Universiteit Utrecht

Energy and Material efficiency

Consultancy paper

Improving the sustainability of buildings on the University of Utrecht campus "de Uithof"

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Abstract

Buildings generate a substantial amount of energy consumption worldwide and often have a lifetime of over fifty years. A variety of materials is used in the construction of buildings, resulting in an intense energy consumption for production and transportation to the construction site, adding to the energy footprint of a building. Hence, creating buildings with the least possible energy footprint is an imperative considering the problem of climate change that is currently happening and is potentially disastrous. In this study we focus on one of the new buildings that are about to be built in the Uithof campus of the Utrecht University: the Geotower. We try to track best practices aiming to decrease the energy footprint of the building. We focus on the technical applications that will be installed targeting better efficiency and the reduction of the energy footprint of the materials about to be used in the construction phase.

Contents

1. Introduction

Since the industrial revolution the emission of greenhouse gasses has been rising. Many negative effects like the enhancement of the greenhouse effect and climate change have been linked to this (Miller & Spoolman, 2009). In the last few decades societies few on emissions started to change. Different measures like the Kyoto protocol and the European 2020 climate targets have been implement in an attempt to decrease emissions. These sustainable measures are not only being done on a nationwide scale, but on a smaller household and company scale as well. By being more efficient, companies can reduce energy use and contribute to a more sustainable world while saving money. One of the main sources where energy can be saved is in buildings. Buildings use 25-45% of energy worldwide and are responsible for 30-40% of carbon dioxide emissions during the use phase (Worrel, 2014). Moreover, the construction of a building requires an intensive use of materials that add to the energy footprint since large amounts of energy are needed for the extraction, process and transportation. According to the fourth assessment report of IPCC buildings have the greatest potential to reduce greenhouse gas emissions as depicted in figure 1.

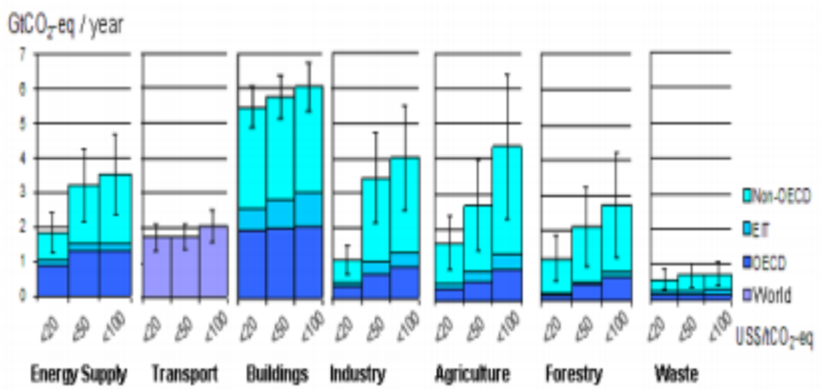

Figure 1, GHG mitigation potentials of different sectors (IPCC, 2007 in: Worrel, 2014)

Buildings represent roughly one third of the total energy consumption in the Netherlands, and cause the same share of CO_2 emissions (Worrel, 2014). According to the policy statement of the Utrecht's University (UU), they are among the most ambitious universities in the Netherlands regarding sustainability issues (Universiteit Utrecht, 2014). They view the development of a sustainable society as one of the biggest challenges of the 21st century and want to set an example by making an active contribution to this challenge. Comparably to all universities, a large share of energy use and corresponding GHG-emission is related to the utilization of the buildings. Therefore, it is key to look at their building envelope, and connected energy and materials consumption, to improve their sustainability. To contribute, this paper conducts a study on the possibilities to increase the sustainability of the university campus "de Uithof".

1.1. Aim of the project

The purpose of this study is to investigate, characterize and analyze ways to reduce the energy and material footprint of a new building that will be built at the Uithof campus in the coming years. The scope includes looking at energy and resource use throughout part of the buildings' life cycle: construction, exploitation & maintenance. The project 'Geotower', which is currently in the concept design phase, will be used in this paper as a case study. The goal is to provide an overview of possible sustainable measures that could be implemented to improve the concept design and will add to the sustainability of the building. The sustainable measures will be judged on their contribution on reducing energy consumption and material use, and ultimately an advice will be given on the application and consequences of the different measures. In this advice, technical and economic aspects of the sustainable measures will be taken into consideration. After reading this report, the reader will have an answer to the question:

What energy efficiency measures can be implemented in order to improve the energy footprint of the Geotower?

By answering this question a list of possible measures that can be implemented will be made. All these measures should be a more sustainable alternative to already planned installations and materials. Considering the university's aim to become more sustainable, making the Geotower sustainable would greatly contribute to this goal. The proposed measures can possibly be incorporated into the real Geotower project and contribute to a more sustainable Uithof campus.

1.2. The scope

Since the aim of this paper is to advice the UU on sustainable improvements within their building envelope, it is important to specify this category. Based on the life cycle of buildings, we distinguish three phases that will contribute to sustainability:

1. **Construction phase.** Sustainable improvements could be implemented in the design phase, either by implementing technologies that will reduce the energy use in the user phase or by using materials and construction methods with a low energy footprint;
2. **User phase.** Sustainable improvements could be implemented by the adjustment or the replacement of existing technical installations or by the behavioral change. Furthermore, performance could be monitored and improved.
3. **Demolition/renovation phase.** Sustainable improvements will result either from renovation or demolition.

Based on this characterization, this project focuses on the first two phases. In the design phase, decisions are made that affect the sustainability performance of buildings during these first two stages. Specifically, the scope is narrowed down to one project, namely the Geotower. The concept design for this project is currently known, but it is possible to adjust this design before the realization phase will start in July 2014. Therefore, this research has the ability to introduce sustainable improvement and affect the energy use during the construction and use phase.

1.3. The client

Since the UU is responsible for the real estate at the Uithof, the UU is recognized as the client. In the following paragraphs the different departments of the UU are described and their specific role regarding sustainability and real estate within the UU is emphasized.

1.3.1.Real Estate within the UU

Within the UU organization, different entities have a responsibility within the real estate decision-making process.

Board of directors: this department is responsible for the highest level of decision-making within the University. The supervisory board selects the members of the executive board and is responsible for supervision over the board. The members and their specific involvement with the project are explained in table 1.

Function	Name	Responsibilities/specifics
President	M.J. Oudemans	Financial responsibility
Vice President	A. Pijpers	Start of work on the 1st of April, 2014 *
Rector	b. van der Zwaan	Housing responsibility

Table 1, Responsibilities overview of the board of directors of Utrecht University

Direction Vastgoed (real estate) and Campus (V&C): this department supports the Executive Board in issues regarding housing, real estate development and maintenance. After approval of the board of directors, V&C is responsible for the project-management, including the control of the design and construction phase. They guide the design-process, in which third parties, such as architects and advisors are involved. After the final design is approved, they guide the selection-procedure of suitable construction companies. In the annual presentation V&C (2012) the department showed the following ambition:

- *Realize an energy efficiency improvement of 13% as compared to 2005 in 2016. This ambition is translated into an executive 'Energy-Efficiency Plan (EEP) 2013-2016' and is published in the notation 'University Utrecht and Sustainability'.*

The V&C department is divided into eight sub-departments. In table 2 the field of the different sub-departments is explained, including their role in the project that is covered in this advice.

ID#	Sub-department	Field	Contribution to project
1.	Project-Management	Provide initial and final advise to program-management regarding project realization (new development and redevelopment)	• Guide third parties in design- and construct phase • Final responsibility and delivery of final project to technical maintenance department
2.	Energy	Long-term energy policy development	Provides criteria and boundary conditions for project
3.	Program-Management	Long-term housing policy development	Provides criteria and boundary conditions for project
4.	Technical Maintenance and	Development maintenance planning and selection of third party	Provides criteria and boundary conditions for project and test before final acceptance of the

	Advisory	executors	project
5.	Real Estate Information	Administration of project-files and information management	ICT-architecture and interior
6.	Safety and Environment	Safety- and risk-management regarding environmental and social concerns	Not relevant
7.	Control	Financial Real-Estate administration	Not relevant
8.	Commercial-Maintenance	External and internal commercial transactions and insurance issues	Not relevant

Table 2, Role of V&C sub-departments in the realization of building projects

The different entities within the UU form a structure in which decisions regarding sustainability and housing issues are formed. This paper focuses specifically on the Project-Management-Team (PMT) since this team is responsible for the decisions that are made regarding the 'Geotower project'. Figure 2 illustrates the roles of the different entities in the design-process for new buildings, specifically the Geotower, with a central role for the PMT in the process.

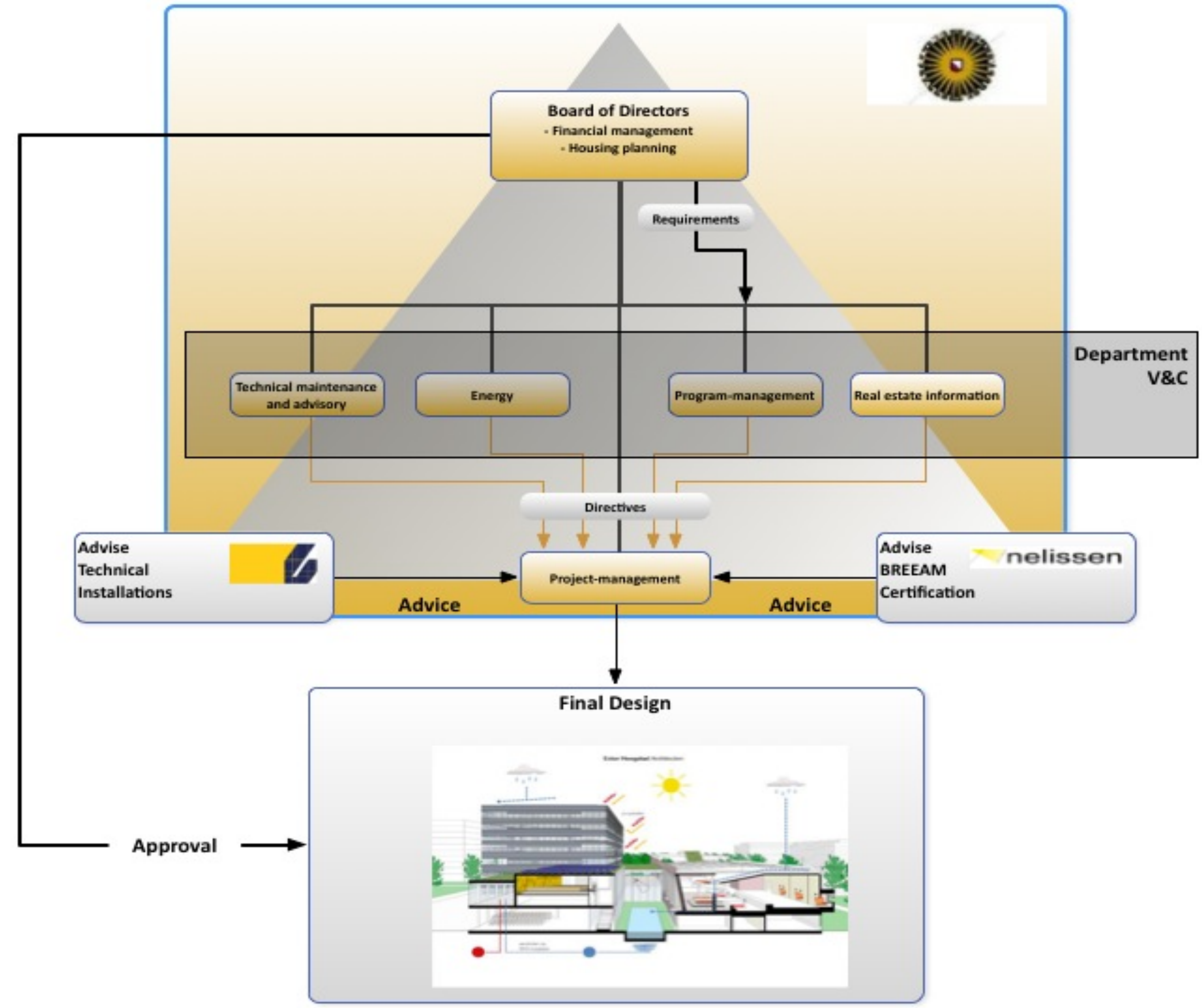

Figure 2, Visualization of the different roles of different departments within the Geotower project.

In this process, the board of directors recognizes the new housing needs and provides requirements to the program-management (V&C) to reconsider or execute their housing policy. This program-management department, as well as other V&C departments such as 'Technical Maintenance and advisory', 'Energy' and 'Real Estate Information' provide directives, which will be used as guidelines by the program-management. To complete the PMT, the Project-management department selects a number of project managers. These managers select a number of external (consultancy) companies and architects and are responsible for the design process and, finally, the realization of the building.

1.3.2. Project organization

Since the Geotower is chosen as the case study, this paper has the opportunity to act upon the recent development in the design process, which resulted in the concept design. Figure 3 illustrates the design-process for the Geo Tower and the contribution of the project team in this process.

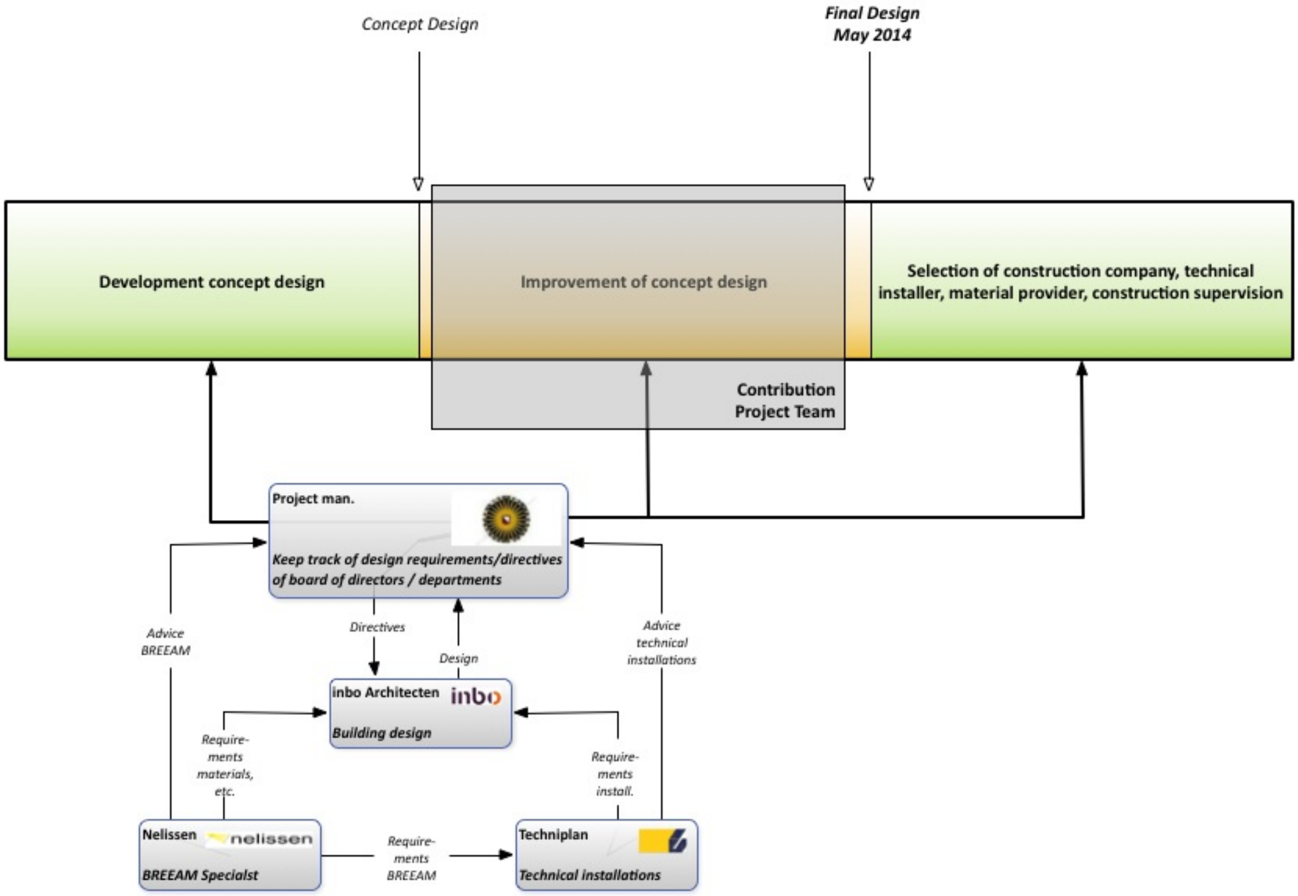

Figure 3, Contribution of Project Team in Geotower design process

The most important interactions among the involved companies and departments are listed below:

- Nelissen is the advising company that is responsible for the BREEAM calculations. They provide information to the Project-managers and the other external advisors about the requirements to meet the BREEAM level 4 'excellent';
- Techniplan provides advice to the project-managers and the architect (Inbo) related to technical installations and following design issues;
- Inbo receives information from the BREEAM and technical consultants. Together with the directives established and prepared by the project-managers, this forms the basis for the building design.

1.4. Overview of paper

This paper aims to provide an overview of the possibilities for the implementation of sustainable measures at the Uithof. After the aim, scope, client and method are described in the first chapter, the background information about the casus 'the Geotower' will be provided in the second chapter. In the third chapter, background information about the sustainable vision of the UU, the energy provision at the UU and the applied sustainable certification framework is given. In addition, in this chapter, the building life cycle, which forms the structure for the rest of the essay, is covered. In the fourth chapter, the concept design and the outcomes for the different stages in the building life cycle is analyzed. In the fifth chapter, the market analysis and the overview of best practices are applied to the concept design. Therefore, this chapter consists of opportunities for sustainable improvements. Again, the building life cycle is used as guideline. Lastly, the discussion covers advisement about best practices in the design process and 'lessons to be learned' for new building projects in the future.

2. Background information for Utrecht University Campus

In this chapter some background information is provided, which gives an overview of the context of the Geotower.

2.1. Sustainability at the Utrecht University

Sustainability has been given an important place in Utrecht University's strategies. In the 2012 strategic plan, sustainability has been made one of the four strategic theme's (UU, 2012). This way the university wants to take its societal responsibility to contribute in an ecological, economic and social manner to a sustainable future (UU, 2014b). One of the ways to achieve this is to conduct focused research on sustainable subthemes , such as water & climate, energy & resources, sustainable cities & regions, smart materials and governance of transitions. Scientists of different backgrounds work together to find multidisciplinary solutions for these sustainability issues.

The role of sustainability has gained high priority in their daily operations. One of its 2010-2020 goals is to make its business operation sustainable. To succeed, the UU focuses on energy, development, management, mobility and procurement. An expert team with members of different task groups was created (UU, 2014a) to guide the transition to a more sustainable future. One of the most visible examples of their sustainable vision is the development of a program for sustainable housing. According to the UU, the aim of this program is to: *"Ensure that buildings and building environment contribute to the health, welfare and comfort of people, where impacts on humans and the environment now and in the long term is taken into account"* (UU, 2014c). One of the most important points in this program is that all new university buildings should be built in accordance with the BREAAM-NL Excellent criteria (UU, 2012).

2.2. Energy at the Uithof

As stated in their sustainability program, the UU considers energy use and energy provision as an important part of their sustainable performance. Their current policies and decisions that are made in the past, are of large influence on the opportunities for energy efficiency improvements and sustainable energy provision.

2.2.1.Combined Heat and Power (CHP) plant

The Utrecht University has four ways to get the energy required to keep the building operational and comfortable. In the city center this is done by buying 100% green electricity from the power companies Delta and Electrabel. The heat for these buildings is provided by district heating from Eneco. The majority of this heat is residual heat from electricity plants in the city area (V&C, 2012b).

At the Uithof the university derives its power trough different means. 'Energy Company UU' generates all used electricity, which is the universities own power plant. Natural gas is bought from Delta to power the 6 gas engines of the plant that have a combined power of 13 MW. The residual heat from this plant is used to heat the buildings at the Uithof, making this a Combined Heat and Power (CHP) plant (UU, 2005). Since it started operation in 2005, the universities CO2 emission went down with 32% in 2011 (UU, 2014a). This is mainly due to a combined generation with a total efficiency of 80.5%, resulting in a 23% saving of energy compared to separate generation (V&C, 2013). In figure 4, the activity of the CHP plant is visualized.

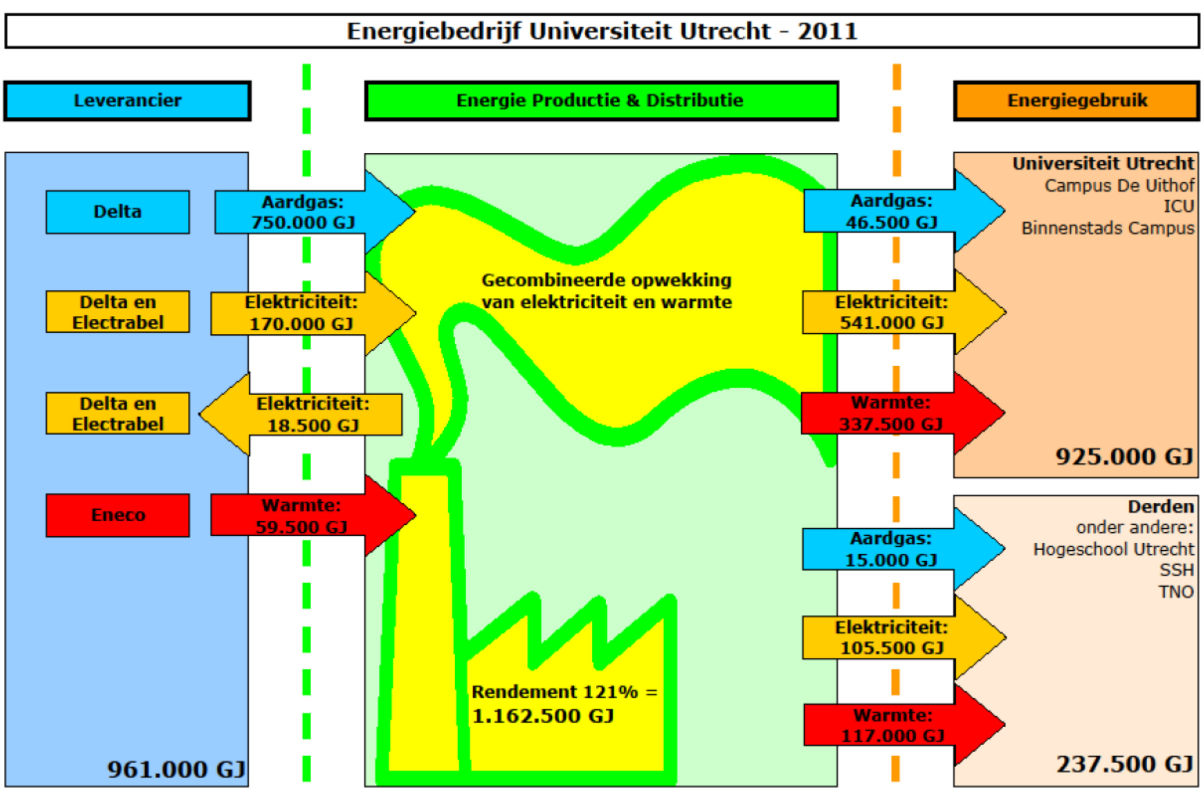

Figure 4

2.2.2.Aquifer system of the Uithof

Furthermore, the university has its own geothermal heat pump or aquifer (WKO) that provides 1,2% of the university's energy. This system uses an aquifer to store seasonal heat and cold, which can be extracted when needed (Miller & Spoolman, 2009). In the summer a heat exchangers uses the cool water from the aquifer to cool a building. Simultaneously the heat exchangers heats up the water that will be stored in the aquifer. In the aquifer the temperatures stay relatively stable. Therefore the warm water can be extracted in the winter to heat the building, while cold water will be stored to cool the building during the summer (Miller & Spoolman, 2009). This process is visualized in figure 5.

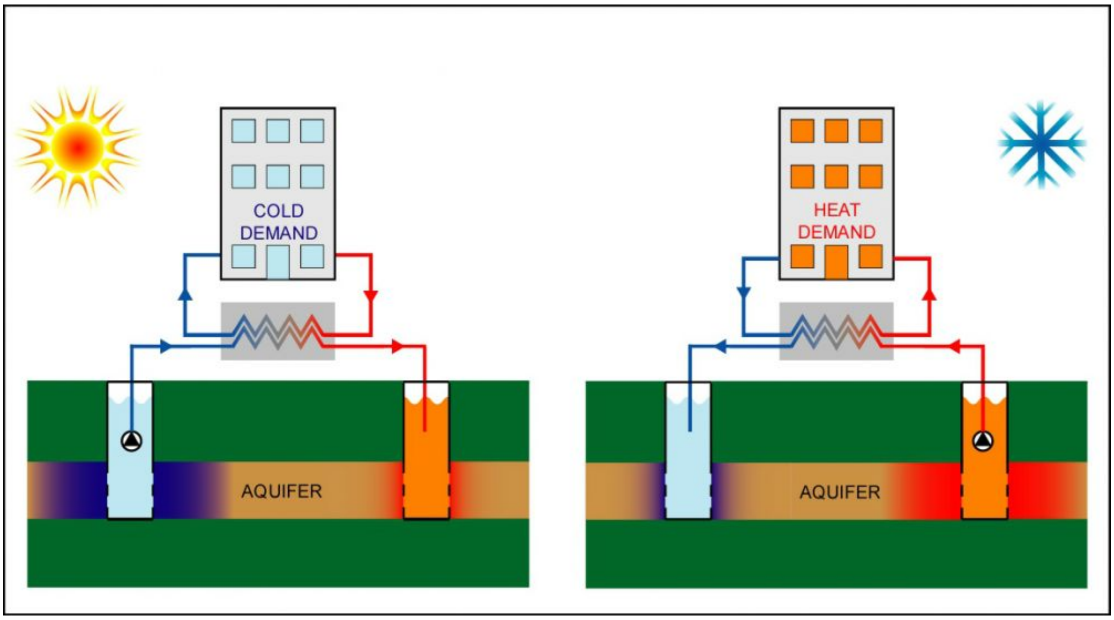

Figure 5: aquifer systems during summer (left) and winter (right)[1]

[1] Source image: http://www.sonicsampdrill.com/news/geothermal-drilling-energy-saving-with-sonicsampdrill-rigs.htm

At the northwest cluster there are currently 4 doublets, points where heat or cold is stored in the aquifer. With the new buildings 2 more doublets will be created, bringing the total to 6 with the capacity of 82,5 m3/h (Doorn, 2013). For heating, the supplied water will be between 45°C and 55°C and the COP (Efficiency) of the system will be between 3,6 and 4,2 (Cauberg-Huygen, 2012; Techniplan, 2012). The aquifer systems and storage capacity at the Uithof is visualized in figure 6.

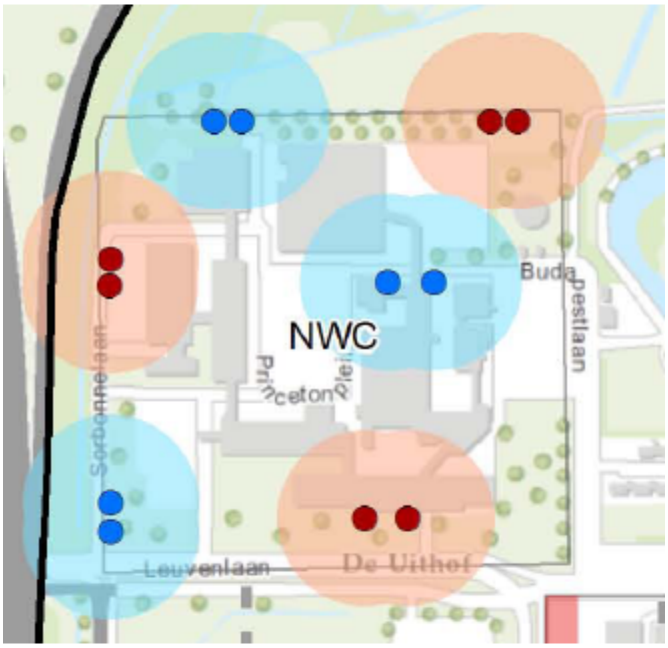

Figure 6: aquifer capacity at the Uithof (Doorn, 2013, p. 52)

2.3. Certification

As mentioned before, the UU attempts to realize ‘4 star’ BREEAM certification for new buildings, which refers to ‘Excellent performance’, according to the BREEAM certification system. In order to achieve this level of sustainability, building should meet specific criteria. These criteria are qualitative, meaning that their purpose is to give general directions towards the improvement of the sustainability level of a building. However, the design will be quantified by an auditor, who is authorized by the BREEAM organization, in order to indicate a score and categorize the building in one of the BREEAM categories. The specific measures that will be implemented in a new building in order to meet the requirements of a certain level of the BREEAM certificate, should be integrated in the building design by the project managers guided by specialized consultancy companies.

The BREEAM organization developed a scoring process in which they calculate a total score on the basis of a number of criteria. Every criteria is quantified by different sub criteria. These criteria are organized in five categories. This paper focuses on two criteria, knowingly materials and energy.

In table 3, the sub-criteria that are used to quantify the sustainable performance of buildings regarding materials, according to the BREEAM method, are shown. Clearly, the method focuses on the environmental impact of the materials during the entire life cycle of the building. This includes extraction, transportation and resource depletion. The performance is quantified by the calculation of ‘environmental shadow costs’, expressed in euro’s. The maximum number of points that could be gained as part of the total BREEAM score is 13. Noteworthy, currently, the concept design of the Geotower scores 3 out of 13.

Materials criteria of BREEAM
Building Materials Identifying and encouraging the use of the materials with low environmental impact during the entire life cycle of the building.
Substantiated origin of materials Encouraging the use of materials substantiated / sound source in the main components.
Robust design Identifying and encouraging policies to protection of exposed parts of the building and ground facility, allowing the replacement frequency of this is minimized.

Table 3: category materials in the BREEAM certification method

Based on the BREEAM certification method, one can conclude that the energy performance of the building is a more important part of the sustainability performance of a building since 26 points refer to this energy performance. A large part of the score, 8 out of 26, is part of the energy performance during the operational phase. Noteworthy, the concept design of the Geotower scores 16 out of 26 in the category energy.

Energy criteria of BREEAM
Energy Efficiency Encouraging that buildings are designed and realized with a low CO2 emission of building-related primary energy consumption in the use phase.
Sub metering energy consumption The use of sub metering of both area zones within the building and significant consumption groups, so that in the use phase of a monitoring energy use recorded, monitored and if necessary can be adjusted
Energy efficient outdoor lighting Boosting energy saving and CO2 reduction by the use of energy-efficient outdoor lighting.
Application of renewable energy Encourage the use of renewable energy.
Minimizing air infiltration Encouraging energy efficiency and CO2 reduction by application and design of the loading / unloading platforms and / or shipping rooms with a minimum loss of heat or cold.
Energy efficient refrigeration and freezer storage Encourage energy saving and CO2 reduction by applying energy efficient refrigerated storage.
Energy-efficient elevators Encouraging energy efficiency and CO2 reduction by apply to the use customized , energy efficient elevators.
Energy-efficient escalators and moving walkways Encouraging energy savings and CO2 reduction application of energy efficient escalators and moving walkways.
Assuring quality thermal envelope Encouraging that buildings are constructed , as they are designed and realized with the lowest possible CO2 emissions.

Table 4: category energy in the BREEAM certification method

3. Life Cycle Analysis

Dependent on the function of the building, life times of buildings vary significantly. While residential homes are known for a relatively long lifetime, commercial buildings are constructed with a short-term vision. The short timeframe is related to the investors and owners of the commercial buildings, who attempt to realize return on investment in the short run. The Geotower will be used for educational purpose and will be owned by the University. Buildings of this kind are usually constructed for a useful life of in between 20 and 30 years.

3.1.1.Background LCA

In order to make buildings (more) sustainable, one needs to look at buildings from a long-term perspective – as with all sustainability issues. In this long-term perspective various issues require attention: material usage (and thereby depletion of resources), energy usage (and accompanying emissions), pollution and emissions. Although the sustainability field is plagued with ambiguous terms and definitions, the above-mentioned fields of interest are common sustainability criteria.

The environmental impact of buildings is difficult to evaluate due to scale, complexity in both materials and function and dynamicity in the phases of construction, usage and decommission. One way to evaluate the environmental impact of buildings is by performing a Life Cycle Analysis (LCA). In a LCA the different phases are evaluated. One can then evaluate for each phase properties of interest. To evaluate the environmental impact of a building one can look at (but not limited to) emissions, pollution of soil and air, energy use, water consumption and material consumption. Each phase in the Life Cycle of a building has its own characteristics and impact, LCA is thus a process by which the material and energy flows are analyzed and quantified. One way of starting a LCA is by constructing a Life Cycle phase diagram, of which an example is shown in figure 7. The phases in the following text are adapted from Scheuer *et al*. (2003).

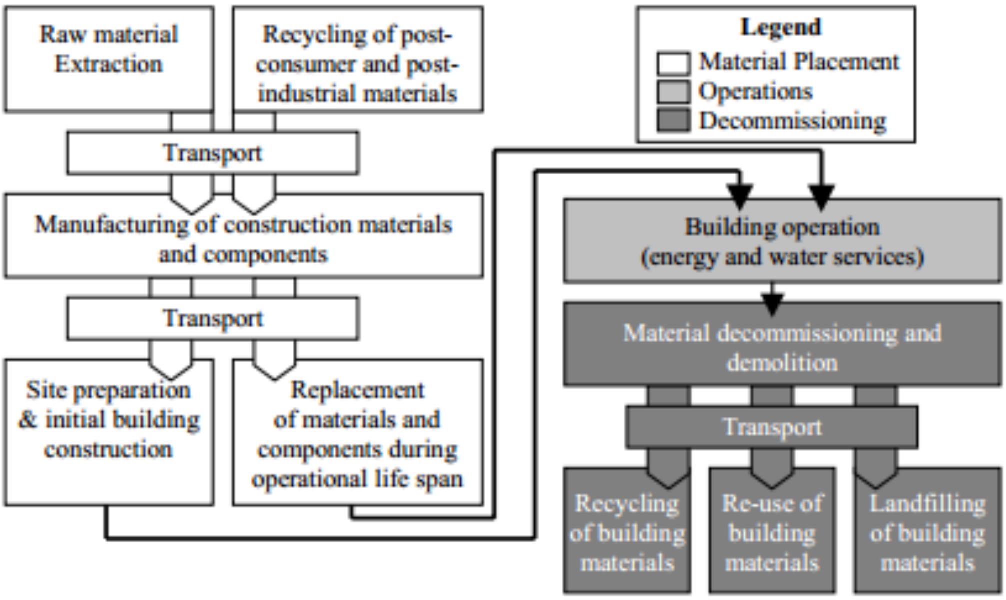

Figure 7: Life Cycle phase diagram (Scheuer et al., 2003)

3.1.2. *Transport Phases*

Between most phases transportation of materials is required. By smart selection of source and decommissioning locations of materials and sites one can decrease the amount of transportation needed, thereby decreasing fuel consumption and accompanying emissions. Smart selection of location also allows for more options in transportation modes. One can then utilize more environmental friendly forms of transportation such as by ship.

3.1.3. *Material Generation Phase*

In this phase raw materials are extracted and post-consumer and post-industrial materials are recycled. The impacts of this phase are diverse. Raw material extraction often depletes non-renewable resources (depending on the material), is often accompanied by pollutions and emissions as well as high-energy usage. Smart selection of material types and quantities (thus in building design) can decrease these negative impacts. Although recycling of post-consumer and post-industrial materials can be costly in energy and capital, it greatly decreases impacts such as pollution. An assessment of recycling opportunities should be made in order to find out which ones are cost effective or come at least an acceptable capital cost.

3.1.4. Manufacturing Phase

The manufacturing of construction materials and components is a necessary step that can be performed in two ways: in specialized manufacturing locations and on-site. The former option is usually accompanied by a higher efficiency, resulting in a lowering of energy consumption, emissions, pollution and waste generation, while the latter has the advantage of greatly reduced transportation requirements. Depending on the material or component one should therefore analyze which option is preferred, both from a capital and an environmental perspective.

3.1.5. *Site Preparation and Initial Construction Phase*

In this phase one is under Dutch regulations obligated to take special care for the local flora and fauna. Rare or threatened species need to be preserved. This can be done in the form of relocation or by including suitable replacement habitats in the building or area design. This phase comes with an increased risk of soil pollution, which should therefore be a point of focus.

3.1.6. *Construction Phase*

In this phase the actual building construction takes place. In the construction phase the energy consumption (often in the form of primary energy – fossil fuels) and accompanying emissions should be considered. One can opt for more efficient machinery and methods, which often also result in a decrease of capital needed in this phase. Another area to be considered is waste generation. Building materials and components should be used as efficient as possible, directly reducing capital costs and materials needed.

3.1.7. *Building Operation Phase I*

In this phase there should be two points of focus: energy use and water consumption. There are different methods to decrease both. Energy use can be decreased by (but not limited to) increasing the insulation levels, heating efficiency, lighting efficiency, more efficient installations, efficient heat circulation and reuse and behavioral change (possible through both smart design and signs/guidelines). Water use can be decreased by for example including (grey) water circuits and more water-efficient toilets and cleaning. Another field of interest is the source of energy and water. One can generate their own electricity and heat efficiently or opt for a more environmental energy scheme by energy provider selection, thereby implicitly decreasing environmental costs of energy use. Rainwater can be captured and made suitable for flushing (toilets) or cooling purposes and (grey) water cycles can be included. One should also monitor energy and water usage in this phase, see Building Operation Phase II.

3.1.8.Building Operation Phase II

During this phase various building components will have to be replaced. The amount of replacements needed can be decreased by smart design (decreasing the amount of building components) and selecting more durable components. After the water and energy usage has been monitored in the first phase of the building operation, energy schemes can be adapted and building components replacements can be chosen with more accurate knowledge of energy and water consumption. Due to learning costs of new technologies, as we progress in time more technologies will be economically viable, resulting in further efficiency gains. Results of the monitoring of energy and water consumption can also be used to develop new behavioral change projects.

3.1.9.*Material Decommission and Demolition Phase*

Where possible one should opt for the reuse of building materials and components. This can either be done internally in another building of the same owner or by selling materials and components to external parties. If reuse is not an option recycling can be. Although recycling comes at an extra cost in energy and possibly emissions, the environmental impacts are usually favorable since the other option is landfilling and new extraction of resources for another building project. The remaining option is landfill. If one opts for landfill, one should pay attention to pollution risks with certain materials.

Demolition of a building can be done in a more sustainable way by reducing emissions and confining by containing airborne particles and materials. Before demolishing the building, reusable materials and components can often be extracted. Care can be taken to insure recyclable materials are separated.

3.1.10. *Material Decommission and Demolition Phase*

Before, a detailed overview of the building life cycle is provided. Noteworthy, all these different stages are affected by the design phase, in which important decisions about material use and energy consuming installations are made. In order to narrow the scope of this essay, for the Geotower, the focus will be on two phases. First, the construction phase includes the materials used and the effect of these choices on emission and resource depletion. Second, the operation phase consists of energy use due to functional use of the building. This includes installations to facilitate air circulation and temperature regulation, but also additional appliances, such as computers and fridges. These two phases form the structure for the further analysis of the Geotower design.

4. The Case: Project Geotower

As mentioned in the introduction, the Geotower will be the unit on analysis in this paper. The concept design of this building is currently in development. This means that criteria are defined and that the architectural design is largely finished, but that adjustments to the specific interpretation, regarding e.g. technical installation and material use, can still be made. In this scope, this paper attempts to introduce sustainable measures that could be implemented in the final design.

4.1. The project in timeframe and scope

The UU is responsible for multiple buildings in the Uithof area. In figure 8, an overview of projects over the past years is provided. Noteworthy, in the past 10 years, 5 building projects where started (and partly completed) before the Geotower.

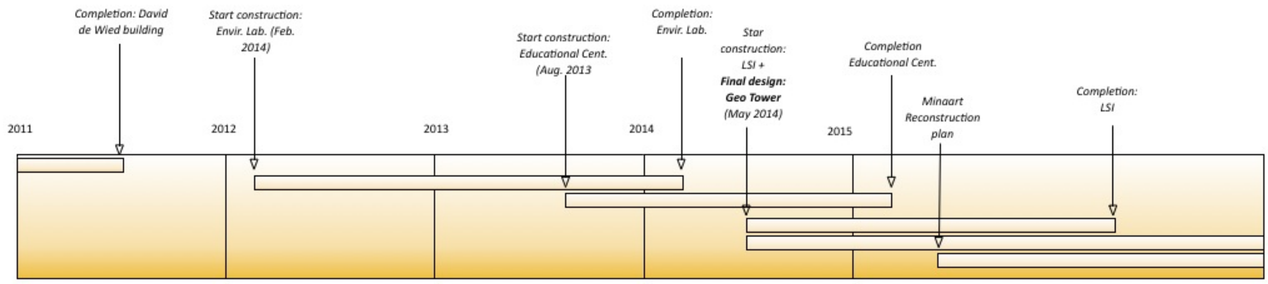

Figure 8, timeline project at the Uithof

It is useful to note that there has been some progress in the integration of sustainable measures into the building design:

- In the first two projects, the David de Wied building and the Environmental lab, there was not a clear set of goals regarding sustainability;
- For the Education center, the third level of the BREEAM certification is realized. In an advanced stadium of the design, a more ambitious goal was developed, namely fourth level certification. However, since a substantial part of the design was already established, a higher level did not belong to the realistic options;
- In June 2012 the department V&C stated a standard for new building development, regarding a standard aim to realize fourth level BREEAM certification (V&C, 2012) This standard is applied to the Life Science Incubator and the Geo tower.

4.2. The unit of analysis: the GEO Tower project

The Geo Tower will consist of 16.811 square meters on the Princetonlaan 8B in Utrecht. The most important features of the building are the office- and working-units, the restaurant, the bike storage, and some area for applied technics. The following boundary conditions apply to the building design:

- The building should meet the BREEAM criteria for level 4 'excellent' (V&C, 2012);
- Boundary conditions defined by the Energy department, knowingly, the building should be connected to the aquifer system and the grid that connects the CHP plant;
- Boundary conditions defined by the Program-Management department, knowingly, the number of employees that should be seated and other needed features. One of the main concerns at the moment is the layout of the office space, with options for either private office space or flexible area's for a larger number of employees;
- Boundary conditions defined by the Technical Maintenance and Advisory department, knowingly, the conditions of acceptance regarding future maintenance.

The building should have several connections to the Environmental Laboratory (GML), knowing architectural to the communal entrance at the ground floor, to the energy plant in the GML building, and a connection to the building-maintenance installation in the GML building.

5. Methods

This chapter contributes to the validity and reliability of this research by explaining the methodology and design. This paper uses a case study design to get a comprehensive overview of the current design of the Geotower and the process that facilitated this. According to Yin (2003), there may be some major arguments to consider a case study approach. First, the aim of the study is to answer "how" and "why" question, which is relevant for this research since it first aims to study how the Geotower is designed and why certain choices are made accordingly. Besides, a case study research design allows covering the contextual conditions, which are relevant to the contemporary phenomenon under study. The context regarding the function of the Geotower and the directives set by the involved departments is relevant for the choices that are made in the design process. As discussed by (Saunders & Lewis, 2012), the qualitative approach will be used to reach the research objective.

5.1.1.Data collection

Data collection is organized by conducting semi-structured interviews. More specifically, open-ended interview allow the creation of an open conversation, in which improvisation and interpretation is possible. According to Patton (2011), this data collection method results in valuable qualitative data. In addition, the interviews are guided by a general interview-guide, in which the main focus points are listed. Most importantly, as Maxwell (2005) describes, data collection is a process that is continuously open for change. Therefore, the interview-guide is changed on the basis of information that is gathered during previous conducted interviews. Besides interviews, multiple documents are analyzed to get an overview of the best practices that are currently available in the sector. These include case studies of comparable buildings. In addition, companies and research institutes where contacted to gain information about the most sustainable and efficient products that are available in the market nowadays. This market analysis is used to analyze the possibilities for improvements.

5.1.2. Participants

Interviews were conducted with all parties that had a contribution to the concept design, knowingly the project manager, Nelissen and Techniplan. Besides, as a way to collect background information about the design process and the different roles within the UU, interviews were conducted with the project manager of the 'Education Center', a building project that is currently in the construction phase. Lastly, an interview with the head of the Energy Department within the V&C department of the UU, provided us with detailed information about the energy policy of the UU and the requirements they developed for new buildings, such as the Geotower. These participants provided documents in which applied technologies and choices are explained in quantitative ways, such as the BREEAM analysis of the current design.

6. Geotower: analysis of the concept design

In this chapter, the concept design will be analyzed. Specifically, the effect of the design choices on the construction phase and the operational phase is studied.

6.1. The construction phase

As described before, the applied materials largely affect the environmental impact of the design phase. In larger building projects such as the one for the Geotower, a large array of building materials is used. The production, transport and application of these materials contribute significantly (up to 20%) to the total lifetime energy use and CO_2-emissions of a building (Ramesh et al., 2010). Possibly large savings can be made in this phase to both energy use and CO_2-emissions. In appendix A, a table is presented that shows the most important building materials used in the construction of Geo tower derived from the tender made by INBO, the architect of the building. Not all materials are included; things like doors, faucets, and stairs are highly controlled by the architect, who wants things to look a particular way and there is little flexibility to change these types of features. The most important materials that might show room for improvement are concrete, cement, a material used for walls called metalstud, and different types of floors and ceilings that are all used in vast quantities. In Table 5, an overview of the applied materials in the Geotower is provided.

Building construction part	Used material	Environmental impact
Walls, roof, floor	Concrete	GHG emissions
Roof, façade	Aluminum	Embodied energy
Window frames	Wood	Deforestation, GHG sink
Building frame	Steel	Emissions, depletion
Pipes, sewage	Plastics	Emissions, pollution

Table 5: overview applied materials Geotower

6.2. The operational phase

In the operational phase the environmental performance consists largely of the energy use by technical installations. However, the impact on replacement of appliances and maintenance of the buildings should be taken into account as well. In appendix B, a list of all technical installations that will be installed in the Geotower is included. Most important installations are related to climate control, such as heating, cooling and ventilation. Besides, lighting forms a large share of the energy consuming installation. For the design of the Geotower, the consultancy firm Techniplan is, as one of the advising companies, responsible for the technical installations within the building design. As described in their Concept Design Technical Installations (Techniplan, 2013), the following criteria are applied in the design process:

- The maintenance of the installations should be considered. The aim should be a design with low maintenance, resulting in a minimization of preventive as well as corrective maintenance;
- Sustainability should be considered. The Energy Performance Coefficient (EPC) should meet the requirements from the legally conducted 'building-decision'. Besides, it is a requirement that the office part of the project scores BREEAM level four 'excellent';
- The energy consumption in the user phase should be considered. The aim should be a low energy use during use, initial investments may have a payback time of 12 years maximum (Techniplan, 2013);
- The maintenance of the installations should be considered. The installations should fit as much as possible the knowledge and experience of the department Technical Maintenance and Advisory.

Besides the criteria and directives given by the client, Techniplan recognized three subsidy possibilities:

- Energy Investment Deduction (EIA);
- Environmental-investment-deduction (MIA);
- Random depreciation environmental investments (VAMIL).

Based on the guidelines, criteria and directives mentioned above, Techniplan conducted an estimate of the energy use of the building, once it is in use, as well as a projection of the annual CO_2 emissions associated with that energy use (table 6).

Primary energy use	**MJ y^{-1}**
Heating	965 600
Warm tap water	278 340
Cooling	385 601
Ventilation	770 158
Lighting	1 933 015
Subtotal	**4 332 715**
Electricity production building-bound (solar)	-327 894
Purchased Energy	**4 004 820**
Electricity production, not building-bound (aquifer)	-307 605
EPtot	**3 697 215**
EP;adm;tot (MJ y^{-1})	5 367 100
EPtot / EP;adm;tot	0.69
Specific energy performance (MJ y^{-1} m^{-2})	261
EPC meets requirement of building directive 2012	yes
Surface total (m^2)	14 182
Shell/energy loss surface (m^2)	2 000
Total CO_2 – emission (kg y^{-1})	245 451.69

Table 6, Estimated energy consumption of Geotower

Different uses of energy are given, as well as their total. Then, energy that is generated by the building by solar panels is subtracted. Finally, energy that is taken from a sustainable source outside of the building is subtracted, meaning the cooling and heating energy saved by the aquifer system that the Geo tower is connected to. This gives an Energy Performance of 3,7 TJ per year. The Energy Performance (EPtot) is compared to the admissible Energy Performance (EP;adm;tot) based on the government's building directive and the size of the building.

In figure 9 the relative contribution of the different energy uses to the total demand is given. It becomes clear from the graph that lighting takes up the largest portion of energy in the new Geo tower, followed by heating and then ventilation.

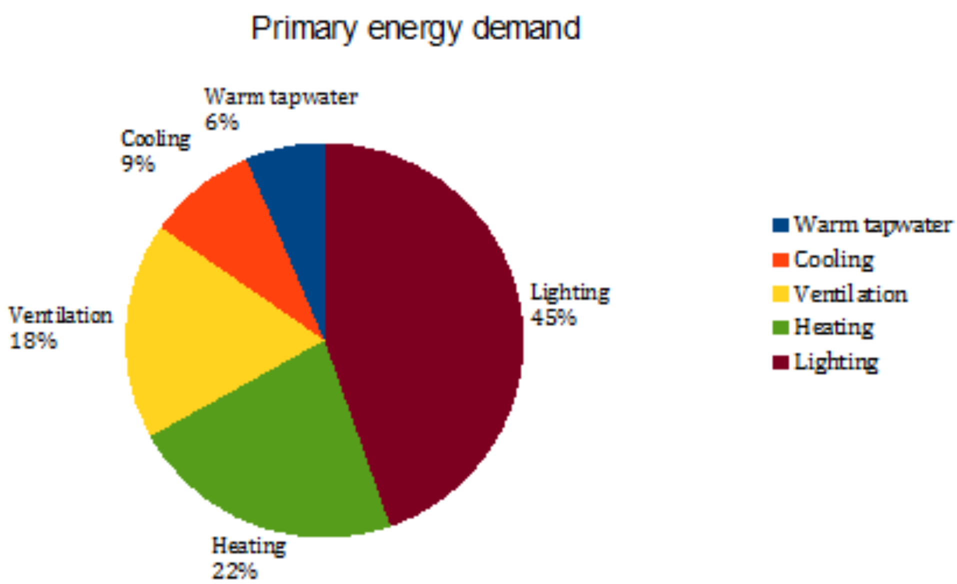

Figure 9, Distribution of primary energy consumption in Geotower.

7. Geotower: analysis of opportunities for improvement of the concept design

In this chapter, best practices that are derived from case studies of sustainable buildings and market analyses analyzed for potential integration in the concept design. Again, a distinction is made between the construction phase and the user phase.

7.1. The construction phase

Based on the concept design and the best practice study, a number of substitutes for materials are recognized that contribute to the sustainable performance of the concept design.

7.1.1. Use of recycled waste materials

Scarcity of resources and the need to reduce the environmental impact of winning and processing construction materials and products is placing a greater emphasis on resource efficiency within the construction industry. It is estimated that the construction industry consumes some 420Mt of materials annually and generates some 90Mt of (construction, demolition and excavation) waste, of which 25Mt ends up in landfill. Therefore there is significant scope for improving resource efficiency within the industry.

By recycling, we contribute to more sustainable development by eliminating or reducing waste and by saving primary resources. Also, recycling some materials, like metals, saves energy (and reduces carbon emissions) since it requires less energy to re-melt scrap than it does to produce new metal from primary resources. In table 7, an overview of the recycled materials that could be applied is provided.

Recycled Materials	Uses	Local examples
Steel	Expanded on below	Expanded on below
Aluminum	Expanded on below	Expanded on below
Aggregate	Sub-base material for road construction, hardcore for foundation works, base/fill for drainage, aggregate for concrete manufacture and general bulk fill	Pilot studies carried out by works departments
Asphalt	Aggregate fill and sub-base fill	Under investigation by Highways Department
Excavated materials	Filling materials	Housing Department's building projects
Public fill	Land reclamation	Land formation at Public Filling Areas
Pulverized fuel ash	Manufacture of concrete products, uses in fill and reclamation, highway construction and reinforced soil structures	Construction of Chek Lap Kok Airport, use in structural concrete for foundation works in the Housing Department's building projects
Metals	Manufacture of new metals	Widely practiced in local construction industry
Glass	Manufacture of eco-pavers, eco-partition blocks and glassphalt, substitute for sand and aggregates as mortar, backfilling and reclamation materials	Use of eco-pavers by Works Departments for road paving. Studies and trial uses are being carried out by Works Departments for other applications
Plastic	Synthetic materials in form of plastic lumber for landscaping, horticulture and hydraulic engineering	Use at some public recreational facilities as garden furniture
Rubber	Manufacture of rubber slate tile use in roofing and sport / playground surface mat	Use at some public recreational facilities as playground surface mat
Expanded polystyrene	Manufacture of lightweight concrete for non-structural works	Use in manufacturing lightweight concrete in Housing Department's building projects

Table 7: overview recycled materials (CW, 2013).

7.1.1.1. Recycled steel

Steel is one of the metals that can be totally recycled without losing any of its vital properties. Therefore it can be used in the construction of heavy weight constructions, such as buildings without adding any risk in the function of the building. The production of steel is one of the most energy intensive industries, something that is depicted in the figure 10 and in figure 11.

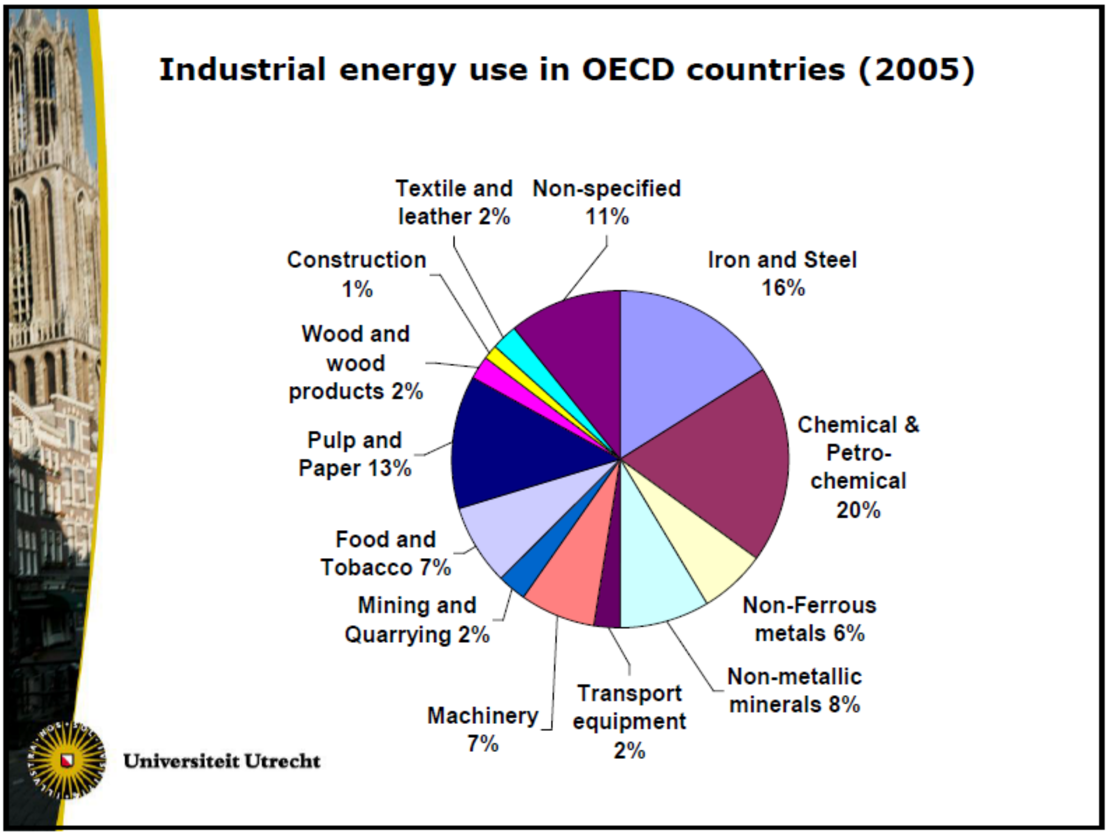

Figure 10, Industrial energy use in OECD countries.

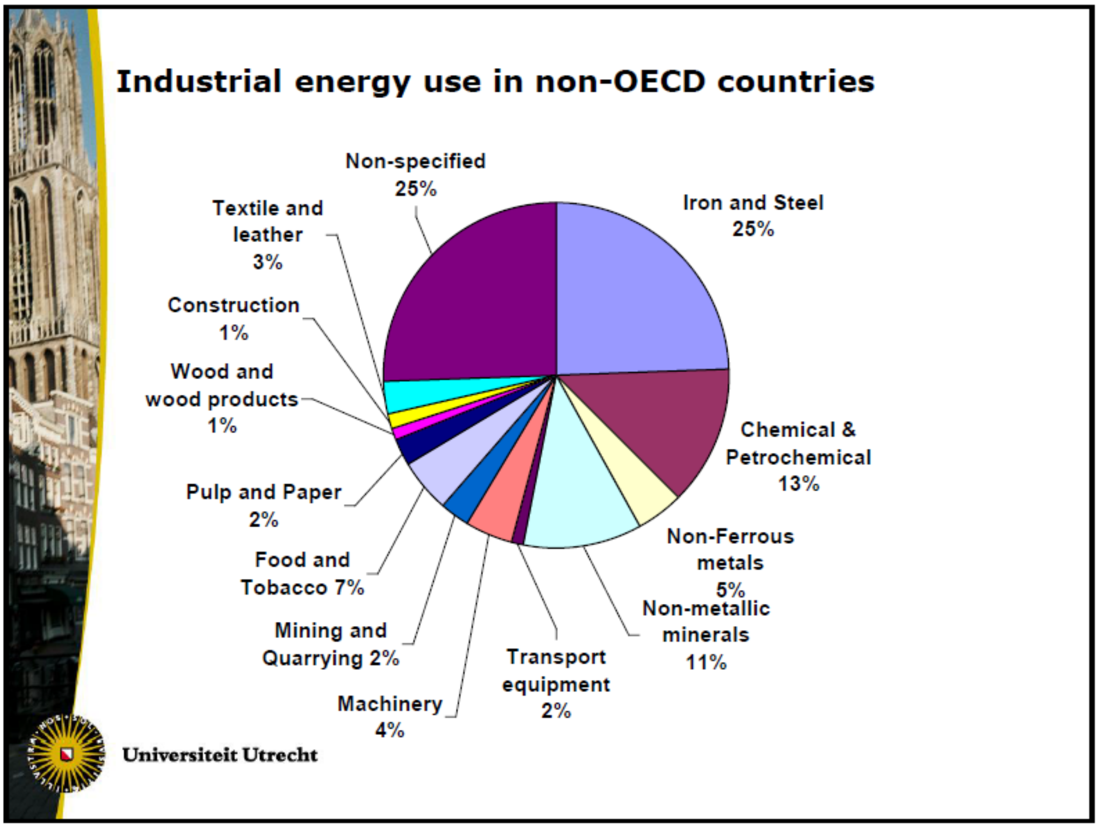

Figure 11, Industrial energy use in non-OECD countries.

Taking into account these figures we should think of ways in the direction of reducing the energy footprint of steel production. One of these ways, and the most effective one, is the recycling of steel as the material does not lose any of its vital properties and can be used for the same constructions as the new one.

In Geotower, steel will be used in the construction of reinforced concrete used in the main body of the building. Due to lack of information regarding the volume of steel used in this construction, we cannot give a clear number for the energy savings and the reduction of the energy footprint of Geotower after the use of recycled steel instead of virgin one. Nevertheless, we know that the embodied energy of virgin steel is between 32MJ/kg to 59MJ/kg whereas the recycled steel values range from 8.9MJ/kg to 12.5MJ/kg (Tufts, N.D.). Therefore by using recycled steel instead of virgin one the energy footprint of the new building will be reduced by 39-85%. Finally, taking into account the average CO2 intensity for electricity production in Netherlands, which was 0.9 Kg CO2/kwh (European Commission, 2009), the emission savings will be between 8.01kg CO2/kg of steel to 14.75kg CO2/ kg of steel.

7.1.1.2. Recycled aluminum

Aluminum has a number of characteristics that contribute to the sustainability of the material. To illustrate, corrosion resistance results in low maintenance and durability and infinite recyclability allows energy savings. Therefore, the use of aluminum in building construction results in energy savings, emissions and wastes throughout the lifecycle. Moreover, exceptional high strength-to-weight ratio of aluminum makes it very useful as a structural material. The use of aluminum in the construction of buildings reduces the use of materials with a high environmental impact, such as cement and steel, contributing eventually to lower energy footprint of the building.

An alternative point of view is to think of buildings, and other assets in which a lot of materials are being used, as a 'material bank'. Specifically, this is relevant for materials that are rare or being threatened by depletion. A study by Delft University of Technology recently revealed considerable recycling potential for aluminum in the building sector. Aluminum collection rates from a cross-section of commercial and residential buildings in six European countries were found to be in excess of 92%, demonstrating the industry's commitment to sustainable development (GARC, 2009). Since aluminum can be recycled, buildings with an extensive use of this material could be seen as 'banks' of aluminum for the next generations. Thus, although the building value decrease over the years due to new market demand, the material that is used in the building increases in value due to increased scarcity. As a result, when the applied materials are taken into account in the valuation of the building, the depreciation of the buildings is much less. However, to realize material banks, it is important that buildings are build according to the cradle to cradle principles, which means that materials can be easily separated during the demolition phase so that materials can be reused.

Several studies have been conducted on the compatibility of recycled aluminum for heavy constructions showing that the levels of impurities suitable for this use are easily reachable. Furthermore, aluminum scrap can be recycled without any loss of value properties. Recycling aluminum saves 95 percent of the energy associated with primary metal production. Similarly, it reduces 95 percent of the environmental footprint (AA, N.D.). Furthermore, the use of recycled aluminum as substitute for regular aluminum and/or for steel, will contribute to the creation of a sustainable society and will help to promote this material worldwide.

In the Geotower, the 7,392 m2 aluminum in the façade is one of the most important construction parts of the building that is suitable for the application of recycled aluminum. Due to lack of information regarding the volume of aluminum used we cannot provide the exact number of energy and CO2 savings. Nevertheless, we know that in 2007, 38 million tons of primary aluminum and 38 tones of remelted aluminum were produced globally having an energy requirement of 6500 PJ and 250 PJ respectively (GARC, 2009). Hence, in line with the aforementioned energy requirements, for every kilogram of aluminum used in Geotower possible energy savings from the use of recycled aluminum are up to 171.05 MJ. This is translated to 42 kg of CO2 emission savings per kilogram of aluminum, taking into account the average CO2 intensity for electricity production in Netherlands, which was 0.9 Kg CO2/kwh (European Commission, 2009).

7.1.1.3. Recycled glass

One of the most significant materials during the construction phase is glass. Glass used in today's window and facades does more things than many people perhaps realize. From prime concerns like safety, security, and environmental protection to convenient functions like self cleaning or practical qualities like scratch resistance or design aspects, the choices are many and varied. As the depletion of the earth's raw materials has been a growing issue for many years, it is worth separating and collecting any materials when referring to construction phase, where large amounts of material are being exploited, in order to recycle them. The same applies to waste sheet glass. Sheet glass is a general term for the different types of glass used in residential and utility buildings like offices, health centers and other business premises. Sheet glass is normally meant to be used as a construction material for windows and doors. However, sheet glass has actually endless applications, since glass is an extremely versatile material. The construction sector and more specifically in the demolition phase generates thousands of tons of waste glass on an annual basis. There is an urgent need of recycling on a bigger scale this waste in the hopes of sustainable demolition and renovation techniques.

In order to accomplish this goal, organizations like Vlakglas Recycling Nederland coordinate all the activities associated with recycling and collecting waste glass in an efficient, environmentally friendly manner and at the lowest possible cost and support and coordinate the participating companies and agencies.

The idea behind the separate collection and recycling of sheet glass aspiring to the sustainable future of the construction sector is the 'cradle-to-cradle' philosophy, which in other words involves the principle that after use, materials should become the raw materials for new products. Glass is a perfect example to this philosophy, since it is -with the exception of glass wool- completely reusable, it doesn't result in any loss of quality and last but not least there is very little waste.

In 2012, waste glass was separated to the different sectors as follows: 12% for sheet glass industry, 36% for insulation products, 51% for packaging glass industry and 1% for glass bead industry. Vlakglas Recycling Nederland proposes a 20% for sheet glass industry in order to achieve a sustainable future for the construction sector alleviating energy and CO_2 footprint of the buildings.

The recycled glass cycle involves various steps. First, waste glass is transported (by boat or truck) to recycling plants. There, the dirt is removed from the glass and it is processed into a material called cullet, which is made up of small pieces of cleaned recycled glass. This cullet can then be used to produce new glass. This process means that 90% of the collected waste sheet glass makes its way back into newly manufactured glass. All kinds of sheet glass are collected, including wire glass, laminated glass, colored glass and double-glazing. The recycling company processes all these types of glass into a final product that is made of 100% pure glass. The incoming waste glass is stripped of any foil, iron or other contaminants. Then it is crushed to pieces of the right size. The pieces are then mixed to the specifications of the purchaser and delivered to glass industry as a high-quality, consistent, homogenous and reliable product. Finally, the glass cullet is delivered to customers who reuse it.

The system of collection should be intended for all those who work with waste glass: painters, glaziers, demolition companies, contractors, glass suppliers, glass processors and glass manufacturers. A main advantage of recycling sheet glass is that dumping sheet glass in landfill as 'normal' waste actually involves high dumping costs, while all producers and/or importers of double glazing who sell their products in the Netherlands are required to pay a waste disposal fee of € 0.50 per m^2, which is a very small amount compared to their profits along with sustainability success. Furthermore, reusing waste glass reduces the amount of waste that has to be processed by landfill sites, which results in reduction of 'fresh' raw materials to produce new glass and ultimately in reduction of the burden on our environment. For instance, 1 (kg) of cullet (glass that is crushed and ready to be remelted) can replace 1.2 (kg) of sodium carbonate and sand, the two main raw materials for glass. Regarding energy and CO_2 footprint, recycled old glass requires less energy resulting in lower CO_2 emission levels during production phase than producing new glass. In fact, for every 10% of cullet used in glass manufacturing energy consumption is reduced by 2.5% and CO_2 emissions by 5% (VRN, N.D.).

7.1.1.4. Recycled plastics

One of the best-regulated recycling cycles in the Dutch material industry is the recycling of plastics. 'Bureauleidingen' is an organization that arranges the collection of used plastic pipes, in which most plastic is used in building constructions. Their collection system is named the 'Buizen Inzameling Systeem' and is totally CO2 neutral, according to their website (www.bureauleiding.nl). One of the major concerns in plastic recycling is the decreasing strength of the recycled materials as compared to primary plastics. However, due to enduring research by Bureauleidingen plastic pipes could be realized with 50% recycled material without losing functional strength. Within the Geotower, requirements on the use of recycled plastic will contribute significantly to the sustainable performance of the building.

7.1.2. Use of fly ash in cement production

According to Feuerborn (2014), using secondary raw materials or "by-products" is a tool of sustainable construction, which is already used by the construction industry since more than 60 years in some European member states. However, this experience is based on coal-ash by-products - not to mix up with pure biomass residues as the chemical/mineralogical properties are different and as therefore not all what is valid for coal ash is automatically valid for biomass ash. The same is valid for calcareous ashes from coal - which are comparably richer in lime (and mostly also sulphur). The properties are important for consideration of their use.

7.1.2.1. Process of cement production using fly ash

Fly Ash is a by-product of the combustion of pulverized coal in electric power generation plants. When the pulverized coal is ignited in the combustion chamber, the carbon and volatile materials are burned off. However, some of the mineral impurities of clay, shale, feldspars, etc., are fused in suspension and carried out of the combustion chamber in the exhaust gases. As the exhaust gases cool, the fused materials solidify into spherical, glassy particles called Fly Ash. Due to the fusion-in-suspension these Fly Ash particles are mostly minute solid spheres and hollow spheres with some particles even being plerospheres, which are spheres containing smaller spheres. The size of the Fly Ash particles varies but tends to be similar to Type I Portland Cement, which is the most widely used type worldwide. The Fly Ash is collected from the exhaust gases by electrostatic precipitators or bag filters. Chemical make-up of Fly Ash is primarily silicate glass containing silica, alumina, iron and calcium. Color generally ranges from dark grey to yellowish tan for Fly Ash used for concrete.

Fly ash acts as a pozzolan. A pozzolan is a siliceous or aluminosiliceous material that, in finely divided form and in the presence of moisture, chemically reacts with the calcium hydroxide released by the hydration of Portland Cement to form additional calcium silicate hydrate and other cementitious compounds. The hydration reactions are similar to the reactions occurring during the hydration of Portland Cement. Thus, concrete containing Fly Ash pozzolan becomes denser, stronger and generally more durable long term as compared to straight Portland Cement concrete mixtures.

A standard specification document for Coal Fly Ash for Use as Mineral Admixture in Concrete has two designations for Fly Ash used in concrete - Class F and Class C. First, class F Fly Ash is normally produced from burning anthracite or bituminous coal that meets the applicable requirements. This class of Fly Ash has pozzolanic properties and will have a minimum silica dioxide plus aluminum oxide plus iron oxide of 70%. Secondly, class C Fly Ash is normally produced from subbituminous coal that meets the applicable requirements. This class of Fly Ash, in addition to having pozzolanic properties, also has some cementitious properties and will have a minimum silica dioxide plus aluminum oxide plus iron oxide content of 50%.

Most state and federal specifications allow, and even encourage, the use of Fly Ash; especially, when specific durability requirements are needed. Fly Ash has a long history of use in concrete. Fly Ash is used in about 50% of ready mixed concrete (PCA, 2000). Class C Fly Ash is used at dosages of 15 to 40% by mass of the cementitious materials in the concrete. Class F is generally used at dosages of 15 to 30% (Information contained in this section is taken from AGR (N.D.).)

7.1.2.2. Implementation potential

Normal concrete contains a binder with up to 30-40 % replacement of cement by fly ash. The mix proportion is kg/m^3 where a mix of 270 kg/m^3 of cement is used together with 70-90 kg/m^3 of fly ash. Special concretes are produced with higher shares of fly ash. The advantages of the use of fly ash are threefold, namely economically, technically and environmental.

Economically, the cost of Fly Ash is generally less than Portland Cement depending on transportation. Significant quantities may be substituted for Portland Cement in concrete mixtures and yet increase the long-term strength and durability. Thus, the use of Fly Ash may impart considerable benefits to the concrete mixture over a plain concrete for less cost. In addition, the social costs of raw material decrease due to durability increase and therefore lifetime (fly ash makes concrete more dense and durable for several application)

Technically advantages are numerous. First, fly Ash improves concrete workability and lowers water demand. Fly Ash particles are mostly spherical tiny glass beads. Ground materials such as Portland Cement are solid angular particles. Fly Ash particles provide a greater workability of the powder portion of the concrete mixture, which results in greater workability of the concrete and a lowering of water requirement for the same concrete consistency. Pump ability is greatly enhanced. Secondly, fly Ash generally exhibits less bleeding and segregation than plain concretes. This makes the use of Fly Ash particularity valuable in concrete mixtures made with aggregates deficient in fines. Third, sulfate and Alkali Aggregate Resistance are considered. Class F and a few Class C Fly Ashes impart significant sulfate resistance and alkali aggregate reaction (ASR) resistance to the concrete mixture. Fourth, fly Ash has a lower heat of hydration. Portland Cement produces considerable heat upon hydration. In mass concrete placements the excess internal heat may contribute to cracking. The use of Fly Ash may greatly reduce this heat buildup and reduce external cracking. Lastly, fly Ash generally reduces the permeability and adsorption of concrete. By reducing the permeability of chloride ion egress, corrosion of embedded steel is greatly decreased. Also, chemical resistance is improved by the reduction of permeability and adsorption.

Environmentally advantages are related to the prevention of the resources depletion and the reduction of required activities to gain materials. Specifically, reduction of emission is related to a decreased number of activities regarding the extraction of raw materials and processing of these materials. The emission and environmental degradation that is related to mining of materials is one of the most important consequences that are prevented. (Information contained in this section is taken from AGR (N.D.).)

7.2. The operation phase

Based on the concept design and the best practice study, a number of substitutes for the, in the concept design applied, technologies are recognized that contribute to the sustainable performance of the Geotower. The concept design shows that the Geotower is considered one of the buildings that will communicate the focus of the university on sustainability. Therefore, the state of art technologies are planned to be implemented in the building contributing notably on the low energy consumption targets that the direction of the university has set. Examples like the DALI lighting operation system of Philips clearly indicate this. Nevertheless, there is room for possible improvements in the field of the technical installations which will operate during the usage phase of the building as well as in certain processes and methods that are applied by the UU.

7.2.1.Tubular lighting

The DALI lighting operation system has the ability of measuring the luminance existing in a room and adjusting the lighting luminance according to temporal needs. Thus, reducing the needs for lighting will reduce the required energy needed. Daylight systems are measures that allow daylight to penetrate the rooms of the building for as long as possible during the whole day. That is because higher luminance of the room would make the DALI system to reduce the luminance of technical lighting and that way save significant proportions of energy that would otherwise be consumed. One application that gives us this opportunity is a daylight guide system using tubes with high reflective interior walls called “Tubular lighting”.

Tubular lighting is already implemented in several buildings around the world and has shown that light guide systems of diameter 500 mm and length 5 m could be used for illumination of rooms without strict requirements for precise visual activity as corridors, bathrooms or auxiliary spaces etc. (Mohelníková et al, 2009). Due to lack of information we cannot calculate the exact amount of energy savings after applying this measure to the new building. Thought the percentage of added luminance in the interior after the installation of the tubes can reach the 1.15% in comparison to the one before the installation.

Tubular lighting cannot be considered as solution for additional lighting for parts of the building where visual activity, like reading and writing is required. In order tubular lighting to be sufficient for these kinds of rooms the installation of two or three tubes would be required. The installation of more than one tube for providing additional light cannot be considered as an option, as the cost for the installation cannot be counterbalanced with the energy savings and the use of materials for constructing the tubes will increase the energy footprint of the building.

7.2.2.Air cleaner

As the design of the project is in an advanced stage there is no room for the development of the HVAC system as it is implemented in the architectural plans being an integrated part of the building. Still the implementation of air cleaners that will keep away from the ventilation system sufficient amounts of a wide range of particulate and gas-phase contaminants, including: ultra-fine particulate, volatile organic compounds (VOCs), odors and biological contaminants, should be applied in the new building. The installation of air cleaner will prolong the lifetime of the ventilation system. Therefore, there will be significantly lower cost for the maintenance of HVAC systems. One of the most developed air filters is the one offered from LG Electronics and is called LG "Dynamic V8 VL Series" Air Cleaner.

LG "Dynamic V8 VL Series" Air Cleaner is designed in this way that has minimal impact on the existing energy system and it can reduce the energy consumption instead of increasing it in a long-term temporal scope (Website LG). Moreover, by reducing the emissions of ion or ozone pollutants, this application will contribute a lot in the goal of constructing the Geotower according to the green building design. Due to the aforementioned, the Air Cleaner, can help in earning BREEAM points.

7.2.3.Energy saving outlets

One of the smaller innovative appliances that could be integrated in the building design are energy saving outlets. These measures allow to set timers and cuts power after those timers expires. One of the most logical areas in which those devices could be applied are the computer rooms in the Geotower. Shutting of electricity after a timer expires, for example after one hour, results in large energy savings.

7.2.4.Electricity rail systems

In the Geotower cables and electricity rails will be used to facilitate the transport of electricity between the main connections provided by the energy company and the different floors and distribution devices. Modularly assembled rail systems allow easy sub metering, horizontally as well as vertically. In turn, data collection enables monitoring, which contributes and guides maintenance, control and even behavioral change. This is covered in the following chapters of this paper.

7.2.5.Energy Recovery Ventilation (ERV) systems

In the Geotower there is no air circulation in the central air-conditioning installation. Techniplan (2014) aims to recover as much thermal energy as possible from the returning airflow if the applied appliances fit the requirements for the return on investments (12 years). ERV systems guide the incoming and outgoing air streams past an exchange core where the energy from the outgoing air is efficiently transferred to the incoming air. As a result, the incoming air in the winter, which is colder than the outgoing air, is warmed before it enters the building. Indeed, in the summer, this effect is the other way around.

Currently, the best forms of ventilation systems are the Balanced Ventilation with Heat Recovery systems. Balanced Ventilation facilitates that the amount of outgoing air and ingoing air is equal, which is arranged by the use of different ventilators. There are different options to recover the heat from the outgoing air with a maximum performance of 95%, when using a heat wheel. This performance is significantly better than for energy recovery from natural ventilation systems. Most importantly, balanced ventilation systems allow, and for optimal performance even require, good insulation or airtight construction of buildings. Insulation in combination with heat recovery through ventilation is an important aspect of more sustainable buildings since heat loss through air circulation is very relevant (Prendergast & Erdtsieck, 2004). Furthermore, an important benefit of the balance ventilation system is the ease of functioning for controlling and regulation. This results in the exactly right amount of fresh air in the building, which creates a healthy environment with fresh air and reduces the heath loss due to additional ventilation.

7.2.6.Regulation functions

As described in the report of Techniplan (2014), numerous presence detectors that activate either or both the lighting or ventilation system are integrated in the building. In line with this best practice, it is possible to connect the windows to the room automation systems via contact. This results in energy savings since the mechanical ventilation is automatically switched off as soon as a window opens. This system is applied in the Süddeutscher Verlag HQ in Munich, which was the first office building that was awarded with the gold LEED certificate by the US Green Building Council in Germany.

7.2.7.Maintenance, monitoring and control

7.2.7.1. Monitoring

Apart from the used building materials and technical installations, there is one other factor that influences the energy use in a building: consumption during the use phase. The most efficient lights still waste energy if they stay switched on when the building is empty. The technical installations in the building should be operated properly in order to achieve the maximum saving capabilities. Therefore next to installing and using the best materials and technologies the operation of the building should be monitored. Looking at the electricity use of the university in 2011 (Directie Vastgoed & Campus, 2013) and the estimated energy demand as seen in section 4.1, the monitoring should focus on the following aspects:

- Lighting
- Ventilation
- Heating
- Cooling
- ICT

Lighting, Ventilation (including heating and cooling) are connected to the measurement and control system of the building f not already implemented, this system should save data on the energy demand and use from lighting, the ventilation system and the heat exchanger. Where possible data should also be collected from air quality, temperature and light sensors. In addition, information on the occupancy of the building can be collected (Washington State University, n.d.). The more aspects that are taken into account, the more effective monitoring can be. In-detail monitoring can help pinpoint where efficiency improvements can still be made, even after construction.

During data collection, all the data must be properly time stamped, making it possible to distinguish between working hours, nighttime and weekends. Possibly even peak times such as exam periods can be considered as can holiday periods. These data can be used to prevent problems like deactivated or falsely set controls, lack of sensor calibration and scheduling problems (Costa, Keane, Torrens, & Corry, 2013). Furthermore, trough monitoring, malfunctioning of installations can come to light. If solved in a timely manner, a substantial amount of energy can be saved.

Monitoring should be a continuous process. During the first year, the system can be tested and results compared to the calculated energy use. After recalibration, monitoring during the second year can confirm if the adjustments improved energy use. It is advisable to keep monitoring throughout the lifetime of the building in order to keep it as efficient as possible. Extra attention to monitoring should be given after large changes in installations or occupancy to ensure the proper operation of the building. In table 8, an overview is given of all the installations that should be monitored, and what information should be measured. Furthermore, a short note is added on what the measured information could be used for.

	What to measure	What to use the measurements for
Lighting	Energy consumption per area	Monitor if it is in conformity with expectations
	Operating times per area	Check if the lights are not switched on out of office hours
	Illumination per area for lights	Monitor the illumination (strength)
	Illumination per area from sensors	Monitor the necessity of the operation of the lights
Ventilation	Indoor temperature	Monitoring the heating/cooling need
	Outdoor temperature	Monitoring the heating/cooling need
	Operating times	Monitoring the necessity of the ventilation
	Air quality sensor	
	Ventilation speed	Monitor if the speed is in conformity with the need
	Ventilation air temperature	Monitor if the system is working properly
Heat exchanger	Temperature ingoing air	Necessary in the determination of the efficiency and proper operation
	Temperature outgoing air	
	Energy consumption	
Electricity	Total electricity consumption	Monitor if it is in conformity with expectations
	Where possible, electricity consumption per area	To determine where efficiency improvements could be made
ICT	Trough electricity consumption	Are appliances switched off when not needed
Occupancy	General knowledge of people in the building in relation to the time	To determine if measurements of sensors are realistic

Table 8: monitoring of installations

Additional to the monitoring through the system, on site 'surprise' monitoring should be performed as well. This could help determine if electrical appliances like coffee makers, computers, printers, etc. have been left turned on during nights and weekends (Smith, 2010). Furthermore, it should be checked if sensors and installations are not manually overruled through the control panel.

7.2.7.2. *Analyzing and applying monitoring results*

If done properly, the monitoring as described above will result in substantial amounts of data. Analyzing these data will be necessary if one intends to save energy. As stated above, following up on monitoring can lead to an increase of building performance. Building design includes a number of performance targets. Data obtained through monitoring gives insight in whether or not these targets are achieved and in what areas. Underperforming areas or building components can be pinpointed and if necessary changes can be implemented. Malfunctioning or underperforming components can be replaced, and when replacements occur, also through maintenance, one should check whether technologies with reduced energy consumption or environmental footprint have become economically available and attractive.

Monitoring over a longer period of time enables effective use of timestamps in mapping consumption during different use phases. One can thus map energy consumption in certain areas during for example weekends, regular weekdays, holidays and exam periods. Seasons and outside temperature should also play a role in this process. Smart energy schemes with for example decreased demands in heating or cooling can then be devised.

Real-time adapting to monitoring by for example CO_2 sensors can further strengthen these smart energy schemes. As an example, when at the end of the day no one is in an office anymore, (part) of the computer monitors can be disconnected from the power grid.

Furthermore, where persistent issues emerge, this can be a starting point for behavioral change projects. Thus students and employees can become involved in the process of making the Uithof more sustainable; increasing the visibility of sustainability, decreasing their own consumption through increased awareness and decreasing overall consumption through the projects.

The effects of above-mentioned measures should again be monitored and reacted upon; it is thus a continuous cycle that only ends once the building is decommissioned.

7.2.8.Behavioral change

The Geotower has some of the most advanced technologies installed, and requires extensive monitoring to assure correct everyday utilization of the building. Even though the technical applications existing in the new building can ensure the low energy consumption, human intervention during the function of the building should not be neglected. Therefore, the placement of a maintenance crew familiar with the (modern) equipment who will be responsible for the everyday function of the building is an imperative.

In addition, we have observed the continuous function of buildings and the appliances integrated in them after the work hours in many of the buildings placed in Uithof campus. It is almost impossible creating a system that will turn on or off any appliances, like lights, personal computers and monitors according to the time schedule of the people working in the building and not only in line with the ambient luminance as the DALI lighting operation system does. therefore the occupants of the building play the biggest role in saving energy trough behavioral change. They are the ones that use the appliances and therefore make the choices on their energy use. If they would change their behaviors to include simple actions like taking the stairs instead of the elevator, manually switching the light off in a toilet stall, manually switching their computer monitor off when leaving their workplace and switching off other appliances when not in use, a large amount of electricity can be saved. Individually these measures only save small amounts of energy, but if all occupants would actively participate these small amounts can total up to large savings.

The university can stimulate this type of behavioral change. Things like hanging up signs to switch off appliances, sending newsletters on the energy performance of the buildings (and possible achieved savings) and sharing energy savings tips will stimulate to actively participate. Furthermore, if this were to include information on how to save energy at home, people are more likely to show a behavioral change at work as well.

Monitoring of the devices and building use is one of the most important aspects of behavioral change since data could facilitate detailed information about change in timing and use of technical installations. Moreover, behavioral change of the UU in other fields than, however sometimes related to, energy could be important. To illustrate, the next paragraph elaborates on waste management. A sustainable policy in this field could be a driver of change in other fields. For example, users of technical appliances will be motivated to make efficient use of their devices if the UU shows to think sustainable about other issues as well.

7.2.8.1. Waste management

Sustainability is not only a matter of energy and materials use and as the UU direction aims on communicating this image, further study should be done on the waste management of the building. Recycling processes should be considered part of the building. Moreover, technology gives the opportunity of ecological sanitation, also referred as ecosan, which is the recycling of human waste.

Recycling should be a process occurring in the new building on a daily basis. Thus, waste bins where the users could deposit their garbage after separation in different materials should exist in many easily accessible points (e.g. entrance of the building). Easily recycled materials are glass, paper, plastic and aluminum. Besides these materials, the recycling of organic materials should be promoted as a restaurant will be placed on the first floor of the building resulting in high amounts of organic waste. The collected organic waste can be used for power generation after its collection and transportation to a biomass based plant. Hence, if this practice were promoted for all the buildings of Uithof campus and the city of Utrecht the construction of a biomass plant, which will generate power, might be possible. The realization of such a project combined with the already existed energy and heat practices of UU (see §3.2) could contribute notably to the sustainable image of UU and according to the magnitude of generated energy reduce the energy consumption of the city of Utrecht. Due to lack of information we cannot be sure that this project is realizable but a study should be conducted in this direction.

Making a step further we advise the implementation of new technologies dealing with human waste called ecological sanitation. This system provides the opportunity of urine diversion into water that can be used for agriculture. Separation of nutrients contained in human waste for further use as a fertilizer is possible as well. Creating a system like this in the new buildings would add a lot to the sustainable image of the building as the products could be used for the creation of a garden placed next to the building and would provide the restaurant with vegetables. Such a project is already in use in Wageningen university.

8. Discussion

In this chapter, the reliability and validity of the research method and, eventually, the shortcomings of the study will be discussed. In addition, recommendations for future research and scientific implication are provided. Noteworthy, practical implications are considered in the advice and conclusion.

8.1.1. Reliability and validity

As discussed in the method section, this study uses a qualitative approach with interviewing as a data-collection method. The overview of the current design is largely conducted by the information and documents provided by the participants. Nelissen, Techniplan and the project manager all play a significant role in the design. Therefore, qualitative data was collected from participants who have in-depth knowledge about the different aspects and factors that affect the design and decision-making process. Consequently, one can conclude that the data that is used for the evaluation of the concept design is reliable and correct. On the other hand, the validity data that is collected in order to conduct a market analysis, aiming to provide an overview of possible measures that could be implemented in the concept design, may be seen as questionable. This information is partly gathered from scientific sources, overall ensuring reasonable reliability, and partly from companies that are active in the building sector. Data collected from companies is considered biased since companies aim to market their product and emphasize the benefits of the project. To overcome this limitation, this paper aims to focus on the possible contribution of sustainable measures without providing specific calculations.

8.1.2. Shortcomings

Although the source of the information is considered reliable, the data collection process contains shortcomings. Most importantly, the project is considered sensitive due to the current phase of the project. To elaborate, the design is under development, which means that the project manager did not start with the selection of the contractor and that information about the design is not yet publicly available. Therefore, the project manager and the corresponding companies could provide only limited information. In detail, a general version of the BREEAM report could be provided in which the scores, and thus the potential for improvements, are mentioned. Among others, the used materials and their effect on the BREEAM score are provided in this report. However, specific information about the quantities is not available. This shortcoming is managed by providing directives and guidelines about applicable materials and possible sustainable savings, mainly in the form of recycled materials. In addition, some choices for integrated building design, including choices for HVAC, for example in relation to vacuum ventilation, are already included in the current concept design. This study advice some technical applications for installations, which can be applied on top of the current concept design. Therefore, the advice concerning technical installations is limited to relatively small measures.

8.1.3. Implications

Most important, it became clear that economic issues play a substantial role in the decision-making. The payback period of 12 years and the low energy price that is paid by the University Utrecht result in the rejection of numerous sustainable options. As for every project in which sustainable measures are implemented, different barriers occur. This study found that effort is made to integrate sustainability in the institutional structure of the University of Utrecht. However, due to the economic requirements economic, information and technical barriers occur. This study aims to overcome the information and technical barriers by conducting market research and advice opportunities for improvements. Besides this practical implication, this research has scientific implications. This paper found that economic barriers are the most significant barrier for the implementation of renewable energy technologies and energy efficiency measures at the University of Utrecht. Future research could focus on the benefits of the implementation of sustainable measures for an organization as the University of Utrecht with a public function, apart from the economic focus.

9. Concluding advice

In this chapter, the possible solutions that were listed in chapter 5 will be briefly summarized, and judged on their merit.

9.1. Construction phase

The sustainability of the concept design of the Geotower can be further improved by implementing several measures during construction phase. Up to 20% of the life cycle CO_2 emissions of a building are associated with the construction of the building, it is therefore a significant opportunity for improvement. Below, several ways are presented by which to make the use of materials more energy efficient and less CO_2 intensive.

9.1.1. Recycling

Many materials can be effectively recycled and given another life. This often presents a substantial saving to energy use and CO_2 emissions. We found three materials that can reasonably be produced from recycled resources.

9.1.1.1. Concrete gravel

A large portion of a buildings internal energy -the energy that is used to construct the building- and CO_2 emissions are related to concrete production. In the Geotower, a total of close to 1300 m^3 of concrete is used during construction. Much of this can be produced from recycled materials. The gravel that is used can be replaced up to 100% with demolition-concrete rubble, this poses a significant saving in CO_2 emissions of up to 25 %.

9.1.1.2. *Steel*

Building grade steel is a resource that is already being produced for the largest part from recycled steel, and in demolition, the average recovery of steel used in the building is estimated to be 96%. This positive fact means that there are little extra improvements to be made to the building in this particular area. Of course, the construction company could ensure that the steel used is in fact produced from recycled steel.

9.1.1.3. *Aluminum*

As with steel, aluminum can be recycled extremely well, recovering nearly 100% of the material in the process, and being recyclable indefinitely. The recovery rate in demolition for aluminum is estimated to be 92%. Recycled aluminum has a definite preference above mined aluminum in terms of internal energy and CO_2 emissions, the construction company could therefor guarantee that the aluminum used is produced from recycled materials.

9.1.1.4. *Glass*

Glass can be produced with the use of cullet. As mentioned above for every 10 % of cullet used in the manufacturing of glass, there is a 2.5 % reduction in energy consumption and 5 % reduction in CO2 emissions. Using this kind of glass will add to the reduction of the energy footprint of Geotower. Therefore, we recommend the use of glass manufactured with the use of cullet in the new building as Utrecht University wants to establish the image of sustainability.

9.1.1.5. *Plastics*

Netherlands has a well-established network for recycling plastic, and as mentioned in paragraph 5.1.1.4, it is possible to construct plastic pipes with 50 % of recycled material without these losing any of their vital properties. As there is no industry manufacturing this type of pipes yet it we recommend the use of pipes made with recycled plastic for the buildings which will be built in the future.

9.1.2. *Fly ash*

An important component of concrete is cement. A relatively well-known technology has been improved over the last decades that allows cement to be replaced by fly ash, a byproduct of coal or biomass combustion. The application of this waste material has a positive effect of the internal energy of the concrete, as well as its CO_2 emissions. The use of fly ash does not compromise the structural integrity of the concrete, nor does is need to cost more. It is therefore our strong suggestion that as much cement as possible is replaced by fly ash in the construction of buildings on the Uithof.

9.2. *User phase*

9.2.1. *Lighting*

An effective and low-cost method of reducing energy use is luminescent-dependent lighting. This means that the amount of artificial light in an area, is adjusted according to the natural light in the room, which is measured by a sensor. In the current design, many lights would burn at full power all the time, wasting a lot of energy. Something that is already implemented in the current design is presence-dependent lighting, meaning that the lights switch off when there is no one in the room. However, this is only applied in a few campus buildings, and would be a powerful improvement of other buildings at the Uithof.

A measure that is advised against is tubular lighting. This is a technology that uses highly reflective tubes, aimed at the sun to increase the natural lighting in a room. The effect, however is marginal (typically a few percent more light) and the economical, energy, and material costs are significant.

9.2.2. *Air cleaner*

The HVAC system that will be implemented according to the concept design has quite a high performance in terms of energy-efficiency, which makes a good contribution to the energy efficiency of the building. There is, however, still room for improvement by applying an air cleaner. Modern air cleaners can effectively remove particulate matter, and ion and ozone pollutants. This both increases energy performance further, and improves the air quality in the building. The latter contributing to a higher BREAAM rating in the health subsection.

9.2.3. *Energy saving outlets*

This simple and cheap application potentially has a very large impact on the electricity use of a building, especially when appliances are not switched off properly or not even at all. These outlets allow the building manager to switch off appliances like computers or coffee machines, also killing any stand-by power that might be used.

9.2.4. *Energy Recovery Ventilation (ERV) systems*

The HVAC system that is described in the concept design can be further improved by applying a more advanced enegy recovery ventilation system. This is a system where the outgoing air is guided past the incoming air, exchanging the heat they contain; in the winter, the warm inside air pre-heats the incoming cold air, and in the summer the cool inside air pre-cools the warm outside air. The best systems on the market take in the same amount of air that they blow out, which means there is no natural ventilation. These systems reach an efficiency of up to 95%, greatly reducing heating and cooling demand.

9.2.5. *Maintenance, monitoring and Control*

9.2.5.1. *Monitoring*

As briefly mentioned before, an important so-called low hanging fruit solution for improving the energy performance of a building is in monitoring and control. This goes beyond simply increasing the performance of the building installations and “skin”. It influences the energy performance by optimizing *how* the installations operate. A high performance building should have a comprehensive approach to monitoring and control that should include lighting, ventilation, heating, cooling, and ICT. Monitoring is then used to operate the installations according to the actual need in the building. This means changing the lights, ventilation, heating, and cooling as a consequence of the people present, temperature, air quality, as well as other variables.

Besides real-time managing of the internal environment of the building based on measurements, energy can also be saved by following certain pre-set schemes for control. Practically, this means that next to the daily variation of heating/cooling during the and not at night, there can also be a seasonal change in temperature control. During the summer people are lightly dressed so the temperature is allowed to be higher, say 23 degrees, and during the winter temperature is allowed to be lower, say 18 degrees. This is a contrast with the current norm where the temperature is maintained at 20 degrees at all times. The seasonal setting would drastically decrease the amount of heating- and cooling degree days, saving large quantities of energy.

The data resulting from the monitoring should be used to identify installations or elements thereof that are not performing optimally. This leads to a better level of maintenance and consequently performance of the installations, something that is of high importance as the predicted efficiency and functioning of many installations is often not the same as the actual in-situ levels. Maintenance is of the highest relevance to keep the building healthy, and energy efficient.

9.2.6. *Behavioral change*

Because smart systems can never perfectly follow demand, without compromising flexibility and user-friendliness, the users of the building can play a role in helping it be more energy efficient. Also in the area of waste separation, behavioral change is very important. Concretely, this means that occupants should be encouraged by signs to switch off their appliances and lights. They should also be encouraged by awareness campaigns and availability of visibly attractive trash cans to separate waste.

One original way to increase awareness and involvement of occupants in sustainability is to place highly visibly attractive elements in- and around the building. For instance, some modern buildings have a fire place in the lobby that burns wood from the direct surroundings of the building to efficiently heat the room. One other way is having a vegetable garden on the roof where students and colleagues can work together to grow supplies for the cafeteria.

10. Conclusion

The main conclusion drawn from this report is that numerous measures exist that would improve the energy footprint of the Geotower. The most important of which being recycling of different building material, dynamic use of lighting, ventilation, heating, cooling, a good monitoring control & maintenance program, and behavioral change. Not all these measures might be economically viable (especially due to the cheap energy available from the UU CHP plant), but all contribute to a more energy efficient building arsenal. The Direction Vastgoed & Campus can use the findings of this report to further improve both new and existing buildings at the Uithof. This will lead to an even more energy efficient campus that accommodated comfortable, healthy, and sustainable housing for all its students, researchers and employees.

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Appendix A: Materials used during construction of the Geotower

Type	Unit	Amount	
Concrete; foundation, floors, walls	M^3	156.0	
		75	
		145	
		101	
		40	
-prefab		88.75	
-prefab		472.5	
-prefab		68.75	
Concrete pillars (at estimate-point 28)		143.2	
Total concrete	*M^3*	*1290.2*	
Cement (screed)	M^3	764.4	
Bubble deck 34cm (contains steel and concrete)	M^2	13897.7	
		368	
		1700	
Total bubble deck 34cm	M^2	15965.7	
Clean sand	M^3	226.4	
Lime sandstone	M^3	27.5	
Aluminium	M^2	128.4	
Roof coverage and insulation	M^2	2140	
Metalstud - Outer wall coverage with insulation	M^2	3673.6	
Metalstud – Inner wall coverage no ins	M^2	9522.9	
Total metalstud	*M^2*	*13196.5*	
Glass (Coollite Xtreme 60/28)	M^2	3719	
Glass door	no.	351	
Outside sunscreens	M^2	502.8	
Wood (window frames)	no.	208	
Ceramic tiles	M^2	2540.7	
Parquet floor	M^2	279	
Carpet tiles	M^2	12568.2	
Plaster ceiling	M^2	2125.6	
		318.9	
		276	
Basic ceiling	M^2	11950.3	
Total ceiling	M^2	14670.8	
Insulated channel plate floor 26cm	M^2	1590	

Appendix B: Technical installations in the Geotower concept design

Type	Function name	Explanation	Technical appliances
Cooling/ Heating	**Energy Connection**	Water used for heating and cooling should be delivered from energy plant	Transportpump; Flow/Energymeter
	Heating/Cooling Capacity	The heating and cooling capacity for the building temperature trajectory	Heating: 800 kW Cooling: 1.250 kW
Mechanical Installations	**Central Heating**	Delivered from aquifer in GML building	Pipelines to air-conditioning and local heating systems
	Decentralized Heating	Office space	Low pressure units
		Entrance ground floor	Underfloor heating and heating elements in façade
		Restaurant ground floor	Underfloor heating and airheating
		Meeting rooms 1st floor	Underfloor heating, airheating, and climate-ceiling
		Other rooms	Panel radiators
	Central Cooling	Delivered from aquifer in GML building	Pipelines to airconditioning and local heating systems
	Decentralized Cooling	Office space	Low pressure units
		Entrance ground floor; Restaurant ground floor	Underfloor cooling and air cooling via (local) airconditioning system
		Meeting rooms 1st floor	Underfloor cooling, air cooling via (local) airconditioning system, and climate-ceiling
		Other rooms	Central and local airconditioningsystems
	Ventilation	Air-treatment installation for primary in- and outlet fresh air	Air treatment plants on the ceiling. Thermal heat is recovered from outgoing air
		Distribution of fresh air to different area's and collection of outlet air	Air intake and outlet features
		Office space	Low pressure units connected to central ventilationsystem (constant volume)
		Rooms in meetingcentrum ground floor; Meeting room 1st floor, multiple individual extraction systems	Ceiling diffusers connected to central ventilationsystem (variable volume)
		Entrance ground floor;	Ceiling diffusers connected to central ventilationsystem (constant volume)
		Restaurant ground floor	Ceiling and sidewalls diffusers connected to central ventilationsystem (variable volume)
		Kitchen	Overcurrent of restaurant area and extraction from cooker hoods
		Ventilation general	Automatic monitoring of CO2 appliance, variable volume control
Plumbing	Cold and hot tap water and fire installation	The water-system is connected to combined drinking- and fire-water-installations	Per floor: two pantries, tap with outlet, and dishwasher. Hot water connection trough electric close-in boiler 10dm3. Several toilets with electrical 20 dm3 per floor
Sprinkler	Sprinkler installation	Sprinkler connected to tapwater and notification system	Two sprinklerpumps organize the connection between the sprinkler installation to the drinking water system. Per 3,6 meter ceiling, one sprinkler unit (7,5 l/m2/min) is installed

Organizing install.	Measure and maintenance system	Combined building maintenance system, displayed at reception GML, digital system capable to organize connected applies according to time program	All climate installations and energy measurement is internally connected and are able to communicate disfunctioning. This system could be connected to the general building maintenance system, the Visonik-systeem of Siemens, Landis&Staefa
Electro installation	Energy	Connect the grid outside the building to provide user-ready energy	Transformer with a capacity of 1,000 kVA provided by Stedin
	Emergency energy measure	For appliances that should function regardless the main network	Decentralized emergency energy provision per appliance
	Switch- and division-structure	Groups of e.g. lighting, air-conditioning, elevators, computers etc.	Main (8 floors together) and sub-structures (per floor) with switch
	Lighting	Offices	Build-in TL-lighting, high frequency, dimmable
		Elevator-hallways, restaurants, central hallways	LED spots
		Bike storage	LED-armatures
		Voids	Pendant armatures, high frequency
		Kitchen	TL-armatures, high frequency (HACCP requirements)
		Outside doors	Security lighting
	and switches	Offices	Presence detectors combined with daylight arrangements connected to a central system
		Elevator-hallways, entrance, central hallways	Connected to central touch screen regulation system GML reception, included installed timer for night and weekend lighting
		Toilets	Stand-alone presence detectors
		Restaurants, kitchen en technic area	Separate switches
		Bike storage	20% function with presence detector for 100% functioning
	Emergency lighting	Emergency lighting and escape way lighting	LED sources and function as nightlight
	Ramp heating	To prevent the bike storage ramp from freezing	Electrical ramp heating
	Security installation	Connects manual and automatic fire-alarm systems	Pro action system