural resources etc.), biotic natural resources (damage to wild plants, ecosystems and domesticated animals) and impact on land use (Finnveden et al., 2009). Even if damage indicators exist for these environmental impacts, they have not been agreed upon (Jolliet et al., 2004). Therefore, it can be difficult to perform an LCA and make it generalisable. LCA can, just like NBEATs, give different results to the same product, e.g. a comparison of the aquatic ecotoxicity impact results of three different LCIA methods for various detergents returned different answers from using different methods (Pant et al., 2004).

### 5.1.5. Sustainability at the expense of environmental concerns

During the years when these studies were done and the Papers written, the assessment tools' focus has moved from being mainly environmental to a wider recognition of social and economic sustainability issues (Paper IV). It is not enough just to measure environmental aspects, even though these studies show the complexity in the environmental area. The assessment of social and economic issues is welcome, but from an environmental perspective there is a risk with tradable indicators, criteria and credits between these aspects. When aiming for a good result NBEAT-users risk giving social and economic aspects a greater priority at the expense of the environmental aspects, which can sometimes be complicated to accomplish and harder to gain acceptance for in a project. Environmental concern will then be traded for social aspect. If other issues and indicators are given more credits the NBEATs indirectly value these aspects higher than the environmental issues with lower credits. The DGNB is one example where the main categories are weighted equally: Environmental quality 22.5%, Economic Quality 22.5%, Sociocultural and Functional Quality 22.5%, Technical Quality 22.5%, Process Quality 10%, and Site Quality (Mandatory). This gives the impression that environmental issues only represent 22.5% of the importance when making a sustainable building. Further, the Environmental Quality category contains six issues with several indicators. The Economic Quality category, on the other hand, contains three issues (Building-related Life Cycle Costs, Flexibility and adaptability, and Commercial Viability). As a result, out of DGNB's entire issues, two of the economic issues are having the highest weighting, i.e. are given the highest value in an assessment (Deutche Gesellschaft für Nachhaltiges Bauen, 2013).

Instead of making environmental aspects into sub-issues under sustainability they would probably benefit from being an independent issue or perhaps several independent issues, e.g. Energy, Water, Material, and Ecology. It would benefit environmental issues if it was possible to shift the understanding of 'environment' from a singular term into one that embraces its plurality so sub-categories as energy, material, and water are put higher in the assessment hierarchy.

Eventually, how environmental aspects are valued in respect to other environmental aspect and in in respect to other aspects such as social and economic, is ultimately an ethical issue. Therefore, it is also important to recognise what values NBEATs are built upon.

## 5.2. NBEATs in relation to ‘environmental’ architecture

### 5.2.1. Influence on architectural design

NBEATs can influence architecture in a variety of ways and to varying degrees. The same building can get different environmental ratings with different tools (Paper II). The differences between tools, presented in section 4.2., not only influence the rating of the tools, and the environmental impact, but also have consequences that may pull the design of ‘environmental’ and ‘sustainable’ building in different directions. The results in section 4.2., show that tools like LEED-NC, CSH and Ecoeffect include indicators that clearly can have an influence on technical and visual aspects that in turn can have an impact on architectural design. In that sense they define and influence the content of environmentally assessed and certified architecture. The identified differences between neighbourhood tools are also confirmed in studies by Sharifi and Murayama (2014) who found that different neighbourhood tools consider different environmental issues, use different indicators, and because of that rate different projects differently. They tested three tools, BREEAM-C, LEED-ND, and CASBEE for Urban Development, on three different projects. Each project had been certified and highly ranked with one of the tools. When they were assessed with the other tools, they were given different ratings, as weighting and criteria were defined different in the tools.

When testing the ENSLIC-tool in Paper III different energy-saving measures were suggested by the tool. Most aspects were of a technical nature with varying degrees of influence on the architectural design. Most measures would seem to have little influence, but it depends on how closely the building is examined. For example, energy-saving windows not only decrease the heat radiation through the glass, often they also decrease the amount of daylight and energy that comes into the building and some influence the view through the window. Further, renewable energy from photovoltaic panels on the roof changes roofing material. More insulation in the walls makes the walls and the window casements thicker. Moreover, in LCA based tools regional differences that influence the assessment result (e.g. climate, daylight conditions, local renewable materials, local energy system etc.) also influence the architectural design. However, in LEED, BREEAM, and CSH, the NBEATs’ large number of indicators — some mandatory, many voluntary — and the rather low criteria level makes it possible to meet the criteria with only a small influence on the architecture design. Even if features and measures achieved to meet the NBEATs criteria are visible, it can still be difficult to distinguish an assessed or certified environmental building or neighbourhood from a conventional building or neighbourhood, or distinguish a building certified with one tool from a building certified with another. This is because NBEATs still leave room for different architectural aesthetics and styles. Therefore, even if NBEATs demand changes in architectural design, the overall observation is that tools criteria, as they are today, don’t demand any major differences in the architectural *style* of our built environment. However, if NBEATs had more mandatory indicators and higher criteria levels they would affect the built environments features, such as method of construction, building materials or energy systems in a way that would make them notable or historically

identifiable, i.e. express an architectural style. Even though many architects think sustainability can be treated separately from architectural design (Hosey, 2012), the small but important changes NBEATs demand from assessed and certified projects will influence design, as location, orientation, massing, form, construction, materials, energy sources, transportation infrastructure, permeable surfaces, and use of native plants influence not only function but also form. Thus, the differences in NBEATs — which also reflect particular understanding of environmental sustainability — seem to translate into particular strategies, planning principles and architectural designs. Consequently, environmental performance and form is not possible to separate from each other (Hosey, 2016).

### 5.2.2. The relation to 'environmental' architecture

In one sense the tools present how architecture with environmental objectives should be operationalised (Schweber, 2013). Assessing, rating and certifying environmental buildings and neighbourhoods is therefore a point of departure in the discussion regarding what characterises an 'environmental' architecture.

The analyses of tools show the complexity of the tools, with a large number of environmental issues connected to the built environment and the design and building process. There are still many differences between tools regarding what and how they assess. These differences express their different views on the definition of 'environmental', 'green' or 'sustainable' architecture and reflect the ambiguity of the word 'environmental', an ambiguity similar to that of the word 'sustainability', where there are differences between weak and strong sustainability (Fainstein, 2012; Vallance et al., 2011). In the end, even if the studied NBEATs assess common environmental aspects, such as Energy & Pollution and Material & Waste, the tools use different indicators which result in different influences.

The limitations of NBEATs with respect to how the indicators relate to environmental sustainability, discussed above in section 5.1., also influence how NBEATs determine, define and operationalise a more environmental architecture. Weather NBEATs view corresponds to this thesis view on 'environmental' architecture can be discussed. The limitations in the tools make the specification of 'environmental' architecture rather vague. Gou and Xie (2016) conclude that information in NBEATS is 'often of relativity and does not delineate what is a sustainable building'. From what the results present regarding the tools content, there is a gap between the NBEATs' definition of 'environmental' architecture and the definition in this thesis.

The voluntary indicators, low criteria levels and benchmarks, lack of important environmental aspects, questionable weighting and lack of a life cycle perspective influence the NBEATs' view of architecture. It also creates a gap between what constitutes 'environmental' architecture and what kind of architecture NBEATs advocate. Cole (1999) distinguishes between 'green' building agendas and 'sustainable' building agendas, where the former is described as measuring 'green' performance in relative terms in comparison to similar buildings, while 'sustainable' building, advocating environmental sustainablility and focusing on absolute energy and mass flows as a prerequisite to measure progress towards sustainability (Cole, 1999). With that as a basis, the criteria based NBEATs, LEED, CSH, and BREEAM, are closer to the

definition of 'green' architecture, focusing on mitigating global and local resource depletion and environmental degradation, improving the health and comfort of the occupants and, according to Cole (2012b), describe those projects that have a higher environmental performance compared with that of typical buildings. 'Green' architecture is directed towards doing less harm (Reed, 2007). The definition of 'environmental' architecture in this thesis is similar to Coles 'sustainable' buildings but also includes the surroundings and whole neighbourhoods.

When examining the architecture NBEATs advocate, and compare it with the three images of sustainable architecture; the natural image, the cultural image, and the technical image identified by Williamson et al. (2003). It would appear that NBEATs concentrate mainly on the technical and the natural images. NBEATs' focus on energy efficient technology and transportation issues, combined with the protection of natural environments when choosing a site. When studying the manuals and the indicators both these images are present. BREEAM-C and especially LEED-ND highlight health issues (e.g. in issues regarding transport) and have a rather technical approach to environmental sustainability. Environmental issues, such as *natural resources*, *nature*, *ecosystems*, *insects* or *animals* are mentioned less than twice in the manuals of LEED-ND, BREEAM-C, CSH, and LEED-NC. Moreover, when looking at certified buildings the natural image is mostly visible as green roofs and green grass in front of buildings, showing low biodiversity, and barely organic in form (BuildingGreen Inc, 2016).

The culture image, with its focus on local building traditions and styles, local material and labour, exists in some of the indicators in the neighbourhood tools as social and economic indicators, but is only included to a lesser extent in the building tools through indicators for local and reused building materials. The limited focus on issues connected to the natural image and the cultural image is further supported by the results discussed in section 5.1. Environmental aspects connected to local natural aspects are included, but to a varying extent in LEED, BREEAM-C, and CSH. EcoEffect has a separate outdoor environment result, which gives the outdoor environmental aspects more prominence.

Possible explanations for the lack of cultural aspects in the tools could be because the tools are made to be decontextualised and easier to export to other countries and regions, or that the increased decontextualised, placeless and building-centric approaches to building and planning have permeated to the NBEATs. It might be a hindrance to local environmental sustainable solutions. This placelessness is connected to both cultural and ecological decontextualisation. In the discussion of 'environmental' architecture, Olgyay and Herdt (2004) highlight the conjoining of the discipline of architecture and that of ecology. They envision 'environmental' architecture as something that is part of the ecosystem of the site.

*'At their best, green buildings are examples of applied ecology, where designers understand the constitution, organization, and structure of ecosystems, and the impacts of architecture are considered from an environmental perspective. By utilizing the concepts, methods, and language of ecology, designers can create architecture that intentionally engages the natural systems of a site.' (Olgyay & Herdt, 2004, p.389)*

Other concepts that have recognised similar aspects is that of regenerative design (Cole, 2012a, 2012b; Cole et al., 2012; du Plessis, 2012; Mang & Reed, 2012) and the tool 'Living Building Challenge' (International Living Future Institute, 2016) has tried to incorporate these ideas into an assessment tool. Among all the different environmental aspects considered in the studied NBEAT manuals, this connection to regenerative design and ecology is found in a limited number of indicators with rather low benchmarks and low weightings. Even buildings meeting the 'excellent' or 'platinum' standard in BREEAM-C and LEED-NC show little greenery or nature surrounding the buildings (BRE, 2013; BuildingGreen Inc, 2016), but, some of them have green roofs and some harvest rainwater and use local plants to decrease the demand for irrigation. Still, there is a lack of this environmental connection to the site and its ecosystems. It is probably because NBEATs are in many ways building-centric, focusing on the building and infrastructure and not the ecosystems of the site, flows of energy, materials and water or socio-ecological aspects of the built environment. Because of this, the assessment tools do not seem to promote buildings that consider and respect the importance of the local ecosystem services we depend upon to the extent Olgyay and Herdt (2004) propose. Apart from the environmental benefits, exposure to nature clearly has positive effects on humans, as it can be a restorative design element which can attenuate stress and shape attitudes towards the environment and environmental protection (Evans & McCoy, 1998; Hartig & Kahn, 2016).

In addition to the variation created by NBEATs flexibility, the variation between them results in a wide variety of definitions and views on 'green' architecture. These definitions reconstruct the concept of 'green' architecture. If NBEATs gain more and more recognition and the number of assessed and certified buildings increases, these tools may establish an emerging discipline of 'green' architecture. In that sense, they could become 'foundational' as they could lay the foundations for defining 'green' architecture. Then it is important what this foundation will be based upon. Currently, that is not explicit in the tools. NBEATs do not seem to be based on principles, as the many indicators have their own ranking and weighting and the varying environmental aspects, indicators and weighting in the tools may partly restrict them from becoming this foundation. The possibility of coming to a clearer definition is however hindered by both regional and cultural differences, which create different environmental demands and restraints on architecture, and by the fact that among different stakeholders there are differences in how quality and sustainability indicators are judged (AlWaer et al., 2008). These conditions will most likely preserve the differences between tools and make it difficult to create a clear and general definition of 'green' architecture.

### 5.2.3. Changing NBEATs' relation to architecture

Environmental aspects are often add-ons to architecture and not naturally incorporated as part of the initial architectural design. In urban planning there is a gap between environmental goals and the actual planning occurring in practice (Svensson, 2015). The existing gap between architectural design and environmental aspects could perhaps be reduced by expressing the elements in NBEATs as architectural theory (including the act of thinking, discussing, and writing about architecture). In comparison with other design suggestions ('theories'), such as Lynch's (1960) famous 'five elements' (paths, edges,

districts, nodes and landmarks), in *The image of the city*, which are meant to be considered in urban design, the validity of NBEATs and the included environmental aspects and criteria, which are connected to environmental research, are rather high. If this validity of the tools' content is enough to base urban and architectural design theory on has to be discussed and studied further.

With their criteria and indicators the tools define what they consider is good 'green' architecture. Just as behavioural science has contributed to design and architectural theory (Lang, 1987), environmental aspects can possibly contribute in a similar way to architectural theory and practice to a larger extent than it does today. This could be one way to bring environmental concerns closer to architecture and to influence architecture in an environmental direction. These environmental architectural theories may, just like other theories, influence both substantive issues concerned with the descriptions and explanations of the physical nature of the built environment (including its materials, structure and aesthetics), and procedural issues concerned with the descriptions and explanations of the processes whereby the built environment, its interiors, buildings and landscapes are self-consciously designed (Lang, 1987). Incorporating NBEATs environmental aspects into architectural theory and practice could further lead to recognition of environmental aspects in building regulations, which have mainly been concerned with protection of humans and property through safety measurements. Just as design for disability has been incorporated more and more, environmental issues could become a more naturally integrated part of building and design.

Architectural theory is sometimes concerned with representative aspects of architecture (what it looks like) and the performative aspects of architecture (what it does). The latter, concerned with the impact architecture may have on peoples' lives and behaviour is an aspect which not is included in NBEATs, but which increasingly is being recognised in environmental research. It has been recognised that technological and social innovation can shape sustainable lifestyles (Mont et al., 2014), which highlights that architecture can have indirect environmental impacts reaching beyond the more direct ones. How architecture influences its inhabitants' consumption is of importance because the continuously increasing levels of consumption pose challenges for living within ecological limits. Adopting more environmental patterns of consumption would be beneficial in order to decrease the total consumption, which is needed (Alfredsson, 2004). Therefore, it is not only material, spatial and thermal standards and norms that influence the resource intensity of environments that is important. A key indicator of the environmental impact related to architecture is found in residents' ways of life (Hagbert, 2016) and can also influence their concern for the environment (Hartig & Kahn, 2016). As these elements are not included in NBEATs today, this is a new aspect which could be included in future assessment tools and in environmental architectural theories. This could be of importance because it could make architecture engage on an ecological sphere of action rather than being a static geographical unit (Harrison, 2013). It could then engage in influencing inhabitants, children and future generations to become more sustainable.

It would be difficult to express NBEATs as architectural theory because of voluntary and tradable indicators, and because NBEATs not only assess the

architecture but also the procedures surrounding it. Further investigation could reveal what such a theory would look like, what an architectural theory that emphasises 'environmental' architecture based on concepts of environmental sustainability could be, and what aesthetic influences it would have. To start with, it would emphasise the whole life cycle of the architecture and its local and global environmental impacts.

### 5.2.4. A building perspective versus a neighbourhood perspective

When comparing environmental assessment tools for buildings and for neighbourhoods respectively, there are some differences which show that the perspectives on environmental aspects in architecture vary with the scale of the project and the perspective of the assessment tool. These differences can also influence architecture.

The results in Paper IV show that a neighbourhood can be certified without having buildings that meet environmental criteria. The environmental aspects found in assessment tools for buildings (Paper I & II) can thus be neglected in neighbourhood tools. This signals that neighbourhoods can be sustainable without having sustainable buildings.

Another difference is that outdoor environments are not measured from the same perspective or in the same way as indoor environments. Indoor environments in the assessment tools for buildings deal with e.g. daylight, acoustics, low VOC, which have a direct impact on the occupants' health. The outdoors, on the other hand, considers predominantly places for parking, transport, and communication, both in the neighbourhood tools and in the building tools. To some extent handling of storm water and ecological qualities is considered in LEED-ND, and BREEAM-C evaluates wind, local climate, and outdoor social areas. Noise, or air quality outside, is not measured in LEED-ND or BREEAM-C. Quality measures for the outdoor environment seem not to be prioritised to the same extent as the indoor environment. Humans spend more and more time indoors, sometimes more than 90% of our lives (Evans & McCoy, 1998). But, having outdoor places for living can have many benefits for both health and the environment, as outdoor spaces can replace and decrease the need for indoor spaces, which are more energy and material intense. Compare for instance an outdoor gym with an indoor gym. Further, when outdoor and indoor environments are assessed in different ways it can result in situations where the indoor quality is achieved at the expense of the outdoor quality, e.g. good air quality indoors is achieved with ventilation systems, which create noise outdoors, which can decrease the outdoor quality and increase the need for indoor spaces; or demand for transportation outdoors can lead to noise and pollution indoors.

Further, the different perspectives can have a large influence on what environmental impacts are measured. The environmental impacts from materials are addressed in the assessment tools for buildings to some degree. However, in the neighbourhood tools they are only included to a limited extent. The importance of the used materials on the neighbourhood scale have been highlighted in LCA studies of dwellings by Hammond and Jones (2008). They observed that there was little difference between embodied energy and carbon dioxide for houses and apartments until external works were taken into account

(energy inputs for roads, connecting pathways etc.). These results indicate that the use of materials should be as important for neighbourhoods as for buildings.

The large variation between building and neighbourhood tools creates ambiguity regarding what constitutes important aspects in 'environmental' architecture. Because, the scale of the project, i.e. if it is a building or a neighbourhood that is assessed, influences which environmental aspects are addressed, even though the environmental aspects connected to environmental sustainability are, in many ways, independent of scale. However, this addresses the importance of scale when planning, designing and constructing architecture. If making plans for a large scale project for several hectares, and using drawings and plans in scale 1:10000 or 1:500, as in the architectural competition *A New City Centre for Kiruna*, important details and environmental considerations are easily diminished. Here, building and neighbourhood tools with their different perspectives on environmental concerns can learn from each other. Building tools could better include a holistic view on creating places for people to live their lives in. Neighbourhood tools could better include the building tools' attention to detail and energy-saving optimisation.

## 5.3. Architects' relation to NBEATs and environmental aspects

This section is based on the results in Paper V, regarding the architects' relation to NBEATs and environmental aspects. To a limited extent the results regarding the NBEATs' content and indicators, in Papers I, II, III, and IV, will also be included. This is because NBEATs encompass performance, feature and procedure indicators which assess not only the physical building but also the building process and then indirectly the professionals involved.

### 5.3.1. Knowledge and use of tools in early design phases

If environmental aspects are incorporated early in a project when the opportunities for making decisions that influence the environment in a positive way is greatest, the most significant environmental effects can be made. Ding (2008) even argues that environmental matters are best incorporated early in the project's appraisal stage and early design stage, because then important choices and selection of more environmentally friendly designs can be made. Relying on the design of a project to achieve the goal of sustainable development, or to minimise impacts through appropriate management on-site, is not sufficient to handle today's problems. To make it easier to make decisions which minimise environmental impact in early design phases, it should be possible to use the tools as decision supports in these phases. But, the survey (Paper V) show that the use of any NBEAT is rather low (47%) among the participants and that the use in early design phases such as the Kiruna competition is even lower (13%).

One barrier to using NBEATs in early phases is that the tools are complex and much information is demanded. Other studies have presented the difficulty with combining assessment tools with innovation (Cole, 2005; Paper II). The early design phase is very much about innovation. In both the history and in current practice of architecture, originality and novelty is often emphasised (Cunningham, 2005). This is contradictory to predefined and environmentally evaluated solutions. Further, architectural practice has a predominantly aesthetic focus, with less emphasis on the people involved in the production of the buildings, or the needs of the users (Conway & Roenisch, 2005). Moreover, NBEATs represent analytical and rational thinking, while creative thinking underlies architectural design. This division can be one reason behind the low usage, and somehow needs to be bridged. Further, the planning and design process is a decision-making process with many stakeholders. According to decision theory and behavioural theory there are many things that can influence such a situation. Not every decision is made on a rational basis (Hammond et al., 1999), and even if an assessment tool is used there are other goals, demands and priorities that shape our built environments. Risk, fear, lack of knowledge, lack of control, negotiation, habits, economic and personal incentives, may influence the outcome.

The fact that the NBEATs have criteria and indicators that are open to subjective interpretations may also form a barrier to using the tools. The experts surveyed in Aspinal et als' study (2012) recommended first, that BREEAM manuals should be written in a much clearer fashion and secondly, that

BREEAM assessors, with the ability to interpret the credits, should be available to support decision-makers regarding these subjective criteria.

Another aspect which makes it difficult to use tools in early phases is that in order to make an assessment with NBEATs, a large amount of information regarding the project is needed. This information may not exist in the early design phase. Moreover, NBEATs contain large number of indicators, which create demands on architects and consultants, who must understand the meaning of all the indicators and also come up with solutions when needed (Tam, 2007). To accommodate architects better, NBEATs would need to work on different incentives and make the manuals simpler to use. For example, by including design guidelines in NBEATs, with clearer set of advice to follow. But that is difficult to achieve without decreasing the validity of the tools. AlWaer et al. (2008) suggests that a more accurate assessment of sustainability issues would involve a more complex operational framework. This show that there is a discrepancy between the user-friendly tools designed for architects and the valid and reliable tools put forward by researchers.

When discussing the role of architects in reducing the environmental impacts from architecture, it is important to remember that there are further actors, support systems, as well as national markets and policies which make people respond to economic opportunities (Lambin et al., 2001), which are important issues to consider. If it becomes easier to design and build architecture that has a positive impact on the environment, it is more likely this will happen.

### 5.3.2. Environmental knowledge

Environmental knowledge is something that could be increased among the participants in the study in Paper V. Using environmental assessment tools could be a way to gain knowledge about environmental urban design, but the results show only a small increase in self-rated knowledge among tool users compared to non-tool users, even though environmental assessment tool manuals contain much information about environmental aspects.

The small difference between NBEAT users and non-NBEAT users regarding knowledge on how to handle environmental impacts could result from the tools primarily dealing with assessing environmental impact, and setting targets. Even though some criteria are specified features and procedures, tools-users will not learn from the tool-manuals how exactly to decrease environmental impacts. Measuring environmental impact will make users and professionals aware of the amount of impact, and can lead to a decrease, but it is not always an automatic result (e.g. measuring energy use, which is demanded in EU (EU, 2002), does not automatically lead to energy efficient buildings). Assessment tools have therefore been criticised, for example by Schendler (2009), who says that LEED is a good idea, but that it cannot solve the problem, because LEED is a certification process, and not a construction handbook – an indication that solutions are required. Others call for the need for relevant educational programmes to increase architects' environmental knowledge (Chen et al., 2008). This education not only needs to provide architects with sufficient specialist knowledge on environmental design principles, but also to improve their communicational skills to facilitate knowledge transfer and educate other stakeholders about these concerns.

Results in Paper V show that interest in environmental issues already exists. Yet still, many architects have not worked with most environmental aspects (Paper V). The relation between NBEATs and architects could be improved by developing the tools further. One option would be to make NBEATs' manuals and indicators (and additional reference guides, web-sites, educational seminars and courses) contain more information on principles and design guidelines on reducing negative environmental impact and maximising positive ones. Understanding ecological limitation and how the built environment is connected to ecological and social aspects then becomes important as there are architects who do not consider nature as part of the built environment (TED, 2005). The constructed environment is the main focus and the natural elements to a large extent are excluded from the built environment. Therefore, knowledge on ecological and social aspects is a prerequisite for taking environmental responsibility and acting pro-environmentally when designing and creating architecture.

To make NBEATs easier to use during early design phases and competition settings, tool developers who are developing, administering and marketing NBEATs should continue working on the content, format and communication of these tools. Criteria and indicators should be suitable for use by both competitors and the jury to evaluate design proposals. For architects, landscape architects and urban planners, the results of the present study show that in the architectural competition, few professionals were skilled in handling environmental aspects or had knowledge of NBEATs and environmental aspects. It can therefore be a competitive advantage to be an expert in this field if the market demands more sustainable buildings.

### 5.3.3. Influence on procedures and decisions in the design process

NBEATs not only influence what decisions are made, but also how, and when decisions have to be taken. A clear effect on the design process is that the tools' high number of indicators demands a high degree of documentation and a detailed design when performing a certification. If the nested indicators are included, it becomes even larger. When NBEATs are used for strategic decision-making they also increase the need to make decisions about detailed information during the early stages. Details which otherwise could have been decided in the final design stage or in the building stage, can influence the assessment rating and therefore need to be included, such as bicycle parking or laundry drying spaces. It also makes it more difficult to change the design late in a building process. Changes made late in the process may have consequences for the assessment result and, therefore, their influence on the environmental assessment also need to be analysed. This is an aspect which could hinder late design changes, and which will further increase the importance of the early design phases.

Studies have identified that early involvement of stakeholders, interdisciplinary teams, plus simultaneous collaboration and transparency in communication and information are success factors for sustainable building (Kovacic & Müller, 2014). Here NBEATs have an important role to play as fundamental changes in the traditional design processes of architecture is required for a more integrated, collaborative practice with life-cycle orientation (Kovacic & Müller, 2014). But, then NBEATs need to develop in the same direction.

Moreover, another step towards implementation could be a change of fee structure for architects and engineers and scope of services (Kovacic & Müller, 2014). These issues are more separated from the influence of NBEATs and the studies in this thesis. Still, the economic aspects together with tools for evaluation and design were also ranked as important by the participants in the Kiruna competition and are therefore aspects of importance according to the results in Paper V.

The content of NBEATs is important as NBEATs also influence the architect's role when designing architecture that has low environmental impact. Today, there is a risk that to follow tools and hunt credits becomes the new goal within the profession (Schendler, 2009). When the environmental goals in the NBEATs are set on a moderate level this credit hunting could limit the increased environmental innovation and knowledge that is desirable.

## 5.4. Ethics in NBEATs, architecture, and among architects

The shaping of architecture is also a shaping of the environment, where the laws around it often constitute the minimum standard of performance. Ethics is then the guide when deciding what ought to be done and what the right thing to do is. These are ethical questions that architects have to deal with in their profession (Wasserman et al., 2000). The presumed intention is to shape physical places which suite human purposes and improve the quality of life, which implicitly demands architects to judge what the right thing to do is. Chen et al. (2008, p.1) even mean that '*it is the architects' responsibility to help other stakeholders make informed decisions*'. This is a task which demands knowledge and understanding about architecture, design and building but also environmental issues. Here the NBEATs can be instrumental in judging and presenting what is right to do from an environmental perspective and can influence architects and other professionals, architecture and in the end the environment.

When discussing NBEATs in relation to environment, architecture and architects, it becomes clear that NBEATs with their defined indicators, criteria and weighting tell us about what is considered positive to do as architects and with architectural design for the environment in a project. In that sense, the studies of NBEATs' contents, in some ways, show us how the tools think tool-users ought to act, which is an ethical question concerning what to do, and how one should behave with regards to nature (Rothenberg, 1993), which is what environmental ethics is about (Lundmark, 2007). Moreover, its implied ethics tell us what to consider in architecture, and becomes a code of conduct for architects, i.e. the duties and standards of conduct for individuals, groups, and professions (Wasserman et al., 2000, p.25).

The criteria and indicators capture the ethical positions of the NBEATs, even though it is not explicitly stated what underlying values have influenced and shaped these tools. If they are based on ethical reasoning about consequences, (utility theory, teleology), principles of duty (deontology), virtues of architecture, or social contracts regarding fairness and justice, which

sustainable development is all about, it is never stated. So far, much of the available indicators, advice and rhetoric about architecture and environmental issues in NBEATs begin from positions where important ethical, cultural and conceptual issues are simply assumed (Williamson, Radford & Bennetts, 2003). One way to discern the ethical content of architecture is through studying the purposes of the building programme (Wasserman et al., 2000). Here the NBEATs can be seen as building programmes whose content and purposes could be studied further.

There is little discussion of these ethics, including assumptions, beliefs, goals and bodies of knowledge that underlie the NBEATs and their perspective on environmental and sustainable buildings and neighbourhoods. This could be because framing of problems emanate from solutions rather than from existing problems, at least in planning, according to Persson (2013). Concepts of sustainable development have been internalised into already existing planning principles and have not been rethinking planning (Persson, 2013). This could also be valid for architectural design, and assessment tools for buildings and neighbourhoods, where some of the criteria have evolved from solutions that exist today, and are not based on sustainability goals. These solutions can then influence principles and ethics. The interpretation of what environmental or sustainable is and entails can, still, influence how planning bodies structure a complex reality into a more or less coherent body of thought (Dühr et al., 2010), which can be called *'a planning doctrine (Alexander & Faludi, 1996) or paradigm (Faludi, 1999), which can be seen as a kind of 'belief system' (Abram, 2011; Alexander & Faludi, 1996; Faludi, 1999) that gives meaning to different planning activities.*' (Persson, 2013, p.302)

When studying NBEATs and their indicators, an initial idea is that the different types of indicators belong to different ethical theories. The *feature* indicators, act as rules or principles, which should be followed independent if they are really to serve their purpose. For example, bicycle parking should be built even if the project was located in Venice, where boat or walking would be the best means of transportation. Because feature indicators are often based on using good technology, they are also likely to be based on ideas about the excellence of things (teleology) that will lead to 'good' results/ends (Wasserman et al., 2000). This is also the case for the *procedure* indicators. Here, criteria concerning procedures and processes represent best practice, and a kind of excellence of practice which is 'good' in itself. The *performance* indicators are more aligned with ideas about consequences of actions and utilitarianism, with the objectives of arriving at good ends and maximising wellbeing (Wasserman et al., 2000), this, for example, is the target in EcoEffect's external environmental impact category. This is because performance indicators give information which could be used when identifying and calculating the maximised benefit of an action often used in cost/benefit analyses. The Japanese tool CASBEE also clearly distinguish between when built environmental loads and built environmental qualities are assessed (JSBC, 2015). This is not as clear in LEED, BREEAM-C or CSH.

Furthermore, when studying NBEATs and their content it appears they are based on anthropocentric values, as architecture often is. NBEATs have also been criticised for being 'building-centric' (Conte & Monno, 2012). The anthropocentric focus in NBEATs can be seen when studying the indicators.

The basic concepts and things to safeguard when working on improving the environmental quality — natural resources, pollution, ecosystems — are almost never included in the indicators nor mentioned in the manuals. Sometimes, social or health reasons are presented as the main aim to meet a criterion, without reference to environmental aspects. Few indicators have a sustainability perspective with a more ecocentric perspective where not only the wellbeing of man is considered, but also the wellbeing of nature and ecosystems. Ecosystem services are, for instance, protected to a limited extent and the addressed indicators connected to nature values are often not weighted very high (Figure 5.). Furthermore, often the concepts of natural and built environments are treated separately, even though they are interconnected and need to be considered when dealing with environmental issues in the built environment.

Knowing about the anthropocentric focus can make it easier to explain and understand why environmental considerations in NBEATs in many respects do not go as far into environmental considerations and the protection of natural environments as a tool based on ecocentric values would do. An ecocentric view is founded on a different concept of what/who has intrinsic value compared to anthropocentrism. Each individual living organism, humans of course included, and collectives, such as ecosystems, are given intrinsic value (Lundmark, 2007). Humans and the rest of nature are considered as truly and deeply interconnected where their mutual and long-term interests and welfare are considered and aimed for (Lundmark, 2007, p.104). Because of these different views, ecocentrism and anthropocentrism have a different orientation towards nature. Then, there are also mixed value systems, such as shallow ecology (Naess, 1973) which focuses on the importance of the environment for the health and wellbeing of people. People with a shallow ecologic value system worry about negative environmental impacts, and want to protect natural resources. They can promote political measures to deal with environmental problems; however, they have been criticised for recommending measures that do not really change industrial and economic systems. Systems, which focus on economic growth and as they are used today, are linked to environmental problems (Hatfield-Dodds et al., 2015). This might be why the NBEATs 'green' architecture is criticised by some environmentalists, companies and scientists that promote alternative tools based on strong sustainability or resilience (Cole et al., 2012; Gou & Xie, 2016).

One also wonders if NBEATs are representing the current view on 'green' architecture, or representing a future vision of 'green' architecture. When the NBEATs set relative criteria levels that relate to a conventional building or neighbourhood, they put the conventional structure as the norm, preserve the existing ideas and anchor the tool in existing views on architecture. This way of making small adjustments to reach e.g. environmental targets within current structures, makes them preserve existing normative scenarios — common in regional planning (Börjeson et al., 2006, p.728-729). As a result of this, environmental aspects might be considered as subjects separated from the main concepts and functions if they deviate from the norm (Svensson, 2015). Here, NBEATs have managed to put environmental aspects onto the architectural agenda by acknowledging environmental value and adding additional values such as market value for meeting the criteria and being certified.

When NBEATs instruct tool-users how they ought to act, it is possible that they influence architects' normative positions, including environmental concerns, which are based on what they know and believe about the world and how the design process should be conducted. These normative perspectives are shaped by designers' world views, which, in turn, are influenced by the societal and professional cultures to which they belong (Lang, 1987). Among architects and other actors in the construction business there are very different views on which environmental indicators should be used to assess sustainable buildings (Dammann, 2004). Dammann and Elle (2006) find that it might be difficult and probably unlikely that all stakeholders in the building and property sector will come to some kind of consensus in the near future. Closer consensus among stakeholders could, however, lead to better results (Chen et al., 2008). Therefore discussion of the environmental views and ethics connected to architecture is welcome. Here NBEATs have had an important role in defining and operationalising 'green' architecture, and can be part of a continuing discussion about environmental indicators, views and ethics.

The differences in content in assessment tools for buildings and tools for neighbourhood discussed in section 5.2.4. could be based on differences in ethics between building and planning disciplines. Analysis of assessments in architectural design and in planning are different from each other (Alexander, 2013). For architecture, as a profession and as a discipline, the built environment is the product of design. This perspective relates design to ethics in three ways. *'One is the link between ethics and aesthetics, another is how ethics relate to function, and the third is the recent concern with ethics of the environment.*' (Alexander, 2013, p.4). He also claims that these ethical differences of forming the built environment can explain the observed differences between 'design professions'. It is also a barrier to developing and applying an integrated ethical code for planning and designing the built environment. Because ethical principles can vary between individual and stakeholder perspectives, it is important to think about and critically examine what values, and whose values are represented in NBEATs. It can, for example, be the tool developers, contractors, architects, developers, researchers, consumers, children, disabled, the biosphere, politicians, other stakeholders, or a mix of all of them. This also calls for a more open and transparent discussion regarding ethics in the architectural profession and among all actors in the building and property sector.

Ethical differences can however change. Historically, the needs and purposes of society as a whole have changed with industrialisation and commercialisation (Merchant, 2006) and thus values have also changed. When new environmental considerations, existing environmental challenges and ecological crises demand change from society and new human and social needs, values will probably need to change (Merchant, 1979, 2006). Established conceptual structures can be undermined by new commercial and technological innovations or new human or social needs. (Merchant, 1979, 2006). Current global and local environmental concerns are aspects, which can undermine existing normative concepts and in a way might require values and codes of conducts to change.

All design decisions with respect to the built environment can be thought of as ethical decisions. The ethics in NBEATs are linked to architectural ethics and architects ethics.

NBEATs and their criteria and indicators are developed to do good. But when discussing their content in this thesis it becomes clear that it is possible to do even better, by having higher benchmarks, having more mandatory issues, and including more environmental aspects. It is relevant therefore to ask a number of ethical questions such as: is it ethical to stop at the present level and not have higher targets and benchmarks?; are NBEATs good enough to become and act as an universal law?; how many species is it permissible to kill in a new architectural development?; and/or is it acceptable to use toxic materials which can be cancerogenic in the pursuit of other functions, means and ends of architecture?

This thesis raises the importance of ethical considerations in the debate about environmental assessment tools, 'environmental' architecture, environmental aspects in architecture, and architects. In many ways it is closely linked to normative behavioural decision-theory concerned with prescribing courses of action that conform most closely to the decision-makers' beliefs and values, and descriptive decision-theory, describing the beliefs and values and the manner in which individuals incorporate them into their decisions (Slovic et al., 1977). Finding a single answer to all the ethical questions present in architectural projects is not the goal, and may not be possible. Because of the urgency in making environmental choices in architecture it may not be possible to wait until all the answers are found, but they need to be discussed in more detail. One progression could be further studies of NBEATs, the essence of their ethical values (their beliefs), vision (a future-oriented declaration of purpose and aspiration) and mission (their aim and purpose).

## 5.5. New perspectives related to NBEATs

### 5.5.1. New perspectives on environmental aspects

In a world where we already are transgressing planetary boundaries (Rockström et al., 2009), it is imperative to find better ways to measure and drive architecture in a more focused direction towards sustainability. Structured frameworks like NBEATs put together large numbers of environmental aspects and have managed to bring environmental aspects into the planning, building and property sector. NBEATs continue to gain greater acceptance. From a low level, they are being used increasingly, new versions are being developed, and they are beginning to be spread across many countries. Even though the available indicators manage to measure important environmental aspects and limit some unsustainable trends they still fall short of defining or ensuring environmental sustainability of architecture. This is mainly because several environmental and health aspects that are important for sustainability are not included or mandatory, and the used indicators are sometimes insufficient, even if they are valid and relevant. Likewise, when using procedure and feature indicators, they do not ensure that the actual outcome will be sufficiently environmental. It is also because criteria levels and benchmarks are not always very high, and the final outcomes measured on-site do not meet the planned performance. Therefore the tools have been criticised for having a limited impact on the environmental performance of buildings. For example, LEED-certification for office buildings, on average, is not lowering source energy consumption and, accordingly, is not delivering reduction in greenhouse gas emission associated with building operation if compared with their non-LEED counterparts (Scofield, 2009).

The important but relatively small effects NBEATs have on the total environmental impact from architecture also depend on the limited use of the tools. For example, having 1% of buildings being certified with 50% lower energy use would in the end have as much influence on the environment as decreasing the energy use for all buildings by 0.5%.

Another environmental sustainability consideration is that as long as new buildings add to total energy use and environmental impacts from architecture, they will increase the pressure on ecosystems and it will be difficult to lower the total environmental impact, not impair ecosystem services, and maintain the stability of life on this planet (Ehrlich, 1988). For example, the amount of square metres of housing per family in the United States has increased much faster than the level of energy use has decreased (Wilson & Boehland, 2005). Therefore, as house sizes increase, consequently the total energy use and environmental impacts increase. When environmental impacts are measured in relation to square metres in conventional buildings, the scale or magnitude of the project's total environmental impact or its contribution to human wellbeing is not considered. It is therefore a risk that measures that are meant to incentivise the expansion of environmental consideration in the housing sector (Jensen & Gram-Hanssen, 2008; Lundqvist, 2004) become relative improvements under the guise of 'green consumption', but then do not adequately address the absolute decrease of total consumption that is needed (Alfredsson, 2004). The result may instead be an increase in total consumption

due to an increase in 'green consumption' (Alfredsson, 2004). In the worst case 'green' labels, can contribute to this and may hide problematic aspects from public scrutiny (Beemsterboer & Kemp, 2016).

The fact that higher benchmarks and more radical changes are not demanded is not altogether strange. More radical transformations or utopian thoughts have been rare in the last decades of planning research and practice for sustainable urban development (Gunnarsson-Östling, 2011). To plan for a sustainable development is instead considered as something that can be reached within the society's current frames (Bradley, 2009; Börjeson et al., 2006). Contemporary development of sustainable buildings has been influenced by ecological modernisation (Jensen & Gram-Hanssen, 2008) and the main Swedish discourse regarding sustainability, is built on equalising sustainable development with ecological modernisation, which according to Lundqvist (2004) holds an inherent contradiction. The difficulty of changing the planning and building structure can also be seen when it comes to gender issues within the sector (Gunnarsson-Östling, 2011). Questioning and changing the current patriarchal order and traditional ways of thinking challenges the present structure (Gunnarsson-Östling, 2011). Perhaps environmental concerns in architecture do the same. To question norms, values and frameworks that have been taken for granted in planning theory and practice is difficult. It needs a more political approach (Gunnarsson-Östling, 2011) and to be successful, a systematic change, not just in the construction sector, but in the broader mores of governance is needed to change the paradigm (Schweber, 2013). Perhaps the same applies for incorporating environmental sustainability in architectural projects. If NBEAT users think that following NBEATs criteria will be sufficient to make architecture environmentally sustainable they are in some ways mislead. It is, therefore, important that NBEATs are transparent with what they assess and their limitations. Finding relevant and precise indicators is also a challenge.

The increased use of NBEATs has put environmental issues on the agenda in the building and property sector. It also creates an opportunity to develop the tools further, increase criteria levels and benchmarks, and plan for future versions of tools with higher environmental goals. Changes in NBEATs over the last ten years have, however, been limited (Paper IV). One step forward is for NBEATs to become more transparent and clearer about the need for increased environmental targets within architecture to get closer to environmental sustainability. If NBEATs and their indicators become institutionalised they can be difficult to change. It is therefore important to have high targets from the beginning, or a plan regarding how to increase the environmental targets and criteria levels.

NBEATs have managed to put environmental issues on the agenda, but a challenge still remains to make environmental aspects compete in a climate where economic aspects dominate in the current global free-market economy. Most products and processes are still optimised according only to their economic performance and disregarding environmental aspects (Carreras et al., 2016). Even energy-saving measures, can be difficult to prioritise if they not are financially beneficial, or if they challenge or change existing relationships, work practices, and customer relations (Thoresson, 2015). The economic impact even influences which indicators are used. Those that cost the most tend to be the

ones that are least attained (Wu et al., 2016). If market signals remain the ideologically preferred mechanism by which sustainability is implemented, Schweber (2013) concludes that it is likely that assessment methods will continue to affirm technical, mechanistic models of sustainability.

It is positive that NBEATs have included LCA calculations to some extent, and have managed to introduce life cycle perspective into building and planning. However, there is still a long way to go before life cycle assessments of architecture are made on a regular basis. Making LCA assessment of buildings easy is a challenge but with the use of digital design, modelling and specification of architecture, the use of BIM (Building Integrated Modeling), and hopefully future low-cost, or free LCA databases, it would become less demanding and more universal. Using LCA during early design phases when all the choices have not been made will, however, call for simplified versions where one needs to compromise between the level of detail and the practical use to the designer (Din & Brotas, 2016), which leads to a risk of sub-optimisation. The use of LCA calculations only for the main construction in buildings ignores other relevant materials, such as materials in ventilation systems and electricity installations, even though materials used to a limited extent can be responsible for a significant proportion of the buildings total life cycle impact (Graubner & Pohl, 2015).

### 5.5.2. New perspectives on Architecture

#### *Place making instead of decontextualisation*

The results in this thesis show the complexity of NBEATs and the wide variation in used indicators, which lead to different assessment results and drives architecture in different directions. NBEATs contain several relative measures, and many indicators have no relation to the specific, site, region or cultural context in which the architecture is constructed. These relative measures make it easier to adopt NBEATs in different countries, regions, cultures and building codes. The included indicators can however both open up and close down opportunities from local sustainability solutions (Wu et al., 2016). Using local materials and local building traditions, local sustainability solutions, and local workforce — from architects, developers, engineers, constructors, to carpenters — can be one way to decrease the environmental impact from architecture. These aspects are addressed to a limited extent; in LEED-NC there are issues about local materials, BREEAM-C has issues about local vernacular design, and in EcoEffect and the ENSLIC-tool through the inclusion of transport in the LCA calculations. NBEATs are therefore largely spatially decontextualised. Simultaneously, very little of their content concerns what kind of habitat and lifestyles certified buildings promote and create. Issues regarding what kind of life people are expected to live in the certified buildings and neighbourhoods are only integrated by considerations such as creating mixed communities where housing, services and offices are available and configuring rooms in apartments as home offices.

This decontextualisation from place and culture, creates a distance from architectural considerations connected to the place, such as genius loci, i.e. the special atmosphere and spirit of a particular place (The Free Dictionary by Farlex, 2016). This creates a focus on creating spaces, and not places. The value

of place making is therefore not included in NBEATs. A major challenge for NBEATs is therefore to consider the uniqueness of places, ecosystems, and cultures and, if possible, at the same time combine it with: flexibility, that makes it possible to transfer the tools to other regions and countries; and standardisation that makes it possible to compare different buildings from different places built in different contexts.

### *Architecture and health*

A strength with NBEATs is that they bring architecture and health issues closer. The connection between architecture and health aspects is put forward primarily in the indoor environment issues, such as air quality, and in transport issues, which are connected to physical activity. It is primarily local environmental aspects that are described in the manuals as linked to health concerns. Therefore, a weakness is that many other environmental impacts connected to health are not put forward, such as climate change influence on health (Wang & Horton), toxic substances relation to adverse health outcomes (Olsén et al., 2012; Wennberg et al., 2015), the beneficial effects of access to urban green space and ecosystem services on physical health aspects (Mitchell & Popham, 2008) as well as on psychological health aspects (Alcock et al., 2014; Hartig et al., 2014).

Here, NBEATs have an opportunity to inform and educate NBEAT-users about the direct and indirect health-related aspects to a greater extent and include it even more. Designing architecture which could prevent health problems would be an easier and more cost-effective way of making people healthy and happier instead of trying to find the right treatment when the damage has been done and it is too late. Here, the challenge for NBEATs is not only to address the health aspects relating to architecture and environment, but also to find strategies and solutions for preventing health problems caused by local and global environmental aspects.

### *Linking environmental aspects and design together*

A strength of NBEATs is that they focus on environmental aspects and often leave it open to meet the criteria in optional ways. A limitation is that they do not recognise that environmental aspects are related to architectural design and aesthetic considerations, even if issues and indicators clearly have an aesthetic influence, such as on-site renewable energy, or green roofs. This makes NBEATs distanced from architectural theory and practice and traditional architectural debate.

Using environmental assessment tools may be one way to get closer to the solutions of how to design and create ‘environmental’ architecture. But, their influence and importance as instruments for changing architecture and the building and property sectors towards environmental sustainability will not be substantial if the use of NBEATs does not increase to substantial levels, not adapt to fit better into early design phases, and not continue to develop and embrace criteria at levels that aim for environmental sustainability. Even though small-scale individual actions can be of great importance and should not be underestimated, it is also necessary to have action that has large-scale impact to limit the total environmental degradation caused by architecture. A more fundamental and transformative change may be needed.

Environmental indicators have a direct and indirect connection to the design of architecture and create demands and restrictions on the design. This connection between environmental targets and architectural design is not highlighted either in tools or in research. Adding environmental considerations into architectural design and aesthetics and at the same time recognise the design and aesthetic aspects of 'environmental' architecture could be a way forward. Palladio (1570) thought that architecture ought to deliver Vitruvius's design imperatives: *durability*, *convenience,* and *beauty*, and if all three of them were not present in architecture, it could never be perfect. In a similar way, architecture which does not take important environmental considerations into account and results in major environmental damage cannot be perfect and beautiful, nor contain virtue.

Architecture is about the physical structures that are built, how it is built, what it looks like, the process of design and constructing buildings. Ultimately it is about the future, as the buildings we design or refurbish today are the ones that we will inhabit. Therefore they are important as they will shape our society in the future. Churchill said in 1943 *'We shape our buildings and afterwards, they shape us'* (Swindler, 2008; Wasserman et al., 2000). NBEATs are designed as assessment tools and decision support tools. If they are used they influence architects, architecture and the environment. Therefore NBEATs need to acknowledge that they have an aesthetic impact on architecture and it is important to investigate further what sort of architecture they lead to, and to consider what architecture we want them to lead to.

Achieving 'environmental' architecture is fundamentally an ethical challenge. This could also motivate discussion, and the implementation and transparency of ethical principles linked to environmental concerns and NBEAT indicators — guiding the transition towards 'environmental' architecture. Existing architecture, building codes, and codes of conduct in the building and property sector, mainly deal with local human safety issues. Here NBEATs can play an important role and put forward many issues, such as environmental, social, technical, professional, psychological and ethical issues, and their criteria can be transformed into building codes. It would then become clearer what values the tools reflect and what values we want them to create.

### 5.5.3. New perspectives related to architects

NBEATs contain a large number of relevant environmental issues and indicators that are related to architecture. But, it is not clear how much they affect the NBEAT-users' knowledge and skills regarding how to handle environmental aspects. Perhaps users learn how to measure environmental impacts without learning how to decrease them. When NBEATs are used in projects they provide an opportunity to give architects new perspectives by educating users about the environmental benefits of planning, designing and building architecture that has a limited negative impact on the environment. They could give new perspectives on how our built environment is strongly connected with technological, social and ecological aspects. Here, NBEATs can play an important role in combining ecological, technological, social and also psychological concerns. Social and psychological factors among the different individuals involved in the architectural processes, are relevant barriers for

more ‘environmental’ architecture (Hoffman & Henn, 2008), and therefore needs to be studied and considered more in NBEATs.

The challenge is to reach out not just to the specialists working with the assessments. In a democratic planning process, it is important that all those involved are educated and aware of the environmental impacts and possible solutions and strategies for dealing with the problems. If only a minority of individuals, assessors or those familiar with environmental considerations are involved, there is a risk that their influence will be limited. Therefore, relevant educational programmes are needed to give architects and other actors sufficient specialist knowledge, and also to improve their communication skills so they can transfer knowledge and educate other stakeholders into more collaborative roles (Chen et al., 2008).

Maybe neither NBEATs nor science can really determine what is sustainable. Independently, they can offer evidence about the problems that concern sustainable development (Beemsterboer & Kemp, 2016; Bond & Morrison-Saunders, 2013). They can also make people mindful of the normative aspects in their own thinking, valuations and assumptions about progress, and then reveal different perspectives on sustainability issues. As sustainability is both objective and subjective, a fixed set of criteria that is valid irrespective of time, place and topic cannot be constructed (Bond & Morrison-Saunders, 2013; Gibson et al., 2013). At best, NBEATs can wed theory to practice and encourage us to rethink the relationship between architecture, architects and the environment. They could allow architects and other tool-users to foster new ways of understanding and of experimenting with ‘environmental’ architecture and its linked ethics, which might help us to choose indicators that are appropriate, meaningful and contribute to living built human environments.

### 5.5.4. New socio-eco-technological system perspectives

This cover essay presents NBEATs’ relation to more than merely environmental aspects. NBEATs also relate closely to architectural design, to architects and other decision-makers, and are linked to applied ethics. The built environment — architecture — is a technical artefact that includes technological aspects interlinked with sociological aspects through the involvement of architects and all other stakeholders in an architectural project’s life cycle and also its inhabitants. It is not possible to separate the latter from the ecological systems they act within. Thus, architecture encompasses a system where social, ecological and technological aspects interact. This holistic system approach needs to be further considered in NBEATs and hopefully also incorporated into an architectural design theory.

Currently NBEATs contain indicators that measure social aspects through procedure indicators, technical aspects through feature and performance indicators, and environmental aspects, directly through performance indicators and indirectly through the features and procedure indicators. Social and ecological aspects could, however, be included to a greater extent, and ecosystem services and architecture’s influence on inhabitants’ lifestyles and cultures could be explored and incorporated further. This calls for a new perspective on NBEATs’ content and on ‘environmental’ architecture.

Sustainability has moved from being only a natural science subject concerned with the protection of natural resources, to: a more socio-technical issue, which sees technology and sociological systems as interactive (Rohracher, 2001); and a socio-ecological issue, where interactions and links between environmental impacts and social and economic wellbeing are highlighted (Berkes et al., 2000; Young et al., 2006). When studying NBEATs and architecture it is valuable to put together these perspectives into socio-eco-technological systems (SETS) perspective. SETS combine the notion of socio-ecological systems, representing complex systems of biogeophysical and social factors that regularly interact, defined by spatial or functional boundaries, and emphasise that humans (social systems) and nature (ecological systems) are integrated systems (Berkes et al., 2000); and socio-technological systems, which recognises the interaction between people and technology in production, distribution and use of technologies (Geels, 2004). The ecological system contains the geobiosphere, the technological system contains the built environment, artefacts, technology, and information technology, and the social system includes culture, institutions, and behaviour of groups or people. SETS are already included to some extent in NBEATs. However, a future task for NBEATs is to evolve into tools that make it possible to assess SETS, as ecological aspects are interlinked with technical and social aspects.

Still, more scientific advances are needed to understand better the linked behaviour of complex social, economic, technical and biophysical systems and to find solutions for environmentally sustainable built environments. In-depth interdisciplinary research between architecture and ecology could lead to new designs and innovations (Gou & Xie, 2016). Then that knowledge can be applied to NBEATs and the design and management of future technologies and infrastructures to meet human needs (Fiksel, 2006), and it could also be extended to policies and legislation. If NBEATs, in combination with other measures, increase our understanding of the relationship between technology, biophysical limits and societal needs, future architecture will hopefully be able to create a safe and just operating space for humanity meeting the UN Sustainable Development Goals (United Nations, 2016). Today, we do not know exactly what is needed to reach this condition (The James Hutton Institute, 2015) but we know that the way we build and manage our urban environments today is not sustainable. A challenge for future architecture and NBEATs is how to combine built environments with natural environments and biodiversity, and bring ‘green’ architecture beyond just green and towards local and global environmental sustainability.

### 5.5.5. Future perspectives

To drive architecture towards environmental sustainability, NBEATs need further development, and there are both philosophical (ethical) and practical considerations to be made. A more environmental architecture is a key aspect of a future sustainable society. To ensure that, NBEATs have some challenges ahead. These include finding indicators that not only: measure the existing state, but have a life cycle perspective; measure change in environmental impacts in dynamic building and property projects; and establish environmental targets and benchmarks which a projects progress can be measured against (Dahl, 2012), which in some way relate to global level indicators of planetary environmental sustainability. In addition, NBEATs’ criteria need to be

mandatory and environmental aspects, ecosystem, services, biodiversity, land use, embedded toxic substances and creation of sustainable nutrient cycles need to be addressed still further. NBEATs also need to provide projects, architects, and other professionals with indicators which reflect the project's specific and individual progress, which can provide positive incentives for further effort beyond NBEATs criteria levels.

To achieve that, it is necessary to analyse problems both before and in parallel with finding solutions. Problems need to be defined correctly in order to come up with solutions that actually work. Here the LCA study in Paper III reminds us that the view on what is the greatest environmental problem can vary with context, as materials were shown to have the largest environmental impact on climate change when compared with the impact from operation when low emitting district heat and Swedish electricity mix were use as energy sources. This is why it is difficult to demand from a tool that its criteria, indicators and weighting should be comprehensive and adoptable in different countries, regions, and cultures, without adapting it to the local context. However, even if the use and knowledge of NBEATs increase and tool-users becomes better in meeting the criteria, NBEATs cannot be responsible for the environmental impacts from architecture. Other measures, such as education, governance and policy responses are needed to protect the environment, and the building and property sector need to continue working with environmental aspects.

What then will the next generation of NBEATs look like? It could be a regenerative sustainability framework that will shift from 'greening projects' to 'greening organisations' (Lu & Zhang, 2016). A socio-eco-technological system perspective is desirable. The current linear assessment approach with single technical measures neglects criteria trade-offs. Especially in early planning stages, the optimisation of single criteria can fail to measure the overall building performance, and trade-offs between stakeholder interests and high sustainability performance. Existing NBEATs need to highlight interdependencies between optimisation and estimation of single measure's influence on overall building sustainability, and stakeholder objectives (Kreiner et al., 2015). Otherwise single parameters may be improved while effects on the overall assessment remain unknown. There are many indications that to actually transfer the principles of sustainable development into the construction sector, a change of paradigm is probably needed (Kreiner et al., 2015).

If NBEATS are going to have any large positive environmental effects and contribute to an environmentally sustainable society, this thesis highlights that they need to be used more, their environmental targets need to be higher to minimise the environmental impact from buildings or even result in positive environmental effects. Criteria and indicators should not be exchangeable and the tools should take the whole life cycle of the architecture into consideration as well as incorporate all aspects that are crucial for a sustainable environment. Together these factors will influence architecture and urban design as the high criteria will demand environmental design solutions. Consequently NBEATs may influence our understanding of environmental aspects and design aspects connected to architecture.

# 6. CONCLUSIONS

This thesis presents and discusses NBEATs' relation to environment, architecture, and architects by studying their function as environmental assessment tools, their role in operationalising more environmental architecture, and their function as decision support tools. Even if NBEATs include issues related to similar environmentally relevant categories, such as Energy & Pollution and Material & Waste, there are differences in terms of the environmental aspects addressed, spatial and temporal boundaries, and what type of indicators and parameters are used. This illustrates the lack of consensus between NBEATs in terms of issues, indicators, criteria, and weighting, however, they have also contributed to the discussion about what environmental aspects should be considered when assessing architecture. This in turn affects ratings, assessment results, environmental issues, need of input data, aggregation methodology, weighting, and their relation to environment, architecture and architects.

### *NBEAT in relation to environmental sustainability*

Most NBEATs studied in this thesis have a relative understanding of sustainable architecture and a focus on internal sustainability with a limited life cycle perspective, especially the neighbourhood tools. Important environmental aspects, such as embedded toxic substances, biogeochemical flows for phosphorus and nitrogen, land use change, and ecosystem services are included to a limited extent and weighted low. A large number of non-mandatory issues make the tools flexible, but signal that environmental aspects are exchangeable thereby making it possible to ignore relevant environmental aspects. As a consequence, buildings and neighbourhoods can be certified without acknowledging relevant environmental aspects that are important for environmental sustainability. As buildings and neighbourhoods are unique and situated in different contexts, fixed criteria, criteria levels and weighting of environmental aspects used in many NBEATs can give decontextualised assessment results that are distanced from the real environmental impacts.

### *NBEATs influence on architecture*

The different criteria and indicators measuring procedures, features and performance lead to different strategies and tactics to gain credits and high overall rating in the tools. This, also influences architectural design in different ways and directions, often with a focus on energy-saving issues, even if it is seldom discussed in what way. The architecture promoted by the criteria in NBEATs like LEED, CSH, and BREEAM can be defined as 'green' architecture, causing less environmental impacts in relative terms in comparison to similar buildings. In contrast, 'environmental' architecture, have higher criteria levels and focuses on absolute energy, mass flows, ecological limitations and progress towards sustainability. NBEATs and their environmental criteria are still treated as separate add-ons to architecture. To make the environmental aspects a more natural part of architecture, it would be desirable to bridge the gap between NBEATs' environmental criteria and architectural theory and practice. Furthermore, the gap between building and neighbourhood perspectives shows

great ambiguity between what constitutes 'environmental' architecture from a planning perspective and 'environmental' architecture from a building perspective.

### *Architects' relation to NBEATs*

It would benefit the environment if NBEATs could support architects and other decision-makers to make more informed and environmental decisions when designing architecture. Apart from NBEATs' limitation regarding environmental sustainability, this thesis presents three additional results. Firstly, key stakeholders, such as architects have a limited general knowledge and use of tools, and few used them in an architectural competition during the important early design phase. Secondly, use of NBEATs seems only to increase knowledge about how to handle environmental aspects to a limited extent, and few professionals self-rate their skill in handling environmental aspects high. These results combined with the high rating of the importance of environmental aspects calls for increasing architects' knowledge and know-how of environmental strategies and solutions. Environmental aspects, NBEATs' criteria and goals can be better integrated into the early design in architectural projects and competitions. The low use of NBEATs could be due to the high demand for documentation and focus on assessment in the tools, which is difficult to combine with innovation and design in early design phases when detailed information may not exist.

### *Ethics in NBEATs*

When NBEATs' content, indicators and weightings aim at guiding architects towards more environmental architecture, they ultimately operationalise ethical positions, which concern what we ought to do to improve life in a given situation. These ethical positions become codes of conduct, which guide tool-users through architectural design choices. Therefore. a continuous discussion regarding the ethics of NBEATs, environment, architecture and architects needs to be integrated into the further development of NBEATs and future building codes. Having clearer ethical principles could make NBEATs more transparent and help to guide the transition towards 'environmental' architecture. Here NBEATs can play an important role, but then it needs to be clearer what values the tools reflect and what values we want them to create.

### *Future perspective — a socio-eco-technological system perspective*

If NBEATs are to drive architecture towards environmental sustainability they need to be further developed into relevant and practical tools that have a life cycle perspective and can be used in early design phases. Then, both practical and philosophical (i.e. ethical) considerations are important, complementing the economic aspects that dominate today. NBEATs, with their environmental consideration of architecture and architects, relate to the environment (ecological aspects), to architecture (technological aspects) and architects and other stakeholders (sociological aspects). This can be combined into a socio-eco-technological system perspective, which is important when developing future NBEATs for assessing and guiding the design of architecture.

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# 8. APPENDICES

## Appendix A.

Summary of Environmental Categories and Issues in EcoEffect according to EcoEffect's own organisation.

| Categories | Issues/Environmental impacts |
|---|---|
| **External Environmental Impacts** | Acidification<br>Nitrification<br>Greenhouse impact<br>Radioactivity<br>Ozone depletion<br>Ozone<br>Toxic substances<br>Deposited waste<br>Depletion of natural resources (stock, funds, and flows) |
| **Internal Environmental Impacts (outdoor and indoor)** | Ill-health, health problems (air and ground pollutants)<br>Discomfort (noise, shade, wind, smell)<br>Joint disorder<br>Sleeping disorder<br>Sick Building Syndrome (SBS)<br>Allergy<br>Air quality<br>Thermal climate<br>Sound environment<br>Light condition, daylight and luminance<br>Electric and magnetic environment<br>Biodiversity<br>Biological reproduction capacity<br>Material circulation<br>Recipient pollution and disordered water stream |

## Appendix B.

Summary of Environmental Categories and Issues in LEED for New Construction and Major Renovations (v3) according to LEED's own organisation.

| Categories | Issues |
|---|---|
| **Sustainable Site (SS)** | SS P1 Construction Activity Pollution Prevention<br>SS C1 Site Selection<br>SS C2 Development Density and Community Connectivity<br>SS C3 Brownfield Redevelopment<br>SS C4.1 Alternative Transport, Public Transportation Access<br>SS C4.2 Alternative Transportation, Bicycle Storage and Changing Rooms<br>SS C4.3 Alternative Transportation, Low-Emitting and Fuel-Efficient Vehicles<br>SS C4.4 Alternative Transportation, Parking Capacity<br>SS C5.1 Site Development, Protect or Restore Habitat<br>SS C5.2 Site Development, Maximize Open Space<br>SS C6.1 Stormwater Design, Quality Control<br>SS C6.2 Stormwater Design, Quality Control<br>SS C7.1 Heat Island Effect, Non-roof<br>SS C7.2 Heat Island Effect, Roof<br>SS C8 Light Pollution Reduction |
| **Water Efficiency (WE)** | WE P1 Water Use Reduction<br>WE C1 Water Efficient Landscaping, Reduce by 50%, No Potable Water Use<br>WE C2 Innovative Wastewater Technologies<br>WE C3 Water Use Reduction, 20-40% Reduction |
| **Energy & Atmosphere (EA)** | EA P1 Fundamental Commissioning of Building Energy Systems<br>EA P2 Minimal Energy Performance<br>EA P3 Fundamental Refrigerant Management<br>EA C1.1 Optimize Energy Performance, Improve by 8-48% for New Buildings<br>EA C2.1 On-Site Renewable Energy, 1-13% Renewable Energy<br>EA C3 Enhanced Commissioning<br>EA C4 Enhanced Refrigerant Management<br>EA C5 Measurement and Verification<br>EA C6 Green Power |
| **Materials & Resources (MR)** | MR C1 Storage and Collection of Recyclables<br>MR C1.1 Building Reuse, Maintain 55-95% of Existing Walls, Floors and Roof<br>MR C1.2 Building Reuse, Maintain Interior Non-structural Elements<br>MR C2 Construction Waste Management, Salvage or Recycle 50-75%<br>MR C3 Material Reuse, Reuse 5-10%<br>MR C4 Recycled Content, 10-20% of Content<br>MR C5 Regional Materials, 10-20% of Manufactured Locally<br>MR C6 Rapidly Renewable Materials<br>MR C7 Certified Wood |
| **Indoor Environmental Quality (EQ)** | EQ P1 Minimum Indoor Air Quality Performance<br>EQ P2 Environmental Tobacco Smoke (ETS Control)<br>EQ C1 Outdoor Air Delivery Monitoring<br>EQ C2 Increased Ventilation<br>EQ C3.1 Construction IAQ Management Plan, During Construction<br>EQ C3.2 Construction IAQ Management Plan, Before Occupancy<br>EQ C4.1 Low–Emitting Materials, Adhesives and Sealants<br>EQ C4.2 Low-Emitting materials, Paints and Coatings<br>EQ C4.3 Low-Emitting materials, Flooring Systems<br>EQ C4.4 Low-Emitting materials, Composite Wood and Agrifiber Products<br>EQ C5 Indoor Chemical and Pollutant Source Control<br>EQ C6.1 Controllability of Systems, Lighting<br>EQ C6.2 Controllability of Systems, Thermal Comfort<br>EQ C7.1 Thermal Comfort, Design (Compliance with ASHRAE 55-1992)<br>EQ C7.2 Thermal Comfort, Verification<br>EQ C8.1 Daylight and Views, Daylight<br>EQ C8.2 Daylight and Views, Views |
| **Innovation & Design Process (ID)** | ID C1.1-1.4 Innovation in Design<br>ID C2 LEED Accredited Professional |
| **Regional Priority (RP)** | RP C1 Regionally Defined Credit |

P Prerequisite/Mandatory

C Credit

## Appendix C.

Summary of Environmental Categories and Issues in Code for Sustainable Homes according to Code for Sustainable Homes' own organisation.

| Categories | Issues |
|---|---|
| **Energy and $CO_2$ Emissions** | Dwelling emission rate (M)<br>Building fabric<br>Internal lighting<br>Drying space<br>Energy labelled white goods<br>External lighting<br>Low or zero carbon technologies<br>Cycle storage<br>Home office |
| **Water** | Indoor water use (M)<br>External water use |
| **Materials** | Environmental impact of materials (M)<br>Responsible sourcing of materials – basic building elements<br>Responsible sourcing of materials – finishing elements |
| **Surface Water Run-off** | Management of surface water runoff from developments (M)<br>Flood risk |
| **Waste** | Storage of non-recyclable waste and recyclable household waste (M)<br>Construction waste management (M)<br>Composting |
| **Pollution** | Global warming potential (GWP) of insulants<br>$NO_X$ emissions |
| **Health and Wellbeing** | Daylighting<br>Sound insulation<br>Private space<br>Lifetime homes (M) |
| **Management** | Home user guide<br>Considerate constructors scheme<br>Construction site impacts<br>Security |
| **Ecology** | Ecological value of site<br>Ecological enhancement<br>Protection of ecological features<br>Change in ecological value of site<br>Building footprint |

M Mandatory

## Appendix D.

Summary of test results and available building changes in the ENSLIC-tool's Excel data sheet, presented in a rearranged table.

| **Test Result** | |
|---|---|
| **Bought energy** | Total (kWh/$m^2$/yr)<br>Electricity (kWh/$m^2$/yr) |
| **Specific $CO_2$** | Energy (kg $CO_2$eq/$m^2$/yr)<br>Materials (kg $CO_2$eq/$m^2$/yr)<br>Total (kg $CO_2$eq/$m^2$/yr) |
| **Total $CO_2$** | Energy (kg $CO_2$eq/yr)<br>Materials (kg $CO_2$eq/yr)<br>Total (kg $CO_2$eq/yr) |
| **Available Building Changes** | |
| **Building form** | Average floor height (m)<br>Perimeter ratio (%) |
| **Building envelope** | Basement (U, W/$m^2$K)<br>Roof (U, W/$m^2$K)<br>External walls (U, W/$m^2$K)<br>Windows, U-values (U, W/$m^2$K)<br>External Doors, U-value (U, W/$m^2$K)<br>Window area/Facade area (%)<br>External door area/Facade area (%) |
| **Energy saving equipment** | External heat pump (air, soil, water)<br>Ventilation heat recovery<br>Waste water heat exchanger<br>Low energy light and whiteware<br>Buildings automatization |
| **Energy supply** | Solar collector ($m^2$)<br>PV-cell ($m^2$)<br>Urban windmill (Ø, m)<br>Heating (kWh)<br>Electricity, Building (kWh/building)<br>Electricity, User (kWh/user) |
| **Time** | Building life time (yr) |

## Appendix E.

Summary of Steps, Categories and assessment Issues in BREEAM Communities 2012 (SD202 – 1.0:2012) according to BREEAM's own organisation.

| Environmental categories and issues | | |
|---|---|---|
| **Step 1** | **Step 2** | **Step 3** |
| | **Governance** | |
| GO 01. Consultation plan | GO 02. Consultation and engagement<br>GO 03. Design review | GO 04. Community management of facilities |
| | **Social and economic wellbeing** | |
| SE 01. Economic impact<br>SE 02. Demographic needs and priorities<br>SE 03. Flood Risk Assessment<br>SE 04. Noise pollution | SE 05. Housing provision<br>SE 06. Delivery of services, facilities and amenities<br>SE 07. Public realm<br>SE 08. Microclimate<br>SE 09. Utilities<br>SE 10. Adapting to climate change<br>SE 11. Green infrastructure<br>SE 12. Local parking<br>SE 13. Flood risk management | SE 14. Local vernacular<br>SE 15. Inclusive design<br>SE 16. Light pollution<br>SE 17. Training and skills |
| | **Resources and energy** | |
| RE 01. Energy strategy<br>RE 02. Existing buildings and infrastructure<br>RE 03. Water strategy | | RE 04. Sustainable buildings<br>RE 05. Low impact materials<br>RE 06. Resource efficiency<br>RE 07. Transport carbon emissions |
| | **Land use and ecology** | |
| LE 01. Ecology strategy<br>LE 02. Land use | LE 03. Water pollution<br>LE 04. Enhancement of ecological value<br>LE 05. Landscape | LE 06. Rainwater harvesting |
| | **Transport and movement** | |
| TM 01. Transport assessment | TM 02. Safe and appealing streets<br>TM 03. Cycling network<br>TM 04. Access to public transport | TM 05. Cycling facilities<br>TM 06. Public transport facilities |

## Appendix F.

Summary of Categories and assessment Issues in LEED for Neighborhood Development v4 according to LEED's own organisation.

| Categories | Issues | Points |
|---|---|---|
| **Smart Location and Linkage (SLL)** 28 points | SLL P1 Smart location | 0 |
| | SLL P2 Imperilled species and ecological communities | 0 |
| | SLL P3 Wetlands and water body conservation | 0 |
| | SLL P4 Agricultural land conservation | 0 |
| | SLL P5 Floodplain avoidance | 0 |
| | SLL C1 Preferred locations | 10 |
| | SLL C2 Brownfield remediation | 2 |
| | SLL C3 Access to quality transit | 7 |
| | SLL C4 Bicycle facilities | 2 |
| | SLL C5 Housing and jobs proximity | 3 |
| | SLL C6 Steep slope protection | 1 |
| | SLL C7 Site design for habitat or wetland and water body conservation | 1 |
| | SLL C8 Restoration of habitat or wetlands and water bodies | 1 |
| | SLL C9 Long-term conservation management of habitat or wetlands and water bodies | 1 |
| **Neighborhood Pattern and Design (NPD)** 41 points | NPD P1 Walkable streets | 0 |
| | NPD P2 Compact development | 0 |
| | NPD P3 Connected and open community | 0 |
| | NPD C1 Walkable streets | 9 |
| | NPD C2 Compact development | 6 |
| | NPD C3 Mixed-use neighborhoods | 4 |
| | NPD C4 Housing types and affordability | 7 |
| | NPD C5 Reduced parking footprint | 1 |
| | NPD C6 Connected and Open Community | 2 |
| | NPD C7 Transit facilities | 1 |
| | NPD C8 Transportation demand management | 2 |
| | NPD C9 Access to civic and public space | 1 |
| | NPD C10 Access to recreation facilities | 1 |
| | NPD C11 Visitability and universal design | 1 |
| | NPD C12 Community outreach and involvement | 2 |
| | NPD C13 Local food production | 1 |
| | NPD C14 Tree-lined and shaded streetscapes | 2 |
| | NPD C15 Neighborhood schools | 1 |
| **Green Infrastructure and Buildings (GIB)** 31 points | GIB P1 Certified green building | 0 |
| | GIB P2 Minimum building energy performance | 0 |
| | GIB P3 Indoor water use reduction | 0 |
| | GIB P4 Construction activity pollution prevention | 0 |
| | GIB C1 Certified green buildings | 5 |
| | GIB C2 Optimize building energy performance | 2 |
| | GIB C3 Indoor water use reduction | 1 |
| | GIB C4 Outdoor water use reduction | 2 |
| | GIB C5 Building reuse | 1 |
| | GIB C6 Historic resource preservation and adaptive reuse | 2 |
| | GIB C7 Minimized site disturbance | 1 |
| | GIB C8 Rainwater management | 4 |
| | GIB C9 Heat island reduction | 1 |
| | GIB C10 Solar orientation GIB C11 Renewable energy production | 1 |
| | GIB C12 District heating and cooling | 3 |
| | GIB C13 Infrastructure energy efficiency | 2 |
| | GIB C14 Wastewater management | 1 |
| | GIB C15 Recycled and reused infrastructure | 2 |
| | GIB C16 Solid waste management | 1 |
| | GIB C17 Light pollution reduction | 1 |
| | | 1 |
| **Innovation (IN)** 6 points | IN C1.1-1.5 Innovation | 5 |
| | IN C2 LEED Accredited Professional | 1 |
| **Regional Priority (RP)** 4 points | RP C1.1-1.4 Regional priority | 4 |

P Prerequisite/Mandatory
C Credit
Total: 110 (40-49 points Certified, 50-59 points Silver, 60-79 points Gold, 80+ points Platinum)