Environmental assessment of residential buildings

- What does it take to build Green?

Master of Science Thesis in the Master Degree Programme Industrial Ecology

ALBERTINA HENRIKSSON

Department of Energy and Environment

Division of Environmental System Analysis

CHALMERS UNIVERSITY OF TECHNOLOGY

Göteborg, Sweden, 2010

Report No. 2010:12

MASTER'S THESIS 2010:12

Environmental assessment of residential buildings

- What does it take to build Green?

Master of Science Thesis in the Master's Programme Industrial Ecology

ALBERTINA HENRIKSSON

Department of Energy and Environment

Division of Environmental System Analysis

CHALMERS UNIVERSITY OF TECHNOLOGY

Göteborg, Sweden 2010

Environmental assessment of residential buildings
– What does it take to build green?

ISSN nr: 1404-8167

Master of Science Thesis in the Master's Programme Industrial Ecology

ALBERTINA HENRIKSSON

© ALBERTINA HENRIKSSON, 2010

Examensarbete / Institutionen för energi och miljö
Chalmers tekniska högskola 2010:12

Department of Energy and Environment
Division of Environmental System Analysis
University of Technology
SE-412 96 Göteborg
Sweden
Telephone: + 46 (0)31-772 1000

Cover:
Kvillebäcken, one of the first neighbourhoods in Gothenburg, where the Green Construction Program will be applied.

Department of Energy and Environment Göteborg, Sweden 2010

Environmental assessment of residential buildings
- What does it take to build Green?

Master of Science Thesis in the Master's Programme Industrial Ecology

Albertina Henriksson
Department of Energy and Environment
Division of Environmental System Analysis
Chalmers University of Technology

Abstract

The City of Gothenburg has developed a Green Construction Program with the intention of increasing the environmental performance of residential buildings. The aim and purpose of this project is to provide a basis for the evaluation of this program by the development of relevant and measurable criteria. This was accomplished by an extensive study of literature in the field. Two levels of fulfillment with the program are specified, fulfillment and good performance.

A balancing act between the two central guidelines of the theoretical framework, the lowest acceptable level of environmental performance and general applicability of the results, is being conducted throughout the analysis. The analytical strategy aims to illuminate the technological and behavioral limiting factors in reaching an environmentally satisfying level of performance, as well as the main actors influencing the requirement fulfillment.

The results are presented in two levels of fulfillment; a fulfillment level indicating that the requirement has been met on a basic level, and one level of good performance indicating that the requirement has been fulfilled with margins and a higher performance level. This is an attempt to encourage proactive behavior. For most of the requirements, required performance levels are established in this thesis, nevertheless for some requirements further research is necessary. Furthermore this thesis reflects the status of technology and behavior as of today. The performance levels will need to be updated to reflect the progress in technology and behavior.

Key words: Green Construction, Gothenburg

Bedömningsgrunder för värdering av bostäder
- Vad krävs för att bygga miljöanpassat?

Examensarbete inom Industrial Ecology
ALBERTINA HENRIKSSON
Institutionen för energi och miljö
Avdelningen för miljösystemanalys
Chalmers tekniska högskola

Sammanfattning

Göteborgs stad har tagit fram ett program för miljöanpassat byggande med ambitionen att höja ribban för miljösatsningarna inom bostadsbyggandet. Denna rapport syftade till att utveckla ett underlag för värdering av byggnaders prestanda ur miljö- och hållbarhetssynpunkt genom att ta fram relevanta och mätbara värden för uppställda krav i programmet för miljöanpassat byggande. En utförlig litteraturstudie genomfördes med avsikt att skapa ett ramverk för god miljöprestanda med avseende på kraven i programmet. Det teoretiska ramverket analyserades efter en strategi innehållandes två grundläggande villkor; i) prestationsnivån representerar ansträngningen som krävs ur miljöperspektiv, och ii) prestationen är rimlig att nå idag. Analysen besvarade vilken prestationsnivå som krävs för respektive krav för att nå god miljöprestanda, vilken faktor av beteende och teknik som var begränsande för kravet samt vilken aktör som påverkar prestationen. Analysen resulterade i prestationsnivåer för respektive krav; godkänd nivå indikerar att kravet klarats och bra prestation indikerar att kravet klarats med marginal och att mer ansträngning har gjorts. Prestationsnivåerna utformades för att uppmuntra proaktivt beteende hos aktörerna. För nästan alla krav kunde en prestationsnivå bestämmas, medan vissa saknar tillräcklig forskning för att kunna bestämmas. Vissa krav begränsades av brist på tillgänglig teknik och då blev villkor ii), det avgörande villkoret för hur nivån sattes. Prestationsnivåerna som satts kommer troligtvis att behöva skärpas och uppdateras allt eftersom ny teknik tas fram och beteenden blir normaliserade. Ett kontinuerligt arbete med uppföljning och uppdatering behövs för att säkerställa aktualiteten i prestationsnivåerna.

Nyckelord: Miljöanpassat byggande, Göteborg

Table of contents

Acknowledgment

First of all, I would like to thank my research partner for this thesis, Erica Bengtsson, master's student in Environmental Science at the University of Gothenburg. I would also like to thank my supervisor at Älvstranden Utveckling, Staffan Bolminger and the rest of the staff at Älvstranden for pleasant coffee and lunch breaks.

Moreover I would like to thank to my academic supervisor at Chalmers University of Technology, Karin Andersson. Finally, thanks to Erik Thoresson for all the support.

Gothenburg June 2010

Albertina Henriksson

1. Introduction

This thesis is written on an initiative from Älvstranden Utveckling AB, a company owned by the City of Gothenburg, contributing to the urban development and planning of certain areas of Gothenburg on the behalf of the real estate office of the City of Gothenburg. For my part, this master thesis is submitted as the concluding part of a master degree in Industrial Ecology at Chalmers University. The thesis is written in cooperation with Erica Bengtsson, who will be presenting a Swedish language version of the thesis for a master degree in environmental science at the University of Gothenburg.

This chapter is intended to give a brief introduction to the thesis by presenting the aim and general limitations of the project and by giving a background of the topics discussed, focusing on the relevance and importance of the issues discussed.

1.1 Background

The construction and property industry is one of the most energy and resource consuming sectors in the world. Around 40 percent of the world's resource and energy usage is related to the constructing and property industry. The sector is challenged to contribute to a sustainable future by becoming more resource efficient, causing a smaller environmental impact and at the same time achieving a good and healthy environment for its tenants and customers. Next part of this chapter is a brief introduction to the environmental impact of buildings and an introduction to various local and global certification schemes aiming to promote a more sustainable construction industry.

1.1.1 The building sector in numbers

In Sweden, the building and property sector in 2005 consumed 60 TWh of energy during the production, excluding the heat during the use phase of the buildings. This corresponds to around 10 percent of Energy use in Sweden total energy use. When heating is included, the corresponding number increases to 29 percent. Of the energy consumed in a household around 10-30 percent is from renewable sources. Furthermore, the building sector is also a large waste producer and in 2005 the sector generated 27 percent[1] total waste production in Sweden. The sector is also a large generator of hazardous waste and produces 1 megaton hazardous waste each year. (Boverket, 2009a) Also, transports within the sector contribute with around 10 percent of the yearly transports in Sweden. (Byggsektorns Kretsloppsråd, 2010a)

1.1.2 Environmental evaluation methods of buildings

As of today, there are numerous programs and systems to evaluate and classify buildings from an environmental and sustainability perspective. The first program in use was the British BREEAM (Building Research Establishment's Environmental Assessment Method), released in 1990. (Ding, 2008) Other widely used systems are LEED (Leadership in energy and Environmental design) in North America, Code for Sustainable Home in the UK, Casbee in Japan and Minergie in Switzerland. Most tools are either assessment or rating tools. Assessment tool quantifies performance and rating tools judges the building within a rating

[1]Input-output analysis is used for evaluation

scheme. All of the above mentioned tools and methods assess mainly the ecological part of sustainability[2] and not the whole concept of sustainability.

Several local evaluation and classification systems are available in Sweden as well, for example EcoEffect and the environmental classification[3] method of Building/Living[4]. Eco-effect is quite a complex system whereas Building/Living is more concise and user-friendly. Building/Living considers only three areas – indoor environment, energy and materials, while Eco-effect has a broader scope of evaluation where the outdoor environment is considered as well. (Bokalders & Block, 2009) The environmental classification ranks building in four different categories, ranked, bronze, silver and gold (Johansson, G., & Jansa, A, justeringar av Bygga-bo-dialogens tekniska råd, 2009).

1.1.3 The City of Gothenburg´s Green Construction Program

The City of Gothenburg has through its real estate office[5] created a Green Construction Program, the "Green Construction for Residential Buildings Program" (author's translation). Similar program has been used in other cities, for example the City of Stockholm implemented a Green Construction Program in 1997 (Stockholms stad, 2008). The program specifies guidelines for the planning, production and service phase of the building life cycle. The program ranges over seven areas – Durability, Environmental impact, Health and indoor climate, Moisture protection, Noise protection, Energy efficiency and Resource efficiency. The different areas are divided into different requirements, in total 60. The requirements are very different in terms of concretization. Some areas contain actual requirements such as "use low energy bulbs", while others are presented in terms of general guidance such as "consider durability".

1.1.4 Kvillebäcken

One of the first areas in Gothenburg to implement the program is the neighborhood of Kvillebäcken. This new residential area will be developed by consortium of seven building proprietors who cooperated in creating a vision for the ambiance of the neighborhood. The building site has a long history as an industrial ground, most recently occupied by plentiful small scale industries and enterprises. Due to contamination from an old paint factory, extensive decontamination work is needed before the building commences. In contrast to the contaminated site, a small brook with rare species and considerable natural value runs along the edge of the area. (Kvillebäckens konsortium, 2010)

The area will have a pronounced "green profile" and all of the new residential buildings will fulfill the requirements for class Silver in the Building/Living environmental classification system. Additionally, the neighborhood will have a sophisticated waste management system using automated vacuum collection. The use of public transport will be promoted and due to parking space restrictions, the ownership of private cars is expected to be limited. The consortium will also try to create a neighborhood environment which "feels green", featuring pocket parks and alleys.

---

[2] Sustainability and sustainable development are defined accordingly to definition from the world commission on environment and development, see page 10

[3] Swedish: Miljöklassning byggnad

[4] Swedish; Bygga-Bo-dialogen

[5] Swedish:Fastighetskontoret

1.2 Problem formulation

The City's Green Construction Program sets a base line for which aspects of environmental responsibility should be included in environmental assessments. However, the program lacks a basic assessment framework for what is to be regarded as good and bad environmental performance. To be able to properly evaluate the requirements fulfillment an assessment framework needs to be established and an assessment scale for each of the requirements in the program needs to be created. This scale should indicate the minimal level of fulfillment required in order to comply with the program as well as a maximum level of fulfillment indicating satisfactory environmental performance. The criteria forming the basis of the assessment scale should be relevant and realistic.

1.3 Aim

The aim of this study was to develop evaluation criteria for building performance from an environmental and sustainability view through the development of relevant and measurable criteria for the listed requirements in the Green Construction Program.

1.4 General limitations

The thesis treats the requirements in the City of Gothenburg Green Construction Program. Only the environmental aspects of sustainable development are considered; social and economical factors are considered only when they are mentioned specifically in the program.

Geographically, the evaluation is limited to the building and its direct surroundings, i.e. the area that the building proprietor controls. For example, storm water management in regard to streets and pavement is not considered because this is issue belongs to the public water administration. Regarding factors like climate and precipitation the evaluation is made according to the circumstances which are prevailing in Gothenburg.

The Green Construction Program is applied when the decision about building has already been made; hence the choice of building site is not a part of the program. In accordance with the Program the following phases of the building life cycle are treated: planning, production and management. In chapter 3, Theoretical background, specific limitations for each of the program areas are presented.

2 Methodology

This chapter describes how the literature study has been performed and presents the analysis strategy.

2.1 Study of litterature

A litterateur study within the area of environmental assessment forms the theoretical basis of the results. The wide range of environmental aspects included in the Program calls for a wide search of information on the areas. Background material was collected from journal articles, publications and reports mainly in electronical form. Numerical data and statistics were collected from authorities and industry organizations such as Energy Agency, Statistics Sweden and Ecocycle[6] Council. As recently published information as possible was used. Also, interviews were made with persons relevant for the project.

2.2 Analytical strategy

A strategy for the analysis of the literature was formed with the purpose of creating a common frame of reference for establishing the target levels for good environmental performance. The underlying theory of the requirements is analyzed with a common starting point. As a standard for good environmental performance and starting point were the national Swedish environment objectives used. The national environmental objectives are well established as a basis of judgment for the achievements necessary to reach ecological sustainability. At the same time, the goal formulation contributes to a striving for a continuously better environmental performance. Since the new residential buildings in Kvillebäcken, which will be evaluated accordingly to the Green Construction Program, have to fulfill at least class Silver in as Building/Living environmental classification (Miljöåtagande för östra Kvillebäcken, 2009), this classification system is taken into consideration for what at least should be achieved in the different Program requirements.

Two basic conditions for the analysis were the established:

1: The level stating the acceptable performance for each of the requirements should represent the performance required for green building, ecological sustainability should be reached.

2: The level for fulfillment of the requirements should be possible to reach at once; the technology should be available and possible to apply since the construction of Kvillebäcken was up started during the time this thesis was written (spring 2010).

The requirements were categorized after which factors decides the performance. For some of them, the performance is dependent on the technical possibilities, for others, the performance is depending on human behavior and actions. Requirements that are depending on technical capabilities have been evaluated in relation to *Best Available Technology (BAT)* [7]. To demonstrate technical opportunities and available solutions, good examples from literature are used whenever possible.

[6] Swedish:Kretsloppsrådet

[7] Defintion of BAT according to EU:s IPPC-directive: *"techniques shall mean those developed on scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator* (Naturvårdsverket, 2010a)*"*

The actors which have influenced the performance were identified as the following groups: construction organization, real estate manager and the occupants. The construction organization includes those involved during planning and production like architects, building proprietors and entrepreneurs. The different actors were identified with the purpose to find the limiting factors for environmental sustainability.

The analytic strategy aims to establish a required level of environmental effort and to find limiting factors for the achievement of this required level:

- Based on the national environmental objectives and other relevant scientific work – what is this required level of environmental performance?
- What is the liming factor in achieving a high environmental performance? Is the performance dependent on technology or behavior?
- Which actors have influence on the performance and fulfillment of the requirement?

3 Theoretical base

This chapter forms a theoretical foundation with data needed for the analysis of the performance criteria. First, the environmental impact of a building is briefly provided and the environmental objectives which will set the environmental performance level for the different areas are presented. Finally, all the part topics are discussed and relevant scientific information is presented.

3.1 Environmental impact of a building

Figure 3.1 below shows the environmental impact of a residential building and the corresponding life cycle perspective which is considered in the program for green buildings.

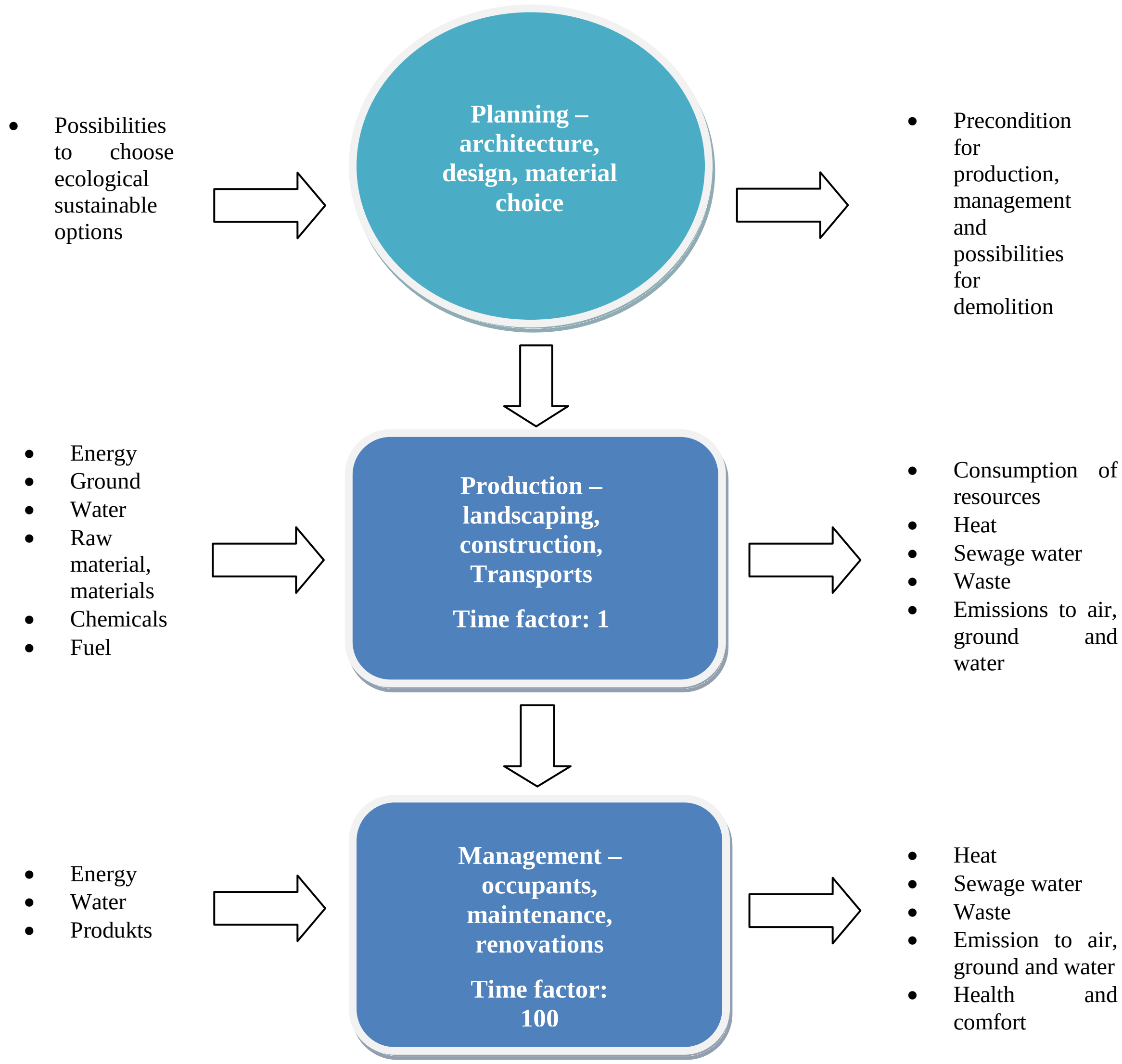


Figure 3.1: Schematically figure over a buildings lifecycle as an interpretation of the Green Construction Program with inspiration of Kohler 99.

As seen are the outcomes from the planning phase of immaterial character, however, it is those decisions and preconditions that comes out there that sets the conditions for the environmental impact of the building during the production and usage phase. The possibilities to influence the environmental impact decreases as the planning processes goes on and more choice are taken. This illustrated in figure 3.2.

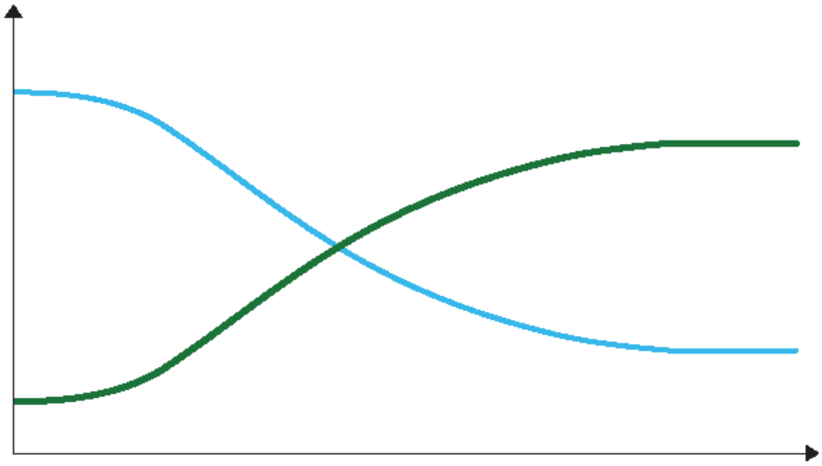


Figure 3.2: Design options and possibilities to influence environmental impact. The y-axis shows the number of possible choices and the x- axis shows the number of decisions. Inspired of (Baumann & Tillman, 2004)

As seen in the figure possibilities to influence the environmental impact from the building decreases as more decisions are taken in the planning process. Due to this is it important to consider environmental impacts and issues already in the beginning of the planning process. When applying the Green Construction Programs, some decisions, crucial for the environmental impact from the building have already been taken, for example concerning that the building will be constructed and the location.

Decisions already taken and which could not be affected by the three identified group of actors could be set in a background system which interact with the foreground system that is the three identified actors. This perspective is mainly used in life cycle analysis. (Höjer, 2008) For example, the present waste management system in society could not be, on short term perspective, affected by the any of the three identified actors.

3.2 Sustainable development and Swedish National Environmental objectives

One of the most commonly used definitions on sustainable development is from the report "Our common future"

"*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*"

(World Commission on Environment and Development, 1987)

The Swedish national environmental objectives, established in 1999, describe which state the environment must be in, to achieve and uphold long term ecological sustainability. The 16 goals are aiming to:

- Promote human health
- Safeguard biodiversity and the natural environment
- Preserve the cultural environment and cultural heritage
- Maintain long-term ecosystem productivity
- Ensure wise management of natural resources.

(Naturvårdsverket, 2009a)

The built environment is in itself one the national objectives – *A Good Built Environment*. The subject is however touched upon in all of the objectives but more or less explicitly. The overall goal is that within one generation, the major environmental problems facing us today will have been solved.

The interim targets in *A Good Built Environment* are:

- Programs and strategies for planning where all land use and community planning should aim to create a more energy efficient mixed use society with preserved green areas and enhanced cultural and aesthetic values.
- Cultural heritage should be preserved. Built environments of high cultural heritage importance should by 2010 be identified and put under long-term sustainable management.
- Noise should be reduced. By 2010, the share of people disturbed by noise in their dwellings should decrease by five percent compared to level in 1998.
- Extraction of natural gravel. In 2010, the extraction of natural gravel will not exceed 12 million tons.
- Waste – to decrease the amount of waste in society and to utilize waste as a resource to as a high extent as possible. This means that the household waste should be recycled, including the biological waste which will be taken care of and used as a resource where the nutrients are recycled.

- Energy efficiency in buildings should increase and the use of fossil energy for buildings should vanish.
- A good indoor environment, by assuring effective ventilation and a low level of radiation from radon.

(Naturvårdsverket, 2009f)

Since the building sector is such a large consumer of materials and chemicals, the environmental objective *A Non-Toxic Environment* is of great concern for green residential buildings since phase out substances are present in building materials and products, and that information on dangerous substances in products are required.

However, the Environmental Objectives Council judge that the generation goal of *A Good Built Environment* will be hard to achieve on time and claims that efforts must be done on all levels, from international agreements to life style changes for individuals, to achieve change. (Naturvårdsverket, 2009b)

3.3 Program Areas

The litterateur study is intended to reflect the content in the requirements and will function as the foundation of the evaluation. The following structure is used within the whole chapter; first limitations are specified, then the environmental relevance of the requirement and the connection to the national environmental objectives is discussed. Finally, where possible, a description of feasible solutions is provided.

3.3.1 Durability

The overall goal for durability in the Green Construction Program is that building should be long standing to reduce the total resource use. It is mainly the framing of the building which should be firm but also the exchangeability of the installations with shorter life than the whole building is considered as a durability aspect. (Fastighetskontoret, 2009). According to the technical definition from The National Board of Housing, Building and Planning, the durability is depending on the load-bearing capacity and stability of the construction part. The load bearing capacity is that possibility to bear load without fraction arises and stability is ability to resist deformation giving a loss of the intended function. The durability aspect is of large importance in the planning phase since material and constructions suitable for the planned life length are chosen there. (Boverket, 2009b) Furthermore, Pettersson claims that durability is a relative concept since a lot of factors influence the durability such as maintenance and surrounding environment. In the thesis, the concept durability is widen from the technical definition and includes three factors that influence resource intensity, technical life length, maintenance interval and embodied energy to achieve the goal of the area within the program. Below, the definition and explanation of those factors are found. Finally, reasoning about the durability of buildings in a changing climate will be found. The requirement of durability takes the whole life time of the building in to consideration. Changes and stress during the whole life cycle must then be considered.(Naturvårdsverket, 2008a)

3.3.1.1 Influencing factors for durability and resource consumption

As mentioned above, two major influencing factors for durability are technical life span and maintenance interval.

Technical life span: Construction elements have a varying life span depending on the construction material used and how much stress they are exposed of. Degradation could be due to chemical, electrochemical, physical and/or biological impact. The technical life span is defined as

"the period of time when a building, construction or parts there off, could be used with normal maintenance for the intended function". (Burström, 2007 s. 148).

The planned life span for the residential buildings in Kvillebäcken is 100 years according to Bolminger[8]. Due to the impacts stated above, the life span of a material is hard to determine. In addition to the mentioned impacts, the load bearing capacity of the material, protection from the climate, design, the requirements on health and security and executed maintenance all have impact on the life span of the material. The data below for life span is valid for a normal environment defined as:

"in air with increased air pollution levels, for example urban areas and industrial estates" (Burström, 1999 s. 41).

[8]Staffan Bolminger, interview

The life span of different building materials showed in Table 1 is given in intervals because the exact life span is hard to determine due the reasons mentioned above. Also, cardinal direction has a major impact on the life span, especially for surface materials and plastic materials. The life span considerably shortens when located in southern or western directions. (Burström, 1999)

Maintenance interval: The maintenance interval is an additional important factor which affects the durability of the material. All construction materials require some kind of maintenance. Maintenance is defined as smaller operations such as painting and plastering. Larger operations, such as when the construction elements need to be exchanged are regarded as demolition and new construction. The life span of the surfaces treatment determines the life span of the underlying material. Since the life span of the surface material is considerably shorter than the life span of the underlying material, repeated maintenance of the surface treatment is required. Hence, the life span of the surface material is the maintenance interval of the underlying material.

In Table 3.1 the life span and maintenance interval for exposed building parts is showed. As seen, is it obvious that façade materials based on concrete, brick and lime stone have long life spans and at the same time the maintenance requirements are minor or non-existent.

Table 3.1 Expected life length and maintenance for different materials divided after construction part.

MATERIAL	LENGTH OF LIFE (YEARS)	INTERVALL OF MAINTENACE (YEARS)
FACADE MATERIAL		
Concrete	50-100, 100[9]	Data missing
Cement plaster	50-100	20-30 (cement paint)
Wooden panel (glazing painted)	30-60	4-8
Wooden panel (cover painted)	30-60	10-17
Glass (isolation glass)	25-30	No surface treatment
Brick (masonry)	50-100	No surface treatment
Lime stone (masonry)	50-100	No surface treatment
Lime plaster	30-60	10-15 (lime paint)
STRUCTURAL MATERIAL		
Concrete (reinforced)	50-100, 100[10]	No maintenance*
Wood		No maintenance*
Steel (beam)	Data missing	No maintenance*

[9] Referens: http://www.fabriksbetong.se/byggvarudeklarationer.aspx 2010-03-30

[10] Referens: http://www.fabriksbetong.se/byggvarudeklarationer.aspx 2010-03-30

Concrete (masonry)	50-100	No maintenance*
ROOFING MATERIAL		
Fibre cement boards	30-35	Data missing
Steel sheet (galvanized and cover painted)	40-45	10-15
Concrete tile	30-70	No surface treatment
Brick tile	30-70	No surface treatment
Waterproofing membrane	25-30	Data missing

-no surface treatment
(*Structural materials are not maintained; instead, they are exchanged after a certain time which correspond to the life time) (Burström, 1999)

Embodied Energy: Embodied energy is the sum of all energy consumed by the extraction of primary material, manufacturing and transportation until the material is available on the construction site. (Harvey D. L., 2006) When the whole life cycle is assessed it can be seen that a large part of the total energy consumption from a building is from the production and transport of materials which should be added to the total resource consumption of a building (Venkatarama Reddy & Jagadish, 2003). The energy used during the production phase is used for working machines, cranes, fans and lighting. The huts on the construction site are additionally large energy consumers during the production phase (Hatami, 2007). When choosing building material with resource optimization as a goal, the embodied energy should be considered. In table 3.2 the embodied energy for commonly used building materials are found.

Table 3. 2 Embodied energy for some common building materials.

MATERIAL	Embodied Energy (GJ/TON)
Aluminium	200-500
Plastic	50-100
Steel	30-60
Glass	12-25
Cement	5-9
Brick	2-7
Concrete	0,8-3,5
Brick of lime stone	0,8-1,2
Timber/Wood	0,1-5

(Harvey D. L., 2006)

The national environmental objectives do not contain any goals directly applicable on the durability aspect of a building as discussed in this chapter. However, resource efficiency in general is a major part of the overall goals of the objectives. One of the three action strategies for the implementation of the environmental objectives, *Non-toxic, resource-saving environmental life cycles*, discusses how the resource efficiency should improve (Naturvårdsverket, 2009p), including resource management within the construction industry. Being resource efficient is of large importance in reaching a sustainable development where the needs of the present generation should not prevent the need of future generations. When using finite resource this goal is important to have in mind.

3.3.1.2 Exchangeability of installations

Within the durability program area is the exchangeability of the parts with shorter life span than the building included. Installations such as heating and ventilation devices are included within those parts. The flexibility and exchangeability should be considered due to the fact that the present circumstances are likely to change during the life span of a building. A possible change is that the heating demand will decrease and the cooling demand increase due to the climate change. (Langseth, 2009)

3.3.1.3 Buildings durability and a changing climate

Accordingly to Intergovernmental Panel on Climate Change *IPCC*, the average temperature on earth is likely to increase with between 1,1 and 6,4 degrees Celsius the coming hundred years due to anthropogenic induced climate change. In Sweden, this may have consequences such as increased precipitation, flooding and raised sea levels. (Naturvårdsverket, 2008a) The physical planning and the design of buildings must adapt to those changes in order to fulfill future requirements on durability (Naturvårdsverket, 2008b). Gothenburg, with its location in the opening of the river Göta älv, between the North Sea and the lake Vänern, is at an exposed geographical location. Calculations from the IPCC substantiates that the sea level will rise with 0,2 – 0,6 meters to year 2100. (Naturvårdsverket, 2008a) Other research claims that a rising of the sea level by 0,8 to 2 meters is more likely. (Göteborgs Stad, 2009) The City of Gothenburg has put security limits for the ground floor level for new buildings along the river line. As of today the margin for the highest levels is one meter, while the City of Gothenburg traffic office claims that the marginal should be raised to 2 meters for important community functions and services in the central parts of Gothenburg (Roth & Falk, 2009).

In table 3 below, the security levels for which height the ground floor should exceed is showed. Today the normal situation in Gothenburg is ten meters above the sea level.

Table 3.3Minimal level above the sea for the ground floor at three different locations along the river Göta Älv.

	Outside the bridge Älvsborgsbron	**Central Gothenburg**	**The bridge N Marieholmsbron**
Decision by authorites, ground floor should not be below	+ 12,5 m above sea level	+ 12,8 m above sea level	+ 13,0 m above sea level

(Göteborgs Stad, 2009)

3.3.2 Environmental impact

The goal of the environmental impact area in the Green Construction Program is to reduce the environmental impact during the whole life cycle of the building. The focus areas included are the choice of material and products, especially considering the content of different chemical compounds, and green areas and the grounds around the building, where storm water management and green roofs are treated. Also, the environmental impact by the building site is evaluated.

3.3.2.1 Choice of material and products

The choice of material and products are treated within several areas in the Program (e.g. Durability and Health & Indoor climate). Within this chapter, the material and products which are specifically considered in the area of environmental impact is found.

Around 50 000 different products and chemical substances are used within the sector (Johansson A.-M., 2007). Some chemical substances are classified as toxic and hazardous for humans and the environments. Information on the health and environmental properties of these substances can be found Sweden's Chemical Agency's[11] database PRIO. In principal, this information should correspond to the data found in European regulation Registration, Evaluation, Authorization and Restriction of Chemicals, *REACH's* list of substances of special concern. The substances are classified in two groups, phase out substances and risk reduction substances. The most toxic substances are listed as out phasing substances, aiming that they should be completely eliminated from the market. A lot substances classified for out-phasing are today prohibited in Sweden. Examples of substances that should be phased out, are carcinogenic, mutagenic and reprotoxic substances (CMR-substances), endocrine disruptors, allergens and acute or long term toxic substances. (Kemikalieinspektionen)

The construction material used will be present in, and affect the surrounding environment for a long time. Due to this fact, it is of great importance to document which materials have been embedded in the building. The knowledge about hazardous materials is constantly growing and having future knowledge about embedded materials is of importance to be able to apply new knowledge. (Kellner & Stålbom, 2001),

To create and enhance the knowledge about construction materials and their environmental impact the construction industry in Sweden through their organization the Ecocycle Council has created guidelines for *building product declarations*[12] (BVD). The declarations were introduced in 1997 and aims to gather and communicate information about the product's chemical properties and additional environmental impact in a life cycle perspective. (Kretsloppsrådet, 2007)

The two main objectives for the use of BVD are to function as guidance for planning and purchasing and to facilitate and simplify the documentation of embedded materials. (Kretsloppsrådet, 2007) For achieving an acceptable knowledge level about building products around 8000 declarations are necessary to cover the most important commodity groups. (Johansson A.-M., 2007) According to the Ecocycle Council, in 2006 around 4000-5000 declarations were available.

In addition to Swedish's building industry BVD, there is a commonly used non-industry specific environmental product declarations, EPD. EPD are executed in accordance with the

[11] Swedish: Kemikalieinspektionen

[12] Swedish: Byggvarudeklarationer

ISO standard for eco-labeling type III and have standardized comparable information about the environmental properties of the products (Baumann & Tillman, 2004).

The use of BVD and EPD gives more detailed information than the traditional use of safety datasheets[13] which only included chemical products and their environmental and health risks. According to Erlandsson at least 75 percent of the weight, volume and numbers of articles should have product declarations to have enough knowledge about the content of the building (Erlandsson, 2003).

The BASTA-system is used for phasing out of hazardous substances in building products. The BASTA-system evaluates the chemical contents of the material. A product that has been registered in BASTA is approved accordingly to the criteria of the BASTA-system. The criteria are based on environmental regulations in Sweden and Europe and are in line with, for example, REACH and the national environmental objective *A Non-toxic Environment*. (Johansson A.-M, 2007).

One commonly used system for product selection is the Building products evaluation[14] (BVB), managed by building proprietors and property owners in Sweden. In this database, the products are ranked in three different categories, recommended, accepted and to be avoided. The ranking is based on an evaluation of the products in terms of chemical properties, raw materials (renewable, recycled content), production (energy use, generation of hazardous waste), distribution, construction phase, phase, demolition, rest and waste production and indoor environment. The chemical properties have twice as large impact as the rest of the categories. Products registered in BASTA are automatically rated as acceptable in BVB. (Byggvarubedömningen, 2009).

The Building/Living Dialogue's Environmental Classification System has criteria for the chemicals and materials used in buildings demanding proper documentation and the phasing out of hazardous substances. In order to receive a Building/Living certification, a declaration of content for the material in the floor, frame, outer wall (including door and windows), outer ceiling and inner walls are required. The surface layer should be included in the declaration and also all products classified as chemical products (joints and similar products). Kvillebäcken should reach at least grade silver in this system. In order to achieve the grade class silver, a digital journal must have been created containing information about type of product, product name, manufacturer, year of production and a complete declaration of content. To reach class gold, the highest ranking, the estimated amount of a material and its placings in the building must be documented. (Johansson & Jansa, justeringar av Bygga-bo-dialogens tekniska råd, 2009)

The demands for hazardous materials for class silver is that they to as a large extent as possible should not be used, and that usage should be documented in a deviation report. For class Gold it is necessary that substances of very high concern do not exceed specified limits in some specific building elements. (Johansson & Jansa, justeringar av Bygga-bo-dialogens tekniska råd, 2009)

Kellner and Stålbom have listed some general steps in how to make the material choices for a building. The first step is to see what kind of structural materials that are needed. For a non-renewable product, what kind of raw materials are needed and are these materials scarce or not? How and where is the raw material extracted? How does the material function in the

[13] Säkerhetsdatablad

[14] Swedish: Byggvarubedömningen

building? Will the material give the products properties that will impact the product's environmental load during the service phase? How does the material affect the recycling potential of the product? Finally, how does the material affect the indoor environment? (Kellner & Stålbom, 2001)

3.3.2.2 Building materials considered in the Green Construction Program and environmental impact

The following materials and products are especially considered in the Green Construction Program, featuring specific requirements on which materials and products that are considered acceptable and also specific material and products limitations in order to reduce certain pollutions. This following chapter contains information concerning those specifically mentioned materials and products.

Paint, lacquer and oil

When choosing paint, lacquer and oil the solvent should be considered. The solver is evaporated during the drying so that only the solid substance is left. There are organic and inorganic solvents. Organic solvents are based on hydrocarbons and are often named in generic terms such as petroleum spirit. The most common inorganic solvent is water. The reason for limiting the usage of paint, lacquer and oils containing organic solvents is due to the negative impacts from solvents which affect both humans and the natural environment. Emissions from volatile organic compounds (VOC) contribute to a reduced air quality. Inhalation of VOC can cause irritation of the respiratory passages and headaches, and repeated exposures can cause damage to the nervous system. VOCs also contributes to the creation of ground level ozone which reduces the air quality and causes stress in vegetables and animals and to building materials. (Sveriges Färgfabrikanters Förening 2005); (Bokalders & Block, Byggekologi - Kunskaper för ett hållbart byggande, 2009)

Emissions of organic substances and the limitation of the creation of ground level ozone are treated in the national environmental objective *Clean Air* where they constitute two interim targets. For ground level ozone the target will not be fulfilled in 2010. The interim target concerning emissions of VOC has decreased to the targeted level and the interim target is fulfilled within the time frame. Figure 3.3 below shows the emissions of VOC in Sweden, the lowest part of the bars shows the contribution from the use of solvents.

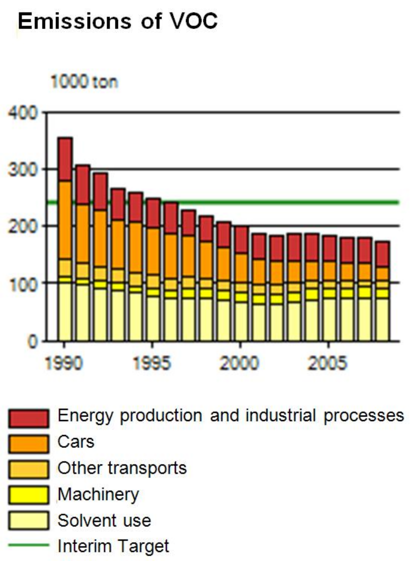


Figure 3.3 Emissions of VOC in Sweden. (Naturvårdsverket, 2009c)

The alternative to paint based on organic solvents is water-based paint. Nevertheless, water-based paint often contains some degree of organic solvents in order to improve the drying performance. Nevertheless, the level of organic solvent in water-based paint is still small compared to paint based on organic solvents and the VOC emissions caused by water-based paint are limited. (Sveriges Färgfabrikanters Förening, 2005) There are two eco-labels for paint in Sweden, The Nordic eco labeling[15] and the EU-flower, both of them limits the highest allowed content of VOC per liter of paint, see Appendix B. (Nordic Ecolabelling, 2008) Today, there is no environmental labeled alternative for all types of paint, lacquer and oil products but for many of them there are water-based alternatives available. The main exceptions are special paints, such as rust protection paint and some lacquers. (Sveriges Färgfabrikanters Förening, 2005)

Copper

For pipes in the tap water system copper is not allowed to be used accordingly to the Green Construction Program. Copper in materials that conveys or in other ways are exposed to water should be avoided from an environmental and health perspective since copper used in this way will cause raised levels of copper in drinking water and sewage sludge. The intake of water with raised copper levels can give sickness and vomiting. (Livsmedelsverket, 2009) Additionally, copper is toxic for water living organism and according to the Swedish Chemical Agency PRIO database, copper and many copper compounds are environmental dangerous, highly toxic and cause long-term effects. The interim targets of the national environmental objective *A non-toxic environment* and *Good Quality Ground Water* states that leakage of copper to the environment should be limited. There are alternatives to copper pipes, for example various kinds of plastic (polypropylene, polyethylene), stainless steel and cast iron. The material selection must be adapted after the chemical composition of the drinking water. (Bokalders & Block, 2009)

Timber products

Concerning timber products the cultivation of the forest is the part of the life cycle that has the largest influence on the total environmental impact (Berg & Lindholm, 2005). In comparing timber products in terms of environmental impact, the forestry phase is the main comparison factor. The system which is considered in this thesis starts with plantation of the forest, spanning over the whole maintenance and cutting phase. Also included are the transports during the maintenance phase and to the purchaser. The purchaser activities such as sawmill is not included in the system. Environmental aspects are viewed in both a local and global perspective depending in the character on the aspect.

Traditionally large scale forestry has a large range of negative impacts on the environment. Forestry is an energy demanding process where activities such as cutting and transport of the timber are major contributors. Those activities cause emission of carbon dioxide, sulfur dioxide and nitric oxide. The use of artificial fertilizers increases the eutrophication and the use of pesticides spreads hazardous substances in the natural environment. At the same time, monocultures are created since one species is prioritized which could lead to that other species are driven out. The thinning of brushwood and low vegetation contributes to the monoculture. This counteracts biodiversity and impacts endangered species and their biotopes strongly negatively. (Bokalders & Block, Grönska och odling, 2010) The impact on forestry on aquatic system can be of physical character such as muddiness and the creation of sludge or of chemical character such as acidification and supply of nutrients and metals. (Löfgren &

[15] Swedish:Svanen

Olofson, 2002) Cutting of forest uses resources and the re-plantation must be equal to the cutting rate so that no shortage of the resource happens. Strong cutting can is some areas contribute to erosion and loss of cultivable soil.

The environmental impacts of large scale forestry are extensive and affect many on the environmental objectives in Sweden. The concerned objectives are *Sustainable Forests, A rich diversity of Plant and Animal life*, *Natural Acidification Only, A Non-toxic environment*, *Clean Air* and *Flourishing Lakes and Streams*.

Figure 3.4: FSC-certified forest after cutting. (Sincerely sustainable, 2009)

To decrease the negative impact sustainability certifications for forestry have been developed. Two large certification schemes are available; Forest Stewardship Council, FSC and Program for Endorsement of Forest Certification Schemes, PEFC. The FSC-labeling combines greening with social and economic responsibility. In Sweden around 10 million ha are certified, which corresponds to around 45 percent of the productive forest areal in Sweden. (FSC Sverige) The other Nordic countries contributes to around 230 000 ha FSC forestry. (FSC International Center, 2010)

Like FSC, PEFC is a global organization for sustainable forestry, but focusing mainly on small and medium foresters. In the end of 2009 barely 8 million ha were PEFC-certified in Sweden. (PEFC, 2010)

The products which in this thesis are seen as tree product and are eligible for buildings are the timber in the framework, walls, roof, windows and flooring. The use of certified timber in these products will decrease the buildings total environmental impact. For using the logo from FSC for commercial purposes, at least 75 percent of the wood products used in a building must be FSC labeled. The situation of the wholesale supply of FSC certified timber products is unclear but, according to a statement, construction companies will regard tree products as

FSC labeled if they originate from FSC-certified forestry, even if the whole supply chain including sawmill is not FSC-certified[16].

Pressure-treated wood

The chemical properties of pressure –treated wood products can render them environmental and health dangerous. Examples of substances used for wood impregnation are arsenic, chrome, copper and creosote. All of them are either being phased out, or risk reduction substances. Arsenic and arsenic compounds are environmental dangerous and some of the compounds are classified as CMR substances, cancerogenic, mutagenic and reprotoxic substances. Chrome, chrome compounds, copper and copper compounds also have the same properties but are in addition also allergenic and highly acute toxic. Creosote compounds are cancerogenic and all of them are classified as phasing out substances within the PRIO-database. (Kemikalieinspektionen, 2006)

Pressure-treated timber are mentioned in the national environmental objective *A non-toxic environment* and the interim target of the phasing out of toxic substances which states that CMR-substances should be phased out as fast as possible (Naturvårdsverket, 2009d). Alternatives to the use of pressure-treated timber are wood treated with linseed oil (Linotech, 2007) or paint for protecting the wood from biological attacks and moisture or to choose other materials than wood.

Fluorescent lamps

Fluorescent lamps and low-energy bulbs contains mercury, which is a volatile compound. Mercury affects the surrounding environment and is toxic for humans. Mercury can cause disruption on humans nervous and reproduction systems. Due to the volatile character of mercury emissions are spread easily by the wind and can be transported far away from the original source. Mercury is not biodegradable and is accumulated in the biosphere. Efforts are being made to limit the supply of mercury on national and international level (Kemikalieinspektionen, 2006) and are treated in the environmental objectives since mercury is classified as a CMR-substance and is therefore included in the interim target of phasing out of hazardous substances. (Naturvårdsverket, 2009d)

Today there are no mercury free fluorescent lamps on the market, but alternatives are about to leave the research lab[17]. The fluorescent lamps marketed as “low-mercury” have a mercury content between 1,4 mg Hg and 5 mg Hg per lamp. (Harvey D. L., 2007)

3.3.2.3 Grounds, green areas and storm water management

In this chapter the theoretical background for the requirements concerning low impact development and biodiversity is presented. The treatment of these aspects is limited to the building proprietors’ sphere of influence. When necessary, more specific system boundaries are specified.

Storm water management

Storm water is defined as surface water that runs off hard surfaces and is not infiltrated into the ground or evaporated to the atmosphere. The management of storm water in urban environment is important in many aspects. The main issue concerns the broken hydrological cycle, which is disturbed when surfaces are made impermeable. In an undisturbed cycle,

---

[16] Staffan Bolminger, interview, 2010-04-12

[17] For example, see Lightlab at http://www.lightlab.se/en.aspx

rainwater reaching the ground, partly evaporates or filtrates in to the ground and creates ground water. The water which is not evaporated or infiltrated into the ground runs to the closest watercourse, lake or sea. The large areas of impermeable surfaces within the urban environment create large amount of storm water that needs to be managed. (Kruuse & Widarsson, 2005)

Ground water levels can drop due to the decreased infiltration levels. The decreased ground water level can threaten the supply of potable water and also cause damaged vegetation and settlements in the ground causing damage to the built environment. (Bokalders & Block, Hydrologi, 2010) Moreover, storm water is environmental harmful due to the common content of pollution in the water. The impermeable surfaces are often contaminated and storm water running on the surface can become polluted. The main sources of pollution in this case are particle borne substances and heavy metals, which cause considerable negative impact on the affected watercourses. The chemical content in the storm water is affected by the activities within the runoff area, but common sources are industries and traffic. (Muthukrishnan, 2006) Traditionally, storm water management has meant to drawing off the water to the sewage system for treatment in sewage plants or to lead it directly to water courses. However, when there is heavy rain or quick melting of snow the load on the sewage plants increases to a level which the plants cannot handle, they are over flooded. In those cases untreated sewage water (including storm water) are directly discharged to the recipient water course. (Bokalders & Block, Hydrologi, 2010)

In the national environmental objectives storm water is discussed in the objectives dealing with water in the natural environment. The objective *Flourishing Lakes and Streams* states that those environments should be ecological sustainable with preserved biodiversity, meaning for example that the pollution level in lakes and streams should not threaten the biodiversity (Naturvårdsverket, 2009e). This target can be directly related to the management of storm water since storm water, as previously mentioned, often is heavy polluted in urban environments.

The environmental objective *Zero Eutrophication* (Naturvårdsverket, 2010c) is also related to the management of storm water. When the sewage plants are over flooded high levels of nitrogen and phosphorus are supplied to the recipient, which causes eutrophication.

The ground water level is discussed in the objective *Good-Quality Groundwater*, and one of the interim targets states that management of storm water should increase the ground water levels. The target declares that land and water use should not be utilized in a way that changes ground water levels, affecting the supply of potable water, ground stability and adjacent eco-system. The end year of the interim target is 2010 but the evaluation from Environmental Objectives Council shows that the goal will not succeed within that timeframe. (Naturvårdsverket, 2009g) Also affecting storm water management is the national environmental objective *A Balanced Marine Environment, Flourishing Coastal Areas and Archipelagos* since the sea is the final recipient for surface water. Accordingly to the EU Directive for Water, the sea water should have good chemical properties. (Naturvårdsverket, 2009h)

In the concept of low impact development[18], the water is treated on-site; either detained or treated as a resource. There are different solutions for low impact development and many of them have been tested in different neighborhoods with ecological profiles in Sweden. The conditions for low impact development are closely linked with the permeability of the ground

[18] Swedish: Lokal omhändertagande av dagvatten

and the amount of vegetation. The larger amount of vegetation, the more water can be taken up and evaporated through the plants; however, plants cannot live on impermeable surfaces. (Kruuse & Widarsson, 2005)

Figure 3.5 Storm Water pound in a residential area (Malmö Stad, 2009)

The two main principles for low impact development are as previously indicated to detain the storm water as long as possible or to use the storm water as resource. The aim of detaining the water is to even out the water flow. Slowly running water in open system gives the water a better possibility to infiltrate or to evaporate and the outflow decreases; an example is seen in figure 3.5. The water which is not managed on-site can be directed to the closest watercourse or to artificial made pounds which functions as water storage and after that directed to the recipient. During heavy rains the whole water flood may not be possible to detain, but still local impact development is a relief to the ordinary sewage plant. (Kruuse & Widarsson, 2005)

A well functioning method for even out the rain water is to construct green roofs, as seen in the figure 3.6 below. Moss, sedum, herbs and grass are covering the roof and form a plant bed with a good water regulating ability. A roof covered with sedum can take care of 60 percent of the total yearly precipitation. When designing a green roof the inclination of the roof needs to be between a few degrees and a maximum 45 degrees. In addition, green roofs also functions as noise moderation, particles is bind to the green roof, evens out temperature differences during warm and cold days and protects the construction from UV-radiation. (Bokalders & Block, Hydrologi, 2009)

Figure 3.6 Green Roofs. (Green Roof)

There are also solutions where storm water is used as a resource[19]. A basic example is storage of water for irrigation purposes during the warm part of the year. Moreover, on locations where there is a shortage of water, toilets can be flushed with rain water. Solutions for using storm water as resources are common in Denmark and Germany. Storm water can also be used as an aesthetical resource with small brooks and ponds on the yard that also serves as a habitat for animals and plants. (Kruuse & Widarsson, 2005)

Permeability and green areas

The ground permeability is of large importance to maintain the hydrological cycle. The permeability is closely related to the design of the yard and the presence of green areas. For considering and evaluating those two aspects at once the biotope area factor can be used. The biotope area factor is a tool that evaluates the quality of green areas and the possibilities for infiltration. The tool was developed to be used for urban planning in Berlin and was introduced in Sweden during the development of the ecologically profiled neighborhood Bo01 in Malmö. The tool calculates the presence of green areas and their ecological value within the urban environment. The overall objective with the biotope area factor is to minimize the impermeable surfaces and increase the vegetation. Areas with different levels of permeability are given a value between 0,0 to 1,0, where the value 0 is given if the surface is totally impermeable (asphalt and concrete) and 1,0 when the surface allow total permeability (vegetation with connection with the ground). A table of values and how to apply the biotope area is factor found in Appendix C.

The presence of trees gives additional credit depending by the circumference of the trunk. When the biotope area factor is used for urban development in Berlin, the following target levels are given; residential areas 0,6, mixed used 0,45 and for business and shop areas 0,3. During the development of Bo01 the ambition was that the yard should reach a biotope area factor of 0,5, this was achieved by less than 50 percent of the yards, nevertheless some of them had reached a level up to 0,6. (Andersson, 2008) A high biotope area factor has not only positive effects in the hydrological cycle; it also contributes to a better micro climate as the vegetation contributes to sun protection and shelter from the wind. The moisture content in the air also increases, which is seen as positive since urban air often is relatively dry. (Persson, 2005)

[19] Swedish: Lokal Utnyttjande av Dagvatten

The environmental objective affected is *Good-quality Groundwater*, with the end year of 2010. The environmental council judges that the goal will not be fulfilled, hence the permeability is of importance to in further urban planning. Noteworthy is that permeability should not be strived for on contaminated sites. (Stockholms Stad, 2005)

Biodiversity

Biodiversity evaluates the level of diversity of living organism within a certain area. Varieties of livening organisms are important on all levels of the ecosystem, levels in this case meaning the living environment, species and genes within one species. For preserved and enhanced biodiversity the ecosystem services, such as pollination, photosynthesis, regulation of water and degradation of biological material are crucial. Ecosystem services are of equal importance for humans and the preservation of those services is given high priority within the international environmental work. A common way of measuring biodiversity is to count the numbers of species within an area. The found number of species reflects the condition of the eco-system, however not entirely. Another measurement is indicator species, used to evaluate the condition of the ecosystem in terms of the number of individuals of one species ((Sveriges Lantbruksuniveristet)

The environmental objective which connects to biodiversity is A *Rich Diversity of Plant and Animal Life*. The interim targets of the objectives deals with stop the loss of biodiversity, decreasing the number of threatened species and reaching sustainable exploitation of biological resources. The council of environmental objectives judge that all of the interim targets are hard or impossible to reach within the time frames (Naturvårdsverket, 2010b). As an indicator of the environmental objective the number of breeding birds is used. Breeding birds function as an indicator for biodiversity due to their elevated position in the web of nutrients. They reflect the conditions further down in the system, at the same time are birds easy to observe and inventory. (Sveriges Lantbruksuniveristet)

To create good conditions for enhanced biodiversity within built areas, yard planning and action is needed. Biodiversity can be enhanced by creating different biotopes where different species and groups of organism are favored. The design of vegetation is of large importance for biodiversity as trees and bushes often constitute space for nests. The construction of pounds gives an additional living environment. Birds are favored by nesting boxes and food tables for birds. To achieve good possibilities for a number of organisms there should be vegetation on all layers, i.e. tree, bush, field and ground layer. (Hjort, 2002)

However, when vegetation is chosen the presence of allergens must be considered as humans with allergic problems are not should be hindered from utilizing the yard. Examples of plants feasible from an allergic perspective are found in appendix A. During the previously mentioned Bo01 nesting birds were used as an indicator for biodiversity. The results from Bo01 were compared to ten year old results from an inventory of a similar unexploited area and were a considerable improvement on all areas. (Kruuse & Widarsson, 2005)

3.3.2.4 Construction site

The environmental impact from the construction site is depending of the size of the site and emissions from material, machinery, noise and vibrations. The construction site has impact on both on humans and the ecosystem. The main measure for reducing the impact on the surrounding ecosystems and biodiversity is to limit the area of the building site. Different ways of measuring and evaluating the suitable size of the construction site have been suggested, for example area for construction site per square meter build floor area (Gangolells et al, 2009). Other system for environmental assessment of buildings, for example, LEED, uses distance from the foundation to the limit of construction site as a measure of the environmental impact. (U.S. Green Building Council, 2008)

One of the direct local impacts on the construction site is the compaction of the soil due to landscaping. Hence, the vegetation will have difficulties to restore after the finished construction. On the construction site valuable vegetation could be found, for example endangered species and ecological valuable broad-leaf trees. In the environmental objective *A Rich Diversity of Plant and Animal Life* the conservation of natural environment, endangered species and biodiversity is treated, but also peoples' access to the natural environment. To reduce the environmental impact on the construction site an inventory of the concerned area should be done in order to preserve and protect valuable vegetation. For decreasing the compactions of the soil, a layer of gravel could be placed above the soil or the restoration of the ground afterwards through some kind of loosening activity. (Bokalders & Block, 2009)

Vehicles and machinery

Vehicles and construction machinery used during the construction process causes emissions to the air. Machinery powered by fossil fuels emits nitrogen oxides, sulfur dioxides, carbon dioxide and particles. These emissions will affect the national environmental objectives for *Clean Air* and *Reduced Climate Impact.*

To reduce those emissions, low emission vehicles can be used. In the Green Construction Program electrical fueled vehicles is the primary option and vehicles fueled by *alkylate* gas/petrol or synthetic diesel[20] is the second option with low content of aromatic hydrocarbons (Projektet Grön Kemi, 2008).

The City of Gothenburg has established an environmental zone in the central parts of the city. Within the zone environmental demands are applied to heavy vehicles (> 3,5 ton). This means newly built vehicles are allowed to drive in the environmental zone at least six years after the vehicle is manufactured. Depending on the euro class (EU-classification for emission, with regard to NO_x and particles) the vehicles can be allowed to drive in the environmental zones for longer. (Göteborgs stad et al, 2009) The highest euro class today is 5, but vehicles of class four are also allowed within the environmental zones. In the extended environmental commitment for Kvillebäcken, the vehicles used for the construction work should fulfill those requirements as well, even though the area is outside the environmental zone in Gothenburg.

Handling of chemicals

A number of chemicals and fuels are used on the construction site. To prevent pollution and that the substances end up in the eco-system and/or affect human health negatively, the substances need to be carefully used and stored. A basic guideline for the handling of chemicals and toxic substances is to handle them separately from nontoxic substances since the risk for carelessness arises when toxic and non-toxic substances are intermixed. Additionally, documentation of the hazardous waste is important. Proper documentation is also necessary for the transportation of hazardous waste. (Kellner & Stålbom, 2001)

Noise

On the construction site a considerable amount of noise is generated, both from activities on the construction site and from personal and materials transports to and from the building site. For more information of the health effects of noise, see chapter 3.7. The environmental

[20] Synthetically diesel contains a lower level of aromatic hydrocarbons and more paraffines which gives lower emission of environmental and health hazardous substances. Synthetical diesel are today produced by natural gas. (Miljöfordon, 2007)

agency has guidelines for the highest noise acceptable levels depending on the time of day and the nature of the disturbing activities. In general, the indoor noise level should not exceed 45 dB(A) equivalent level, during any kind of activity. (Åkerlöf, 2007)

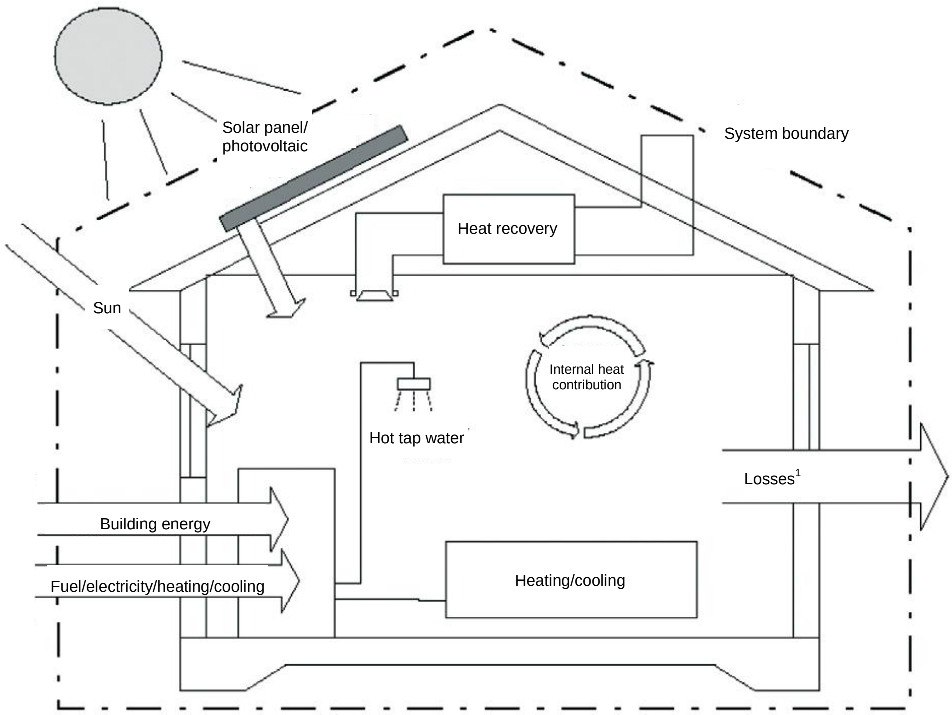
In addition to only reducing the disturbances to the surrounding neighborhood to the largest extent possible, information and communication is necessary and routines for this should be present. Suitable information channels are the daily press, meetings with affected neighbors and newsletters (Åkerlöf, 2007).

3.3.3 Energy efficiency

The general goal of energy efficiency in the Green Construction Program is to reduce the impact on climate change from dwellings. This chapter discusses available energy technologies and energy sources making a reduction of climate impact from residential buildings possible.

In this chapter the terminology concerning energy will be simplified. For example, the transformation of energy from different forms will be called production and consumption since this is the most relevant terminology for the purpose of the thesis.

This chapter focuses on energy efficiency during the use and to some extent the production of residential buildings. The system boundaries and limitations are drawn around the building, as seen is figure 3.7, and the use of energy considers the end use of energy, even though primary energy is briefly discussed later. The embodied energy in solar panels and photovoltaic integrated in the building are not assessed[21] since building material in general is not included in the Green Construction Program.



[1]Transmissionlosses, air leakage, ventilation losses and similarities

Figure 3.7: System boundaries for energy consumption and supply for a building. (Boverket, 2009c)

Yet one of the goals of the program is to increase the usage of renewable energy. This thesis' simplified analysis of primary energy will consider the abundance of the energy source and the impact on the natural environment of harvesting the source.

[21] For more about this issue see (McManus, Gaterell, M.R., & Coates.L.E., 2010)

A general trend in the research, discussion and concepts concerning energy efficiency and buildings is the discussion about primary energy (Wall & Hastings, 2005). Included in the concept of primary energy is in addition to the end use of energy, conversion losses and the use of energy for extraction of raw material. (Jansson, 2008) However, there is no consensus in Sweden today about the conversion factors for different kinds of energy. The Energy Efficiency Report[22] points out that a weighting system for different kind of energy carriers transmissions losses is needed. (Näringsdepartementet, 2008) Hastings & Wall uses the conversion factor of 2,35 for the EU-mix of electricity (Hastings and Wall 2005). While providing an insight of the structural changes in the energy system primary energy does not however influence the energy efficiency of buildings. (Nässen & Holmberg, 2005)

There are different ways of measuring the energy consumption and the long term environmental impact of a building due to its energy consumption. Examples of different measurement includes bought energy, which is used in this thesis and in the Green Construction Program, primary energy as previously mentioned and explained, heat and cooling demand, CO_2 emissions or CO_2 equivalents (Blomsterberg, 2009).

To limit the amount of bought energy two strategies can be used, either to reduce the energy need or to increase the share of “on-site” renewable energy production, like wind and solar power. Or, of course, a combination of the two strategies. Forum for Energy Efficient Building[23] recommends that the builder first to optimize the performance of the building and then optimize the building in an energy system perspective. (Forum för energieffektiva byggnader, 2009a)

Another way to illustrate this is, are exemplified in figure 3.8, the Kyoto pyramid.

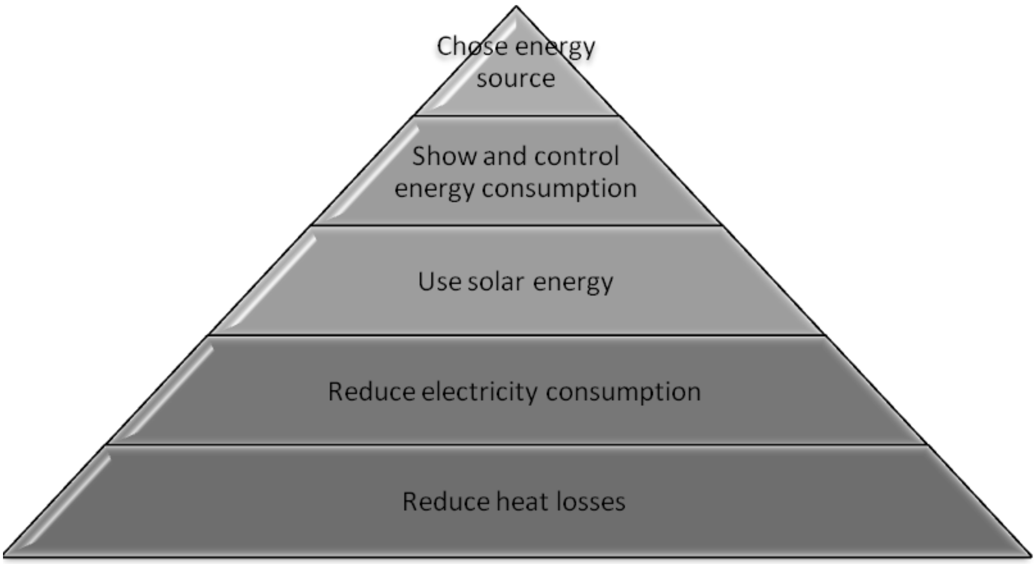


Figure 3.8 The Kyoto Pyramid. *Adapted from (Lavenergiboliger.no, 2005)*

The national environmental objective of Sweden concerning energy efficiency, *A Good Built Environment*, has guiding lines for the reduction of consumed energy per area for residential buildings. Compared to the base year of 1995 should the reduction be 20 percent in 2020 and 50 percent in 2050. By 2020, the dependence on fossil fuels in the building sector should be broken. The amount of renewable energy should be constantly growing. (Naturvårdsverket,

[22]Swedish: Energieffektiviseringsutredningen

[23]Swedish: Forum for Energieffektivt Byggande

2009j) If the system boundaries are extended to concern more than the end use, energy efficiency also connects to more or less of all of the national environmental objectives but mainly *Reduced Climate Impact, Clean Air, Natural Acidification Only, Zero Eutrophication, Sustainable Forest* and *Flourishing Lakes and Streams*.

3.3.3.1 Building performance, technology and installations

The energy consumed for the heating and hot water supply of a building is depending on transmission losses through the building envelope, convection losses through the building envelope and ventilation. Contributions from house hold electricity, solar gains, heat water and inhabitants lower the energy demand. (Petersson, 2004)

There is an abundance of definitions and concepts for energy efficient buildings, focusing on different requirements. One of the most common concepts is the passive house.

> ”*A Passive House is a building for which thermal comfort (ISO 7730) can be achieved solely by post-heating or post-cooling of the fresh air mass, which is required to fulfill sufficient indoor air quality conditions (DIN 1946) – without a need for recirculated air*.” *(*www.passivhaustagung.de*)*

There is today a voluntary standard for what could be defined as a passive house is in Sweden, established by Forum for Energy Efficient Building. For Gothenburg, the peak load is 10 $W/m^2A_{temp + garage}$[24] for apartments and for single-family houses 12 $W/m^2A_{temp + garage}$. The passive house standards for total bought energy, including household electricity, is 50 $kWh/ m^2A_{temp + garage}$, year and for buildings where the heat comes from electricity the limit is 30 $kWh/ m^2A_{temp + garage}$, year in Gothenburg. (Energieffektiva byggnader, 2009a) This number deviates from other sources, for example Jansson puts 45 kWh/m^2 in bought energy as a guide line for the southern climate zone in Sweden where Gothenburg is located (Jansson, 2008). Nevertheless, those numbers can be compared to the average energy use is in an apartment building which today is 145 kWh/m^2. (Energimyndigheten, 2009a). In 2001 the average single-family house used around 25 000 kWh/year. 60 percent of this total usage is for heat and ventilation, hot tap water accounts for 20 percent and house hold electricity accounts for around 20 percent of the total energy use (end use figures). (Kungliga Ingenjörsvetenskapsakademin, 2002)

The passive house has a heat recovery mechanism from the exhaust air to the fresh air and has a thick and closed building envelope. Most commonly additional heat is added to through the supplied fresh air and not radiators. It should be pointed out that the passive house concept is not the only way to reach a high energy efficiency in buildings, a more traditional house with mechanical ventilation and a traditional heating system could perform equally well in an environmental perspective.

Additionally, when discussing energy efficient buildings with high performance thermal envelope it should be noted that the relative impact from the number of habitants and the indoor temperature rises. Relevant measuring and evaluation methods need to be applied when comparing the energy consumption and energy need of energy efficient buildings to standard buildings. (Forum för Energieffektiva byggnader, 2009b)

In addition to passive houses there are other concepts focusing on energy efficiency with preserved thermal climate. For example the Swiss Minergie houses with demands for energy efficiency, primary energy and energy source; the 3 liters houses where the energy demand per m^2 for heating on a yearly basis should not exceed the primary energy content in three

[24] A_{temp} are defined as all areas within the buildings envelope heated to at least 10 degrees.

liters of oil. The German passive house standard requirements for the amount of supplied primary energy distinguish between different energy sources used. (Blomsterberg, 2009)

When evaluating the economic performance of energy efficient buildings with additional investment cost for improved insulation and thermal performance of windows, life cycle costing (LCC) can be used to find the optimal economic efficiency level. (Fuller & Petersen, 1995) When LCC is used the additional cost for a more energy efficient building envelope is compared to a regular building with different scenarios for the price of energy. With the present value method the formula is:

$$LCC = CC + \sum_{n=1}^{N}(C_n/(1 + i)^n) - S/(1 + i)^N$$

Where CC is the capital investment, C_n is operating cost per year (including price of energy), S is the value of the investment at the end of the analysis period, N is the period of the analysis and i is the chosen interest rate. The result will depend on the projected future energy cost and the required interest rate. For a building the period of the analysis is mainly around 20-40 years (Davis Langdon Management Consulting, 2006). A European project researching passive houses concludes that in order to be cost effective, the additional investment cost for a passive house should be returned during a period of 30 years or less (Harvey D. L., 2007).

3.3.3.2 Buildings heated with electricity including use of heat pump

For a building heated by electricity the requirements of maximum bought energy differ compared to a building heated by other energy sources. The BBR (Swedish building code) demand for electrically heated climate zone III building (where Gothenburg is situated) is 55 kWh/m^2 A_{temp} and year, compared to a building with an alternative energy source where the legal requirements is 110 kWh/m^2 A_{temp} and year. In addition, if the building is heated by electricity there is a legal requirement setting maximum power installed to 4,5 kW for a house smaller than 130 m^2 (≈34 W/m^2) plus 0,025 kW for each additional m^2. This requirement applies for all kinds of electrical heating devices such as heat pumps, direct electricity, electrical boilers etc. (Boverket, 2009c)

Consequently, buildings using heat pumps for heating are normally regarded as an electrically heated building due to the installed power capacity. According to the definition from the National Board of Housing, Building and Planning[25] buildings with installed electrical power, including additional peak power, larger than 10 W/m^2, are regarded as electrically heated. (Boverket, 2009c)

3.3.3.3 Energy production on site by sun

To limit the amount of bought energy, renewable energy can be produced on site, as seen in figure 3.7, p27. This is most commonly done by actively using solar energy for heat and electricity production.

Electricity producing photovoltaic is getting more commonly used on buildings and the development of photovoltaic is an active field with prices rapidly decreasing (Energimyndigheten & Boverket, 2005). There are varying numbers for the efficiency of the various photovoltaic technologies available. Under Swedish conditions each installed kW_p can deliver around 600-900 kWh/year. If photovoltaic produced by crystalline silicon is used, an area of 8 to 10 m^2 is needed for each installed kW_p. (Hastings & Wall, 2006) In an additional example from 2005 by the Swedish Energy Agency a 40 m^2 large roof in southerly direction

[25] Swedish: Boverket

located in the South of Sweden produces 4200 kWh/year. (Energimyndigheten & Boverket, 2005)

Since Sweden has considerable climate variation during the year, the production of electricity will differ vastly between the seasons. For a photovoltaic the output is ten times larger during July compared to the output during December and January. (Bokalders & Block, 2009) Since the production of electricity from photovoltaic differs from the demand of electricity, storage is needed. A grid connection can function as a kind of storage for electricity for the individual user. (McManus, Gaterell, M.R., & Coates.L.E., 2010)

Using solar energy for heating and hot tap water production the size of the solar energy system is usually determined by the maximal need of energy during the summer months. According to Hastings & Wall a solar hot water system should cover up to 40 percent of the annual need for a multi residential building and in a single family house up to 70 percent of the annual demand and all of the summer demand. (Hastings & Wall, 2006) If the house is connected to a district heating system the heat surplus can be distributed in the district heating system and the dimensions and capacity for the system could be larger. (Hållén, 2010)

Heat and electricity could also be produced in solar hybrid systems where modules produce both of the energy carriers. (Chow, 2010)

3.3.3.4 Examples of energy efficient buildings

During the last years the interest in energy-efficient buildings in Sweden has been raised considerably as new energy efficient buildings have been built and old buildings have been renovated to a higher energy standard. The first passive house in Sweden was built in 2001 and today there around 400 such dwellings in the country.

One of the first construction projects according to the passive house principle in Sweden was the block Oxtorget in Värnamo, a city in the southwestern parts of the country. The peak load is 8,3 W/m^2 when the indoor temperature is 20 degrees and heating demand (without hot tap water) is 9,8 kWh/m^2 annually. (Jansson, 2008) The bought energy was for heat, tap water and electricity for the premises 19 kWh/ m^2 and year (Finnvedsbostäder, 2008). Today in the region of Västra Götaland almost ten percent of the newly constructed buildings are built according to the passive house standard. (Dahlqvist, 2010)

The latest concept for energy efficient buildings is the plus energy buildings. These are energy efficient buildings that in some way produce more energy than they use on a yearly basis. In Sweden, only one plus energy house, Villa Åkarp, has been built, a single family house that will deliver the surplus energy out on the grid during the warm months while buying electricity during the cold months. The total yearly heat demand will be 15 kWh/m^2 (Blomsterberg, 2009) The 32 m^2 photovoltaic will produce 4000 kWh during the bright part of the year.

In Lerum, the public company Förbo is building plus energy houses that will deliver heat surplus to the district heating grid. The energy use will be 54 kWh/m^2 and year and the heat production from the solar panels will be 58 kWh/m^2 and year. (Hållén, 2010) On a yearly basis the bought energy would then be -4 kWh / m^2.

Moreover, it is the goal of the energy agency in Sweden that buildings in the future could be a supplier of energy (Energimyndigheten, 2010a)

3.3.3.5 Lighting installation and use of daylight

Of the total electricity used in dwellings ligthing makes up for around 10-20 percent and has a large potential for decreasing the electricity need by becoming more efficient. The general strategy for a more efficient lighting system is similar to the strategies for a more energy efficient building in terms of heating. First, the use of daylight should be maximized as much as possible without compromising other requirements put on the building, such as avoidance of solar heating, see next chapter. Lighting should be supplied when it is needed, where it is needed and in the right quantities. Finally, the most efficient light sources should be selected. (Harvey D. L., 2007) Bokalders and Block claims that, due to the climate in Gothenburg daylight is seen as something positive that should be encouraged both inside and outside the building. Except for the evident energy saving, increased amount of day light enhance human well being. (Bokalders & Block, 2009)

The use of daylight is depending on window/floor ratio, building shape, height of the window and their placement – for example if there are skylights. A common measurement for the amount of daylight within buildings is the daylight factor, which measures the ratio between the intensity of illumination indoor and outdoor without shielding. The ratio is measured 0,85 meters above the floor, halfway into the room. (IVL Svenska Miljöinstitutet, 2004) Research states that the day light factor should at least be one percent for guarantee that the inner parts of the room feel lighted by day light (Hult & Malmqvist, 2005). This corresponds roughly to a window area which is ten percent of the floor area (Johansson & Jansa, justeringar av Bygga-bo-dialogens tekniska råd 2009). There are more sophisticated methods considering more parameters as well such as angles and yearly variations. [26] The recommendations from Block and Bokalders are more user friendly. The kitchen and living rooms should be reached at least four hours of sun during equinox. If the kitchen and living room are in different cardinal directions they should be reached of five hours of sun in total. (Bokalders & Block, 2009)

Additionally, occupancy sensors, day light sensors and dimmers make sure that lighting in common areas is turned on only when necessary and on the right level.

As already stated the lighting needed should be as energy efficient as possible and low energy bulbs are a requirement in the Green Construction Program. There is an ongoing EU directive to phase out ordinary bulbs and instead introduce low energy bulbs. Low energy bulbs are not the only way make the illumination more efficient. Other technologies can be used as well; LED (light emitting diodes) is one of them. The development of LED-illumination is ongoing and the use of LED gives energy efficient, mercury free lighting with a long life span compared to low energy bulbs, however at a comparatively high cost and with reduced light quality. (Harvey D. L., 2007)

As an example of the last measure a public housing company that changed upgraded the armatures and installed occupancy sensors in the staircase areas that earlier were always illuminated, made energy savings of around 75 percent. (Energimyndigheten, 2005)

3.3.3.6 Avoidance of overheating

To have a comfortable indoor climate during the whole year, the risk of overheating, especially when the building is designed to utilizing passive solar heating and day light for lighting must be considered. Influencing factors for overheating are solar radiation, window area and a reduction factor. The radiation is depending on direction and gradient, and the reduction factor is depending on the shadowing, which could be statical or flexible (i.e. depending on behavior) and how much of the solar radiation is transmitted through the windows. (Energirådgivarna, 2005) For assessing the thermal comfort the operative

[26] http://www.thedaylightsite.com/filebank/Climate-Based%20Daylight%20Analysis%20for%20Residential%20Buildings.pdf

temperature can be used. The operative temperature is decided by the air temperature and surrounding surfaces temperatures in the room. (Peterson, 2004) For achieving grade silver in the Building/Living environmental classification the operative temperature should not exceed 27 degrees during daytime, the warmest seven-day period in July. Petterson sets as a guiding standard for the maximum temperature within the building that the floor temperature should not exceed 27 degrees. (Peterson, 2004) Moreover, it is worth noting that the experience of overheating is depending of the outdoor temperature and during a hot day a high indoor temperature is more acceptable to the occupants. (Humpreheys & Nicol, 2002)

Additionally, in the previous mentioned Minergie house no eletrical cooling system is allowed. A common solution is the use of a buried air duct which conveys the air supply into the building. The supply air then gets the same temperature as the surrounding ground which function as a cooling system. The same system will during the winter months instead decrease the heating demand. (Jagemyr & Olsson, 2008)

3.3.3.7 Choice of appliances

For further reducing the need for electricity in buildings the most energy efficient appliances and installations should be used. In Sweden home appliances are energy classified according to an EU-standard ranging from A to G, where A is the best. (Energimyndigheten, 2007)

The best available appliance in each class is for washing machines A, tumble driers A, ovens A, refrigerators A++ (however, the “++” label is for marketing purposes) and freezer A++. For hobs are there no energy classification, ceramics and induction are nevertheless much more energy efficient than cast iron hobs. (Energimyndigheten, 2007)

An example from 2002 showed that if all refrigerators and freezers bought were of energy class A instead of C, the energy consumption for food storage would decrease by 30 percent. Equal figures are showed for all white goods. (Kungliga Ingenjörsvetenskapsakademin, 2002)

3.3.3.8 Energy source and carrier

The Green Construction Program recommends that renewable energy or district heating should be prioritizes as choice of energy source. Research has showed that of equal importance as building an energy efficient house is to choose an environmental friendly energy source. (Brunklaus, Baumann, & Thormark, 2008)

Regarded as renewable energy sources are “free” energy sources like wind, wave and hydro but also bio fuels and geothermal sources. (Energimyndigheten, 2008) Potentials, limitations and environmental aspects for the different renewable energy sources are discussed below. Solar energy for on-site production has already been discussed but will be described in a large scale production context. For giving a small grasp about the potential and situation in Sweden’s energy system today, this information will give a brief introduction.

The figure below shows the electricity supply in Sweden, where buildings uses around 30 percent of the total electricity consumption.

Figure 3.8: Supply of electricity in Sweden (Energimyndigheten & Statistiska Centralbyrån, 2010)

As seen in the figure 3.8, the largest share is divided between hydro and nuclear power, where wind power still supply a small share of the total electricity supply.

Table 3.3: LCA of electricity, cradle to end-user. (Baumann & Tillman, 2004) (Vattenfall, 2005)

Energy source	Emission	Reference:
Hydropower	3, 76 g/kWh 5,62 g/kWh	Baumann & Tillman Vattenfall
Windpower	16,4 g/kWh 15 g/kWh	Baumann & Tillman Vattenfall
Biofuel	32,27 g/kWh	Baumann & Tillman
Nuclear	11,03 g/kWh 4,4 g/kWh	Baumann & Tillman Vattenfall
Oil	992 g/kWh	Baumann & Tillman
Hard Coal	832,7 g/kwh	Baumann & Tillman

There are large differences between which energy sources that are used in singe family houses compared to multi residential houses as seen in the figure 3.9 on the next page.

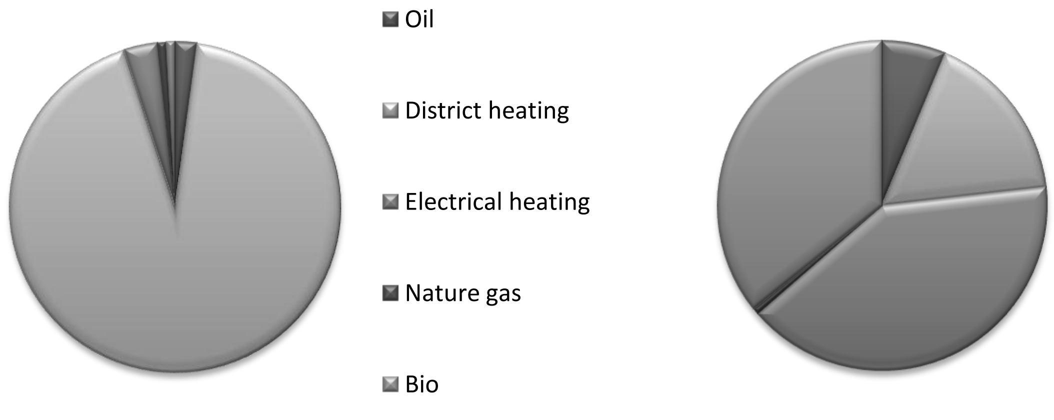


Figure 3.9 Heat supply in multiresidential house (left) and in a single family houses (right) after type of energy (TWh) (Energimyndigheten & Statistiska Centralbyrån, 2010)

As seen in figure 3.9 the district heating is the main energy used for residential building, while electrical heating and bio energy are the main energy sources used for single family houses.

Today the marginal electricity on an annual basis is based on fossil fuels and more installed electrical heating will increase the emission of CO_2. (Fastighetskontoret, 2009)

Wind

The kinetic energy in wind can be harvested and transformed to electricity. The output from wind plants has the opposite character compared to solar energy. In Sweden the output during October to January gives double as much energy as during the rest of the year. Today wind power produces around 2,5 TWh but the government is aiming to expansion the production to 30 TWh by 2020. (Energimyndigheten, 2010b)

Hydro

Hydro power can be used in a large (>1500 kW) and small scale (<1500 kW). Large scale hydro today provides for around half of the electricity (in 2008 46,6 percent of total 68,4 TWh) demand in Sweden. Hydro power is used in the base load since it one of the cheapest way to produce electricity. The largest rivers in Sweden are fully exploited but there are possibilities to make the plants more efficient and enlarge the small scale hydro plants. The output from Swedish hydro power can vary by around 20 percent on a yearly basis compared to the normal yearly production. (ÅF, 2009)

Bio fuels

Bio fuels can be used for electricity generation and heat production. Bio fuels come in various forms – solid, liquid and gas. When solid bio fuels are used, the virgin material is often processed to a homogeny fuel e.g. wood chip, pellet or firewood. In addition, waste products from the agriculture and peat are counted as bio fuels. Peat is however not longer counted as a renewable energy source. (Energimyndigheten, 2009b) Waste from households and industries can be classified as bio fuels as they consist to a large part of organic waste. (Ångpanneföreningen, 2009)

When bio fuels are used for heating the environmental impact and efficiency is depending on the performance of combustion processes. For domestic use of bio fuels there a large gap between best and worst performance concerning emission and efficiency. In large scale production of energy from bio fuels a combined heat and power plant (CHP) can be used. (Bokalders & Block, 2009)

An interest group's forecast claims that CHP fueled by bio fuels could supply 15 percent of the total electricity need in 2015. (Svebio, 2008) The main limitation for bio fuels is land use and the inherent competition with other land uses. For further information on the environmental impact, see forest product in Chapter 3.3.1

District heating

The environmental impact from district heating is depending on the energy source of the system. Since district heating systems can use flexible energy sources such as solar, bio, waste, fossil fuels, and waste heat the impact varies vastly. Figure 3.10 below shows the average supply of fuel and energy to the district heating grids in Sweden 2008.

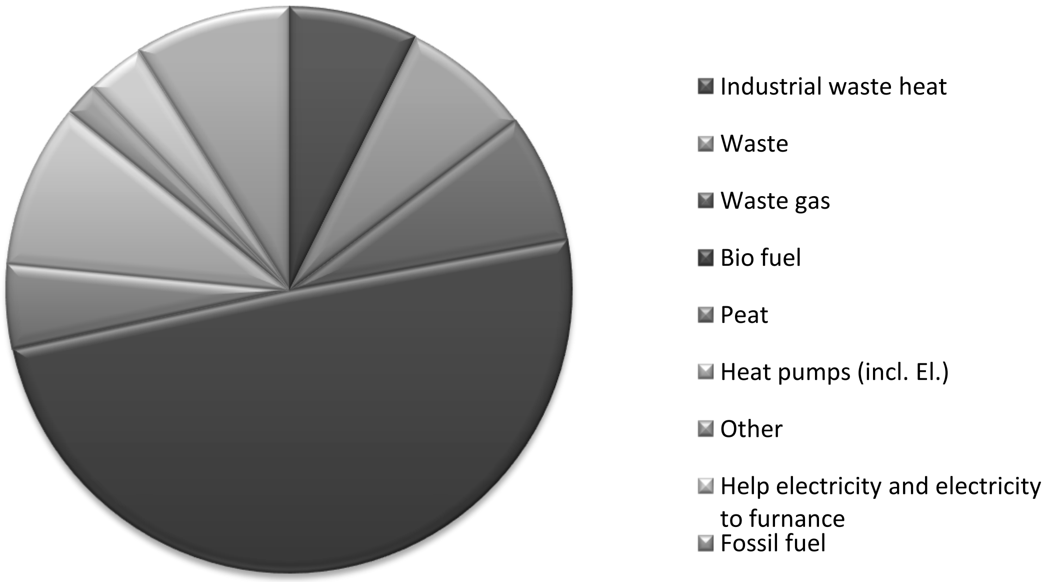


Figure 3.10 Supplied fuel/energy for district heating in Sweden 2008 (Svensk Fjärrvärme AB, 2009)

In Gothenburg the district heating mix is different from the national mix. The largest share is composed of waste heat from refineries and industries which in 2008 made up for around 60 percent of the heat supplied to the district heating grid. Of the heat produced specifically for the district heating system the largest share, 40 percent, was produced from natural gas where electricity is co-generated as well (ratio 0.9 between heat and electricity). The secondly largest share, 30 percent, is from the incineration plants where waste and bio fuels are used. Third, by accounting for 17 percent, is the heat from sewage water harvested through heat pumps. The rest consisted of small facilitates heated by fossil fuels and bio fuels. (Göteborgs Energi, 2009)

Depending on the location the feasibility of central produced heat or "on-site" produced heat varies.

Natural energy sources

Besides sun, solar, wind and bio there are other natural energy sources that could be used for heating. The concept of natural energy sources includes surface water, ground water, air and geothermal heating. Most commonly, these energy sources need a heat pump for extraction usually giving about three units of energy for each input unit. (Ångpanneföreningen, 2009)

Choice of energy source

Depending on availability and the technical systems of the building different energy sources could be combined and used. There are also possible limitations due to the buildings location. A heat pump using geothermal heating is limited by the surrounding bore holes, solar energy is limited by daylight and climate and the use of district heating is limited to dense areas and so on. (Mumovic & Santamouris, 2009)

Combining different energy sources is common, for example when a geothermal energy is used with the help of a heat pump, additional energy is often needed during cold days because the heat pump is not dimensioned for supplying the peak demand. Commonly as previously mentioned, when solar panels are used for heating, those are dimensioned to cover the need during the summer month and during the rest of the year additional heat is necessary.

However the choice of energy source is influenced by many parameters except for environmental impact and availability. Economy, convenience and reliability are all issues that needs to be considered when choosing energy source and heating system.

Long-term perspectives and planning

As seen from the statistics, the energy use per m^2 is decreasing at the same time as the share of renewable energy is increasing like the district heating system which is already to a large extent based on renewable sources. Concerning electricity used for heating purposes either directly or for heat pumps, the system is already based on renewable energy to some extent due to the extensive use of hydro power in Sweden. If wind power is expanded as planned the domestic production of renewable electricity will stand for half of the present energy consumption. In order to achieve a sustainable use of intermittent energy in the electricity grid there are a few thing to consider in the planning process. Firstly, how does the demand and supply system look – what kind of energy services are needed and when? Secondly, how large must the back-up from other fuels be, for example solid biomass and fossil fuels due to the intermittency? (Mumovic & Santamouris, 2009)

For meeting the challenges of climate change and to achieve the environmental objective it is necessary to remember that new buildings, even though they are highly energy efficient will not decrease the energy need for the built environment. (Energimyndigheten, 2010a)

3.3.3.9 Measurement of energy during use phase

To verify that the finished building and the design phase energy calculation are made correctly the energy consumption when the house is in use needs to be measured. An energy measurement examines deviations from calculated levels from the actual energy consumption. A follow-up from a building exhibition in Malmö 2001, Bo01 showed that the actual energy consumption exceeded the calculated consumption in nearly all of the analyzed buildings. (Rolén, 2005) Also the first passive houses in Sweden, the terrace houses in Lindås, displayed slightly higher energy consumption than the calculated values. Studies showed that the individual behavior of the occupants varied to a large extent and influencing the demand for supplied energy. (Wall, 2006)

Because the influence of individual behavior matters a lot when it comes to energy savings this gives incentives to implement individual measuring and debiting of electricity and heat. Figures from 1999, shows that the potential for energy savings for space heating is 5-10 percent and for hot water saving 15-30 percent. (Nässen & Holmberg, 2005) Today, only a small amount of the apartments are furnished with individual charger. (0,6% in 2005). (Berndtsson, 2005)

In addition, measurement of the air tightness of the envelope and control of eventual thermal bridges could be found and measures can be taken to care of the defects during the production. Forum for energy efficient buildings have compiled a manual for relevant measurements that could be used for the purpose. (Forum för Energieffektiva byggnader, 2009b)

For measurement of heat there are two possibilities, either to measure the indoor temperature or to measure the flow of supplied energy. (Boverket, 2008b) The standard for passive houses in Sweden has standardized way for what should be measured, as an example should the heat power losses be measured during 3-6 weeks during winter. The standard also puts a deviation of 15 percent from the calculated losses as an acceptable value for building smaller than 1000 m^2. (Forum för Energieffektiva byggnader, 2009b)

3.3.3.10 Production phase

On the construction site a considerable amount of energy is consumed, in Sweden a total 300 million kWh/year. Builders' huts, constructions fans, lighting are examples of equipment that consume heat and electricity. (Hatami, 2007) Hut and lighting uses around 70 percent of the energy during the production phase. They are often poorly isolated and lighted also when not in use. Each hut uses around 8000 kWh/year, three times as much as an equally large newly constructed apartment building. For saving electricity district heating could be used for hot water and heating. Also the halogen lamps used today are possible to exchange to low energy lights. The company Cramo claims that their energy efficient establishment will save half of the energy normally used on a construction site. This is done by occupancy controlled lighting, insulated store containers, better elevators, more energy efficient builders hut's and arrangement of those so that they take a more energy efficient form with reduced leakage of heat. (Cramo, 2010)

3.3.3.11 Building/Living requirements of energy efficiency building performance

The Building/Living environmental classification has requirements for energy use, energy source and energy requirements, due to heat loss and solar radiation. The demands for energy use is measured in bought energy, kWh/m^2A_{temp} excluding house hold electricity. To reach grade silver bought energy is 0, 75 times the legal requirements and for grade gold, the bought energy should not succeed 0, 65 times the legal requirements. The requirements for heat losses from ventilation, climate shell and sewage water is for grade silver less or equal with than 40 W/m^2 and for gold less than or equal with 25 W/m^2 DVUT (dimensioning winter outdoor temperature). For buildings heated with electricity is the requirements even lower 30 W/m^2 for silver and 20 W/m^2 for gold.

There are also requirements for choice of energy source, regardless of how much energy is used in the building, which could be seen in table 3.4 below.

Table 3.4: Grading due to energy sources in environmental classification

Grade	Non-renewable energy sources (percent of supplied energy)	Non-environmental labeled hydro-environmental approved biomass (percent of supplied energy)	Sun and eco-labeled hydro (percent of supplied energy)
Silver	<25	>50	>10
Gold	<20	>20	>20

(Johansson & Jansa, justeringar av Bygga-bo-dialogens tekniska råd, 2009)

According to Bygga-Bo dialogen is it possible to reach grade “Guld” with environmental labeled district heating and electricity for common spaces. (Johansson & Jansa, justeringar av Bygga-bo-dialogens tekniska råd, 2009)

3.3.4 Resource efficiency

The aim of the area of resource efficiency in the Green Construction Program is to decrease the use resource and the amount of waste during the life span of a building. Within this chapter building materials, water consumption, waste and recycling are discussed from a resource perspective.

3.3.4.1 Building materials

Concrete is an important and common building material used for buildings. Concrete consists of ballast which is bound together by cement and water. For reaching specific qualities, various chemical substances are added. Ballast consists of sand, gravel or rock. Natural gravel such as sand, gravel and rock is commonplace in the nature and has traditionally been the main virgin material used for ballast. However, natural gravel is a finite resource which is running short in a lot of places in Sweden. Hence the extraction of natural gravel must be limited. (Sveriges Geologiska Undersökning-SGU, a) In addition the extraction has a negative impact on the ground water sources and flows. A large part of the ground water is produced in ridges consisting of natural gravel and to secure a long term supply of drinking water those ridges needs to be preserved. Natural gravel formations also have a large value for culture and outdoor life. (Naturvårdsverket, 2009k)

Figure 3.11 Extraction of gravel in the north of Hedemora in Dalarna, Sweden. (Sveriges Geologiska Undersökning, c)

The national environmental objective *A Good Built Environment* holds a decrease of the extraction of natural gravel as an interim target. According to the target, the total withdrawal should not exceed 12 millions of ton per year in 2010; however, the target has not been fulfilled. (Naturvårdsverket, 2009k) According to the yearly report from SGU concerning production and supply of material for ballast the yearly production increased during 2008 and amounted to around 101 million tons, of which 19 percent consist of natural gravel, a lower production than during the previous years. This is illustrated in figure 3.12 on the next page. (Sveriges Geologiska Undersökning - SGU, 2009). This is however considerably more than the target of 12 million of ton per year. The environmental objective *Good Quality Ground Water* holds an interim target dealing with natural gravel and its effect on ground water resources. Today, 53 percent of the extraction of natural gravel is done in areas with the important ground water resources (so-called class 1 areas, calculated flow larger than 25 l/s) (Naturvårdsverket, 2009g). The region of Västra Götaland has the same problems as the rest of Sweden – the extraction decreases but not fast enough. Furthermore, the rate of reduction has slowed down during the latest years and more than half of the most important ground water reservoirs in the region have been affected by natural gravel extraction. The county administration[27] limitation requirement on natural gravel is from 2010 sets the limit for extraction to 1,4 million ton per year. The total extraction in 2008 was around 2,3 million ton.

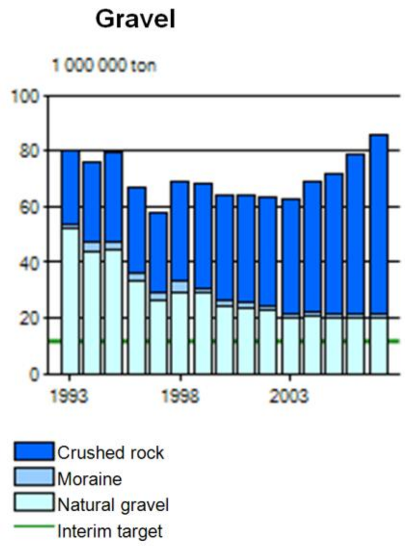


Figure 3.12 Deliveries of natural gravel, crushed rock and moraine from permitted facilities in Sweden and the interim target for natural gravel. (Naturvårdsverket, 2009k)

Since ballast is a component in concrete which is used in large quantities within the construction of multi residential buildings, decreased use of natural gravel is important measure for a green construction processes. Year 2008 the concrete production accounted for around 40 percent of the total use of natural gravel (other uses includes use as filler and use for road constructions). The alternative option to natural gravel, is crushed rock, which is rock crushed to the required size. As the extraction of natural graves has decreased, the production of crushed mountain has increased steadily and the supply is in principal infinite. Waste material from construction work can also be used as ballast. The largest obstacle for this is the quality aspect. There are some purposes for which it is not technical feasible to replace natural gravel. (Sveriges Geologiska Undersökning-SGU, b) According to SGU, fractions smaller than 2 mm (sand) not replaceable. Calculations show that around 3 millions of ton natural gravel per year cannot be replaced by other materials, the main use for this required natural gravel is within the concrete industry. (Naturvårdverket, 2009k) SGU presents examples of circumstances where natural gravel has been replaced with crushed rock. (Sveriges Geologiska Undersökning-SGU, b).

3.3.4.2 Water consumption

In this chapter limited to the water situation in Gothenburg since the application area for the program is the City of Gothenburg. The environmental impact analysis includes production, consumption and treatment of tap water, other aspects are considered outside of the system boundaries.

Water used as tap water is delivered either from surface water or ground water. In Gothenburg, the drinking water is produced by surface water from the river Göta Älv or the lakes Delsjöarna or Rådasjön by the water plants Alelyckan or Lackarebäck. There is no immediate shortage of water supply in Gothenburg, but due to the pollution risks along the river there is a potential for shortage of potable water. During times with risk of, or with pollution, the water intake in Göta Älv is closed and the reservoirs in the lakes Delsjöarna and

---

[27] Swedish: Länsstyrelsen

Rådasjön are used instead. This is done around hundred times each year. (Göteborgs Stad, 2006)

Economizing with tap water usage improves the conditions for a well functioning water supply. At the same time, energy and resources are saved. Except from the obvious energy saving with decreased consumption of domestic hot water, energy can be saved within the process of tap water production and in the treatment of the sewage water. Additional resources can the saved thanks to the decreased amount of chemical necessary for water treatment. Yet another reason for economizing the use of tap water is that the emission limits for the discharging of purified water are measured in concentration mg/L, hence high flows reduces the need for sewage water treatment possible causing increased emissions levels. (Gryaab, 2009)

In order to decrease the consumption of water more efficient water armatures can be installed. A household can decrease the energy consumption for tap water by around 40 percent if traditional taps is replaces by more efficient ones. Existing taps can also be made more efficient by installing a percolator, which by mixing air into the water jet giving a decreased flow of water. (Energimyndigheten, 2010c)

3.3.4.3 Waste and Recyclings

This chapter deals with both domestic and construction waste. Resource use and waste generation are as previously mentioned important environmental aspects within the construction sector.

Domestic waste

Domestic waste refers to waste that has been generated by households. The system boundaries used for household waste within this thesis, starts when the households considers a product as waste, i.e. when that the occupants decide the get ride off the product. The system boundary stops when the waste is within the waste container. Within the use phase of a building waste is generated by the occupants and management activities. Domestic waste is a resource that should be utilized since a large part of the waste consists of materials feasible for recycling. During 2010 a new EU waste directive will be implemented in Sweden. The waste directive establishes a waste hierarchy, setting a priority list for waste management. As a first choice the generation of waste should decrease, secondly the material should be recycled. As a third choice, the material should be recycled through energy recovery and finally as a last option, the waste should be put on deposit. (Naturvårdsverket, 2009l) Recycling waste and closing material loops, will facilitate better economizing with natural resources and a smaller amount of raw material will be extracted. In addition, a well-functioning waste management decreases the emission of hazardous substances, (Naturvårdsverket, 2009m)

The environmental objective of *A Good Built Environment* has an interim target concerning waste. The general goal of the interim target is to decrease the amount of waste and increase the recycling rate; also the amount of hazardous waste should be decreased. The rate of sorted organically waste should increase compared to the present level and be treated biologically. The interim target states that in 2010 50 percent of the domestic waste should be recycled including the biological treatment for the organic waste. Of the sorted organic waste at least 35 percent should be treated biologically. In 2007, 20 percent of the organic waste was treated biologically. The target achievement is mixed: less waste is put on deposit and the recycling of materials is increasing. At the same time, the rate of improvement for the treatment of biological waste is slow and the interim target will not be achieved on time. Above all, the total amount of domestic waste is steadily increasing. (Naturvårdsverket, 2009n) The trend for domestic waste can be seen in the figure 3.13 below.

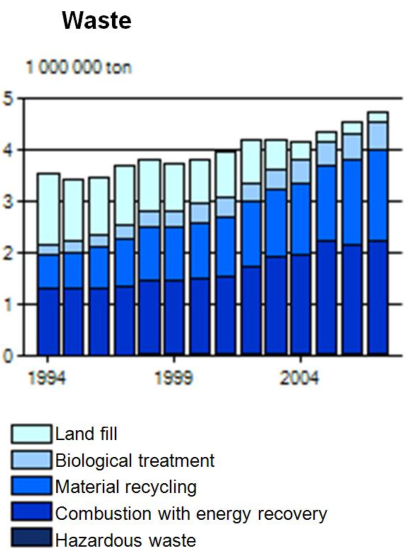


Figure 3.13 Domestic waste per year, in total and divided after different management methods. (Naturvårdsverket, 2010e)

For onsite sorting of domestic waste many different solutions are available. Yet, the area has a large space for innovation. The system for sorting of domestic waste should be flexible since the waste situation is continuously changing. Examples of systems that have been used in neighborhoods with ecological profiles in Sweden are automated vacuum collection and waste disposers with central collection. (Appelqvist et al, 2005) The City of Gothenburg has developed a folder with recommendations and requirements for how to build good space for waste in a building; *Make room for the environment – Plan and build for a safe and efficient waste treatment in Gothenburg.*

Building waste

The production of a building as well as the demolition process generates large quantities of waste. The waste consists of many different materials that need to be separated and treated separately. Common types of waste generated at a construction site are timber, plastic, plaster, hazardous and mixed waste. The waste management on the construction site has a large impact in decreasing the deposited waste and minimized emissions to nature. It is mainly the mixed waste that has to be decreased in order to reduce the amount of waste put on deposit and increasing the resource efficiency. Landfills result in a large environmental load due to leakage of toxics and green house gases. (Naturvårdsverket, 2009n) The EcoCycle council in their 2010 environmental program specifies goals for increasing the resource efficiency within the construction industry. The primary goal is to reduce the amount of deposit waste. The EcoCycle Council has developed guidelines for waste management in the construction site. (Byggsektorns Kretsloppsråd b). The interim target concerning waste in *A Good Built Environment* specifies that the amount of waste deposited should be 50 percent of the amount in 1994. According to the Environmental Objective council this has target been reached and is steadily decreasing. (Naturvårdsverket, 2009n)

There are different measures for decreasing the amount of waste on the construction site. The building material can be custom made, for example plastic boards. To decrease the amount of waste during the end of the building's life cycle the possibility to separate the different fractions is of high importance. The conditions for separation of the different materials are decided already during the planning processes when dismount ability of the different materials is set (Sveriges Byggindustrier, 2009). The environmental benefits of using mounting methods which are easily dismountable are considerable. Resource and energy is saved and the amount of land used for landfill decreases. (Thormark, 2002)

3.3.4.4 Transports

Accordingly to the program for environmental adapted constructions, the transports need during the construction time should be decreased. The efficiency of transports can be measured in the load factor, either by weight or volume, depending on what the limiting factor is (Frenander, 2009). There are different well-established methods for increasing the transport efficiency used in manufacturing, but which could be used in the construction industry as well, for example, Cross-Docking and Lean. (Bengtsson & Gustad, 2008) Reasonable demands to put on load levels in trucks are around 65-75 percent. (Leu & Ottoson, 2002)

3.3.5 Health and indoor climate

The quality of the indoor environment is important for human health and well-being. Humans spend a lot of time indoors, around 70-90 percent of their life time accordingly to different sources. (Namiesnik, 1992) The indoor environmental quality depend on factors of different character such as temperature and emission levels but also subjective factor such as comfort and safety. The architecture is of major importance both for the aesthetical experience, but the design also sets conditions for the physical properties of the building. Factors such as light, electromagnetically radiation, thermal conditions, emissions of particles, radon and ground level ozone are crucial for the indoor environment. (Kellner & Stålbom, 2001) In this chapter the theoretical background for the health and indoor issues considered in the Green Construction Program is discussed; electromagnetic radiation and air quality due to emissions and ventilation. Only factors influenced by the design and construction of the building are considered.

3.3.5.1 Electromagnetic radiation

Electromagnetic fields are generated by electronic devices within the building and by outside sources such as electrical lines, base stations for cell phones, radar and television transmitters. The electromagnetic field intensity is measure in µT (micro Tesla). The field intensity from electrical devices and installations varies a lot. For example, a TV causes a 0,1- 0,2 µT intensity on one decimeter distance while the corresponding number for a vacuum cleaner are 15-35 µT. (Bokalders & Block, Installationer, 2009) For exposure at low levels, i.e. numbers below the recommended value from The National Board of Housing, Planning and Development, 0,2 µT no scientific results concerning negative impacts on human health have been presented (Samuelsson, 1998). Nevertheless, there are two areas where the long term effects are not fully elucidated; exposure of electromagnetic fields from electrical lines and from radio waves from mobile phones. For those two areas, the advice from the Swedish Radiation Safety Authority is that the precautionary principle[28] should be applied. (Strålsäkerhetsmyndigheten, 2010)

The environmental objective *A Safe Radiation Environment* requires mapping and research about the electromagnetic fields. The Environmental Objectives Council judges the target as fulfilled thanks to ongoing research within the field. As an example, the research is following the development of the increasing use of wireless devices. The total exposure of electromagnetically fields has not increased during the latest years. (Naturvårdsverket, 2010d)

There are various measures in order to decrease the exposure of electromagnetic fields. Electrical lines can be buried, this is however costly. The location of the electrical distribution board in residential buildings is important for decreasing the electromagnetic fields. The electrical distribution boards should not be placed in proximity to where humans reside and should always be encapsulated with sheet metal and grounded. When wiring the house the shortest distances possible should be chosen and a TN-S[29] system should be used. (Samuelsson, 1998) Screened cabling should be used, instead of having the wires in plastic pipes; pipes with sheltering film should be used.

---

[28] "If measures generally reducing exposure can be taken at reasonable expense and with reasonable consequences in all other respects, an effort should be made to reduce fields radically deviating from what could be deemed normal in the environment concerned. Where new electrical installations and buildings are concerned, efforts should be made already at the planning stage to design and position them in such a way that exposure is limited." (Arbetsmiljöverket, 2003)

[29] Swedish: femledare system.

3.3.5.2 Air quality

As mentioned in the introduction to this chapter, the indoor air quality is of major importance for the overall quality of the indoor environment. Factors influencing the indoor air quality are the rate of air turnover, levels of carbon dioxide, NO_X, VOC, microorganisms such as viruses and bacteria, radon, particles and allergens, mould, dust, fiber and tobacco-smoke. (Bokalders & Block, Installationer, 2009) There are reference values and guidelines for the majority of the factors which are listed above.

The air turnover affects the air quality, in particular the perceived air quality – whether the air "feels fresh" or nor. For achieving the required comfort the air turnover rate should be at least 0,53 turnovers per hour (in a room a roof height of 2,40 m) (Peterson, 2004). Ventilation controls the air turnover regulating the moisture level, reducing overheating, emissions and odor. (Bokalders & Block, Installationer, 2009)

The level of carbon dioxide is commonly used as an indicator for the quality of the indoor air. The indoor carbon dioxide level fluctuates between 500 ppm and 3000 ppm, the higher number is typical for densely populated, poorly ventilated rooms. The level of carbon dioxide in outdoor air is between 350-400 ppm. A carbon dioxide level of 3000 ppm is not harmful for human health, the hygienic value for carbon dioxide in indoor air is 5000 ppm and for short-term exposure the limit is 10 000 ppm. At this high level discomfort and increased exhaling rate occurs. Around 40 000 ppm dizziness, head ache and palpitation arise. Mortal danger occurs around 50 000 ppm. Such high levels do not occur in ordinary buildings, only in closed areas such as shelters, submarines and strong rooms. (Bokalders & Block, Installationer, 2009) (Kellner & Stålbom, 2001)

In addition, the indoor air quality is affected by a range of chemical substances. Those substances and compounds can occur in gaseous form, as particles and as aerosols (small particles suspend in a gas – common biological aerosols are pollen, spores and bacteria). The chemical substances, come either from the supply of fresh air (outdoor air), are emitted from the interior, arise from activities such as cooking or cleaning or are emitted by the occupants, trough exhaust air, sweat or skin residues. Chemical reactions on surfaces and in the indoor air can also create chemical compounds. High relative moisture content increases the emission rate of VOC since the moisture improves the living conditions for microorganisms creating VOC (MVOC). (Socialstyrelsen, 2006) For a summary of reference- and guidelines see table 3.5 on page 53. Noteworthy, due to the unclear relations between VOC and health, the precautionary principle should be applied in this area as well.

An example of a chemical compound that can be emitted from building materials is formaldehyde. The substance can for example be found in water based color and particle boards. The compound is a suspected carcinogen at high levels of exposure. (Naturvårdsverket, 2005) There are restrictions on the emission rate of formaldehyde from building materials and target levels for the content in air of formaldehyde. (Kemi, 2007) In the building product judgment are there limits for total VOC (TVOC) emissions from different materials. For example, flooring material should not exceed 40 µg TVOC/ m^2, h. (Byggvarubedömningen, 2009)

The occurrence of allergies and hypersensitivity has increased during the last centuries. The indoor air may contain allergens that cause allergic reactions for humans. Common sources of allergens are pets, mould, airborne pollen and spores. Mites however are the most common allergen in the indoor air. (Brunetto B et al, 2009)

Particles are formed during incomplete combustion of fossil and renewable fuels and consist of sot residues, at the most as large as a tenth of millimeter. In a health perspective, it is mainly the smallest particles, PM_{10} and $PM_{2,5}$ which are of the largest concern since they can reach deep down in the lungs. According the Institute for environmental medicine, the health impact of particles is not fully elucidated but is depending on the amount, size and surface of the particles. The research shows that particles can be a contributing cause of some cases of respiratory passages problems, cancer and cardiovascular diseases. The level of particles in the urban air is steadily increasing; levels today are 10-40 $\mu g/m^3$ compared to 3-12 $\mu g/m^3$ outside urban areas. (Karolinska Institutet, 2009).

Radon is a problem in many residential buildings in Sweden. The radon comes from uranium naturally occurring in the bedrock. Radon is the only gas in the uranium decay chain. Uranium decays and forms radium, which in turn decays and forms radon. The radon reaches the indoor air by leakage through the building's foundation or through the drinking water, in case the building has its own well. Radon has also been present in building material such as autoclaved aerated concrete,[30] which was commonly used from 1945 until 1975. The ways of getting radon into a building is shown in figure 3.14.

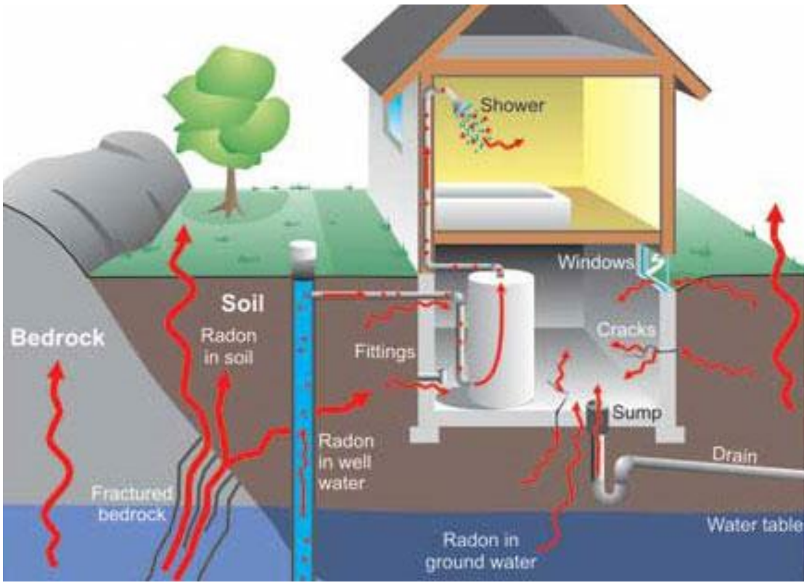


Figure 3.14 The radons way in to the building. (Geoscape Canada, 2008)

Radon is radioactive and decays emitting α-particles, which may cause effects in human tissue. The national Board of housing, Building and Planning allow levels of radon in the indoor air up to 200 Bq/m^3 with an average value within residential buildings of 108 Bq/m^3. The Institute of radiation protection estimates that more than a half million residents are living in houses where the exposure limits are exceeded, facing increased risk for lung cancer. (Bokalders & Block, Tekniskt utförande , 2010)

[30] Swedish: Blåbetong

Table 3.5 Air quality factors and recommended values for chemical substances in the indoor air.

Factor	Target level	Value	Reference
Air turnover	0,53 turnover/hour	Daily average	Petersson, 2004 p. 108
CO_2	1000 ppm	Recommended value	Samuelsson, 1998 p. 14 (The National Board of Housing, Building and Planning)
Formaldehyde	< 50 µg/m^3 < 50 µg/m^3	Recommended value Recommended	Samuelsson, 1998 p. 14 (The National Board of Housing, Building and Planning) BVB:s criteria
VOC: Toluene **Styrene**	0,26 mg/m^3 0,26 mg/m^3	Weekly average Weekly average	WHO AQ Guidelines for Europe[31]
NO_X	200 µg/m^3 40 µg/m^3	Hourly average Yearly average	WHO AQ Guidelines for Europe
O_3	120 µg/m^3	Average value 8 hours	WHO AQ Guidelines for Europe
Particles **PM10** **PM2,5**	< 30 µg/m^3 *30 µg/m^3* *10 µg/m^3*	Recommended value *Daily average* *Yearly average*	Samuelsson, 1998 p. 14 (The National Board of Housing, Building and Planning) *IMM:s suggestions for limits*
Radon	200 Bq/m^3 100 Bq/m^3	Limit Level where measure should be taken when exceeded Yearly average	The National Board of Housing, Building and Planning WHO AQ Guidelines for Europe

Formaldehyde: WHOG states 100 mikrogram /m3. The lowest values found in the litterateur have been chosen to be presented.

The indoor air quality is discussed within the environmental objective *A Good Built Environment* and the interim target A *Good Indoor Environment*. The interim target states that buildings should not affect human health negatively and that this should be reached by 2020. The interim target focuses on well functioning ventilation system and lowering the levels of radon in preschool, schools and dwellings. The present evaluation judged that the target will not be achieved on time without large measures. The environmental objective *Clean Air* contains interim targets and indicators concerning the indoor air quality, since the quality of the outdoor air directly affect the quality and composition of the indoor air. (Naturvårdsverket, 2009o)

To conclude, all the factors described above have impact on the indoor quality. For improving the indoor air quality one measure is to evaluate the placement of the fresh air intake, which should be placed where the air is as clean as possible and preferably where the air is not affected by the wind. Smoking should not be allowed indoors since it is a major source of

[31] World Health Organization (WHO) Air Quality Guidelines for Europe, 2nd edition, Copenhagen 2000

pollution, not only locally but also spreading to other parts of the building through the ventilation system. The level of VOC can be reduced by choosing low emitting materials and paints. (Bokalders & Block, Installationer, 2009) Window airing can be an effective way to increase the indoor air quality since the turnover can be up to 300m^3/hour with open windows. Increasing air turnover through opening windows may however cause large energy losses and an increased level of airborne pollution such as particles and pollen, which usually gets trapped in the ventilation filters. (Kellner & Stålbom, 2001)

3.3.6 Moisture protection

The goal of moisture protection is to avoid harmful moisture during the building's life time, both for the functioning of the building and for the health perspective. The boundaries for this assessment go from choices made during the planning process to efforts made during the usage phase. The area in the Program is mainly focused on routines and self monitoring. The risks for harmful moisture during the production phases are due to precipitation falling on the construction project and building materials, and moisture in the grounds and materials. During the use phase there is risk for harmful moisture due to leakages from installations, an unclose building (exposure from weather and wind) and moisture in the indoor air (from, for example, laundry, cleaning, flowers or humans). Moisture in buildings is a major problem, as much as the half building stock in Sweden can be affected (World Health Organization, 2009).

The conditions for good moisture protection are established already during the planning phase, but the continuous work is required during the whole life span of a building. Elmeroth define moisture dimensioning as:

"Every measure in the building- and management phase that contributes to guarantee that a building not gets damages or health inconvenience that directly or indirectly is caused by moisture." (Kellner & Stålbom, 2001) (Author's translation)

Moisture dimensioning is important since high levels of moisture in buildings can affect human health through micro-organisms and cause larger emissions from materials. The negative impacts on human health from living in a damp building are mainly problems with the respiratory passages which can be struck by infection and asthmatically problems. Living in a damp building can also cause general health issues like headache and tiredness (Sundell, 2004). The micro-organisms that can cause the problems can either be mould, bacteria or mite. There can be around hundreds of different species growing in indoor air when there is a sufficient amount of moisture present. However, the direct cause-effect of damp buildings concerning the presences of micro-organism and human health is still unclear. (World Health Organization, 2009)

In addition, harmful moisture can cause large economical losses when buildings are damaged, for example from rot. Additionally buildings with unsatisfying moisture protection will in the long run have a larger environmental impact due to decreased durability (for more about this issue see chapter 3.3.1) (Sikander, 2000) An example of where bad moisture management caused both health and durability impacts is the glue used to fasten plastic carpets to concrete floors with a high relative moisture content that turned out to be chemically degraded by the moisture and gave rise to VOC emissions.

Building parts exposed to moisture must be dimensioned for the additional load, for example wet- and laundry rooms. Critical building parts such as water installations and moisture sensible materials should be placed visibly and be easy to maintain. In addition to measures taken during the planning phase the work during the production phase is very important. This concerns both the quality of the workmanship for moisture protection solutions and the treatment of construction materials on the construction site. (Boverket, 2010) Of high importance is that the building materials is given sufficient time to dry out and to reach equilibrium with the relative moisture level during the buildings use phase. Noteworthy is that it would take years to let all moisture dry out of newly built houses, instead the goal is to reach a non-harmful moisture level. (Peterson, 2004)

The building parts especially considered in the Green Construction Program are joints on pipes and connections on water pipes. The heating and sanitation industry in Sweden has compiled guidance for such matters.[32]

In addition to the issues discussed above, a well functioning ventilation system is crucial for achieving sufficient moisture control. For more about the ventilation systems, see chapter 3.3.5.

3.3.6.1 Environmental objectives

Although there are no environmental objectives or interim targets directly concerning moisture protection, there is a interim target concerning a good indoor environment in *A Good Built Environment.* A good moisture protection is a large part of that ambition; however the target only concerns ventilation and level of radon in the indoor air. According to Environmental Objectives Council in 2008, the knowledge base is still too low for setting a target for moisture, rot and emissions from building materials (Naturvårdsverket, 2008c) and at the writing moment (April, 2010) there are still no target values available.

3.3.6.2 Manuals and quality assurance

There are different schemes and methods available for the moisture protection of buildings. A common label for moisture protection of buildings in Sweden is the P-labeling[33] which has requirements for routines necessary to ensure a high quality moisture protection (SP Sveriges Tekniska Forskningsinstitut, a). The scheme ByggaF, is an extensive method containing manuals and guidelines for the different actors to ensure satisfying moisture protection. (Mjörnell & Sikander, 2005) A common ways is to establish checklists that contain information about expected moisture sources and loads for each of the building parts. The checklists are mainly used during the planning phase. (Johansson & Stjernedal, 2005) The rules from The National Board of Housing, Building and Planning states that that neither humans nor the construction should be affected by harmful moisture. (Boverket, 2008b)

For good moisture management during the whole project the building proprietor should consult a moisture specialist, who can set demands and perform a follow up through meetings and moisture rounds on the construction site together with the entrepreneur. (Mjörnell & Wihlborg, 2007) Already before the procurement, the building proprietor should have set the moisture requirements so the entrepreneur knows the required performance level. Those requirements could for example be in terms of relative moisture content in the different materials or the requested documentation. An example of such a requirements list featuring different risk levels can be found in Sikander 2005. The selection of risk level is made by the building proprietor due to how large risks and deviations it is willing to accept. For example: is it acceptable that the materials have the required moisture level at the time of mounting or should the highest acceptable moisture content never have been exceeded. For education of the construction workers, a reasonable level is at least 2 hours and a more ambitious level is 4 hours. (Sikander, 2005)

For moisture protection documentation, the established moisture protection description can be used and properly documentet together with moisture measurements, deviation report and maintenance instructions. (Stockholms stads stadsbyggnadskontor, 2007)

---

[32]For more information see: http://www.fuktsakerhet.se/sv/delar/vatrum/regler/Sidor/default.aspx and http://www.sakervatten.se/?use=publisher&id=1391

[33] Swedish:P-märkning

When measurements are made during the construction phase it is important that the selected spots for measurement are unfavorable. This means measurement on parts exposed to precipitation or where the drying out process has been limited. (Sikander, 2005) Since some embedded parts cannot be measured in the final review, the controls during the production phase are important (Stockholms stads stadsbyggnadskontor, 2007). There are standard guidelines available for measurement procedures and the number of tests that should be carried out on the ground plate and the beams. (Rapp, 2002)

The moisture conditions during the use phase can change. Routines and inspections are necessary to monitor moisture conditions in the building during the use phase. Changes in moisture conditions can be due to altered behavior from the user or changes in the building's climate systems. (Peterson, 2004) Moreover, certain parts of the building like the roof and the rain gutters need inspection. (Elmarsson & Nevander, 1994) Periodical inspection routines should be performed each three to five years (Sikander, 2005). Moisture protection instructions for operation and management should be available and contain information about the correct measures for leakage, damage and cleaning methods (Norling Mjörnell, 2007).

3.3.6.3Weather protected construction

As previously mentioned, it is always important to protect the ongoing building projects and stored building materials from moisture and dirt. This could be achieved by different methods, reaching from simply covering the scaffold to perform the whole production under a tent (SP Sveriges Tekniska Forskningsinstitut, b). In between those extremes there are other methods which less or more cover the ongoing construction work. There are static or dynamic roof protections that can consist of either clothing or the finished roof constructed as early on as possible; there are roof weather protections that are lifted away in the beginning of each working day. Another solution is to have a climbing weather protection which is lifted up as the construction proceeds and number of floors is increasing. (Norling Mjörnell, 2007)

Except for the protection of the building from moisture and dirt, the weather protected construction has other advantages such as better working conditions (except for the risk heat during the summer months) and managing the schedule (Sandqvist, 2008).

The storage of materials must be done thoughtfully as well. For example, just to wrap a tarpaulin around the material is not good enough and can even be harmful during hot summer days when moisture raises from the ground and creates a humid environment inside the tarpaulin. Sikander identifies three performance levels for storage of material and protection of the construction processes: no weather protection partly protected and completely weather protected. (Sikander, 2005)

Attention should be given to the fact that moisture is equally harmful no matter when it is injected. When moisture has been embedded it can take 5 -10 years until the damage is visible. (Boverket, 2008c) Even more, material that is dry when it is embedded, but has earlier on been damp, can if it is exposed to water again have the preconditions for micro-biological growth. (Stockholms stads stadsbyggnadskontor, 2007)

3.3.7 Noise protection

When noise protection is discussed in the Green Construction Program the focus is put on the elements within the building that protect the apartments from noise with its source from within the building such as human activity, installations and bathrooms. Other noisy activities in the building such as restaurants or day care for children may require additional measures. Traffic, not being a part of the building, is not included in the Green Construction Program. The national environmental objectives only consider noise from traffic; hence, no objective can be related to the Green Construction Program. Noise from traffic, is briefly discussed in chapter 3.3.1

The aim of noise protection is to create a good sound environment for the dwellers and to reduce inconvenient noise. This is important because noise affects human well-being and health. Living in noisy environments can cause stress symptoms like high blood pressure, sleeping distributions and concentration disturbance. (Socialstyrelsen, 2009)

In the Swedish standards for sound classes consists of four grades – sound class A,B,C, and D where A is the best performance and D is the worst. Sound class C more or less equals the legal requirements (more than 80 percent of the occupants are satisfied), however sound class D can be useful for renovation of old buildings where a higher sound class might not be possible to reach. Sound class B, the requirement selected for the Green Construction Program, ensures that the majority of the users are satisfied with the sound environment. In general, the difference between each class is 4 dB.

To ensure that a good sound environment is fulfilled both airborne sound and structure born noise (impacts sound, e.g. sound from footfalls) needs to be considered. (Kellner & Stålbom, 2001). In the standards for sound and noise (SS 2526) six different technical areas are considered – airborne sound, impact noise, sound insulation from traffic and other outer noise sources, sound pressure level on front and patio, installations and echo time within the rooms. (Boverket, 2008d) However, the Green Construction Program discusses only three of there – airborne sound, impact noise and installations.

3.3.7.1. Building acoustics

To achieve sound class B, the construction elements separating apartments must fulfill a number of requirements. The required reduction number must be fulfilled for R_w (the ability to reduce airborne sound between two spaces) and for L_w (the ability to reduce structural borne sound) which are weighted values for 21 frequencies between 100 – 3500 Hz. The reduction numbers measured in the building is called R'_w and L'_w where indirect sound transmission (flank transmission) is included. The actual reduction numbers in a building are often lower than the laboratory values.

The most common dB weighting curve is the A-weighted curve, designed after how the human ear perceives sound. In order to give a greater weight to low frequency noise from installations a C-weighted curve is often used as well giving equal weight to all frequencies (Åkerlöf, 2007). For reduction values an adjustment term is added, $C_{50\text{-}3500}$. (Gyproc, 2008)

Other activates in the building such as laundry rooms, garage, shops and restaurants may be a reason for extra insulation for reducing air born sounds.

Table 3.6 Sound reduction for different reduction numbers.

R'$_w$	Mumble	Normal speech. Office machines in a quiet environment	Normal speech Office machine s	Loud speech	Scream	Loud speaker sound, reasona-ble level	Disco thumbin g
35							
40							
44							
48							
52							
60							

White – no noise
Light grey – there can be noise, but does not distrurb during normal conditions
Dark grey – noise (Boverket, 2008d)

For sound class B the R'$_w$ + $C_{50\text{-}3500}$ value for apartment separating construction must be ≥ 56 dB. (SÖDRA) As seen in the table, the chosen value effectively reduces everything except for loud noise.

Installations (devices that maintain thermal climate, hygiene, health and environment such as white good, fans, pump etc) generates airborne sound and structure born sound. In dwellings, kitchen appliances gives rise to airborne sound and must be selected in order to comply to the sound class of the building. Worth consideration is that the demand must be fulfilled when all of them are used on the same time. Most of the installations also generate structure born noise and the noise from installation must always be carefully considered. (Åkerlöf, 2007)

In the Swedish Standard for sound classes for installations the noise is divided in short-term and long-term duration. For short-term noise the guiding value is the maximum value, for long term noise the equivalent value is guiding. (Åkerlöf, 2007)

3.3.7.2 Measurement of sound in the completed building

There are standards on how to perform sound measurements and how verify noise levels against noise requirements. This is usually done either by measurement according to the standard protocol in a limited number of apartments or simplified measurements in a larger number of apartments. At least five percent of the apartments of a building or at least 3 apartments must be measured and the average value must fulfill the required demands. (Svensk Byggtjänst)

3.3.7.3 Building/Living dialogue

For achieving class silver in the Building/Living environmental classification, there are two options: either to fulfill sound class C and that more than 50 percent of the parameters in SS 25267 or SS 25268 are graded as sound class B or an alternative assessment of how noise is perceived in different circumstances. Traffic noise must only be heard when it is otherwise quiet in the room. Sound from installation should only be heard when listened for and when listened for, very faintly. When the ventilation is turned off in the evening it should be barely noticeable. From a normal conversation in an adjacent room faint sounds can be heard, but the content of the conversation should not be understandable. Finally, only faint sounds from furniture being moved and people walking with hard heels are allowed. (Johansson & Jansa, justeringar av Bygga-bo-dialogens tekniska råd, 2009)

There is a large difference between the perceived noise environment from sound class C to sound class B. However the level of satisfaction is primarily dependant on the expected noise level due to cost and other circumstances. (Boverket, 2008d)

3.3.8 Quality insurance, submitting information and up-following

The Green Construction Program contains information regarding the information that should be passed over to the management of the house. To assure that the energy requirements are achieved, information about energy efficient usage of the building should be available together with instructions for green maintenance. (Fastighetskontoret, 2009) In addition, the program has developed a routine for following up. The building proprietor should report to the City of Gothenburg how the program is incorporated in the planning of the project, and during the production documentation and protocols should be presented. The building management should present an energy declaration and certification of ventilation controls. (Fastighetskontoret, 2009) According to Memborn the proprietor's past performance in fulfilling the Green Construction Program requirements should have an impact on the handing out of new land directions.[34][35]

[34] Lukas Memborn, interview 2010-02-23

[35] Swedish:Markanvisning

4 Analysis

The requirements are analyzed according to the strategy described in chapter 2, in order to establish a performance level required for green construction.

As seen in chapter 2, two conditions where set for the analysis; i) the performance level should represent the measures needed to be green ii) the performance level should be possible to reach with present conditions.

And the chosen analytical strategy was:

- Based on the national environmental objectives and other relevant scientific work – what is this required level of environmental performance?
- What is the limiting factor for achieving a high environmental performance? Is the performance dependent on technology or behavior?
- Which actors have influence on the performance and fulfillment of the requirement?

When analyzing if the requirement is depending on behavior or technology, the requirement is perceived as depending on behavior when the technology (including know-how) has left the experiment stadium and is available on the market accordingly to the *BAT* definition. When setting the criteria for the requirements, proactive behavior has tried to be encouraged. Technology is perceived to be the limiting factor in the cases where there are no developed solutions and products on the market which can be utilized.

In addition to analyzing if the requirement is depending on technology and behavior, the actor which influence the fulfillment on the requirement is analyzed. The influencing actor is closely related to the time perspective and the different phases during a building life cycle. However, in some cases the effects of earlier choices is not possible to evaluate until the building is occupied. It is during the choices made in the planning process where the environmental impact from the building is mainly influenced, but due to the long life span of a building, there are possibilities to influence the environmental impact during the whole life time. Consequently, the behavior of the management and occupants cannot be neglected either. A lot of the requirements are aiming to, already during the production phase to influence the behavior of the occupants and prepare for a green management. Although, in the long run their behavior that influence the environmental performance. Those cases are pointed out in the analysis.

The behavior of the management organization and occupants also sets the improvement possibilities, if it is possible to further improve the environmental performance during the use phase.

During the life cycle of a building it is the planning, production and operation phase that are treated as the most relevant, except where the Green Construction Program says something else. The demolition phase is to a large extent neglected since the building operation phase is long and the lifetime uncertainty since it is depending on the level of maintenance and habits from the occupants.

The general treatment of requirements which are handling routines are treated as the affected actor should have routines for the concerned area and for good performance the routines should have been developed by an specialist (i.e. someone with good knowledge about the concerned issue) and the routines should be updated and up followed on regular basis. This is due to the fact that there are no clarifications of what the content of the routines should be.

For each of the requirements a scale have been developed; for the requirement should be considered as met, the criteria for the *acceptable performance* level has been fulfilled. To achieve *good performance,* a larger effort should have been made; this level should be aimed at. There is no space on the scales for performance below accepted level. For a lot of requirements, there are already within the text of the requirement a set level for what is needed to meet the requirement. Those requirements are treated as *accepted* or *not accepted.*

The following analysis is made after the areas in the Green Construction Program, where each of the requirements below each area is analyzed separately. Firstly, the text of the requirement (translated by the author) is presented followed by the limiting conditions and influencing actor. After that are the basis for evaluation presented with motivation and environmental relevance presented.

4.1 Durability

D1: During the planning process, consider the requirement for durability for all construction parts. Preconditions for service and maintenance should also be considered.

The requirement is mainly depending on the performance of the construction organization. In the long run, the durability performance is also depending on the maintenance and occupant behavior, however this thesis's criteria evaluates the performance of the construction organization.

The criterion for durability measures how well the construction organization pay regard to durability in the selection of building materials and design choices. The scale is designed after how well the factors included in the durability perspective, technical life span, maintenance interval and embodied energy, are considered.

For *acceptable performance* the construction organization should have paid regard to the technical life span. For *good performance,* the technical life span should be balanced against the predicted maintenance interval and the embodied energy, with the aim of optimizing the resource flow, the main goal of the durability area in the program. The longer a building can maintain its required function, the higher embodied energy is acceptable.

The demolition phase is not included within the assessment due to its small impact on the long time perspective and the large uncertainties about future demolition methods. Climate change will also have an impact on the technical life span and maintenance interval of the construction, a factor that cannot be disregarded. The requirement is in line with the general goal of the environmental objectives.

D2: The placement of installations within the building should be accessible for service and maintenance. Installations should be exchangeable if they are estimated to have a shorter life than the building in general.

The requirement is depending on the behavior of the construction organization. The criterion for the requirement is *acceptable performance* or *not acceptable performance.* The environmental relevance of the requirement is the same as for the requirement above **(D1)**.

D3: Controls should be performed in order to verify that conditions are suitable for service, maintenance and exchange of constructions/installation.

The requirement is depending on the behavior of the construction organization and determined as either *acceptable performance* or *not acceptable performance*. The requirement is striving to achieve the same environmental benefits as the requirements above (**D1 & D2**) and to assure that the requirements above has been fulfilled.

4.2 Environmental impact

The overall goal of the Program area *Environmental impact* is to reduce the negative environmental impact from a building from a life span perspective. One of the main guidelines connected to this area is the environmental objective *A non-toxic environment*. The developed criteria for the requirements relating to a *Non-toxic environment* are all aiming to fulfill the environmental objective as well. First the requirements concerning building materials are discussed, after that grounds and green areas and last the requirements concerning the construction site.

E1: Routines for material selection should be designed so that the completed building constitutes the least possible environmental load.

The concept of environmental load is given the same definition as in the Green Construction Program, as emissions affecting humans and the environment negatively.

The requirement is depending on the behavior of the construction organization. The criteria measures if a routine is present established by an expert and properly followed up and updated. For *acceptable performance* routines should be present and for *good performance* the routines should be established by an expert and updated and followed up. Since building materials represents a large share of the hazardous materials used in Sweden, it is necessary that routines exist for avoiding an arbitrary selection of building material and that those routines are updated as new knowledge becomes available.

E2: For material selection "Building product declarations/Environmental product declaration" data should be used as a first choice and "Safety Data sheets/Part Information sheets" be used as a second alternative.

The requirement is depending on the behavior of the construction organization, since they actively chooses which materials and products should be used. The criterion for *acceptable performance* is that at least 75 percent of the articles have Building product declarations/Environmental product declarations and that all articles should have Safety Data sheets/Part Information sheets. For *good performance* declarations are required for 100 percent of the used material and products. Declarations contain more information concerning the impact on the environment and the chemical content; hence, more declared products gives better information and facilitates for a better mapping of the embedded material in the building.

E3: All materials, products and chemicals needed in the building process should be of the best possible choice concerning environmental and health aspects.

The requirements are depending on the behavior of the construction organization and to a lesser extent on the technology in the cases where no green alternatives are available.

E3a: The BASTA-system is used for choice of products.

The requirement is depending on the behavior of the construction organization. The BASTA-system is used for choice of products. To criterion is either *acceptable performance* or *good performance.* For *acceptable performance,* 90 percent of the materials used should be found in BASTA and for *good performance* 100 percent of the material should be found in BASTA.

E3b: Materials are assessed by Building Product Evaluation.

The requirement is depending on the behavior of the construction organization. The criterion is either *acceptable performance* or *good performance.* For *acceptable performance*, 100 percent of the assessed materials are accepted in the Building Product Evaluation and for *good performance* 100 percent of the materials are recommended in the building product declaration.

E3c: Materials containing phase-out substances listed in PRIO data base from the Swedish Chemicals Agency should not be present in materials and chemicals used.

The requirement is depending on the behavior of the construction organization. The criterion is either *acceptable performance* or *not acceptable performance*. For acceptable performance, no phase-out substance should be used either during the production or in the finished building. This in line with the general Swedish requirement, that the use of such substances should be fully eliminated due to the severe effects on humans and the environment. In addition, it is illegal to use such substances in newly built buildings.

E3d: Risk reduction substances should be identified.

The requirement is depending on the behavior of the construction organization. The criterion is either *acceptable performance* or *not acceptable performance*. For acceptable performance of the requirement risk reduction substances should have been identified and documentation of their placement within the building should be available. Risk reduction substances cause severe effects on humans and the environment but cannot fully be replaced by less harmful substances. When risk reduction substances are used, the usage needs to be under controlled circumstances, so that measures can be taken later when more harmless alternatives are available. The identification is also necessary for a safe handling of those substances on the construction site.

E3e: Building materials is chosen so that storm- and ground water is not affected negatively due to poor management of building and waste materials

The criterion is either *acceptable performance* or *not acceptable performance*. Since there is always a risk that materials are handled incorrect, intentionally or not, substances that easily spread in water should not be used. Those substances can in the extension reach water courses and ground water, which could damage aquatic ecosystem and in the long run be harmful for human health. To note is that this requirement is closely connected to the requirements **E3 a)-d),** where the fulfillment of those requirements will lead to that this criterion is accepted as well.

E4: Paint, lacquer and oil based on organic solvents should not be used where equivalent alternatives are available or where those products can be avoided by using alternative designs.

The requirement is depending on the construction organization since they are responsible for the purchasing of paints, but also available technology since there are no alternatives for all kinds of paint, lacquer and oil today, for example color for rust protection. The criterion is either *acceptable performance* or *not acceptable performance*. The criterion for the requirement is based on the content of VOC in paint, lacquer and oil (g/l). For *acceptable performance,* the levels of VOC stated in the eco-label the Nordic Swan should not be exceed (see appendix B).

E5: Copper elements should not be used in the tap water system. Copper is not allowed to be used as roof and front material where it can be transferred through storm and waste water.

The requirement is depending on the behavior of the construction organization. The criterion is either *acceptable performance* or *not acceptable performance*. For *accepted performance* no copper should be used in the tap water system and where there is a possibility for the emission of copper to storm and waste water.

Copper is toxic for water living organisms and to decrease the emission of copper to aquatic ecosystem new pollution sources should not be added. Hence; other materials than copper must be selected for building parts that are in contact with water.

E6: Timber products should be FSC labeled. PEFC labeled tree is only allowed if it is locally grown in the region of Västra Götaland. As a first choice Nordic FSC/PEFC labeled tree should be used and as a second choice, FSC labeled tree grown outside the Nordic countries.

The requirement is depending on the behavior of the construction organization. The requriement are divided in to two parts. The criteria is either *acceptable performance* or *good performance*. Concerning the first part for *acceptable performance* at least 75 percent of the used timber products should be label by FSC/PEFC. For *good performance*, 100 percent of the used products should be certified. Concerning the second part, for *acceptable performance* all forest should be certified, however, tree from outside Scandinavia are accepted as well. For *good performance*, 100 percent of the forest product should be from Scandinavia. The use of certifies products decrease the total environmental impact of the building. A number of environmental aspects are influenced positively, both on a local and global scale.

E7: Pressure – treated wood except linseed oil treated is not allowed.

The requirement is depending on the behavior of the construction organization. The criterion is either *acceptable performance* or *not acceptable performance*. The criterion for acceptable performance is that no pressure-creosoted wood should be used at all. Impregnating agents are, except for linseed oil toxic, toxic and the fundamental principle for decreasing the emission of toxic substances is to not create new pollution sources and therefore no pressure-treated wood should be used.

E8: Choose fluorescent lamps with the lowest mercury content available on the market.

The requirement is depending on the construction organization and available technology. The criterion is either *acceptable performance* or *not acceptable performance*. For *acceptable performance* no fluorescent lamp with higher mercury content than 5 mg should be used. For *good performance*, low energy lighting without mercury should be chosen. The importance of closing loops should not be forgotten in order to prevent emissions of mercury in to the nature.

GROUNDS AND GREEN AREAS

E9: Storm water should be utilized as a local resource where feasible and appropriate. If the technical preconditions are missing, the storm water should be detained within the grounds and drained off together with drainage water to a public sewage plant or directly to a water course. Storm water should be treated when needed. Pollutions should not diffuse uncontrolled. Design solutions as close as possible to the source, so that the pollution does not spread but instead is handled as locally as possible.

The requirement is depending on the behavior construction organization but also the conditions on site. The criterion is either *acceptable performance* or *good performance*. For *accepted performance* the water is utilized as one of the resources mentioned below. For *good performance* the water is utilized as all of the resources mentioned below.

The resource of water is defined either as a *biological* resource which enhances biodiversity, a *hydrological* resource which substitutes the use of tap water or an a*esthetical* resource which enhances the aesthetical value of the ground. Since the possibility for low impact development differs due to local conditions on the site the requirement is regarded seen as fulfilled if the water is *detained* when it is not possible to utilize it as a resource. The resources are closely interconnected and the application of one of the uses is likely to have an effect on the other resource uses as well.

Taking proper care of the storm water has multiple environmental benefits. The overall benefit is that the disturbance on the hydrological cycle is decreased and that the groundwater levels are preserved. Furthermore, low impact development decreases the load on the sewage treatment plant during high flows. Low impact development decreases the risk that pollution from impervious surface is diffused. In a larger perspective the use of tap water will decrease if substituted by storm water, for example for irrigation purposes.

In the end the long term performance of low impact development system is depending on the management, crucial for the performance during the use phase. In the neighborhood of Kvillebäcken there are a number of managers which will require cooperation and joint planning.

Worth mentioning is that while the knowledge about local water treatment seems to be expanding by presenting "good examples", the evaluation of these good examples is often poor.

E10: Use permeable material on the ground to facilitate infiltration. Consider accessibility for disabled (compare to the City's policy for accessibility).

The requirement is depending on the behavior of the construction organization, however also to some extent on the conditions on the site. The criterion is either *acceptable performance* or *good performance.* The permeability is measured by the biotope area factor which, except functioning as a measure on how green the yard is also functions as an indicator on the infiltration capability, though dependent on the soil. For *acceptable performance* the biotope area factors should at least be 0,5 and for *good performance* 0,7.

E11a: Vegetation on the yard should promote biological diversity, not cause allergies and be non toxic.

The requirements are depending on the behavior of the construction organization which is responsible for the planning of solutions for enhancing biodiversity on the yard. The criterion is either *acceptable performance* or *not acceptable performance*. For *acceptable performance*, all layers of vegetation should be present on the yard. The biodiversity in urban environments is limited; hence it is important to create good preconditions for species on all levels in the food web. A large biodiversity can be seen an indicator on that the eco-system is well-functioning and is of importance for the resilience of the ecosystem.

E11b: Save particularly valuable vegetation.

The requirement is depending on the building organization. The criterion is either *acceptable performance* or *good performance.* For *acceptable performance* particularly valuable vegetation should be identified and for *good performance* particularly valuable vegetation should be saved as well. The definition of particularly valuable vegetation is either exposed species or old trees which cannot be replaced by other species or new trees while at the same time keeping the same ecological value

E11c: Use green roofs to the increase the green mass in the built area and as a contribution for treatment of the storm water, contributing to a smaller and more even flow of storm water.

The requirement is depending on the building organization. The criterion is either *acceptable performance* or *good performance.* The conditions for green roofs differ between different sites and are scale goes from 0 percent to 100 percent of green roof per total roof area. 0 percent is *acceptable performance* and 100 percent are *good performance*. To note, is that this criterion needs further investigation.

The vegetation is likely to improve with time and the long term responsibility for the prerequisites of biodiversity is the management's since the maintenance of the ground will be deceive for how good the performance will be.

CHOICE OF PRODUCTS

E12: Routines should be present so that the purchases of materials and products made directly by the construction sites which are ordered prescribed by product name in the building document are verified against the environmental and health demands of the project.

The requirement is depending on the behavior of the construction organization. The criterion measures if a routine is present, or established by an expert and followed up and updated. For *acceptable performance* routines should be present and for *good performance* the routines should be established by an expert, updated and followed up. The requirement decreases the total environmental impact from the building since the products use affects the total impact.

CONSTRUCTION SITE

E13: Plan the production site so that the area of the construction is minimized. Protect valuable vegetation.

The requirement is depending on the behavior of the construction organization. The criterion is depending on whether virgin or previously developed grounds are being used. If previously developed grounds are used, the used area is less important and the construction site will more likely be limited by nearby developed areas. The criteria for the requirement are measured in the establishment area per m^2 of finished ground floor area. The criterion for the requirement concerning valuable vegetation is either *acceptable performance* or *not acceptable performance*. The protection of valuable vegetation is treated in **E11b).**

E14: Special environmental demands should be applied to the vehicles used on the construction site. As the first choice of fuel electricity should be used and as a second choice alkylate gas/synthetic diesel.

The requirement is depending on the behavior of the construction organization and available technology. The vehicles used on the construction site should have permit to drive in the Gothenburg environmental zone, i.e. be in Euro class IV and V. The criterion is measured in the fraction of vehicle working hours where electricity has been used and numbers of working hours where alkylate gas has been used. For *acceptable performance* level, 100 percent of the vehicle hours should be fueled by alkylate gas/synthetic diesel. For *good performance* the required level has not yet been established, however the evaluation scale goes to 100 percent.

When electricity is used, the total environmental impact is of course depending on how the electricity is generated.

E15a: Routines should be present for:

- **Storage of chemicals and fuels during the construction time to prevent spillage and leakage to the ground, water and sewage.**
- **Safe handling, storage and treatment of hazardous and environmental dangerous waste.**
- **Information to and communication with the neighbors.**
- **Limitation of dust, noise and vibration during the construction time.**

The requirement is depending on the behavior of the construction organization. The criterion measures if a routine is present or established by an expert and followed up and updated. For *acceptable performance* routines should be present and for *good performance* the routines should be established by an expert, updated and followed up.

E15b: Personal/sub contractor has documented environmental education.

The requirement is depending on the behavior of the building organization. The criterion is either *acceptable performance* or *good performance*. For *acceptable performance* the education hours per worker and year is four hours and for *good performance* 16 hours per year and worker.

4.3 Energy efficiency

The main goal for the criteria is to establish which performance level is necessary for achieving a reduced climate impact from the energy use of a building. The set criteria will reflect the national environmental objectives but also what is technical feasible and economically reasonable. The environmental performance of the technical systems should not be compromised due to the behavior of the occupants and management, the complexity of the systems should not be too great. The energy supply for residential heating is already today based on renewable energy to a large extent, resulting in a limited climate impact. However, since the energy production has a broader environmental impact than only increased global warming, a main goal is to decrease the total impact as well; as low energy consumption as possible should be strived for. It is important to decrease the electricity consumption in the building since the marginal electricity used is based on fossil fuels increasing climate change.

EE1a: Calculate the buildings expected energy use. The calculated values should be realistic and verifiable.

The requirement depending on the construction organization. The criterion for the requirement is either *acceptable performance* or *not acceptable performance*. For *acceptable performance* the expected energy use should be calculated.

For a multi residential building:

EE1b: The total amount of bought energy (excluding house hold electricity) should not exceed 60 kWh/m^2 per year (floor area A_{temp}). The main energy source should be district heating or alternative energy sources based on renewable energy. For buildings where electricity is the main energy source, for example where a heat pump or similar is used, the amount of bought energy should not exceed 45 kWh/m^2, year (floor area A_{temp}).

The requirement is influenced by the behavior of the construction organization. The criterion is either *acceptable performance* or *good performance.* For *accepted performance*, the total amount of bought energy should not exceed 60 kWh/m^2, year. It is however highly feasible to perform better reaching a lower amount of bought energy and for *good performance* the amount should not exceed 20 kWh/m^2, year. The criteria for buildings heated by *acceptable performance* is set to 45 kWh/m^2, year and *good* performance to 20 kWh/m^2, year. The requirement could either be fulfilled by a high performance thermal envelope or by using a large share of on-site produced energy.

For reaching a net-zero or plus-energy consumption on a yearly basis supporting infrastructure is required, functioning as energy storage since it is not reasonable to store large amounts of energy on the premises for adjusting for seasonal differences.

The requirement in the environmental objective concerning the average heating demand per area unit is regarding the entire building stock. Newly built houses will only be a small part of the entire stock and a direct calculation deriving from the environmental objectives of how good the performance needs to fulfill the objective is outside the scoop of this thesis.

Finally, it is likely that the requirement for peak power demand in the Program (15 W/m^2 respectively 17 W/m^2) will have a major influence on the amount of bought energy.

For single family houses smaller than 200 m^2

EE1c: The total amount of bought energy (excluding house hold electricity) is not allowed to exceed 55 kWh/m2, year (floor area A_{temp}) in houses where the main energy source is district heating or alternative energy sources with renewable energy. For buildings where electricity is the main energy source, for example, where a heat pump

or similar is used, the amount of bought energy should not exceed 40 kWh/m^2, year (floor area A_{temp})

The requirement is influenced by the behavior of the construction organization. As the requirement says, the bought energy should not exceed 55 kWh /m^2. It is however feasible to perform better and reach an ever lower amount of bought energy. So the scale for the performance goes from *acceptable performance* at 55kWh/m^2, to *good performance* at *30* kWh/m^2. For buildings heated by electricity *acceptable performance* is 40 kWh/m^2 and *good performance* is 30 kWh/m^2 of bought energy on a yearly basis.

The same circumstances applies as for (**E1b**) above.

EE1d: Peak power: Maximum gross power for heating of the entire building should not exceed 15 W/m^2. For single family houses smaller than 200 m^2 the allowed peak power is 17 W/m^2.

The requirement is influenced by the behavior of the construction organization. As stated in the Program, the *acceptable performance* is 15 W/m^2.and for single family houses 17 W/m^2. It is possible to perform better by reasonable effort and *good performance* is set to 10 W/m^2. Examples of good performing buildings are found in the literature study. The requirement of peak load is hard compared to legal requirements and the environmental classification of a building.

A low peak demand is of the large environmental concern since the marginal energy in the present energy system is based on fossil fuels.

EE2 a: Prioritize renewable energy, for example sun, wind, bio fuels, district heating for reduce CO_2 emissions.

The requirement is depending mainly on the construction organization which sets the conditions for flexibility in the heating system within the building, and if they chose to install any solutions for harvesting on-site energy. However the building organization does not influence which energy source is used for the production of the electricity bought by the occupants or for maintenance uses for common areas.

Due to the different circumstances of the electricity system and energy sources used for heating the criteria are split between energy sources used for electricity and energy sources used for heating.

The environmental objective concerning renewable energy and buildings states that the whole building sector should use renewable fuels. District heating is seen as based on renewable energy even though that is not the case in Gothenburg.

The amount of renewable energy that could be used for energy supply in residential building is depending on what perspective on the energy system that is taken. As for electricity, one additional building is possible to supply with green electricity. It is not however feasible that the total residential building stock is supplied with green electricity. Nevertheless, in this thesis is judged as newly constructed building can be supplied with renewable energy.

<u>Electricity</u>: The requirements is measured in share of electricity coming from “free” resources such as wind and solar energy and share electricity generated from bio fuels, waste and hydro. For *acceptable performance* all electricity supplied to the building should be based on renewable sources. For *good performance* 30 percent of the electricity should be based on solar and wind and the rest based on hydro, bio and *performance* waste.

<u>Heat (excluding electricity for heating purposes):</u> The requirement is measured in heat produced on-site and additional supply of renewable energy. The criterion for use of energy

for heating (excluding electricity, accordingly to definition from The National Board of Housing, Building and Planning) is that for *acceptable performance*, all heat should come from renewable energy sources (still including district heating). For *good performance*, a larger share should be produced on-site, 40 percent for multi residential houses and 70 percent for single family houses. The additionally supply is based on district heating and bio fuels.

EE2b: Energy exchange between residential areas and premises are investigated in relevant cases.

The requirement is depending on the behavior of the construction organization. The requirement is judges as either *acceptable performance* or *not acceptable performance*. For *acceptable performance* an investigation has to be made where there are premises near the residential area generating surplus heat.

EE3: Design the buildings indoor climate with regard to sun radiation and indoor temperature. Avoid over temperature.

The requirement is depending on the behavior of the construction organization. The requirement is judges as either *acceptable performance* or not *acceptable performance*. For *acceptable performance*, the indoor climate should fulfill the demands as set in the environmental classification for grades silver, where the daily average operational temperature not should exceed 27 degrees during the warmest seven days in July.

LIGTHING/ILLUMINATION

EE4: Plan for day light dimming, occupancy controlled lighting and low energy bulbs in common areas.

The requirement is influenced by the behavior of the construction organization. The use of day light dimming and occupancy controlled lighting are judged as *acceptable performance* or *not acceptable performance*. For *acceptable performance* day light dimming and occupancy sensors should be used in common areas. For low energy bulbs the performance is judged as either *acceptable* or *good*. For *acceptable performance*, low energy bulb should be used and for *good performance*, innovative lighting such as LED-lighting should be used.

The requirement connects to the general environmental objective of a more energy efficient society and decreased energy use. As seen in the litterateur study there is a large potential for decreasing the energy use from lighting.

EE5: Plan for good conditions regarding day light and sun light in the residence and on the patio/grounds.

The requirement is depending of the behavior of the construction organizations. The criterion is either *acceptable performance* or *not acceptable performance.* For *acceptable performance,* the daylight factor should be at least one percent, which is indicated in litterateur and other classification system as necessary for good daylight conditions.

BUILDING TECHNOLOGY AND INSTALLATIONS

EE6: Design the thermal envelope for long- term energy economy.

The requirement is depending on the behavior of the construction organization. The criterion is either *acceptable performance* or *not acceptable performance*. For *acceptable performance,* LCC analyses should be made for optimizing the insulation level and the design of critical building parts where thermal bridges are likely to occur. This will ensure that long-term energy economy is considered when designing the thermal envelope. The analysis should be transparent and the economical preconditions should be clear.

EE7: Choose energy efficient installation and appliances in best available energy class.

The requirement is influenced by the behavior of the construction organization. The criterion is either *acceptable performance* or *not acceptable performance*. *For acceptable performance*, energy efficient appliances should be chosen.

Appliance	**Best available energy class**
Washing machine	**A**
Tumble drier	**A**
Dishwasher	**A**
Refrigerator	**A**
Freezer	**A (++)**
Owen	**A (++)**
Hob	**Ceramic or induction**

No official classification scheme exists for hobs, but as seen in the literature study ceramic and induction hobs are much more efficient the cast iron hobs.

EE8: Installations should be in place for the measuring of:

a) **The building's total energy use for heating.**
b) **Energy use for heating of tap water.**
c) **Premise electricity.**
d) **The premises total electricity use.**
e) **The premises total energy use**

The requirement is depending on the behavior of the construction organization. The criterion is *acceptable performance* or *not acceptable performance*. For *acceptable performance*, the above mentioned measurement equipment should be installed in the building. Having measurement installations for the entire premises energy consumption will increase future energy efficiency improvements since the entire energy use will be monitored.

EE9: Each apartment should have individual measurement and charging equipment for the use of tap water and electricity.

As seen in the theoretical background individual payment of electricity and heating decreases the energy consumption by around 15-20 percent.

CONSTRUCTION DETAILS

EE10: Execution control of workmanship for the building's heat insulation and airtight layers should be performed where there is risk for increased heat leakage, for example in connection points between building parts, splice blocks, thermal bridges, window connections and installations lead-trough etcetera.

The requirement is depending on the behavior of the construction organization. The criterion is *acceptable performance* or *not acceptable performance*. For *acceptable performance* building parts with increased risk for heat-leakage should be checked, for example by the method described the manual established by Forum for energy efficient building.

INSTALLATIONS

EE 11: Measurements of, and actions for minimizing the energy, heat and electricity use during the production of the building.

The requirement is depending on the behavior of the construction organization. The criterion is *acceptable performance* or *good performance*. For *acceptable performance*, the construction site should have well isolated builders' huts, occupancy control of lighting in the huts and energy efficient lightning on the construction site. For *good performance* the use of alternative heating, such as district heating when possible, or the use a heat pump is required.

ENERGY USE

E12: Measure the amount of bought energy during one year of operation and evaluation of the result against the requirements. The second heating season should be included in the measurement. The measurement period should cover 1 April of the building's first year and 31 March of its second year.

The requirement is depending on the management. The criterion is *acceptable performance* or *not acceptable performance*. For *acceptable performance* the measure should be performed in accordance with the requirement. Also the deviations from the energy calculations are assessed, in percent deviation from the original calculation, where the deviation for *acceptable performance* not should exceed 15 percent and for good performance 0 percent deviation.

4.4 Resource efficiency

The environmental improvements due to enhanced resource efficiency have impact on a multiplicity of areas. The main improvement is the decreased extraction of renewable and non-renewable resources. Decreased resource use has additional impact on other areas connected to resource use such as decreased impact from manufacturing, transportation and waste management. The requirements R8 and R2 have been combined since the two requirements are aiming at the same target and get a common criterion.

R1: Decrease waste generation and transportation needs during the construction phase. Plan for custom made building materials and easy dismantling.

The requirement has been divided in to three different parts. a) Decrease waste b) Decrease transport c) Plan for custom made building materials. All requirements are depending on the construction organization since the requirement is affected by the purchasing and material choice.

R1a: The criterion for the requirement is depending on the waste production on the construction site and the amount of waste sent to deposit (land-fill). To fulfill the requirement the amount of waste should not exceed 2 kg/m^2 built floor area and *good performance* is reached when the amount of waste does not exceed 1 kg/m^2. The amount of waste sent to deposit (land-fill) should not exceed 20 percent of the total waste amount for *acceptable performance* and for *good performance* no waste should go to landfill. This requirement is to a large extent depending on the construction workers since they handle materials and waste on site.

R2b: The criterion is depending on the load level of the goods transports to and from the construction site. *Acceptable performance* is achieved when the filling level in the transports is above 65 percent and as *good performance* when the filling level is above 80 percent. To notice, is that the load level concerns the only the transport to the sight, return trip is not included in the assessment.

Outside the requirement but still important is to have a policy for personal transports to and from the construction site.

R2c: The requirement is depending on the level of building materials that has been custom made. For *acceptable performance* materials suitable for custom ordering have been identified and for *good performance* the identified materials have been custom made, for example gypsum boards.

The requirements relate to each other since custom made building materials will decrease the transportation need from and too the construction site and the amount of waste produced.

R2 & R8: Natural gravel can only be used in exceptional cases. Use recycled gravel and crushed rock as much as possible. Natural gravel is not allowed to be used as ground filling and only in sparse amounts for ballast in concrete. Co-ordination between the purchaser and the executer for an optimal mass treatment for preserving the environmental, use of deposits, temporarily storage and similarities.

The requirement is depending on behavior and technology, since there are some applications where natural gravel cannot be replaced. The criteria for the requirements are designed after the use of natural gravel and are judged as either *acceptable performance* or *good* *performance*. The mentioned exceptional cases are defined as when the required ballast material fraction is smaller than 2mm. For *acceptable performance*, no natural gravel should be used with fractions larger than 2mm. For *good performance*, no natural gravel should be used at all.

Due to the fact that natural gravel is a finite resource the extraction rate must rapidly decrease. When comparing the present extraction rate with the target level in the environmental objectives the extraction rate must decrease by 40 percent to meet the target level. The main purpose of decrease the extraction rate is to secure the future supply of ground water. Meeting the environmental objective may not even be sufficient for the purpose; further decreases of the extraction rate might be necessary.

Water

R3: Hot- and cold water saving armatures and WC is chosen.

The requirement is depending on behavior of the construction organization. The criterion is either *acceptable performance* or *not acceptable performance.*

Water saving armatures gives reduced environmental impact in a range of perspectives. The obvious water savings also gives decreased impact from the production of tap water described in the theoretical study. Decreased consumption of hot water reduces the environmental impact from energy production which could give a substantial savings since around 20 percent of the energy in a building is used for hot tap water production. Waste water gives causes heat losses which in energy efficient building could consist of a substantial part of the total heat losses. There are different of goals for reaching a more energy efficient society, for example the European Union goal to save 20 percent energy, which is the same target as the interim target in an environmental objective *A Good Built Environment*.

R4: For each apartment should measurement and debiting of hot water consumption be present. Cold water consumption should be measured voluntarily.

The requirement is depending on behavior of the building organization. The requirement is judged as either *acceptable performance* or *good performance.* For *acceptable performance,* the consumption of hot water is measured and for *good performance* consumption of cold water should be measured. Since research has showed that individual charging decrease the consumption of hot water with up to 20 percent this measure could give a substantial effort to meet the interim targets concerning energy use in the built environment. The environmental relevance for this requirement is the same as for the requirement above.

Waste

R5: Within each apartment a special space or cupboard insert intended for sorting out house hold waste should be present.

The requirement is depending on behavior of the construction organization. The criterion is either *acceptable performance* or *good performance.* For *acceptable performance,* a space intended for waste sorting should be available in the apartments and for *good performance* a system for the sorting out of organic waste should be installed directly in the kitchen. Organic waste is a resource and for enhancing the utilization of this resource the installation of such a system will increase the level of sorted out organic waste, creating a better cycle of resources. The sorting out the other fractions of waste is also important for closing loops of materials and resources.

R6: Create spaces for waste management that encourages good resource efficiency. A large enough and distinct space should be arranged on the premises for sorting of

household waste, including waste that is reused and waste left for the municipality's waste treatment, including bulk waste.

Waste sorting spaces should be easily accessible. Collection conditions should be considered from a safety, transport, working condition and noise perspective. Flexibility is important since the waste management system is changing over time.

The requirement of creating space for good resource efficiency is depending on the behavior of the construction organization. To measure the success, the fraction of non-sorted waste will be measured; it is assumed that the behavior of the occupants is depending on how good the waste space is. The criterion is either *acceptable performance* or *good performance.* For *acceptable performance*, the level of unsorted waste is 40 percent. For *good performance* the level is 10 percent. The indicator is measured in percentage of weight since the fractions which are prioritized from a recycling perspective are those of the highest densities such as metal, glass and organic waste. If the unsorted wastes makes up for a small part of the total weight it is an indication that the recyclable fraction have been sorted out well.

The environmental relevance of sorting out the waste is the same as for the requirement above (**R5**).

Building material

R7: Use mounting methods designed for demounting whenever possible to simplify exchange and recycling.

The requirement is depending on technology and behavior of the construction organization. The criterion is *acceptable performance* or *good performance*. For *acceptable performance,* an analysis of the demolition should be made. For *good performance* recommended dismantling methods should be used and documented. The construction organization is responsible for the choice of construction methods, but is limited to some extent by technical prerequisites since dismantling methods are not available for all mounting methods.

Building waste

R9: Establish plan for sorting building waste. Consider:

- **Appoint waste responsible person**
- **Analyze which material fractions that arises and how they are to be sorted for recycling. Rest products that arise during production should primarily be sent for material recycling.**
- **Sorting of building waste is should primarily be done on the construction site.**
- **Fractions left for recycling should be clean.**

The requirement is depending on the construction organization. The criterion is either *acceptable performance* or *not acceptable performance.* For *acceptable performance* the aspects above should be present in the waste plan. The guidelines from the EcoCycle Council are suitable to use for this requirement.

Analyzing and sorting of the on-site waste contributes to raising the awareness about the amount of waste produced, giving an increased understanding about how large the amount of waste actually is, possible increasing the incentives for decreasing the amount.

4.5 Health and indoor climate

The criteria for all of the requirements below aim to reduce impact on human health from the surrounding environment. Many the requirements concern topics where there today are no scientifically established limits for emissions and exposure. Instead, the precautionary principle has been used to establish many of the limits. Throughout the analysis conservative guidelines are used to ensure the least possible environmental impact. In the environmental objectives of Sweden there are no guidelines for the explicit requirements on indoor environmental quality, only a general goal stating that buildings should not affect human health negatively. Due to the limited knowledge about the effects on humans and the environment the application of the precautionary principle is highly important.

H1: Routines should be present for scanning and risk assessment of material choice with regard to emission from materials known to be injurious to health and allergens.

The requirement is depending on the behavior of the construction organization. The criterion measures if a routine is present or established by an expert, updated and followed up. For *acceptable performance* routines should be present for scanning and risk assessment of material choices. For *good performance* the routines should be established by an expert, updated and followed up. The chemical content of materials affects the quality of the indoor air quality and some substances are hazardous for the health, for example formaldehyde. Consequently, it is important to consider possible emissions when choosing material for the indoor environment so that materials harming human health are not chosen.

H2: Chose low emitting materials and constructions. Use the material manufacturer's description of emission rate for the choice of material.

The requirement is depending on the behavior of the construction organization. The criterion is either *acceptable performance* or *not acceptable performance*. For *acceptable performance* documented emissions rate for total volatile organic compounds (*TVOC*) and formaldehyde should be available. In addition, the emission rate should not exceed the following health limits: TVOC from flooring materials should not exceed 40 $\mu g/m^2$, h, and formaldehyde emissions should not exceed 50 $\mu g/m^2$, h. Documentation does not need to be present if bricks, stone, tile, clinker, glass, metal or hardwood is used. The environmental relevance is the same as for the requirement H2.

H3: The ventilation system should be designed so that good separation of particles and other pollution in the supply air is attained. Attention is paid to the placement of air intakes with regard to exhaust gases. Consider the need of operational windows.

The requirement is depending on the behavior of the construction organization. The criterion is either *acceptable performance* or *not acceptable performance*. For *acceptable performance* the ventilation system should be designed so that the supply air does not exceed the lowest recommended guidelines for pm_{10} (30 $\mu g/m^3$, daily average), pm_2 (10 $\mu g/m^3$, yearly average), radon (100 Bq/m^3), and NO_x (40 $\mu g/m^3$, yearly average). The level of pollution in the air depends on the traffic situation; however the location of the building is outside the boundaries for this thesis.

ELECTRICAL INSTALLATIONS

H4: Electromagnetic fields from stationary electrical installation should be minimized within the building, especially in bedrooms. The precautionary principle is applied. TN-S system should be used.

The requirement is depending on the construction organization. The criterion is either *acceptable performance* or *not acceptable performance*. For acceptable performance electromagnetic fields in the building should not exceed 0,2 µT, which is the established value for the application of the precautionary principle. Electrical and magnetic fields are also generated by the occupants and their usage of electrical devices.

H5: Screen powerful electromagnetic fields, for example from the buildings distribution plant and electrical central.

The requirement is depending on the construction organization. The criterion is either *acceptable performance* or *not acceptable performance*. The requirement is closely connected with the requirement above **(H4).**

AIR QUALITY

H6: Routines should be present in order to assure that material combinations are suitable from a health perspective, for example the choice of glue in combination with the surface layers.

The requirement is depending on the construction organization. The criterion measures if a routine is present or established by an expert, updated and followed up. For *acceptable performance* routines should be available. For *good performance* routines should be established by an expert, up dated and followed up.

Unsuitable material combinations should be avoided since they can give rise to hazardous emission which will reduce the air quality and comfort of the occupants.

H7: Make sure air channels are clean.

The requirement is depending on the behavior of the construction organization. The criterion is either *acceptable performance* or *not acceptable performance*. For acceptable performance the air channels should be controlled. The requirement is of importance since if there is pollution in or blockage of the air channels the ventilation will not function as intended causing poor air quality.

ELECTRICAL INSTALLATIONS

H8: Electrical wires and installation should be mounted so that the risk of electrical fields is minimized.

The requirement is depending on the behavior of the construction organization. The criterion is either *acceptable performance* or *not acceptable performance*. This requirement will contribute to the performance of the requirement (**H4).**

H9: The requirements from Program are fulfilled during the use phase.

The requirement is depending on the behavior of the management organization. The criterion is either *acceptable performance* or *not acceptable performance*. Ensuring a healthy living environment for the occupants requires continuous work.

4.6 Moisture protection

The moisture protection area in the Program mainly concerns human health. The criteria are designed to to ensure that no negative impact on human health can be derived from inadequate moisture protection. To ensure adequate moisture protection, the issue must be given attention during the entire construction process. Even though no scientific consensus exists on general limits concerning damp buildings and human health it is important to avoid carelessness. The lack of scientifically established limits and measuring methods means that no established indicators have been developed for moisture protection. There is no environmental objective concerning moisture in buildings since it is not possible to evaluate the impact from moisture. Due to the high relevance of the issue, various manuals and guidebooks have been developed to ensure sufficiently moisture protected constructions and those tools has been used when developing the criteria for this requirement. The moisture manuals mainly used for the development of the criteria are ByggaF and the documentation manual from the City of Stockholm. As in most of the analyses, the requirements which have not space for additional performance are judges as *acceptable performance* or *not acceptable performance*.

M1: Choose method to secure moisture protection in the building production, for example “Manual - moisture protection in the buildings process”.

The requirements are influenced by the construction organizations behavior. The requirement is judged as either *acceptable performance* or *not acceptable performance.*

M2: Use a moisture protection specialist and establish moisture protection description.

The requirements are influenced by the construction organizations behavior. The requirement is judged as either *acceptable performance* or *not acceptable performance.*

M3: Execute moisture protection planning according to ”ByggaF” or similar. Investigate the possibility of using a test for the production.

The requirement is depending on the construction organization, both behavior and technology influence the performance. The requirement is judged as either *acceptable performance* or *not acceptable performance.* For *acceptable performance*, a documented analysis of the possibilities of weather protected production and a clear statement on which weather protection method is chosen and why should be available.

M4: Create a moisture plan and follow the moisture protection description. Make sure all of the construction staff is up to date on the moisture issue.

The requirements are depending on behavior within the construction organization. The criterion is either *acceptable performance* or *good performance*. The requirements concerning the continuous information to all building workers are measured in hours. For *acceptable performance* 2 hours of education is required. For *good performance* 4 hours or more.

M5: Secure the construction process so all building materials and constructions are protected against damaging moisture and dirt. Secure materials against weather, both at storage and during the construction phase.

The requirement is depending in the construction organizations behavior. The criterion is either *acceptable performance* or *good performance*. For *acceptable performance* materials and constructions should be partly covered. For *good performance* materials and constructions should be fully covered.

M6: Routines should be present for assure material combinations suitability from a health view, for example choice of glue in combination with surface layers.

The requirement is depending on the construction organization. The criterion measures if a routine is present or established by an expert, updated and followed up. The criterion is either *acceptable performance* or *good performance.* For *acceptable performance* routines should be available. For *good performance* routines should be established by an expert, updated and followed up.

M7: Quality inspection of pipe joints. Connection on water pipes should be placed easily accessible for maintenance and inspection purposes.

The requirement is influenced by the construction organizations behavior. The criterion is either *acceptable performance* or *not acceptable performance*. For *accepted performance* the execution of water pipes should be made according to the standards in Safe Water.

M8: Compile moisture protection documentation consisting of final moisture protection description and inspection and measurement results.

The requirement is influenced by the construction organizations behavior. The criterion is either *acceptable performance* or *not acceptable performance*.

As a clarification of the requirement all running inspections and the results from those should be documented in the moisture protection documentation.

M9: Define routines for running moisture controls and measures in case of moisture damage/leakage (preparation for management).

The requirement is depending on the construction organization. The criterion measures if a routine is present or established by an expert, updated and followed up. The criterion is either *acceptable performance* or *good performance.* For *acceptable performance* routines should be available. For *good performance* routines should be established by an expert, updated and followed up.

M10: Execute regular inspections of the moisture protection. Inspect moisture critical construction in connection to running rounds.

The requirements are influenced by the construction organizations behavior. The criterion is either *acceptable performance* or *not acceptable performance*. For *acceptable performance* the control should be performed every fifth year. For *good performance* the controls should be made every third year or more often.

4.7 Noise protection

The environmental goal concerning noise only considers traffic noise which is not a part off the Program. Nevertheless there are legal requirements and other recommendations for acceptable noise levels in order to ensure human well-being and health.

N1: Sound class B is fulfilled for apartment separating construction between different activities and sound level indoors from installations and washrooms. Specially sound isolating measurements are needed if noisy activities, e.g. restaurants, day care centers, commonly premises are present within the building and within the proximity of apartments.

The requirement is depending on the behavior in the construction organization. The criterion is either *acceptable performance* or *good performance*. For *acceptable performance* sound class B according the Swedish standard should be fulfilled between the apartment and other kind of activates. Also for installations within the building and inside the apartments sound class B should be fulfilled. For *good performance* sound class B should be fulfilled between apartments as well.

N2: Carry out sound measurements of completed apartments, in particular known noise sources and parts of the construction where the risk for noise is higher.

The requirement is depending on the behavior of the construction organization. The criterion is either *acceptable performance* or *good performance.* For *acceptable performance*, noise sources should be identified and special measures are taken when needed. Also a sound measurement accordingly to the Swedish standard should have been carried out.

N3: The requirements in the program are fulfilled.

The requirement is depending on behavior of the management. The criterion is either *acceptable performance* or *not acceptable performance.*

5 Results

To note that the performance level, acceptable performance and good performance are only valid when there are different performance level available.

Table 5.1 Result table with the requirement and corresponding criteria for the area durability

Code	Durability – Requirements	Base for evaluation	Performance level	
			Acceptable performance	Good performance
	Durability			
D1	During planning processes consider the requirement on durability for all construction parts. *Even prerequisite for service and maintenance is considered.*	Level of consideration	Technical life length----maintenance interval----embodied energy	
D2	Installations within the building are placed accessible for service and maintenance and are exchangeable if they are estimated to have a shorter life length than the building in general.	Accomplishment	Not acceptable---	Acceptable
D3	Control should be done so that prerequisite is available for service, maintenance and exchange of constructions/installation so the guidelines are fulfilled.	Accomplishment	Not acceptable---	Acceptable

Table 5.2 Result table with the requirement and corresponding criteria for the area environmental impact

Kod	Environmental impact – Requriements	Base for evaluation	Performance level	
			Acceptable performance	Good performance
Code				
	Choice of material and products			
E1	Routines available for product choice and risk assessment of material	Routine	Available -------- Developed by expert ------- Follow-up and update	
E2	Building product declaration/Environmental product declaration or security information sheet/description of goods sheet	Volume-%	75 % BVD/MVD--100% BVD/MVD	
		Products used -%	75 % BVD/MVD--100% BVD/MVD	
E3a	The BASTA-system is used for choice of products	Products used (%)	90 % BAST --100% BASTA	
E3b	The material is assessed accordingly to Building Product Judgment data base	Material used (%)	100 % Accepted --------------------------------- 100% Recommended	
E3c	Out phasing substances should not be present	Accomplishment	Not acceptable ---Acceptable	
E3d	Identification of risk decreasing substances.	Accomplishment	Not acceptable ---Acceptable	

E3e	Building materials is chosen so that storm- and ground water is not affected negatively due to poor management of building and waste materials.	Accomplishment	Not acceptable ---Acceptable
E4	Paint, lacquer and oil not based on organic solvents VOC-content do not exceed the limits for eco-labeling (Appendix B)	Volume-%	Not acceptable ---Acceptable
E5	No copper in the tap water system.	Accomplishment	Not acceptable ---Acceptable
E5	No copper in roof and surface material	Accomplishment	Not acceptable ---Acceptable
E6	Tree products labeled with FSC/PEFC from region of Västra Götaland	Volume -%	75 % FSC/PEFC-WG------------------------------ 100 % FSC/PEFC-WG 100 % Outsider Scandinavia FSC ---------------- 100 % Scandinavia
E7	Pressure-creosoted wood is not used.	Accomplishment	Not acceptable ---Acceptable
E8	Fluorescent lamps with as less mercury as available on the market (> 5 mgHg)	Accomplishment	Not acceptable ---Acceptable
	Grounds and Green areas		

E9	Low impact development. One of the four resources should at least be used for acceptable performance.	Detaining Aesthetic Hydrologic Biologic	1----------------------2----------------------3----------------------4 Number of uses for storm water
E10	Permeable material on the yard to facilitate infiltration.	Biotope area factor	0,5 -- 0,7
E11a	Enhance biodiversity Vegetation should be present in all four layer; tree, bush, ground, bottom	Layer of vegetation	Not acceptable --Acceptable
E11b	Save especially valuable vegetation	Accomplishment	Identified-- Saved & Identified
E11c	Green roofs. Conditions for green roofs must be available	Percent (%) m^2 green roofs/ total roof area	0% -- 100%
	Choice of products		
E12	Routines in construction site so materials and products are controlled against the environmental and health requirements	Routine	Available---Developed by expert---Up-date and conformation

	Construction site		
E13	Plan the construction site to establishment area is minimized.	Establishment area m^2/floor area	
E14	Special environmental requirements are put on machinery and trucks. Electricity -------------Alkylate gas/synthetically diesel	Environmental zone requirements Working hours Percentage (%)	Not acceptable ---Acceptable 100% -- 100% Alkylate gas /synthetically diesel Electricity
E15a	Routines available: • Storage of chemicals and fuel during the construction time to prevent leakage to ground, water and sewage • Safe handling, storage and management of toxic and hazardous waste • Information and communication for neighbors • Limitation of dust, noise and vibration to the neighbors during construction time	Routine	Available -------- Developed by expert ------- Follow-up and update Available -------- Developed by expert ------- Follow-up and update Available -------- Developed by expert ------- Follow-up and update Available -------- Developed by expert ------- Follow-up and update
E15b	Personal has documented environmental education Sub-contractor has documented environmental education	Average education hours/worker and year	4 -- 16

Table 5.3 Result table with the requirement and corresponding criteria for the area energy efficency

Code	Energy efficiency (EE) – requirements	Base for evaluation	Performance level	
			Acceptable performance	Good performance
	Energy			
EE1a	Calculate the buildings expected energy use. Numbers for calculated bought energy use should be reached and be verified from set demands.	kWh/m^2	Not acceptable --	Acceptable
EE1b	Multi residential buildings:		60 --	20
	Total amount of bought energy (excluding house hold electricity) will not exceed 60 kWh/m^2, year (A_{temp}) where the main energy source is district heating or alternative energy source with renewable energy.	kWh/m^2		
	For building with electricity as main energy source where for example heat pump or similar is used, the amount of bought energy should not exceed 45 kWh/m^2, year (A_{temp}).		45 --	20
EE1c	For villas smaller than 200 m^2:			

	Total bought energy (excluding house hold electricity) is not allowed to exceed 55, year (A_{temp}) where the main energy source is district heating or alternative energy source with renewable energy. For building with electricity as main energy source where for example heat pump or similar is used, the amount of bought energy should not exceed 40 kWh/m^2, year (A_{temp})	kWh/m^2	55 -- 30 40 -- 30
EE1d	Peak power: Multi residential: Maximum gross power for heating of the whole building will not exceed 15 W/m^2. For villas smaller than 200 m2 is the power 17 W/m^2	W/m^2	15 -- 10 17 -- 12
EE2a	Prioritize renewable energy, for example sun, wind, bio fuels, district heating for reduce CO_2 emissions Electricity: Heat: Multi residential Single-family	Percent (%)	Bio, Hydro, Solar, wind 100-- 30 Bio, District heating On-site solar 100 -- 40 100-- 70
EE2b	Energy exchange between residential areas and premises are investigated in relevant	Accomplishment	Not acceptable -------------------------- Acceptable
EE3	Design the buildings climate with regard to sun	Accomplishment	Not acceptable -------------------------- Acceptable

	radiation and indoor temperature. Avoid over temperature i.e daily average operational temperature should not exceed 27 degress during the warmest seven days in July		
EE4	Plan for:	Accomplishment	
	day light dimming		Not acceptable -- Acceptable
	occupancy controlled lighting		Not acceptable -- Acceptable
	low energy bulbs in common areas		Low energy bulb-------------------------------------Innovative lighting
EE5	Plan for good conditions regarding day light and sun light, in the residence and out on the patio/grounds Daylight factor >1 percent	Daylight factor (%)	>1
EE6	Design the thermal envelope for long- term energy economy through the use of LCC for isolation level and to prevent thermal bridges	Accomplishment	Not acceptable ----------------------------- Acceptable performance
EE7	Choose energy efficient installation and white goods in best available class i.e class A. (including ceramic and induction hob even though no classification exist)	Accomplishment	Not acceptable ----------------------------- Acceptable performance
EE8	Installations should be present for measuring of:	Accomplishment	
	- The building total energy use for heating		Not acceptable -- Acceptable
	-Energy use for heating of tap water		Not acceptable -- Acceptable
	-Premise electricity		Not acceptable -- Acceptable

	-The buildings total electricity use		Not acceptable -- Acceptable
	-The buildings total energy use		Not acceptable -- Acceptable
EE9	In each apartment installation for individual measure and charging for the use of tap water and electricity.	Accomplishment	Not acceptable -- Acceptable
EE10	Quality of workmanship for the building heat insulation and airtight layers are controlled where there is risk for increasing heat leakage, for example in connection between building parts, block joints, thermal bridges, window connections, installations lead-trough etcetera.	Accomplishment	Not acceptable -- Acceptable
EE11	Measurement of and measure for minimizing the energy use, during the production of the building, heat and electricity.		Well isolated huts District heating Low energy bulbs or heat pump Occupancy control of lighting in huts
	Measure the bought energy during one year of operation and after that evaluates the result against set demands. The second heating season should be included in the measure. The period of measure should include April first the first year to Mars 31 the second year after moving in.	Accomplishment Acceptable deviation (%):	Not acceptable -- Acceptable 15 ---0

Table 5.4 Result table with the requirement and corresponding criteria for the area resource efficiency

Code	Resource efficiency – Requirement	Base for evaluation	Performance level: Acceptable performance	Performance level: Good performance
	BUILDING MATERIAL			
R1	Decrease waste generation and transportation need during the construction phase.			
	a) Decrease waste	Waste/m^2	< 2 kg/ m^2 ----------	< 1 kg/ m^2
		Deposit/m^2	< 20 % ----------	0 %
	b) Decrease transport	Load factor (%)	≥ 65 ----------	≥ 80 %
	c) Plan for custom made building materials	Custom made building materials:	Material identified ----------	Suitable material custom made
R2&R8	Natural gravel is used only in exceptional cases.	Ground filling	Not acceptable----------	Acceptable
	Reuse gravel and crushed material as far as possible. Natural gravel should not be present in ground filling. Ballast in concrete natural gravel should be minimized. Co-ordination between purchaser and executer for an optimal mass treatment for preserving the environmental, use of deposits, temporarily storage and similarities.	Use as ballast in concrete	Only fractions ≤ 2 mm----------	No natural gravel used

	WATER		
R3	Hot- and cold water saving armatures and WC is chosen.	100 % water saving armature	Not acceptable--Acceptable
R4	For each apartment should measurement and debiting of hot water consumption be present. Cold water consumption should be measured voluntarily.	Individual-water measurement	Hot water --- Cold water
	WASTE AND RECYCLING		
R5	Within each apartment a special area or cupboard insert for sorting out house hold waste should be present.	Space available	Space available -------------------------- System for organic waste present
R6	Create waste space which encourage to good resource efficiency. Special and large enough space should be arranged in the dwellings, for sorting of household waste which is material reused or left to the waste treatment of the municipality for be taken care of bulk waste.	Percent unsorted waste, weight-% (or volume-%)	40 % waste--10 % waste
R7	For mounting are dismantling methods used when it is possible to simplify exchange and recycling.	Performing of investigation	Dismantling methods identified ----------- Disassembly methods applied
R9	Establish plan for sorting building waste. Consider:		
	a) Appoint waste responsible person.	Appointed	Not acceptable--Acceptable

	b) Analyze which material fractions that arise and how they are sorted for recycling. Rest products that arise during production are sorted out for material recycling as a first alternative.	Map material flow	Not acceptable--Acceptable
	c) Sorting of building waste executed on the construction site as a first alternative	Base level for fractions	Not acceptable--Acceptable
	d) Fractions left for recycling should be clean.	Accomplishment	Not acceptable--Acceptable

Table 5.5 Result table with the requirement and corresponding criteria for the area health and indoor climate

Code	Health and indoor climate -Requirements	Base for evaluation	Performance level: Acceptable performance	Performance level: Good performance
H1	Routines should be present for scanning and risk assessment of material choice with regard to emission from known materials which are injurious to health and allergens.	Routines	Available -------- Developed by expert ------- Follow-up and update	
H2	Chose low emitting materials and constructions i.e. bricks, stone, tile, clinker, glass, metal or hardwood . Use the material manufacturer's description of emission rate for choice of material.	Emission rate Flooring material $<40\ \mu g/m^2$, h Formaldehyde $< 50\ \mu g/m^2$, h	 Not acceptable -- Not acceptable --	 Acceptable Acceptable
H3	The ventilation system should be designed so that good separation of particles and other pollution in the supply air is attained. Pay attention to the placing of air intakes with regard to exhaust gases. Consider the need of operational windows.	$PM_{10} < 30\ \mu g/m^3$ $PM_{2,5} < 10\ \mu g/m^3$ Radon < 100 Bq/m^3	Not acceptable-- Not acceptable-- Not acceptable--	Acceptable Acceptable Acceptable

H4	Electrical and magnetically fields from stationary electrical installation are minimized within the building, especially in bedrooms. The precautionary principle is applied.	Field intensity	< 0,2 --μT
	TN-S system (separate protective earth (PE) and neutral (N) conductors from transformer to consuming device) are used	Accomplishment	Not acceptable -- Acceptable
H5	Screen powerful electrical and magnetically fields, for example from the buildings distribution plant and electrical central.	Accomplishment	Not acceptable -- Acceptable
H6	Routines should be present for assure material combinations suitability from a health view, for example choice of glue in combination with surface layers.	Routines	Available -------- Developed by expert ------- Follow-up and update
H7	Control air channels so they are clean.	Accomplishment	Not acceptable -- Acceptable
H8	Electrical wires and installation is mounted so that the risks for electrical fields are minimized.	Accomplishment	Not acceptable -- Acceptable
H9	The requirement which has been set in the program is fulfilled during the use phase.	Accomplishment of the part requirements	Not acceptable -- Acceptable

Table 5.6 Result table with the requirement and corresponding criteria for the area moisture protection

Code	Moisture protection - Requirements	Base for evaluation	Performance level	
			Acceptable performance	Good performance
M1	Choose method to secure moisture protection in the building production, for example "Manual moisture protection in the buildings process".	Accomplishment	Not acceptable ---	Acceptable
M2	Chose moisture protection specialist and establish moisture protection description.	Accomplishment	Not acceptable ---	Acceptable
M3	Execute moisture protection planning according to "ByggaF" or simular. Investigate the possibility to building production in tent.	Investigation	Not available ---	Available
		Clear decision	Not available ---	Available
M4	Execute moisture plan and follow moisture protection description. Give continuous information in moisture issues to all building workers.	Hours of education	2 --	<4
M5	Secure building process so all building materials and constructions are protected against damaging moisture and dirt. Secure materials against weather, both at storage and during construction phase.	Level of coverage	Partly covered ---	Fully covered
M6	Routines should be present for assure material combinations suitability from a health view, for example choice of glue in combination with surface layers.	Routines	Available ----- Developed by expert ------ Up-date and conformation	

M7	Quality insurance the performance of pipe joints. Connection on water pipes is placed easily accessible for maintenance and inspection.	Executed accordingly to Safe Water Accomplishment	Not acceptable --- Acceptable Not acceptable --- Acceptable
M8	Execute moisture protection documentation consisting of final moisture protection description and compilation of control and measurement results.	Accomplishment	Not acceptable --- Acceptable
M9	Define routines for regular moisture controls and measures with moisture damage/leakage (preparation for management).	Accomplishment	Not acceptable --- Acceptable
M10	Execute regular controls of moisture protection. Control critical moisture construction in connection to running rounds.	Intervall of control (years)	5--- 3

Table 5.7 Result table with the requirement and corresponding criteria for the area noise protection

Code	Noise protection - Requirements	Base for evaluation	Performance level	
			Acceptable performance	Good performance
N1	Sound class B is fulfilled for apartment separating construction between different activities and sound level indoors from installations and lavatory.	Sound Class B	Activity/Apartment------------------------------------	Apartment/Apartment
	Specially sound insolating measurements is needed if noisy activities, e.g. restaurants, day care centers, commonly premises is present within the building and is about on apartments.	Accomplishment	Not acceptable --	Acceptable
N2	Carry out sound measure of completed buildings. Control especially sound sources and construction parts where there is risk for noise disturbance.	Accomplishment	Not acceptable --	Acceptable
N3	The requirements in the program are fulfilled.	Accomplishment	Not acceptable --	Acceptable

6 Discussion

The validity, verifiability and generality of the executed work are discussed, as well as the issues concerning contradictory interest.

6.1 Methodology, analysis and results validity

While the criteria developed in this project are the result balancing act between achievable levels, required levels and what is measurable, the acceptable level of environment performance has been in focus for this project. The criteria are designed to raise the bar of environmental performance of residential buildings, reflecting what ought to be done in order to build green buildings. Within the time frame for this thesis quantifying criteria for all of the requirements have not been possible to develop, mainly missing, are the requirements concerning the management of the construction processes.

An overall issue when analyzing the requirements has been the identification of limiting factors in terms of behavior, technology and the main influencing actors. In many cases and in the long run, it may well be the behavior of the occupants that sets the final environmental performance level; nonetheless, the building proprietors sets the initial conditions for this behavior, and it is these conditions that is the main target for this evaluation. For example, concerning the sorting of domestic waste, it is hard to decide which actors' performance that should be evaluated. Even if the building proprietor creates spaces encouraging recycling, it is the occupants that in the long run determine the outcome. Most likely, the three groups of actors identified in this study have been influenced by external factors or secondary factors. For example, campaigning for improved waste sorting in the households of the City of Gothenburg is likely to influence that the performance of the occupants.

Finally, there is the choice about how to consider the routines specified throughout the Program. Is it the specified routines that should be evaluated, or is it the intended effects of the routines?

The time and scale of the environmental impact differs vastly between the requirements; hence, different system boundaries have been applied to different requirements. Although the work has been forward looking, system conditions of the present have been chosen. Some cases, for instance concerning energy, the valuation of different kinds of energy (e.g. primary energy), generation and supply is likely to change and for future evaluations this must be taken in to account. In the same way, the knowledge about harmful substances and their impacts on humans and the surrounding environment is likely to increase and change the requirements on material and product use.

The demolition phase is not included in the Program or this thesis; however it is clear that many of the conditions for the demolition are laid out already during the planning processes.

The uncertain and often long time span of a building is causing uncertainties about the total environmental impact, but as illustrated in chapter 3.1 the largest contributor to the environmental performance is still the planning phase. Nevertheless, there are possibilities during the whole use life cycle for improvements. The maintenance of a building, aiming to retain the required functions will have regular opportunities for improvement and upgrading to best available technology, reducing environmental impact. The environmental performance of biodiversity, green areas and low impact development improve and the level of sorted household waste can be improved by community and individual actions. The share of on-site produced energy can be increased as the technologies improve and the potential for production may not have been fully exploited when the building was originally designed.

Technological and behavioral progress towards environmental sustainability over time needs to be feed back into the Program and evaluation methodologies. Behavior that today represents good performance can become the norm, thus making an update of requirements of the two performance levels necessary. Energy efficiency is seen as an aspect where there are possibilities for a steady improvement. The requirements constraining hazardous and toxic chemicals in building materials will be tougher as the awareness and knowledge about the chemical properties is raised, due to the ongoing work with REACH and the widening extension of the use of the BASTA-system and the Building Product Judgment system, two current tools for decreasing the use toxic materials.

To reach the expected outcome of the Program, the feedback and follow-up mechanism must be efficient. Deviations from, as well as fulfillment of the program must have consequences. The land directions from the City's real estate office are one possible instrument to promote fulfillment of the program.

6.2 Study of literature – verifiability

Due to the wide array of topics in the requirements the search for relevant literature has been a major part of the work for this thesis. Due to the wide array, the information has been of different quality in terms of scientifically consensus and relevance. To the largest extent possible peer reviewed articles have been used, however this has not been possible for all requirements – especially the requirements concerning specific advices concerning the execution of the construction work. In those cases the information has been found in information material from interest groups and companies. These more practical guidelines have not been possible to be find within the scientifically literature and are instead collected as "good examples" from other relevant literature. However, proper evaluation and follow-up have been missing in some cases of the "good examples". For example, there is an abundance in different solutions for low impact development presented in various literature, but only a selected few of those solutions has been evaluated regarding efficiency and goal fulfillment.

6.3 Generality of the results and conclusions

Many of the requirements and the corresponding criteria are based on the national environmental objectives of Sweden and could be used as a benchmarking on a national level. As said in the discussion above the results are valid today, but will need to be updated as technology and behavior change.

6.4 Interactions and conflicts between the requirements – balancing different interest

There are synergies and conflicts between the different requirements. Overall, the requirements are contributing to the fulfillment of each other, but in some cases cases they counteract each other.

Apparent examples are the requirements concerning green roofs, biodiversity and low impact development. If one of the requirements is enhanced, the others are most likely to be improved as well. Other examples of positive connections include the relation between moisture protection being well executed during the construction process and the indoor air quality in terms of emissions and allergens. Lower energy consumption makes it possible to increase the amount of renewable energy within the energy mix.

On the other hand there are several examples of negative relationships as well. One possible conflict is the one between biodiversity, as executed in nearby plantations and the indoor air quality in general and the presence of allergens in particular. If hardwood is used for flooring in order to limit the emission of VOC, a conflict with the requirement to use only FSC/PEFC labeled forest is possible. There is another conflict concerning the limitation of VOC as well; low emitting materials, such as brick and stone are recommended to be used for limiting VOC-emission. However, those substances have a high embodied energy which counteracts the general requirement of resource efficiency. The requirement that all building waste should be sorted on site it is likely to counteract the requirement that the area of the construction site should be as small as possible.

7 Conclusions

The foundation has been laid for the evaluation of requirement fulfillment for the Green Construction Program for Residential Buildings. Nevertheless, some of the criteria need further investigation and research. In order to be constantly valid the criteria needed to be in progress due to technology progress and the normalization of behavior. The results are valid for all new residential construction in Gothenburg, but could also be applied for residential construction projects outside Gothenburg. There are conflicts and interactions between the different requirements in the program, where priorities must be made.

The use of the program is likely to raise the level of environmental performance of new residential buildings within the City of Gothenburg compared to the present level.

8 Recommendations

In this chapter follows recommendations for further development of the Green Construction Program which has been developed during the work with the thesis.

The aspect *durability* is today a bit unclear due to vague requirements and the perception of what durability includes could vary between different readers due to the relativity of the concept of durability. The general goal of more resource efficient building in a life cycle perspective could then be more explicit in the requirements and definition of the concept would be helpful to reach the goal. Close connected to *durability* is aspect *resource-efficiency* which today is mainly focused on waste management. The only building material considered in a resource efficiency perspective is the use of natural gravel. However, for future development of the requirements in the program for green buildings, concerning resource efficiency the use of resource efficient and recycled building materials should be sat.

A natural continuation, after having formed a base for evaluation, is to communicate the results of the assessment. Some of the requirements are though better suitable and interesting for external communication and visibility. The authors' recommendations of requirement suitable for those purposes are:

- Energy – efficiency, the amount of bought energy.
- Renewable energy, how much come from renewable source, where the amount of energy produced on-site is compared with the total amount of renewable energy sources.
- Biotope area factor and the use of low impact development.
- Use of natural gravel.
- Durability, considered technical life length against embodied.

As for future research and development concerning the evaluation method, a large focus area is how to evaluate routines and possibilities to evaluate those.

9 References

Andersson, K. (2008). *Grönytefaktorn - ett pussel med bostadsgårdens grönska.* Alnarp: Sveriges Lantbruksuniversitet, SLU.

Appelqvist, B., Aspegren, H., Fagerström, B.-M., Gruvberger, C., & Hallmer, M. (2005). Avfallskvarnar och sopsugar - från gastronomi till gasturbin. In B. Redaktör Persson, *Bo01 HÅLLBAR FRAMTIDSSTAD Lärdomar och erfarenheter* (pp. 91-95). Stockholm: Formas.

Arbetsmiljöverket. (2003, February 3). *Low-frequency electrical and magnetic fields - the precautionary principle for national authorities - guidance for decision-makers.* Retrieved June 3, 2010, from http://www.av.se/dokument/inenglish/broschures/adi_478.pdf

Baumann, H., & Tillman, A.-M. (2004). *The Hitch Hicker's Guide to LCA.* Studentlittertur: Lund.

Bengtsson, J., & Gustad, Ö. (2008). Kartläggning av materialflödet i Peabs försörjningskedja till byggarbetsplats, med SCOR. Linköping, Sverige.

Berg, S., & Lindholm, E.-L. (2005). Energy use and environmental impacts of forest operations in Sweden. *Journal of Cleaner Production* , 33-42.

Berndtsson, L. (2005). *Individuell mätning av värme och varmvatten i lägenheter.* Stockholm: Boverket.

Blomsterberg, Å. (2009). *Lågenergi - En studie av olika koncept. Energi och inneklimat.* Lund: Lunds University.

Bokalders, V., & Block, M. (2009). *Byggekologi: Kunskaper för ett hållbart byggande.* Stockholm: AB Svensk byggtjänst.

Bokalders, V., & Block, M. (2009). Grönska och odling. In V. Bokalders, & M. Block, *Byggekologi kunskaper för ett hållbart byggande* (pp. 351-370). Stockholm: AB Svensk Byggtjänst.

Bokalders, V., & Block, M. (2010). Hydrologi. In V. Bokalders, & M. Block, *Byggekologi Kunskaper för ett hållbart byggande* (pp. 383-386). Stockholm: AB Svensk Byggtjänst.

Bokalders, V., & Block, M. (2009). Installationer. In V. Bokalders, & M. Block, *Byggekologi Kunskaper för ett hållbart byggande* (pp. 105-138). Stockholm: AB Svensk Byggtjänst.

Bokalders, V., & Block, M. (2009). Planering och genomförande. In V. Bokalders, & M. Block, *Byggekologi - kunskaper för ett hållbart byggande* (pp. 158-162). Stockholm: AB Svensk Byggtjänst.

Bokalders, V., & Block, M. (2010). Tekniskt utförande . In V. Bokalders, & M. Block, *Byggekologi kunskaper för ett hållbart byggande* (pp. 139-154). Stockholm: AB Svensk Byggtjänst.

Bokalders, V., & Block, M. (2010). Trafik. In V. Bokalders, & M. Block, *Byggekologi Kunskaper för ett hållbart byggande* (pp. 403-404). Stockholm: AB Svensk Byggtjänst.

Boverket. (2008a, October 14). *Individuell mätning och debitering av flerbostadshus.* Retrieved April 13, 2010, from http://www.boverket.se/Global/Webbokhandel/Dokument/2008/Individuell_matning.pdf

Boverket. (2008b, May 26). *Hygien, hälsa och miljö.* Retrieved April 21, 2010, from http://www.boverket.se/Global/Bygga_o_forvalta/Dokument/Bygg-%20och%20konstruktionsregler/BBR_avsnitt_6/BBR_avsnitt6_hygien_halsa_o_miljo.pdf

Boverket. (2008c). *Bygga-bo-dialogen - Utbildning i byggande för hälsosam innemiljö och effektiv energi- och resursanvändning.* Karlskrona: Boverket.

Boverket. (2008d). *Bullerskydd i bostäder och lokaler.* Karlskrona: Boverket.

Boverket. (2009a). *Bygg- och fastighetssektorns miljöpåverkan.* Stockholm: Boverket.

Boverket. (2009b, december 7). *Bärförmåga, stadga och beständighet*. Retrieved mars 22, 2010, from boverket-webbplats: http://www.boverket.se/Bygga--forvalta/Bygga-nytt/Barformaga-stadga-och-bestandighet/

Boverket. (2009c). *Energihushållning enligt Boverkets Byggregler.* Karlskrona: Boverket.

Boverket. (2010, Mars 25). *Fukt i byggnader.* Retrieved April 19, 2010, from http://www.boverket.se/Bygga--forvalta/Bygga-nytt/Fukt-i-Byggnader/

Brunetto, B et al. (2009, Vol. 45 No. 4). Differences in the presence of allergens among several types of indoor environments. *Ann Ist Super Sanità* , pp. 409-414.

Brunklaus, B., Baumann, H., & Thormark, C. (2008). Miljökrav måste ställas när energikällor väljs. *Husbyggaren Nr 5* , pp. 30-33.

Burström, P. G. (1999). *Livslängdsbedömningar av byggnadsmaterial.* Lunds Tekniska Högskola, Avd. Byggnadsmaterial. Lund: Lunds Universitet.

Burström, P. G. (2007). Beständighet. In P. G. Burström, *Byggnadsmaterial - Uppbyggnad, tillverkning och egenskaper* (pp. 148-). Danmark: Studentlitteratur.

Byggsektorns Kretsloppsråd b. (n.d.). *Kretsloppsrådet Materialhushållning*. Retrieved Mars 10, 2010, from Kretsloppsrådet-webbplats: http://www.kretsloppsradet.com/home/page.asp?sid=5287&mid=2&PageId=42859

Byggsektorns Kretsloppsråd. (2010a). *Kretsloppsrådet*. Retrieved Februari 17, 2010, from Kretsloppsrådet-webbplats: http://www.kretsloppsradet.se/home/page.asp?sid=5287&mid=2&PageId=42131

Byggvarubedömningen. (n.d.). *Byggvarubedömningen*. Retrieved april 30, 2010, from Byggvarubedömningen -webbplats: http://www.byggvarubedomningen.se/sa/node.asp?node=303

Chow, T. (2010) A review on photovoltaic/thermal hybrid solar technology. *Applied Energy* 365-379

Cramo. (2010, April 13). Retrieved Aprl 13, 2010, from Cramo Energietableringar: http://www.cramo.se/Web/Core/Pages/Article.aspx?id=23450&epslanguage=SV

Dahlqvist, H. (2010, April 8). *Snart tio procent passivhus på västkusten*. Retrieved May 6, 2010, from http://www.byggvarlden.se/nyheter/energi_miljo/article139639.ece

Davis Langdon Management Consulting. (2006, June). *Literature review of life cycle costing (LCC) and life cycle assessment (LCA).* Retrieved May 8, 2010, from http://www.tmb.org.tr/arastirma_yayinlar/LCC_Literature_Review_Report.pdf

Ding, G. (2008). Sustainable construction - The role of enviornmental assessment tools. *Journal of Environmental Management* , 451-464.

Elmarsson, B., & Nevander, L. E. (1994). *Fukt handbok. Praktik och Teori.* Stockholm: AB Svensk Byggtjänst.

Energimyndigheten & Boverket. (2005, May 18). *Solceller i byggnad - nya möjligheter.* Retrieved April 4, 2010, from http://www.energimyndigheten.se/Global/Forskning/Kraft/Solceller%20i%20byggnader%20-%20OH-presentation.pdf

Energimyndigheten. (2005, June 30). *Modern belysningningsteknik - sparar energi och pengar.* Retrieved April 20, 2010, from http://webbshop.cm.se/System/ViewResource.aspx?p=Energimyndigheten&rl=default:/Resources/Permanent/StorageItem/89a27222ab4d48fca3a596ee3cde915a/ET2005_16utskrift.pdf

Energimyndigheten. (2007, November 23). *Energimärkning.* Retrieved May 3, 2010, from Energimyndigheten-webbplats: http://www.energimyndigheten.se/sv/Hushall/Din-ovriga-energianvandning-i-hemmet/Energimarkning/

Energimyndigheten. (2008, February 11). *Energikällor*. Retrieved April 13, 2010, from Energimyndigheten-webbplats: http://www.energimyndigheten.se/sv/Energifakta/Energikallor/

Energimyndigheten. (2009a, November 11). *Energistatistik för småhus, flerbostadshus och lokaler 2008.* Retrieved April 13, 2010, from http://webbshop.cm.se/System/ViewResource.aspx?p=Energimyndigheten&rl=default:/Resources/Permanent/StorageItem/2bdad6589c6a4dabb6edb7609fb1d305/ES2009_10W.pd

Energimyndigheten. (2009b). *Energiläget 2009.* Eskiltuna: Energimyndigheten.

Energimyndigheten. (2010a). *Fokus III - Byggnaden som energisystem.* Eskilstuna: Energimyndigheten.

Energimyndigheten. (2010b, February 12). *Planeringsram år 2020*. Retrieved April 13, 2010, from http://www.energimyndigheten.se/sv/Om-oss/Var-verksamhet/Framjande-av-vindkraft1/Mal-och-forutsattningar-/Nytt-planeringsmal-for-2020/

Energimyndigheten. (2010c, Januari 19). *Energieffektiva kranar och munstycken*. Retrieved Mars 02, 2010, from Energimyndigheten-webbplats : http://www.energimyndigheten.se/sv/Hushall/Din-ovriga-energianvandning-i-hemmet/Vatten-och-varmvattenberedare/Energieffektiva-kranar-och-duschmunstycken/

Energimyndigheten & Statistiska Centralbyrån. (2010, February 26). *El-, gas- och fjärrvärmeförsörjningen 2008.* Retrieved April 19, 2008, from http://www.scb.se/statistik/EN/EN0105/2008A02/EN0105_2008A02_SM_EN11SM1001.pdf

Energirådgivarna. (2005, June 24). *Energideklarering av bostadsbyggnader - Delområde: Klimatskärm.* Retrieved April 22, 2010, from Energirådgivarna-webbplats: http://www.energiradgivarna.com/siteadmin/upload/pdfarkiv/delrapport_klimatskarm.pdf

Erlandsson, M. (2003). *Miljöanpassade byggnader - specifika regler för bedömning av byggnader i ett livscykelperspektiv.* Stockholm: Miljöinstitutet IVL.

Europeiska kommissionen. (2009, december 12). *Klimatåtgärder - bättre energieffektivitet*. Retrieved maj 13, 2010, from Europeiska kommissionen - Klimatåtgärder: http://ec.europa.eu/climateaction/eu_action/energy_efficient/index_sv.htm

Fastighetskontoret. (2009). *Miljöanpassatbyggande Göteborg Program för bostäder.* Göteborg: Göteborgs Stad Fastighetskontoret.

Finnvedsbostäder. (2008, August 8). *Kv. Oxtorget i Värnamo - 40 lägenheter i passivhus.* Retrieved June 5, 2010, from http://www.passivhuscentrum.se/fileadmin/pdf/Rapporter_definitioner/Slutrapport_Oxtorget_2008-08-08.pdf

Forum for energieffektiva byggnader. (2009a, Oktober). *Kravspecifikation för Passivhus.* Retrieved Mars 1, 2010, from Energieffektiva byggnader: http://www.energieffektivabyggnader.se/download/18.712fb31f12497ed09a58000142/Kravspecifikation_Passivhus_version_2009_oktober.pdf

Forum för Energieffektiva byggnader. (2009b, Juli). *Mätning och Verifiering - Underlag till kriteriedokument till Passivhus och Minergihus*. Forum för Energieffektiva byggnader.

Frenander, C (2009). *Vägledning för samordnade leveranser.* Retrieved June 9, 2010, from http://www.msr.se/Documents/publikationer/vagledn/vagledn_samordnade_leveranser.pdf

FSC Sverige (n.d.). *Statistik och fakta*. Retrieved Februari 22, 210, from FSC Sverige-webbplats: http://fsc-sverige.perseid.se/statistik-och-fakta

FSC International Center. (2010). *Global FSC certificates: type and distribution.* Bonn, Germany: Forest Stewardship Council.

Fuller, S., & Petersen, S. (1995, February). *Life-cycle costing manual.* Retrieved May 8, 2010, from http://www.uniformat.com/support-files/nist-handbook-135.pdf

Gangolells et al. (2009) *A methodology for predicting the severity of environmental impacts related to the construction process of residential buildings.* Building and Environment Vol. 44 558-571

Geoscape Canada (2008, Mars 1). *Radon: gas from the earth*. Retrieved 2010, June 10 from Natural Resources Canada http://geopanorama.rncan.gc.ca/whitehorse/radon_e.php

Green roofs (n.d). *What is a green roof?* Retrieved 2010, June 10, from Green Roof-Augustenborgs Botanical Roof Garden: http://www.greenroof.se/?pid=19

Gryaab. (2009). *Miljörapport enligt miljöbalken 2008.* Göteborg: Gryaab.

Grönskande levande gårdar och närsamhällen. (2003). Vatten som resurs på gården. Stockholm, Stockholms Län, Sverige.

Gyproc. (2008, November18 April). *Byggnadsakustik.* Retrieved April 14, 2010, from http://www.gyproc.se/files/PDF/Sweden/HB7/HBKap4.1.pdf

Göteborgs Energi. (2009). *EMAS redovisning 2008 Göteborgs energi fjärrvärmeproduktion.* Göteborg: Göteborgs Energi.

Göteborg stad, (2006, May) *Extrema vädersituationer - hur väl rustat är Göteborg?* Göteborg: Göteborgs Stad. Retrieved June 9, 2010 from http://www.goteborg.se/wps/wcm/connect/1a78480042171f9c9edcff3d2a09bb7a/huvudrapport_extrema_vadersituationer_maj+2006.pdf?MOD=AJPERES&CONVERT_TO=URL&CACHEID=1a78480042171f9c9edcff3d2a09bb7a

Göteborgs stad et al. (2009, November 4). *Miljözon. Tunga fordon - lastbilar och bussar i Sverige.* Retrieved April 9, 2010, from http://www2.trafikkontoret.goteborg.se/resourcelibrary/Miljozon_2009-11-04.pdf

Göteborgs Stad. (2009). *Extrema väderhändelser Fas 2.* Göteborg: Göteborgs stad.

Harvey, D. L. (2007). *A Handbook on Low-Energy Buildings and District-Energy system.* Earthscan: London.

Hastings, R., & Wall, M. (2006). *Sustaianble Solar Housing, Volume 2.* London: Earthscan publications.

Hatami, Valid (2007) *Kartläggning av energianvändning under byggfasen vid nyproduktion av flerbostadshus.*Uppsala:Uppsala Universitet Retrived at June, 3 2010 http://www.teknik.uu.se/ftf/education/effektiv_energi_byggn/bredvid/examensarbeten/Valid_Hatami_07.pdf

Hjort (2002).*Ekologi-för miljöns skull*. Stockholm:Liber p.272-274

Hult, M., & Malmqvist, T. (2005). *Miljövärdering av bebyggelse, Innemiljövärdering, Ecoeffectmetoden.* Gävle: Högskolan i Gävle, Byggd Miljö & KTH, Bebyggelseanalys.

Humpreheys, M., & Nicol, J. (2002). Adaptive thermal comfort and sustainable thermal standards for buildings. *Energy and building Vol. 3* , 563-572.

Hållén, J. (2010, Mars 22). *Så går huset med plus*. Retrieved May 3, 2010, from http://www.nyteknik.se/nyheter/energi_miljo/energi/article742098.ece

Höjer, e. a. (2008). Scenarios in selected tools for environmental systems analysis. *Journal of Cleaner Production* , 1958-1970.

IVL Svenska Miljöinstitutet. (2004, February). Retrieved April 20, 2010, from System Hållbara Byggnader: Bedömningsgrunder för innemiljön: http://www3.ivl.se/rapporter/pdf/B1604.pdf

Jagemyr, L., & Olsson, D. (2008). *Minergi. En förstudie av förutsättningar att införa Minergie i Sverige.* Göteborg: CIT Energymanagement AB.

Jansson, U. (2008). *Passive houses in Sweden. Experiences from design and construction phase.* Lund: Lunds University.

Johansson, A.-M. (2007). *Regeringsuppdrag om Bättre information om farliga ämnen i byggmaterial.* Stockholm: Kemikalieinspektionen.

Johansson, D., & Stjernedal, M. (2005). *Entrepreörens verktyg för fuktsäkert byggande - rekommandationer och rutiner.* Göteborg: Chalmers Tekniska Högskola - Institutionen för bygg- och miljöteknik.

Johansson, G., & Jansa, A, justeringar av Bygga-bo-dialogens tekniska råd. (2009). *Miljöklassad byggnad- Ny/projekterad byggnad.* Karlskrona: Boverket Bygga-bo-dialogen.

Karolinska Institutet. (2009, november 27). *Partiklar - Institutet för miljömedicin (IMM)*. Retrieved april 28, 2010, from Karolinska Institutet-webbplats: http://ki.se/ki/jsp/polopoly.jsp?d=11353&a=5712&cid=11355&l=sv

Kellner, G., & Stålbom, G. (2001). *Byggande och Miljö. Om hälsa, välbefinnande och hållbar utveckling.* Stockholm: Byggförlaget.

Kemi. (2007, Mars 13). *Formaldehyde*. Retrieved June 3, 2010, from http://www.kemi.se/templates/Page.aspx?id=4783

Kemikalieinspektionen. (2006, november 13). *Lösningsmedel-KemI*. Retrieved mars 15, 2010, from Kemikalieinspektionen: http://www.kemi.se/templates/Page.aspx?id=3687

Kemikalieinspektionen. (2006). *Prioriteringsguiden-PRIO*. Retrieved mars 12, 2010, from KemI-webbplats: http://www.kemi.se/templates/PRIOframes____4045.aspx

Kohler, N. (1999). The relevance of Green Building Challange: an observer's perspective. *Building Research & Information* Vol. 27, pp. 309-320.

Kretsloppsrådet. (2007, Juni). *Byggvarudeklarationer - Kretsloppsrådets riktlinjer.* Retrieved May 13, 2010, from http://www.kretsloppsradet.com/home/page.asp?sid=5287&mid=2&PageId=45786

Kruuse, A., & Widarsson, L.-E. (2005). Första steget mot myllrande mångfald. In B. Persson (Ed.), *Bo01 Hållbar Framtidsstad - lärdomar och erfarenheter* (pp. 129-142). Stockholm: Formas.

Kungliga Ingenjörsvetenskapsakademin. (2002). *Energianvändning i bebyggelsen. En faktarapport inom IVA-projektet energiframsyn Sverige i Eurpoa.* Retrieved April 13, 2010, from http://www.iva.se/upload/Verksamhet/Projekt/Energiframsyn/Bebyggelse%20v1.pdf

Kvarnbäck, M. (2009). *Highlights from the EU conference on urban development and climate change.* Stockholm: Miljödepartementet.

Kvillebäckens konsortium. (2010). *Kvillebäcken - Om Kvillebäcken*. Retrieved Februari 19, 2010, from Kvillebäcken.

Langseth, L. (2009, nr. 5). Klimatsmarta byggnader för morgondagens klimat. *Samhällsbyggaren* , pp. 8-10.

Lavenergiboliger.no. (2005, October 23). *Hvordan planlegge en lavenergibolig*. Retrieved April 4, 2010, from http://www.lavenergiboliger.no/hb/lavenergi.nsf/viewWebAktuelt/21D511B305509669C125708F004520D1?OpenDocument

Leu, E. & Ottoson, M. (2002). *Miljözon för distribution av gods i Göteborgs innerstad - ökad miljökrav för fordon*. Stockholm. Institutet for transportforskning.

Linotech. (2007). *Linoguard*. Retrieved 04 19, 2010, from Linotech-webbplats: http://www.linotech.se/sv/produkter/linogard

Livsmedelsverket. (2009, december 15). *Koppar*. Retrieved april 7, 2010, from Livsmedelsverket-webbplats: http://www.slv.se/sv/grupp1/Risker-med-mat/Metaller/Koppar/

Löfgren, S., & Olofson, H. (2002). *Övervakning av akvatiska system i brukad skog - nuvarande status och förslag till framtida program.* Uppsala: Sveriges Lantbruksuniversitet.

Malmö Stad. (2009 October 10) *Projektering-Dagvatten*. Retrieved 2010, June 10 from Teknisk handbok: http://www.projektering.nu/pages/proj/proj2.html

McManus, A., Gaterell, M.R., & Coates.L.E. (2010). The potential of the Code for Sustainable Homes to deliver genuine "sustainable energy" in the UK soical housing sector. *Energy Policy* , 2019-2019.

Miljöåtagande för östra Kvillebäcken. (2009) *Miljöåtagande för östra Kvillebäcken.*

Miljöfordon. (2007, augusti 30). *Syntetisk diesel*. Retrieved maj 04, 2010, from Miljöfordon-webbplats: http://www.miljofordon.se/miljoaspekter/miljofakta/syntetisk-diesel.aspx

Mjörnell, K., & Sikander, E. (2005, 5). ByggaF Metod för fuktsäker byggprocess. *Vbyggaren* , pp. 36-38.

Mjörnell, K., & Wihlborg, C. (2007, October 4). Retrieved April 19, 2010, from Fuktsäkring i byggprocessen: http://www.fuktsakerhet.se/sv/fakta/Documents/5_05_21.pdf

Mumovic, D. & Santamouris, M. (2009). *Sustainable Building Design and Engineering : An Integrated Approach to Energy, Health and Operational Performance.* London: Earthscan.

Muthukrishnan, S. (2006). *Proceedings of the Annual International Conference on Soils, Sediments, Water and Energy - Treatment Of Heavy Metals In Stormwater Runoff Using Wet Pond And Wetland Mesocosms.* USA: U.S. EPA.

Namiesnik, J. (1992). Indoor Air Quality (IAQ), Pollutants, their Sources and Concentration Levels. *Building and Environment , Vol. 27* (Nr. 3), pp. 339-356.

Naturvårdsverket. (2005, September). *Formaldehyde - En kunskapssammanställning och riskbedömning.* Retrieved June 3, 2010, from http://www.naturvardsverket.se/Documents/publikationer/620-5399-X.pdf

Naturvårdsverket. (2008a, februari 19). *Så påverkas Sverige*. Retrieved mars 22, 2010, from Naaturvårdsverket-Swedish EPA -webbplats: http://www.naturvardsverket.se/sv/Klimat-i-forandring/Sa-forandras-klimatet/Sa-paverkas-Sverige/

Naturvårdsverket. (2008b, februari 19). *Behov av anpassning*. Retrieved mars 22, 2010, from Naturvårdsverket-webbplats: http://www.naturvardsverket.se/sv/Klimat-i-forandring/Att-anpassa-samhallet/Behov-av-anpassning/

Naturvårdsverket. (2008c). Retrieved April 23, 2010, from Miljömålen - nu är det bråttom: http://www.naturvardsverket.se/Documents/publikationer/620-1264-9.pdf

Naturvårdsverket. (2009a, November 20). *Om miljömålen - Miljömålsportalen*. Retrieved Februari 16, 2010, from Miljömålsportalen - webbplats: http://www.miljomal.nu/Om-miljomalen/

Naturvårdsverket. (2009b). *Miljömålen - i halvtid de Facto 2009.* Bromma: Naturvårdsverket.

Naturvårdsverket. (2009c, december 29). *Utsläpp av flyktiga organsiska ämnen*. Retrieved april 30, 2010, from Miljömålsportalen.webbplats: http://www.miljomal.se/Systemsidor/Indikatorsida/?iid=82&pl=1

Naturvårdsverket. (2009d, juni 9). *Utfasning av farliga ämnen 2007/2010*. Retrieved april 7, 2010, from Miljömålsportalen-webbplats: http://miljomal.nu/4-Giftfri-miljo/Delmal/Utfasning-av-farliga-amnen-20072010/

Naturvårdsverket. (2009e, juni 9). *Levande sjöar och vattendrag*. Retrieved april 8, 2010, from Miljömålsportalen-webbplats: http://www.miljomal.nu/8-Levande-sjoar-och-vattendrag/

Naturvårdsverket. (2009f, Mars 30). *Delmål*. Retrieved june 9, 2010 from http://www.miljomal.nu/15-God-bebyggd-miljo/Delmal/

Naturvårdsverket. (2009g, juni 9). *Grundvatten av god kvalitet*. Retrieved april 8, 2010, from Miljömålsportalen: http://www.miljomal.nu/9-Grundvatten-av-god-kvalitet/

Miljömålsrådet. (2009h, juni 9). *Hav i balans samt levande kust och skärgård*. Retrieved april 8, 2010, from Miljömålsportalen-webbplats: http://www.miljomal.nu/10-Hav-i-balans-samt-levande-kust-och-skargard/

Naturvårdsverket. (2009j, Mars 30). *God bebyggd miljö - definition*. Retrieved Februari 16, 2010, from Miljömålsportalen - webbplats: http://www.miljomal.nu/15-God-bebyggd-miljo/Definition/

Naturvårdsverket. (2009k, juni 9). *Grusanvändning-Miljömålsportalen*. Retrieved mars 8, 2010, from Miljömålsportalen-webbplats: http://www.miljomal.se/Systemsidor/Indikatorsida/?iid=62&pl=1

Naturvårdsverket. (2009l, november 5). *Ramdirektivet för avfall*. Retrieved april 15, 2010, from Naturvårdsverket Swedish EPA-webbplats: http://www.naturvardsverket.se/sv/Produkter-och-avfall/Avfall/Lagar-och-regler-om-avfall/Ramdirektivet-for-avfall/

Naturvårdsverket. (2009m, februari 20). *Miljöpåverkan från avfall*. Retrieved april 15, 2010, from Naturvårdsverkeyt Swedish EPA-webbplats: http://www.naturvardsverket.se/sv/Produkter-och-avfall/Avfall/Mal-strategier-och-resultat/Miljopaverkan-fran-avfall/

Naturvårdsverket. (2009n, Juni 9). *Avfall (2005-2015)*. Retrieved Mars 11, 2010, from Miljömålsportalen-webbplats: http://www.miljomal.se/15-God-bebyggd-miljo/Delmal/Avfall-2005-2015/

Naturvårdsverket. (2009o, juni 9). *God inomhusmiljö (2010/2015/2020)*. Retrieved april 27, 2010, from Miljömålsportalen: http://miljomal.nu/15-God-bebyggd-miljo/Delmal/God-inomhusmiljo-2010-2015-2020/

Naturvårdsverket. (2009p, Mars, 30) *Strategin för giftfria och resurssnåla kretslopp*. Retrieved June 10, 2010, from Naturvårdsverkets-webbplats: http://www.miljomal.nu/Tre-atgardsstrategier/Giftfria-och-resurssnala-kretslopp/

Naturvårdsverket. (2010a, januari 22). *IPPC-direktivet begrepp bästa tillgängliga teknik (BAT)*. Retrieved mars 24, 2010, from Naturvårdsverket-webbplats: http://www.naturvardsverket.se/sv/Verksamheter-med-miljopaverkan/Industrier/Basta-mojliga-och-basta-tillgangliga-teknik/IPPC-direktivets-begrepp-basta-tillgangliga-teknik-BAT-/

Naturvårdsverket. (2010b, May 31). *Ett rikt växt- och djurliv.* Retrieved June 9, 2010 from Miljömålsportalen-webbplats http://www.miljomal.se/16-Ett-rikt-vaxt--och-djurliv/

Naturvårdsverket 2010c, May 31).*Ingen övergödning*. Retrieved June 9, 2010 from Miljömålsportalen-webbplats http://www.miljomal.se/7-Ingen-overgodning/

Naturvårdsverket 2010d, May 31.*Säker strålmiljö*. Retrieved June 9, 2010 from Miljömålsportalen-webbplats http://www.miljomal.se/6-Saker-stralmiljo/

Naturvårdverket, 2010e, May 31.Hushållsavfall. Retrieved June 9, 2010 from Miljömålsportalen-webbplats http://www.miljomal.se/Systemsidor/Indikatorsida/?iid=40&pl=1

Nordic Ecolabelling. (2008). *Nordic Ecolabelling of indoor paint and varnishes.* Stockholm: Nordic Ecolabelling.

Norling Mjörnell, K. (2007). *ByggaF Metod för fuktsäker byggprocess.* Göteborg: Sveriges Byggindustriter.

Näringsdepartementet. (2008, Mars 11). Retrieved 20 April, 2010, from Ett energieffektivare Sverige: http://www.sweden.gov.se/content/1/c6/10/01/76/3f6ab8ff.pdf

Nässen, J., & Holmberg, J. (2005, May). Energy efficency - a forgotten goal in the Swedish building sector? *Energy Policy* , pp. 1037-1051.

PEFC. (2010). PEFC och FSC - standarder för ett uthålligt och ansvarsfullt skogsbruk. Retrieved June, 9 2010 from http://www.pefc.se/media/fakta_om_certifiering_av_skogsbruk_100415.pdf

Persson, B. (2005). Grönytefaktorn - för första gången i Sverige. In B. r. Persson, *Bo01 Hållbar Framtidsstad lärdomar och erfarenheter* (p. 52). Stockholm: Formas.

Petersson, B.-Å. (2004). *Tillämpad byggnadsfysik.* Lund: Studentlitteratur.

Projektet Grön Kemi. (2008, August 14). *Alkylatbensin.* Retrieved April 30, 2010, from http://www.gronkemi.nu/alkylat.html#upp

Rapp, T. (2002). *Manual - Fuktmätning i Betong.* Stockholm: Sveriges Byggindustrier.

Regeringen. (2010, Januari 20). *Hållbar Stadsutveckling*. Retrieved Februari 16, 2010, from Regeringen och Regeringskansliet - webbplats: http://www.regeringen.se/sb/d/3358/a/66735

Rolén, C. (2005). Miljövärdering - en komplicerad uppgift. In B. Persson, *Bo01 Hållbar framtidstad Lärdomar och erfarenheter* (pp. 53-63). Stockholm: Formas.

Roth, A., & Falk, M. (2009, januari 8). Havsnivåhöjning och samhällsviktiga anläggningar. Göteborg, Västra Götaland, Sverige: Trafikkontoret Göteborgs Stad.

Samuelsson, I. (1998). *Kriterier för sunda byggnader och material.* Karlskrona: Boverket, Byggavdelningen.

Sandqvist, J. (2008). *Luleå Tekniska Universitet.* Retrieved April 27, 2010, from Väderskydd inom bygg- och anläggningsbranschen: http://epubl.ltu.se/1402-1560/2008/06/LTU-YTH-EX-0806-SE.pdf

Sikander, E. (2005). *Byggherrens arbete for fuktsäker byggnad. Krav, uppföljning, hjälpmedel och erfarenheter.* Borås: SP, Sveriger forsknings och provningsinstitut.

Sikander, E. (2000). Fuktsäkerhet - en viktig del i en byggnads miljöpåverkan. *Bygg & Teknik* p. 28.

Sincerely sustainable (2009, September 14) *Paper And Timber Industry's SFI 'Green Certification' Poised For LEED Inclusion*. Retrieved June, 10 from http://www.sincerelysustainable.com/buildings/paper-and-timber-industrys-sfi-green-certification-poised-for-leed-inclusion

Socialstyrelsen. (2006). *Kemiska ämnen i inomhusmiljön.* Socialstyrelsen.

Socialstyrelsen. (2009, Juni 3). *Hälsoeffekter av buller*. Retrieved April 4, 2010, from Socialstyrelesen-webbplats: http://www.socialstyrelsen.se/halsoskydd/inomhusmiljo/buller/halsoeffekter

SP Sveriges Tekniska Forskningsinstitut, a. (n.d.). Retrieved April 19, 2010, from P-märkt innemiljö: http://www.sp.se/sv/index/services/indoor_environment/P-mark/Sidor/default.aspx

SP Sveriges Tekniska Forskningsinstitut, b. (n.d.). *Fuktsäkra Byggnader. Väderskydd*. Retrieved April 19, 2010, from http://www.fuktsakerhet.se/sv/fukt/vaderskydd/Sidor/default.aspx

Statistiska Centralbyrån. (2010, February 26). *El-, gas- och fjärrvärmeförsörjningen 2008.* Retrieved April 19, 2008, from SCB-webbplats: http://www.scb.se/statistik/EN/EN0105/2008A02/EN0105_2008A02_SM_EN11SM1001.pdf

Stockholms Stad, (2005, Mars 11) *Vatten som resurs på gården.* Retrieved June 10, Mars from Stockholms stad- webbplats http://www.stockholm.se/PageFiles/50655/Gronskande%20gardar/file_87660%20Vatten%20som%20resurs%20Material.pdf.

Stockholms stad. (2008, Juni 17). *Miljöbyggande*. Retrieved Februari 17, 2010, from Stockholm stad-webbplats: http://www.stockholm.se/miljobygg

Stockholms stadsbyggnadskontor. (2007). *Stockholms Stad-webbplats.* Retrieved 21 April, 2010, from Fuktskyddsbeskrivning (Fuktsäkerthetsprojektering enligt Boverkets byggregler avsnitt 6:5):
:www.stockholm.se/Global/Stads%C3%B6vergripande%20%C3%A4mnen/Bostad%20&%20Hush%C3%A5ll/BygglovBygganm%C3%A4lan/Fuktskyddsbeskrivning%20(ver%2013).pdf

Strålsäkerhetsmyndigheten. (2010, februari 18). *Magnetfält och trådlös teknik - Allmänhet.* Retrieved april 21, 2010, from Strålsäkerhetsmyndigheten-webbplats: http://www.stralsakerhetsmyndigheten.se/Allmanhet/Magnetfalt--tradlos-teknik/

Sundell, J. (2004). On the history of indoor air quality and health. *Indoor air* , 51-58.

Svebio. (2008, Mars 31). *Rapport om potentialen for bioenergi.* Retrieved April 12, 2010, from Svebio-webbplats: http://www.svebio.se/attachments/33/902.pdf

Svensk Byggtjänst. (n.d.). *Ljudklassning av bostäder*. Retrieved April 14, 2010, from http://ama.byggtjanst.se/Default.aspx?articleId=98&Typ=AmaNytt

Svensk Fjärrvärme AB. (2009). *Statistik 2008.* Retrieved April 15, 2010, from http://www.svenskfjarrvarme.se/index.php3?use=biblo&cmd=detailed&id=1465

Sveriges Byggindustrier. (2009, November 04). *Energi & Miljö*. Retrieved Mars 11, 2010, from Sveriges Byggindustrier-webbplats: http://www.bygg.org/miljofragor.asp

Sveriges Färgfabrikanters Förening. (2005). *Miljöguide vid val av byggnadsfärg.* Stockholm: Sveriges Färgfabrikanters Förening

Sveriges Geologiska Undersökning-SGU, a.(n.d.) *Geologisk information för att planera och bygga*. Retrieved april 14, 2010, from SGU-webbplats: http://www.sgu.se/sgu/sv/samhalle/planering-byggande/planering-byggande_info.html

Sveriges Geologiska Undersökning, b. (n.d.). *Ballast, naturgrus och krossberg*. Retrieved april 14, 2010, from SGU-webbplats: http://www.sgu.se/sgu/sv/samhalle/planering-byggande/ballast/index.html

Sveriges Geologiska Undersökning, c (n.d) *Isälvsformationer.* Retrieved June, 10, 2010 from Sveriges Geologiska Undersökninghttp://www.sgu.se/sgu/sv/geologi/jordtacket/under-istiden/isalvssediment-bilder.html

Sveriges Geologiska Undersökning. (2009). *Grus, sand och krossberg - Produktion och tillgångar 2008.* Uppsala: SGU.

Sveriges Lantbruksuniveristet. (n.d.). *Centrum för biologisk mångfald*. Retrieved april 12, 2010, from CBM-webbplats: http://www.cbm.slu.se/biodiv.php

SÖDRA. (n.d.). *Byggnadsakustik, ännu mer begrepp*. Retrieved April 14, 2010, from http://www.dominoplaza.com/gyproc/highwood.nsf/0/25347D3A66EA26BDC1256CC3002D5E2E?open

Thormark, C. (2002, Februari 6). A low energy building in a life cycle— its embodied energy, energy need for operation and recycling potential. *Building and Environment* , pp. 429-435.

U.S. Green Building Council. (2008, January 18). *LEED for homes rating systems.* Retrieved 4 April, 2010, from http://www.usgbc.org/ShowFile.aspx?DocumentID=3638

Wall, M. (2006). Energy-efficent terrace houses in Sweden - Simulations and measurements. *Energy and Buildings* , 627-634.

Vattenfall. (2005). *Livscykelanalys Vattenfalls el i Sverige.* Stockholm: Vattenfall.

Venkatarama Reddy, B., & Jagadish, K. (2003). Embodied energy in common and alternative building materials and technologies. *Energy and Buildings* , 129-137.

World Commission on Environment and Development. (1987). *Report of the World Commission on Environment and Development: Our Common Future.* 1987: United Nations.

World Health Organization. (2009). *WHO guidelines for indoor air quality: dampness and mould.* Copenhagen: World Health Organization.

Ångpanneföreningen. (2009, Augusti 26). Energi och miljöfakta. Stockholm, Sverige.

Åkerlöf, L. (2007). *Bullerskydd. Byggvägledning 11.* Stockholm: Svensk byggtjänst.

Appendix A

<u>Plants suitable for allergic persons</u>

Apple trees
Pear tree
Cherry tree
Swedish whitebeam
Mountain ash
Chestnut tree
Pine
Spruce
Currant
Gooseberry
Dogrose
Raspberry
Clematis
Maple tree
Roses
Campanula
Perennial crowfoot
Rockery plant
Vegetables such as carrot, dill, parsley, chives, lettuce
Species of grass flowering lately

<u>Plants not suitable for allergic person</u>

Larger grass areas
Birch
Sallow
Hazel
Alder
Aspen
Elm
Lime tree, strongly smelling
Bird cherry
Jasmine
Mock Orange
Stickleback
Broom
Hyacinth
Lily of the valley
Cowslip
Composite plants such as oxeye daisy, marigold, chrysanthemum

Available in (Kellner & Stålbom, 2001)

Appendix B

Criteria for VOC content in paint (g/l) which are required for eco-labeled paint (Nordic Ecolabelling, 2008). The criteria is applied to reach fulfilled level on the requirement E4 under environmental impact.

Criterion №3: VOC content applicable to all products	
Category (indoor)	Requirement, VOC ≤
Interior matt (walls/ceiling) (Gloss <25@60°)	15 g/l
Interior glossy (walls/ceiling) (Gloss >25@60°)	60 g/l
Interior/exterior trim and cladding paints for wood and metal	90 g/l
Interior/exterior trim varnishes and woodstains, including opaque woodstainsincluding undercoats	75 g/l
Interior/exterior minimum build woodstains	75 g/l
Primers & Binding primers	15 g/l
1-pack performance coatings	100 g/l
2-pack reactive performance coatings for specific end uses such as floors	100 g/l
Decorative effect coatings*	90 g/l

*All values are measured and should be given ‘including water at ready to use’ concentration

Criterion №3: VOC content applicable to all products	
Category (outdoor)	Requirement, VOC ≤
Coatings for exterior walls of mineral substrate	40 g/l
Interior/exterior trim and cladding paints for wood and metal including undercoats	90 g/l

Interior/exterior trim varnishes and woodstains, including opaque woodstains	90 g/l
Interior/exterior minimum build woodstains	75 g/l
Primers & Binding primers for exterior use	15 g/l
1-pack performance coatings	100 g/l
2-pack reactive performance coatings for specific end uses such as floors	100 g/l

Appendix C

Retrieved from:

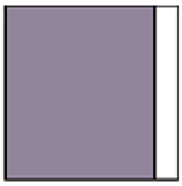
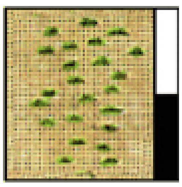
http://www.stadtentwicklung.berlin.de/umwelt/landschaftsplanung/bff/en/bff_berechnung.shtml

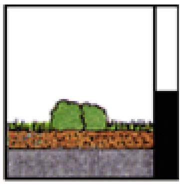
The BAF expresses the ratio of the ecologically effective surface area to the total land area.

$$\text{BAF} = \frac{\text{ecologically-effective surface areas}}{\text{total land area}}$$

In this calculation, the individual parts of a plot of land are weighted according to their "ecological value".

Types of surfaces and weighting factors:
(Surface types not mentioned can be calculated as long as they have a positive effect on the ecosystem)

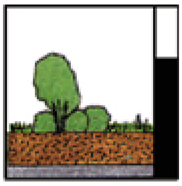
Weighting factor / per m² of surface type		Description of surface types
	Sealed surfaces **0.0**	Surface is impermeable to air and water and has no plant growth (e.g., concrete, asphalt, slabs with a solid subbase)
	Partially sealed surfaces **0.3**	Surface is permeable to water and air; as a rule, no plant growth (e.g., clinker brick, mosaic paving, slabs with a sand or gravel subbase)
	Semi-open surfaces **0.5**	Surface is permeable to water and air; infiltration; plant growth (e.g., gravel with grass coverage, wood-block paving, honeycomb brick with grass)



Surfaces with vegetation, unconnected to soil below

0.5

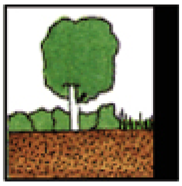
Surfaces with vegetation on cellar covers or underground garages with less than 80 cm of soil covering



Surfaces with vegetation, unconnected to soil below

0.7

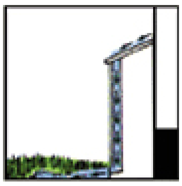
Surfaces with vegetation that have no connection to soil below but with more than 80 cm of soil covering



Surfaces with vegetation, connected to soil below

1.0

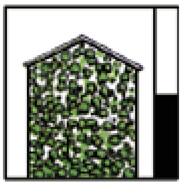
Vegetation connected to soil below, available for development of flora and fauna



Rainwater infiltration per m² of roof area

0.2

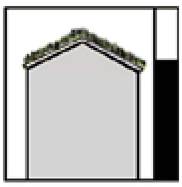
Rainwater infiltration for replenishment of groundwater;
infiltration over surfaces with existing vegetation



Vertical greenery up to a maximum of 10 m in height

0.5

Greenery covering walls and outer walls with no windows;
the actual height, up to 10 m, is taken into account



Greenery on rooftop

0.7

Extensive and intensive coverage of rooftop with greenery