**DOKUZ EYLÜL UNIVERSITY**
**GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES**

# A SUSTAINABLE BUILDING ASSESSMENT MODEL PROPOSAL FOR NEW RESIDENTIAL BUILDINGS IN TURKEY

**by**
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**March, 2013**
**İZMİR**

# A SUSTAINABLE BUILDING ASSESSMENT MODEL PROPOSAL FOR NEW RESIDENTIAL BUILDINGS IN TURKEY

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**by**

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**Ph.D. THESIS EXAMINATION RESULT FORM**

We have read the thesis entitled **"A SUSTAINABLE BUILDING ASSESSMENT MODEL PROPOSAL FOR NEW RESIDENTIAL BUILDINGS IN TURKEY"** under supervision of **Prof. Dr. YEŞİM KAMİLE AKTUĞLU** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Doctor of Philosophy.

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İlker KAHRAMAN

**A SUSTAINABLE BUILDING ASSESSMENT MODEL PROPOSAL FOR NEW RESIDENTIAL BUILDINGS IN TURKEY**

## ABSTRACT

The building sector accounts for 40 percentage of the primary energy use and 36 percentage of the energy related carbon dioxide emissions in the industrialized countries

In order to reduce the impact of the buildings, measurement of the current status is needed. Rating systems were created according to need for measurement of environmental performance.

The main aim of this thesis is developing a building assessment model according to Turkish construction market needs.

In order to develop an assessment model first well known systems such as LEED, BREEAM, SBtool, CASBEE, Open House, LenSe, SBAllience and CEN TC 350, ISO TC 59 SC 17 documents have been evaluated. According to review and evaluation of literature and existing systems the main framework of the model has been prepared; main issues and criterion which generates the framework of the model has been prepared in full, mid, core versions.

A questionnaire is prepared with core version’s issues and criterion and 84 energy identity document experts from Ordu, Adana, Bursa and İzmir fulfilled these questionnaires.

Building assessment systems’ issues and criterion weightings are determined according to developer countries needs. This becomes a problem when using these systems in different regions. For that reason Turkey needs to develop an assessment system which is suitable for Turkish construction market needs.

The importance of the issues and criterion to each other has been determined with the help questionnaires by using pair wise comparisons.

By assessing the questionnaires with analytic hierarchy process the weightings of issues and criterion have been evaluated according to Turkish expert's decisions.

In order to adopt LCA to this model most common 241 different details have been prepared. And these 241 details evaluated by the help of SimaPro software. All these details got a point according to their environmental performance. In adition to these 241 details different window wood, aluminium, PVC window frames have also been evaluated by using SimaPro program's database.

**Keywords**: Sustainability, life cycle assessment, energy efficiency, energy identity document, green house gas emissions.

**TÜRKİYE’DEKİ YENİ KONUT BİNALARİ İÇİN BİR SÜRDÜRÜLEBİLİR BİNA DEĞERLENDİRME ÖNERİSİ**


## ÖZ

İnşaat sektörünün, birincil enerji tüketiminin yüzde 40’ını karşıladığı ve enerji ile ilgili karbon dioksit salınımının yüzde 36’ sına sebep olduğu yaygın bir görüştür

Binanın çevresel etkisinin azaltılması için şu anki durumunun ölçülerek tespit edilmesi gerekir. Bina değerlendirme sistemleri binaların çevresel performanslarının ölçülmesi için oluşturulmuşlardır.

Tezin ana amacı Türk inşaat sektörü ihtiyaçlarına göre bir bina değerlendirme sistemi geliştirmektir.

LEED, BREEAM, SBtool, CASBEE, Open House, LenSe, SBAllience gibi iyi tanınan sistemler ve CEN TC 350, ISO TC 59 SC 17 dokümanları incelenmiş ve inceleme neticesinde ortaya konan benzerlikler ve farklılıklara göre hazırlanacak değerlendirme sisteminin ana başlıklarına ve alt başlıklarına karar verilmiştir. Sistemin ana başlıkları ve alt başlıkları “TAM”, “ORTA” ve “ÖZ” adları ile üç versiyon olarak tanımlanmıştır.

Hazırlanan “ÖZ” isimli değerlendirme sisteminin ana ve alt başlıklarına göre bir anket hazırlanmış ve bu anket 84 adet enerji kimlik belgesi uzmanı tarafından doldurulmuştur.

Bina değerlendirme sistemlerinin ana ve alt başlıklarının ağırlıkları geliştirildikleri ülkelerin ihtiyaçlarına göre belirlenmektedir. Bu durum, sistemin başka bir bölgede kullanılmasında sorun yaratmaktadır. Bir bölge için önemli olan başka bir bölge için çok önemli olmayabilir. Bu nedenle Türkiye kendi inşaat sektörü ihtiyaçlarına göre bir değerlendirme programı geliştirmelidir.

Başlıkların birbirlerine göre önem derecelerine anketlerde ikili karşılaştırmalar yapılarak karar verilmiştir.

Anket sonuçları analitik hiyerarşi prosesine göre değerlendirilmiş ve bina değerlendirme sisteminin başlıklarının ağırlıkları oluşturulmuştur.

Sisteme yaşam döngüsü analizi çalışmalarını ekleyebilmek için Türkiye'de yaygın olarak kullanılan 241 adet detay çizilmiştir. Bu 241 detayı oluşturan malzemelerin birim metrekare ağırlıkları hesaplanarak detayların çevresel etkileri SimaPro programı kullanılarak elde edilmiştir.

Bu 241 detayın beraberinde aluminyum, ahşap ve PVC pencere doğramalarının da çevresel etkileri programın veritabanı yardımı ile alınmıştır.

**Anahtar sözcükler:** Enerji etkinlik, sürdürülebilirlik, sera gazı salımı, enerji kimlik belgesi.

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# CHAPTER ONE
# INTRODUCTION

## 1.1 Definition Of The Problem

In every country, the construction industry is a major contributor to socio-economic development and also a major user of energy and natural resources. This industry is one of the main actors which is responsible for world's environmental degradation at the areas of energy and water consumption, raw material employment and usage of land.

For the services like; lighting, water and climate control, buildings generate considerable amounts of greenhouse and ozone-depleting gases throughout their life cycles. This greenhouse and ozone-depleting gases have enormous impacts on nature

The building sector accounts for 40% of the primary energy use and 36% of the energy related $CO_2$ emissions in the industrialized countries (IPCC,2001).

According to Brian, 1998, in organization for economic co-operation and development (OECD) countries, the building sector generates about half the total carbon dioxide output—the use (or abuse) of which can be greatly influenced by policymakers, urban planners, designers and engineers. In non-OECD countries, the environmental impacts of the building industry are even stronger as they also collide with public health issues, particularly in urban areas.

Transportation related pollution may also be seen as an outcome of building industry's activity.

Till 1990s no one take care of the impact of the activities of industrial sectors, including the building sector. In fact, in order to mitigate the environmental impact of building sector major changes needed. The responsibility of building sector is focusing the design, built and operation phases.

There is concern about how to improve construction practices in order to minimise their detrimental effects on the natural environment (Cole, 1999; Holmes and Hudson, 2000).

Building performance is now a major concern of professionals in the building industry (Crawley and Aho, 1999) and environmental building performance assessment has emerged as one of the major issues in sustainable construction (Cole, 1998; Cooper, 1999; Holmes and Hudson, 2000).

Sustainable assessment tools are tailored for the needs of the countries they born in. The issues and the criterion of each tool are prepared according to the habits and life style of different societies. What about Turkish people's habits? We are using minibuses for transportation purposes; earthquakes are like well known relatives for us.  For the sustainable site issue the distance to a post office is an important criteria in LEED but in Turkey we usually don't use post offices like American people.

Our culture is important for the weights of each issue and criteria. So in order to develop an assessment tool for Turkish market we have to create the issues, criterion according to our needs and we have to decide about the weightings of them afterwards.

## 1.2 Aim of The Thesis

Construction is one of the largest end users of environmental resources and one of the largest polluters of manmade and natural environments. When aiming to reduce these environmental impacts, a yardstick for measuring environmental performance was needed (Crawley and Aho, 1999).

Rating systems were created according to this need for measurement of environmental performance. But it should be noted that most rating systems are developed within a specific region and contain assumptions about the relative importance of issues and appropriate performance benchmarks.

Countries should therefore develop their own systems, adapt one of the existing systems, or else use a general framework supports the development of rating systems suited to any specific region.

Till this time Turkey did not have a rating system or model to assess sustainable performance of buildings. The rating systems which are famous in other countries are getting famous in our country but they are not tailored for our needs.

Nearly all of the sustainable building rating and certification methods are based in local regulations or standards and in local conventional building solutions. The weight of each parameter and indicator in the evaluation is predefined according to local socio-cultural, environmental and economic reality. Therefore the major part of them can only have reflexes at local or regional scales (Braganca, Mateus & Koukkari 2010).

Since the field of building environmental assessment tools is vast, the aim of this study is to clarify that field by analysing and categorising the current environmental building assessment methods used in different countries in terms of their characteristics and limitations in assessing building sustainability; by criticising them creating a new model for the assessment of new residential buildings according to sustainability issues which is suitable to Turkish Construction sector needs.

### 1.3 Method Of The Thesis

A literature review and evaluation of the existing studies has been done. There are lots of different rating systems being used in different countries. The most important ones LEED, BREEAM, SBtool, CASBEE, Open House, LenSe, SBAllience systems and CEN TC 350, ISO TC 59 SC 17 documents have been evaluated. According to review and evaluation of existing studies the main framework of the thesis has been prepared.

As mentioned before the main aim of this thesis is to create a model for the assessment of new residential buildings according to sustainability issues which is suitable to Turkish Construction sector needs. In order to this the main issues which generates the framework of the model has been prepared

After deciding about the main issues of the model another problem was the weightings of issues and criterion under each issue. A questionnaire has been prepared and 84 energy identity document experts have fulfilled this questionnaire. These experts were from Ordu, Adana, Bursa and İzmir.

The results of the questionnaires have been interpreted according to Analytic Hierarchy Process method.

In order to adopt LCA to this model most common 241 different details have been prepared. And these 241 details evaluated by the help of SimaPro software.

SimaPRO is a software which allows you to model products and systems from a life cycle perspective. SimaPRO comes fully integrated with the well known ecoinvent database and is used for a variety of applications.

The writer of this thesis has attended to an international course for SimaPro and got a certificate. He is the first architect in Turkey who got this certificate.

## 1.4 Literature Review

Cam and Ong (2005) defined the roles of building environmental performance domain that can assure innovative design. According to them there are mainly three roles should be taken in concern, first one is “being an institutional setting to raise awareness of building environmental to different players in the design and construction sectors in delivering environmental-friendly housing”, second one is “setting benchmarks for building environmental practice to safeguard the minimum performances standards” and the third one is “evaluating architectural design against these benchmarks; and finally providing a platform for inspiring new designs, ideas and technical solutions”

Cooper (1999) on the other hand, clarified the issues that are needed to be defined at first; which are the issue of absolute vs. relative assessments

Young (1997) goes on to describe sustainability as a three-legged stool, these legs are ecosystem, economy and society. And if any leg is missing that will change the balance of the stool.

Elkington (1997) expands the concept of sustainability to be used in the corporate community, developing the principle of triple bottom line.

Cooper (1999) further states that only the environment directly deals with ecology whilst the other three principles are political and socio-economic issues that are concerned with resource allocation and the decision-making process.

And according to Curwell and Cooper, 1998, “Most building performance assessment methods only tackle the principle of economics and are inadequate in addressing the concept of sustainability ”

Separate environmental indicators were developed for the needs of relevant interest groups. However, the first real attempt to “establish comprehensive means of

simultaneously assessing a broad range of environmental considerations in buildings” was the Building Research Establishment Environmental Assessment Method (BREEAM) (Crawley and Aho, 1999).

BREEAM, the first commercially available environmental assessment tool for buildings, was established in 1990 in the UK (Grace, 2000). Since then many different tools have been launched around the world. (Reijnders and van Roekel, 1999).

In 1998 the Leadership in Energy and Environmental Design (LEED) Green Building Rating System was introduced based quite substantially on the BREEAM system. Since then many different tools have been launched around the world (Reijnders and van Roekel, 1999).

Other tools such as HQE, DGNB, CASBEE, ATM Environmental Impact Estimator, Building, Environmental Assessment Tool (BEAT) 2002, BeCost, Building for Environment and Economic Sustainability (BEES) 4.0, EcoEffect, Eco-Profile, Eco-Quantum, Envest 2, Environmental Status Model, EQUER, ESCALE, LEGEP, Programmation et Analyse de Projets d'Ouvrages et d'Opérations Soucieux de l'Environnement (PAPOOSE), and TEAM™ etc. have also developed after 1999.

Hikmat H. Ali & Saba F. Al Nsairat developed a green building assessment tool for Jordan.

<u>In our country,</u>

The very first study about sustainable buildings is “Yeşil Yıldız ” ( Green Star) certificate which is evaluated by Ministry of Culture and Tourism in 2007. This certificate aims to lead the hotels to a sustainable path.

Another certificate which is mandatory for the buildings ( which gets a permit from any municipality after 01.01.2011) is EKB. (Energy Identity document). The model suggested with this thesis uses energy identity document results as an criteria so you can find detailed information at Chapter 3.

ÇEDBİK( Turkish Green Building Council) and SÜRYAD ( Sustainable Buildings and Materials Council) are trying to develop a sustainable building assessment tools according to Turkish Construction Market needs.

## CHAPTER TWO

## DETERMINING THE ISSUES AND CRITERION OF THE MODEL

### 2.1 Background of Current Methods and Standards

The importance of energy for economic and social development of any nation is very clear. Energy related emissions are the main reason of the most serious global environmental impacts including climate change, acid deposition, smog and particulates.

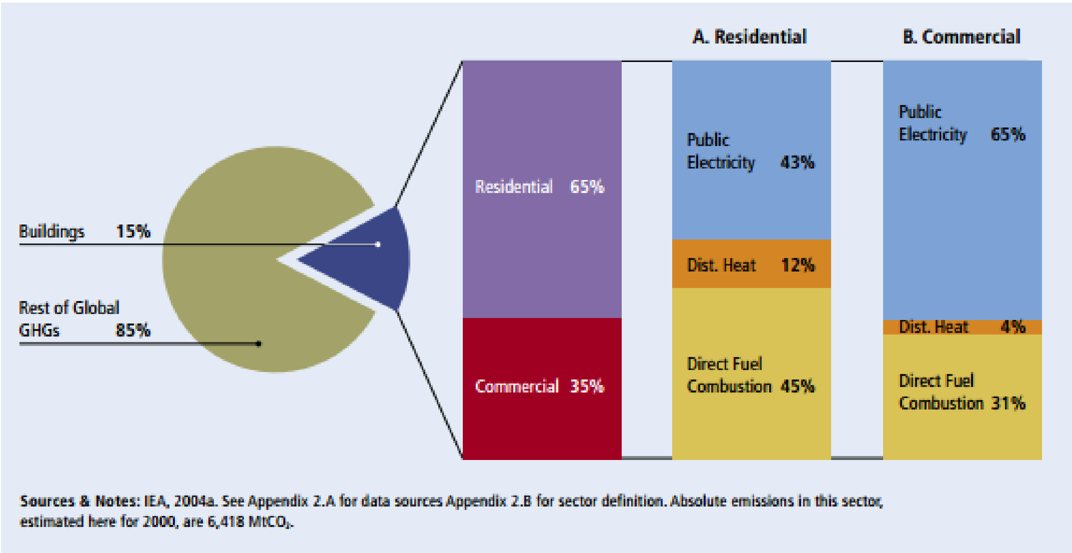



Figure 2.1 C02 from building use (Baumert, Herzog & Pershıng,2005)

In a note to the "Directive of the European Parliament and the Council on the Energy Performance of Buildings 2008" it states: "Buildings are at the core of the European Union's prosperity. They are important to achieve EU's energy savings targets and to combat climate change whilst contributing to energy security"

Till the end of 20th century world economy did not take into consideration the importance of building sector on energy demand and also after World War II, by the help of cheap fossil fuels, the technical progress of building design did not take into consideration energy efficiency or other ecological aspects.

According to Larsson, 2012, “In North America, consciousness about the vulnerability of the natural environment can be said to have emerged from Rachel Carson’s book of 1962, Silent Spring, which dealt mainly with the negative effect of DDT and other pesticides on ecological systems.”

Design and building practices first became a focus of environmental advocates at 1970s, and a green design movement begin to emerge. Europe developed early building envelope regulations in the late 1970s to reduce heat transfer through envelope elements and control vapour diffusion and air permeability. “This was followed by regulations or best practice recommendations on design, calculation and maintenance of building thermal services (HVAC and DHW). Eventually, HVAC equipment was subject for the first time to minimum requirements of energy efficiency ” (Lombard, Ortiz & Maestre,2009, p 272).

According to Rees, 1989, the issue re-emerged under the labels of *sustainable* development in the 1980s. According to St. John, 1992 the issue re-emerged under the labels of sustainable design and the movement was more successful this time.

Public started to realise that, unlike automobiles or washing machines, buildings last decades, sometimes centuries.

A new concept relating to energy efficiency in buildings emerged in the early 1990s. This new concept was essential for reducing energy use and $CO_2$ emissions. In order to measure the system energy certifications has been generated.

The 1990s also saw increasing efforts to give practical advice to design and construction professionals. The Minnesota Sustainable Design Guide (1997), for instance, is providing guidance on how to attain sustainability during the design and planning process (Libovich, 2005, p 1968).

An overall objective of energy policy today in buildings is consuming less energy while providing equal or improved building services.

Since the Kyoto Protocol signed in December 1997, the majority of governments around the world have committed themselves to reducing the emission of the greenhouse gases.

Because of the reduction of natural energy sources (such as petroleum) in the present world, the possible energy shortage in future and global warming became extremely important in the social and political context.

The process of creating a high-performance building is different from the conventional design/build process. The main idea of this changing process is to significantly reduce or eliminate the negative impact of buildings on their occupants and on our environment. The sustainability goals must also support the project's goals for function, aesthetics, security, cost, and schedule. The challenge is to integrate environmental goals without compromising any of the project needs and objectives.

More skilled design teams recognize that successful green design with demanding performance expectations is useful for their design proposals by using the interrelationship between the strategies and systems as it is with their individual merits and consequences.

Broadening the scope of discussion beyond environmental responsibility and embracing the wider agenda of sustainability is an increasingly necessary requirement.

In the present world building design teams and occupants have great concerns about building performance. Till $20^{th}$ century considerable work has been done by different actors in order to develop systems to measure a building's environmental performance over its life.

Systems to measure a building's environmental performance have been developed to evaluate how successful any development is with regards to balancing energy, environment and ecology, taking into account both the social and technology aspects of projects (Clements-Croome, 2004).

To assess and monitor environmental building performance different indicators, or benchmarks have been developed.

There is a broad spectrum of environmental criterion. To achieve the goal of assessing a building a comprehensive assessment tool is need to provide a thorough evaluation of building performance.

By setting sustainable design priorities and goals, rating systems provides an effective framework for assessing building environmental performance and integrating sustainable development into building and construction processes.

Rating systems can be used as a design tool to guide the sustainable design and decision-making processes. They can also be used as a management tool to organize and structure environmental concerns during the design, construction, and operations phases.

The more effective way of achieving sustainability in a project is to consider and to incorporate environmental issues at a stage even before a design is conceptualised. So using environmental building assessment methods during the design stage, when any impairment for the pre-design criteria can be assessed and changes can be applied according to the results of assessment, is the most useful way. By the help of this timing environmental issues can be incorporated in the design process, which can minimise environmental damages.

The development of different tools in the building sector has been active. Different organisations and research groups have contributed new knowledge through experience. The tools have gained considerable success during the past years.

However, the success of the assessment tools has dwarfed all other mechanisms for instilling environmental awareness (Cole, 2005).

The building environmental assessment tools are for different purposes such as researching, consulting and designing. This leads to different user groups. In addition, different tools are used to assess existing and new buildings. Besides, the type of the building influences the choice of the environmental assessment tool.

Furthermore, the International Organization for Standardization (ISO) has been active in defining standardised requirements for the environmental assessment of buildings.

In 1997, ISO Technical Committee (TC) 59 “Building construction” and its Subcommittee (SC) 17 “Sustainability in building construction” have published two technical specifications:

▪ ISO/TS 21929-1:2006 sustainability in building construction — sustainability indicators — Part 1: Framework for development of indicators for buildings (ISO, 2006).

▪ ISO/TS 21931-1:2006 sustainability in building construction— framework for methods of assessment for environmental performance of construction works— Part 1: Buildings (ISO, 2006).

Worldwide, a variety of assessment programs have been developed around environmental and energy impacts of buildings. The first environmental certification system was created in 1990 in the UK, The Building Research Environmental Assessment Method (BREEAM). In 1998 the Leadership in Energy and Environmental Design (LEED®) Green Building Rating System was introduced based quite substantially on the BREEAM system. Since then many different tools have been launched around the world

## 2.2 Properties of Environmental Assessment Methods

### *2.2.1 Regional Variations*

Most environmental building assessment methods were developed for local use and do not allow for national or regional variations to reflect regional variations weighting systems can offer opportunities to revise the assessment scale. However, regional, social and cultural variations are complex and the boundaries are difficult to define. These variations include differences in climatic conditions, income level, building materials and techniques, building stocks and appreciation of historic value (Kohler, 1999, p 311).

GBTool (The name of the tool is now SBTool) is the first international environmental building assessment method and it is unlikely it will be used as intended without incorporating national or regional variations.

For instance the situation for developing countries is different from developed countries. Gibberd (2005) stated that sustainable development in developing countries should address social and economic issues as a priority; he suggested, that environmental sustainable development objectives should be acknowledged and addressed in interventions designed to address urgent social and economic priorities.

Libovich (2005) also believed that nations of the developing world, cannot afford to be looking at environmental performance only. The social and economic problems are at the top of these countries' agendas. As a result, the development of building assessment methods is becoming necessary in the developing countries in order to diagnose the building-stock's performance and to encourage the building industry to get into sustainable track, and thus by default will directly support social and economical aspects.

### *2.2.2 Complexity*

Environmental issues are broad and difficult to capture.

Because of dealing with incorporating environmental criteria and factors like financial and social aspects environmental building assessment methods tend to be too comprehensive. For example, the BEPAC comprises 30 criteria and SBTool comprises 120 criteria (Cole, 1999; Larsson, 1999).

The assessment of environmental performance of buildings includes both quantitative and qualitative performance criteria. Quantitative criteria comprise annual energy use, water consumption, greenhouse gas emissions, etc., whereas qualitative criteria include impact on ecological value of the site, impact on local wind patterns, and so on. Quantitative criteria can be readily evaluated based on the total consumption level and points awarded accordingly (Ding, 2006).

For example, in BREEAM 8 credit points are given for $CO_2$ emissions between 160 and 140 kg/m2 per year and more points are awarded if CO2 emissions are further reduced (BREEAM'98 for Office). However, environmental issues are mainly qualitative criteria, which cannot be measured and evaluated using market-based approaches within the existing environmental assessment framework. Environmental issues can only be evaluated on a 'feature specific' basis where points are awarded for the presence or absence of desirable features (Ding, 2006).

### *2.2.3 Weighting*

Weighting is inherent to the systems and when not explicitly, all criteria are given equal weights (Todd et al., 2001).

According to Lee et al. (2002) weighting is the heart of all assessment schemes since it will dominate the overall performance score of the building being assessed.

However, there is at present neither a consensus-based approach nor a satisfactory method to guide the assignment of weightings (Ding, 2006).

The GBC framework provides a default weighting system and encourages users to change the weights based on regional differences. However, since the default weighting system can be altered, it may be manipulated the results to improve the overall scores in order to satisfy specific purposes (Larsson, 1999; Todd et al., 2001).

In CASBEE the weighting coefficients play an important part in the assessment process. The weighting coefficients were determined by questionnaire survey to obtain opinions from the users of the system such as designers, building owners and operators, and related officials. The weighting coefficients may be modified to suit local conditions such as climate or to reflect the prioritised policies (IBEC, 2004).

The weighting coefficients may need to be updated regularly which can be a time consuming activity. Cole (1998) states that the main concern is the absence of an agreed theoretical and non-subjective basis for deriving weighting factors.

The relative importance of performance criteria is an important part of the decision if the stated objectives are to be achieved, for example, the public sector's opinion will definitely differ from that of the private developer. Therefore, the weighting of the criteria should be derived on a project-by-project basis and reflect the objective of a development. The absence of any readily used methodological framework has hampered existing environmental assessment methods in achieving sustainability goals (Ding, 2006).

## 2.3 Environmental Assessment Methods and Standards

### *2.3.1 BREEAM (Building Research Establishment Environmental Assessment Method)*

BREEAM is a voluntary measurement rating for green buildings that is operated in the UK by the Building Research Establishment (BRE), which describes itself as an independent and impartial, research based consultancy, testing and training organisation.

The first version of BREEAM was introduced in the UK in 1990, and an international concept was presented in 2008 (Breeam,2009).

#### *2.3.1.1 Code for Sustainable Homes*

The Code for Sustainable Homes (CSH) is an environmental assessment method for rating and certifying the performance of new homes based on BRE Global's EcoHomes scheme. It is a Government owned national standard intended to encourage continuous improvement in sustainable home building (Bream, 2009).

#### *2.3.1.2 Weightings of BREEAM*

Table 2.1 Weightings of BREEAM from http://www.breeam.org/page.jsp?id=86

| Category | BREEAM Europe% | BREEAM Gulf % |
|---|---|---|
| Management | **12** | **8** |
| Health & wellbeing | **15** | **15** |
| Energy | **19** | **13** |
| Transport | **8** | **6** |
| Water | **6** | **30** |
| Materials | **12,5** | **9** |
| Waste | **7,5** | **5** |
| Land use & ecology | **10** | **7** |
| Pollution | **10** | **7** |

### *2.3.2 German Sustainable Building Certificate - DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen e. V)*

DGNB was founded in 2007. The aim was to promote sustainable and economically efficient building even more strongly in future. The reaction to the founding of the DGNB was extremely positive (DGNB, 2008).

The German Sustainable Building Certificate was developed by the German Sustainable Building Council (DGNB, a private non profit organisation) together with the Federal Ministry of Transport, Building, and Urban Affairs (BMVBS) to be used as a tool for the planning and evaluation of buildings in this comprehensive perspective on quality. On the more general level, the purpose of establishing DGNB was to create a second generation system for building certification, based on upcoming European standards for sustainable buildings and with focus on sustainability as an entity including ecology, economy, socio cultural and functional topics, techniques, processes, and location. The DGNB certification system was launched in 2009, followed shortly thereafter by the launch of its internationalization The very basic concept of the DGNB scoring and rating system is that the performance in five criteria groups with a fixed relative importance is assessed (Eurima, 2012)

#### *2.3.2.1 Weightings of DGNB*

Table 2.2 Weightings of DGNB ( http://www.dgnb.de/en/council/dgnb/)

| CATEGORY | WEIGHTINGS (%) |
|---|---|
| Ecological quality (subdivided into 11 criteria) | 22.5 |
| Economical quality | 22.5 |
| Sociocultural and functional quality | 22.5 |
| Technical quality | 22.5 |
| Quality of the process | 10 |

### *2.3.3 LEED (Leadership in Energy and Environmental Design)*

LEED (Leadership in Energy and Environmental Design) is a voluntary, consensus-based, market-driven program that provides third-party verification of green buildings. LEED projects have been successfully established in 135 countries (LEED, 2009).

The LEED green building certification scheme is managed by the US Green Building Council (USGBC), a US based non profit organization.

The first LEED Pilot Project Program (LEED version 1.0) was launched at the US Green Building (USGBC) Membership Summit in August 1998. After extensive modifications, LEED GreenBuilding Rating System was released in March 2000, with revisions in 2002 and 2005. Version 3.0 was released in 2009 and today, LEED consists of a suite of nine rating systems for the design, construction and operation of buildings, homes and neighbourhoods. (Eurima, 2012)

#### *2.3.3.1 Weightings of LEED*

Table 2.3 Weightings of LEED (http://www.yesilbina.com/leed-sertifikasi_a18.html)

| CATEGORY | Schools | Commercial Interiors | Existing Buildings | New Construction and Major Renovations | Core and Shell |
|---|---|---|---|---|---|
| SITE | 21,8 | 19 | 23,6 | 23,6 | 25,4 |
| WATER | 10 | 10 | 12,8 | 9,1 | 9,1 |
| ENERGY AND ATMOSPHERE | 30 | 33,6 | 31,8 | 31,8 | 33,7 |
| MATERIALS AND RESOURCES | 11,8 | 12,8 | 9 | 12,7 | 11,8 |
| INDOOR AIR QUALITY | 17,2 | 15,5 | 13,7 | 13,7 | 10,9 |
| INNOVATION AND DESIGN | 5,6 | 5,5 | 5,5 | 5,5 | 5,5 |
| REGIONAL PRIORITY | 3,6 | 3,6 | 3,6 | 3,6 | 3,6 |

### *2.3.4 HQE (Haute Qualité Environnementale / High Quality Environmental Standard)*

HQE is a French certification scheme, administered by the HQE Association a publicly recognized nonprofit Organization established in 1996. The HQE association is recognized as a charity since 2004 (Assohqe, 2005).

HQE certifies both new and existing buildings, but since the scheme is process oriented existing buildings can probably only be certified in connection with a major renovation. In practice, the environmental performance of the building is assessed three times during the project: After establishing the building program, at the end of the conception phase, and at the end of the construction of the project. Also the project management is assessed at the three phases. An assessor is appointed by the certifying body to follow the project from the start, and the role of the assessor is primarily to check that the requested information is available, not to provide guidance to the builder and his team (Eurima,2012).

#### *2.3.4.1 Weightings of HQE*

The certification scheme does not address the relative importance of the categories, meaning in other words that they are equally important for the basic certification. Moreover, the approach also means that a bad performance in one category cannot be counterbalanced by a high performance in another. Please note, however, that the performance in the 14 categories can be aggregated in an overall rating of the building (Eurima,2012).

### *2.3.5 SBTool ( Sustainable Building Tool)*

SBTool Generic is a generic building performance assessment framework, based on the SB Method, for rating the sustainable performance of sites and building projects

The SBTool is a rating framework or toolbox. Countries can use it as a basis to develop their own rating system. Therefore, they have to adapt it to their region and specific conditions like climate or environmental issues. The countries have to set the weights, context and performance benchmarks. It is modular in scope and local criteria can be easily inserted – ranging from 125 criteria to half a dozen. It deals with the four major phases: Pre-design, Design, Construction & Commissioning and Operation. It can handle new and existing buildings and up to three occupancy types ( Larsson,2012)

#### *2.3.5.1 Weightings of SBTool*

Table 2.4 Weightings of SBTool (Larsson, 1999)

| CATEGORY | WEIGHTINGS (%) |
|---|---|
| Indoor Environmental Quality | 21,6 |
| Social, Cultural and Perceptual Aspects | 2,6 |
| Environmental Loadings | 25,7 |
| Cost and Economic Aspects | 5,2 |
| Energy and Resource Consumption | 21,6 |
| Site Regeneration and Development, Urban Design and Infrastructure | 7,8 |

### *2.3.6 CASBEE (Comprehensive Assessment System for Building Environmental Efficiency)*

This situation prompted the formation of the Japan Sustainable Building Consortium (Secretariat: The Institute for Building Environment and Energy Conservation) in April 2001, as a joint project between industry, government and academia, with the assistance of Japanese Ministry of Land, Infrastructure and

Transport. The Consortium's research has produced the Comprehensive Assessment System for Building Environmental Efficiency (CASBEE). Overall management of CASBEE development has been carried out by newly-formed JSBC (Japan Sustainable Building Consortium) and its affiliated sub-committees. CASBEE is a tool for comprehensive assessment of the environmental performance of buildings, based on new concepts such as Building Environmental Efficiency (BEE). The development and promotion of CASBEE is an element in "Japanese Ministry of Land, Infrastructure and Transport Environmental Action Plan" and "The Interim Report of the Environment Working Group of the Social Capital Development Council - Global Warming Countermeasures in the Context of Social Capital Development." ( CASBEE,2004, 35)

The Assessment Results Sheet presents assessment results for each field as radar charts, bar graphs and numerical data for Q (environmental quality and performance of the building) and LR (the building's load reduction). The BEE (Building Environmental Efficiency) result is also presented numerically and graphically, giving a multi-faceted and comprehensive grasp of the environmental characteristics of the evaluated building. BEE is calculated from SQ and SLR, the scores for Q and LR, according to the formula below.

$$\text{BEE} = \frac{\text{Q: Building environmental quality and performance}}{\text{L: Building environmental loadings}} = \frac{25 \times (S_Q - 1)}{25 \times (5 - S_{LR})}$$

The graph points are plotted with Q values on the Y axis and L values on the X axis to determine the Building Environmental Efficiency position, which enables Building Environmental Efficiency ranking on five classes from S down to C.(CASBEE,2004)

*2.3.6.1 Weightings of CASBEE*

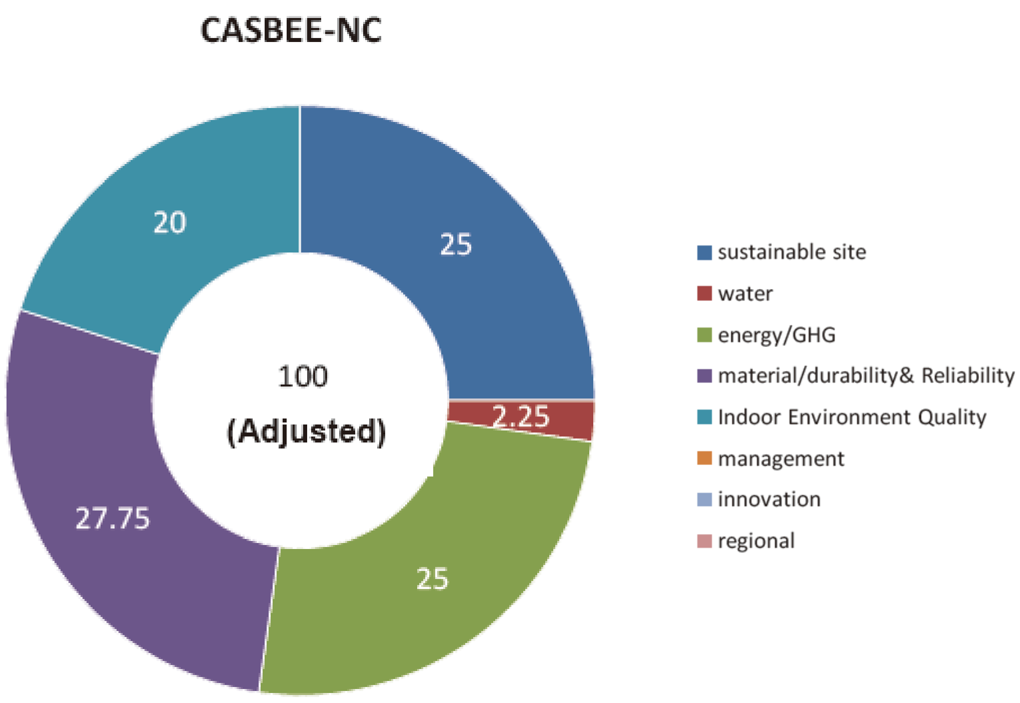



Figure 2.2 Weightings of CASBEE ( CASBEE,2010)

### *2.3.7 Ecolabel for Buildings*

Table 2.5 Weightings of CASBEE (CASBEE,2010)

| Assessment Fields | Non-Factory | Factory |
|---|---|---|
| Q -1 Indoor environment | 0.40 | 0.30 |
| Q -2 Quality of Service | 0.30 | 0.30 |
| Q -3 Outdoor Environment on Site | 0.30 | 0.40 |
| LR - 1 Energy | 0.40 | |
| LR - 2 Resorces & Materials | 0.30 | |
| LR - 3 Off-site Environment | 0.30 | |

According to ISPRA report, 2008, European Ecolabel criteria's main environmental aspects have been organised according to the different phases occurring in the life cycle of buildings.

At the same time an analysis of some selective environmental Ecolabels has been conducted in order to point out the most used criteria according to the main environmental aspects identified and for the different life cycle phases.

The analysis carried out includes the type of the existing criteria and the indicators used by CEN TC 350 for sustainability assessment of buildings.

A specific chapter has been also devised to Green Public Procurement criteria already elaborated at European level especially for construction materials.

#### *2.3.8 OPEN HOUSE – A European Methodology for Assessing the Sustainability of Buildings*

The overall objective of OPEN HOUSE is to develop and to implement a common European - transparent building assessment methodology, complementing the existing ones, for planning and constructing sustainable buildings by means of an open approach and technical platform (Open house, 2010).

In analyzing existing standards and assessment methods OPEN HOUSE is based on a "bottom-up" approach

For the project OPEN HOUSE a European consortium of 20 stakeholders – large companies, high-tech SMEs, research organizations, policy makers – is working since February 2010 on the development of the OPEN HOUSE methodology

The main scientific and technical objectives of OPEN HOUSE are

- to define the OPEN HOUSE baseline: an open and transparent European platform for building sustainability
- to widely communicate the baseline concept and outline the mechanisms for interaction among the project and stakeholders
- to build up the OPEN HOUSE Platform: facilitating a pan EU effort towards a common view on building sustainability
- to pave the way for implementing and evaluating the methodology: selection of case studies and mechanisms for decision making (Sebastian, Natalie, Matthias & Vincent ,2010, p 4).

*2.3.8.1 Weighting*

The weighting system is splinted into two parts:

*2.3.8.1.1 Weighting of Indicators.* Depending on the special needs of each country, the weighting factors for each indicator can be adjusted from 1 (less important) up to 5 (most important).

*2.3.8.1.2 Weighting of Category*. Categories can be weighed against each other in %. In the first version of the baseline methodology the three categories Environmental Quality, Social/Functional Quality and Economic Quality are weighted equally to each other with 33,33 %. Technical Characteristics, Process Quality and the Location are displayed in an extra note and are not part of the main assessment (Sebastian & others ,2010 ).

***2.3.9 ISO TC59/SC 17***

The suite of related International Standards for sustainability in building construction and other construction works is illustrated by the following figure adapted from ISO 15392 "Sustainability in building construction: General Principles" (ISO,2001)

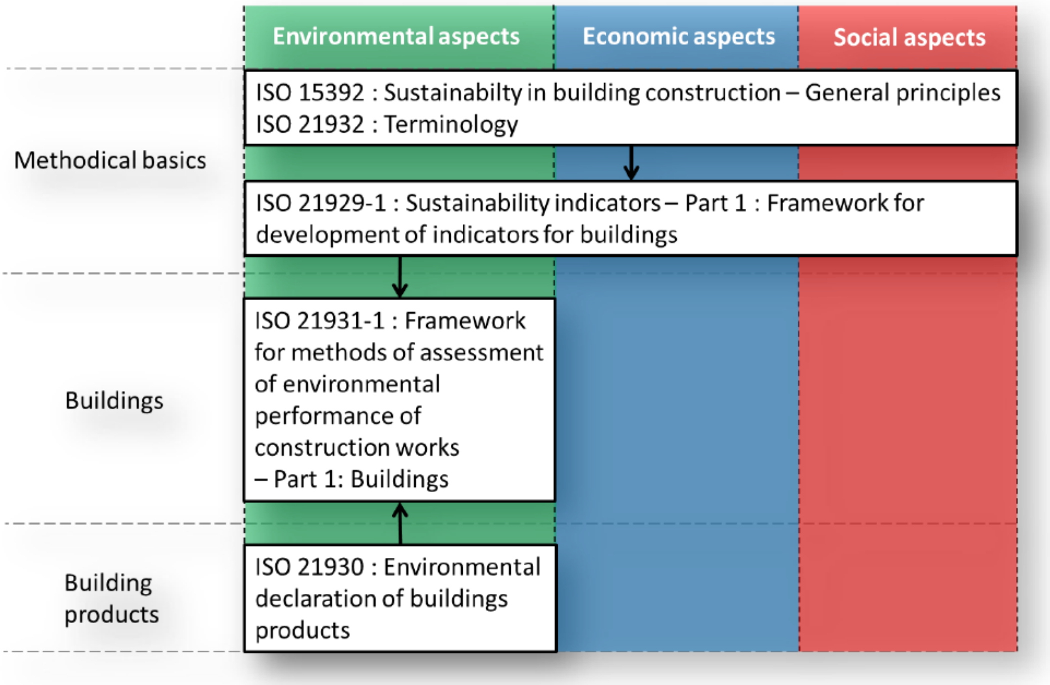



Figure 2.3 Suite of related International Standards for Sustainability of Building Construction (ISO,2001)

Concerning the structure of assessment methods and indicators the ISO 15392 considers the three primary aspects of sustainable development – economic, environmental, and social aspects (with equal importance), while meeting requirements for technical and functional performance of the construction works as well in regard to the whole life cycle of building (from their inception to the end of life).

### *2.3.10 SB Alliance*

The SB Alliance is an international non-profit organization bringing together operators of building rating tools and certification, standard setting organizations, national building research centres and key property industry stakeholders, The purpose of SB Alliance is accelerating the adoption of sustainable building practices through the promotion of shared indicators for building performance assessment and rating ( SB alliance, 2009).

Regarding the SB Alliance, the number of indicators suggested is reduced considerably (6 indicators are suggested), but environmental and social indicators are suggested equally (Sebastian & others ,2010)

### *2.3.11 CEN/TC 350*

CEN/TC 350 "Sustainability of construction works" is responsible for the development of voluntary horizontal standardized methods for the assessment of the sustainability aspects of new and existing construction works and for standards for the environmental product declaration of construction products. In 2004 the Standardisation Mandate M/350 was addressed to CEN for the development of horizontal standardised methods for the assessment of the integrated environmental performance of buildings. The work has been allocated to CEN/TC 350.The existing standards provide the horizontal standardised methodology and indicators for the sustainability assessment of buildings using a life cycle approach in a transparent way. This is the main principle in the CEN/TC350 standards, because without a long-term perspective and life cycle approach it is not appropriate to refer to sustainability (Cen,2008 ).

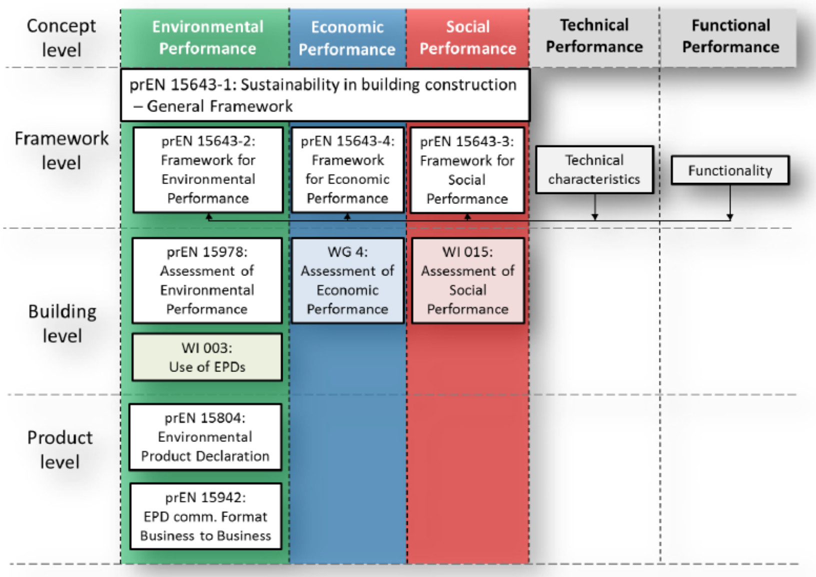



Figure 2.4 Suite of related European Standards for sustainability in building construction (Cen,2008)

European suite of standards of the CEN/TC 350 recommends the assessment of buildings in terms of environmental, social and economic performance taking into account technical characteristics and functionality of a building. The assessment takes in account the whole life cycle of the building with distinction of the four stages:

- Production
- Construction
- In-Use
- and End of life

based on a LCA approach. (Sebastian & others ,2010)

| | Project reference | Title | Candidate citation in OJEU* | Current status | DAV |
|---|---|---|---|---|---|
| 00350015 | prEN 16309 | Sustainability of construction works - Assessment of social performance of buildings - Methods | No (-) | Under Approval | 2013-04 |
| 00350017 | | Sustainability of construction works - Assessment of economic performance of buildings - Calculation method | No (-) | Under Drafting | 2015-05 |
| 00350018 | EN 15804:2012/FprA1 | Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products | No (89/106/EEC) | Under Approval | 2013-10 |

(*) OJEU - Official Journal of the European Union

Figure 2.5 CEN TC 350 Standard under development ( Cen,2008 )

### *2.3.12 LEnSE: Methodology Development Towards A label For Environmental, Social and Economic Buildings*

The LENSE was a European research project that responds to the growing need in Europe for assessing a building's sustainability performance. The main objective of LENSE was to develop a methodology for the assessment of the sustainability performance of existing, new and renovated buildings, which is broadly accepted by the European stakeholders involved in sustainable construction (Cordis,2008).

LENSE aimed to develop a Europe-wide accepted assessment methodology, which also allows for regional or national variances and priorities to be incorporated.

The project managed to develop a list of issues which was included in the assessment methodology. The list was wide enough to be meaningful for all European members, but limited enough to be practical. A broad consensus on these issues was reached through strategic consultation of the relevant stakeholders.

It developed a methodology for assessment of the overall sustainability of existing buildings, major renovations and plans for new buildings. The methodology took into account the existing methodologies and initiatives and ongoing standardisation activities. Guidelines on how to address local variations were also provided. This work was validated by the development of a prototype tool and tested on case study buildings. (Cordis,2008)

> The project also set up a strategic consultation of the stakeholders. In order to ensure a methodology was accepted and used by the stakeholders, these consultations included national meetings with stakeholders and trans-national expert workshops. The consultation and communication activities also raised the stakeholders' awareness about sustainability assessment and the advantages of the LENSE approach. The LENSE project also interacted with standardisation activities at CEN and ISO level to make sure the methodology was in line with the standards in development. (Sebastian & others ,2010,p 6)

Lense is supported by the European Commission within the sixth Framework Program

## 2.4 Sustainable Building Assessment Model For New Residential Buildings According To Turkish Construction Sector Needs

After the research of the current assessment tools and documents (by the help of tables ) 3 versions of assessment tool has been developed by discussing with the experts.

### *2.4.1 Full Version*

#### *2.4.1.1 Management*

*Documentation*

- Home user guide
- Integrated design
- Liquid effluents from building operations that are sent off the site management plans
- Construction waste Management plan
- Solid non-hazardous waste from facility operations sent off the site management plans
- Environmental management system plans
- Storage and Collection of recyclables plan
- Construction site impacts

*User friendly*

- Handicapped accessibility
- Ability for building operator or tenant to modify facility technical systems.
- Adaptation of building and services to IT innovation
- Innovation in Design
- Common TV antenna

- Ensuring the thorough consideration of users' needs in the design and construction process
- Architectural quality of buildings
- Quality of buildings as a place to live and work

*Operation Phase*

- Optimization and Maintenance of Operating Performance
- Operating functionality and efficiency of key facility systems.
- Enhanced refrigerant Management
- Adequate Constructor

*Reliability*

- Seismic Isolation and vibrating damping system usage for the performance to earthquakes
- Security
- Fire Retardant Actions Management

*2.4.1.2 Sustainable Sites*

*Transport*

- Provision of public transport
- Provision and quality of bicycle pathways and parking.
- Provision and quality of walkways for pedestrian use.
- Low-Emitting and fuel-Efficient vehicle parking

*Security*

- Distance to earthquake faults

- Proximity to amenities
- Resistance to hail, storms and flooding

*Nature friendly*

- Enough green areas
- Reducing need for commuting transport through provision of mixed uses
- Brownfield redevelopment
- Protect or restore Habitat
- Changes in biodiversity on the site.

*Density*

- Development Density and Community Connectivity
- Impact of building user population on peak load capacity of public transport system.
- Impact of private vehicles used by building population on peak load capacity of local road system

*Orientation*

- Impact of orientation on the passive solar potential of building(s).
- Impact of site and building orientation on natural ventilation of building(s) during warm season(s).
- Impact of site and building orientation on natural ventilation of building(s) during cold season(s).

*2.4.1.3 Water Efficiency*

- Usage of water efficient equipment
- Rain water collectors
- Grey water usage

- Water Efficient Landscaping
- Recharge of groundwater.
- Reduction of surface water run-off from site
- Decreasing the use of fresh water
- Quality of water for use in buildings

*2.4.1.4 Energy and Resources*

*Performance*

- Adequacy of the building envelope for maintenance of long-term performance.
- Heating energy grade on energy identity document
- Cooling energy grade on energy identity document
- Hot water energy grade on energy identity document
- Provision and quality of exterior lighting.

*Renewable Energy and Emissions*

- Renewable energy usage ratio on energy identity document
- On-site renewable Energy
- Consumption of non-renewable energy for all building operations.
- Converted use of renewable energy
- Greenhouse gas emission class on energy identity document
- Low or Zero Carbon Energy Technologies
- Building footprint
- Destruction of stratospheric ozone layer

*Materials and Goods:*

- Ecolabelled white goods (if decided)
- Household recycling facilities

- LCA results for selected details
- Regional Materials
- Certified wood
- Materials of low environmental load
- Reusability of components and materials
- Reuse of Existing Building Skeleton

*Natural Energy*

- Natural Energy Utilization
- Direct Use Of Natural Energy

*Heat Island*

- Heat island Effect—Nonroof
- Heat island Effect—roof

*Waste*

- Non – Hazardous wastes to landfills
- Hazardous waste to landfill

*2.4.1.5 Health and Well Being*

*Acoustic Performance*

- Acoustic comfort
- Noise control
- Background noise
- Equipment noise
- Sound insulation of openings
- Sound insulation of partition walls
- Sound insulation of floor slabs (light impact)

- Sound insulation of floor slabs (heavy impact)
- Sound Absorption
- Noise attenuation through the exterior envelope.
- Transmission of facility equipment noise to primary occupancies.
- Noise attenuation between primary occupancy areas
- Appropriate acoustic performance within primary occupancy areas

*Ventilation.*

- Openings by orientation
- Natural ventilation performance

*Daylight*

- Visual Comfort
- Daylight performance
- Anti glare measures
- Glare from light fixtures
- Appropriate daylighting in primary occupancy areas.
- Control of glare from daylighting.
- Illuminance level
- Lighting controllability,

*Comfort*

- Thermal comfort
- Appropriate air temperature and relative humidity in mechanically cooled occupancies.
- Appropriate air temperature in naturally ventilated occupancies.
- Odors

*2.4.1.6 Cost and Economic Aspects*

- Construction cost.
- Operating and maintenance cost
- Life-cycle cost.
- Affordability of residential rental or cost levels.

***2.4.2 Mid Version***

*2.4.2.1 Management*

*Documentation*

- Home user guide
- Construction waste Management plan

*User friendly*

- Handicapped accessibility
- Adaptation of building and services to IT innovation
- Common TV antenna

*Operation Phase*

- Adequate Constructor

*Reliability*

- Seismic Isolation and vibrating damping system usage for the performance to earthquakes

- Security
- Fire Retardant Actions Management

*2.4.2.2 Sustainable Sites*

*Transport*

- Provision of public transport
- Low-Emitting and fuel-Efficient vehicle parking

*Security*

- Distance to earthquake faults
- Proximity to amenities
- Resistance to hail, storms and flooding

*Nature friendly*

- Enough green areas

*2.4.2.3 Water Efficiency*

- Usage of water efficient equipment
- Rain water collectors
- Grey water usage
- Water Efficient Landscaping

*2.4.2.4 Energy and Resources*

*Performance*

- Heating energy grade on energy identity document
- Cooling energy grade on energy identity document

- Hot water energy grade on energy identity document

*Renewable Energy and Emissions*

- Renewable energy usage ratio on energy identity document
- On-site renewable Energy
- Low or Zero Carbon Energy Technologies

*Materials and Goods*

- LCA results for selected details
- Regional Materials
- Reusability of components and materials.

*2.4.2.5 Health and Well Being*

*Acoustic Performance*

- Noise control
- Sound insulation of floor slabs (light impact)

*Ventilation*

- Natural ventilation performance

*Daylight*

- Daylight performance
- Daylight devices

*Comfort*

- Thermal comfort

*2.4.2.6 Cost and Economic Aspects*

- Construction cost.
- Life-cycle cost.

### *2.4.3 Core Version*

In order to adapt the Turkish Construction Market to sustainable design issues basic issues and criterion is selected by discussing with experts. This “Core Version” is easy to adapt and contains the basic elements of sustainable design tips.

*2.4.3.1 Sustainable Sites*

- Provision of public transport
- Distance to earthquake faults
- Proximity to amenities
- Enough green areas

*2.4.3.2 Water Efficiency*

- Usage of water efficient equipment
- Rain water collectors
- Grey water usage

*2.4.3.3 Energy and Resources*

- LCA results for selected details
- Greenhouse gas emission grade on energy identity document

- Heating energy grade on energy identity document
- Cooling energy grade on energy identity document
- Hot water energy grade on energy identity document
- Renewable energy usage ratio on energy identity document

*2.4.3.4 Health and Wellbeing*

- Daylight performance
- Natural ventilation performance
- Noise control

# CHAPTER THREE

# WEIGHTINGS OF THE CORE VERSION

The weighting coefficients play an important part in the assessment process.

The weighting coefficients were determined by questionnaire survey to obtain opinions from architects, civil and mechanical engineers. The weighting coefficients have been modified according to results of the questionnaires.

## 3.1 Questionnaire

In order to have collect data the writer of this thesis used a questionnaire

On 02.May.2007 “Energy Productivity Law” published. This law defined “Energy Identity Document”. Energy Identity Document is the result page of an energy assessment program called BEP.TR.

Only Energy Identity Document experts can use this web based program by their passwords. Civil, electrical, mechanical engineers and architects can be experts.

The writer of this thesis is an instructor of BEP.TR for Ministry for Urbanism and Environment.

By the help of being an instructor who works for Chamber Of Architects the writer of this thesis had chance to have these questionnaires in 4 different parts of Turkey (Ordu, Adana, Bursa, İzmir)  with 84 different Energy Identity Document Experts.

The gathered data is evaluated by Analytic Hierarchy Process (AHP).

### 3.2 Analytic Hierarchy Process (AHP)

Thomas Saaty developed the Analytical Hierarchy Process (AHP) to be an effective means of dealing with complex decision-making. AHP is a very popular approach to multi-criteria decision-making (MCDM) that involves qualitative data.

AHP helps capture both subjective and objective evaluation measures, providing a useful mechanism for checking their consistency relative to considered alternatives, thus reducing bias in decision making.

It has been applied during the last twenty-five years in many decision making situations and has been used on a wide range of applications in many different fields. The method uses a reciprocal decision matrix obtained by pair wise comparisons so that the information is given in a linguistic form. (Alanso, Lamata,2006,p 447)

AHP provides a way of breaking down the general method into a hierarchy of sub-problems, which are easier to evaluate.

In the pair wise comparison method, criteria and alternatives are presented in pairs of one or more referees (e.g. experts or decision makers). It is necessary to evaluate individual alternatives, deriving weights for the criteria, constructing the overall rating of the alternatives and identifying the best one.

When confronted with a complex problem, humans tend to group elements of the problem by certain properties that we believe we can compare. Through a series of analytical groupings at successively higher levels of problem abstraction, we eventually arrive at single element resulting from multiple level pair wise comparisons. That single element is the answer to our problem - the goal of the decision making exercise. When an interrelated diagram of comparisons represents the process, we have a decision tree or hierarchy of comparisons that helps name the process AHP uses simple pairwise comparison of components of a decision to produce intensity measures. (Fad, 2006, p 25)

### *3.2.1 Description of the Process*

The matrix of pair wise comparisons $A = [a_{ij}]$ represents the intensities of the expert's preference between individual pairs of alternatives (*Ai* versus *Aj*, for all *i,j=1,2,..,n*). They are usually chosen from a given scale (1/9,1/8,…,8,9). Given *n* alternatives $\{A_1, A_2, A_3, ........., A_n\}$ a decision maker compares pairs of alternatives for all the possible pairs, and a comparison matrix *A* is obtained, where the element $a_{ij}$ shows the preference weight of $A_i$ obtained by comparison with $A_j$ .

Comparisons are made for the upper part of the diagonal because for the lower part of the diagonal we will use the formula below (Yaralıoğlu,Köksal, 2006)

$$a_{ji} = \frac{1}{a_{ij}}$$

$$A = [a_{ij}] = \begin{pmatrix} 1 & a_{12} & \cdots & a_{1j} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2j} & \cdots & a_{2n} \\ . & & & & & \\ 1/a_{1j} & 1/a_{2j} & \cdots & a_{ij} & \cdots & a_{in} \\ . & & & & & \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1/a_{in} & \cdots & 1 \end{pmatrix}$$

If a matrix *A* is absolutely consistent, we notice that *A=W* and in the ideal case of total consistency, the principal eigen value ($\lambda max$) is equal to n, i.e " $\lambda max = n$", the relations between the weights and the judgements will be given by $wi / wj = a_{ij}$ for $i,j = 1,2,\ldots n$. The weights $w_{i,j} =1,2,...,n$, were obtained using the eigenvector method, they are positive and normalized, and satisfy the reciprocity property. Let $A = [\ a_{ij}\ ]$ for all $i,j=1,2,\ldots,n$ denote a square pairwise comparison matrix, where $a_{ij}$ gives the relative importance of the elements *i* and *j*. Each entry in the matrix *A* is positive ( $a_{ij} > 0$) and reciprocal ($aij= 1 / aji \vee ij = 1,2,\ldots,n$. Our goal is to compute a vector of weights $\{w_1, w_2, ........., w_n\}$ associated with *A*. According to the

Perron-Frobenius Theorem, if *A* is an *n x n,* non-negative, primitive matrix , then one of its eigenvalues λ*max,* is positive and greater than or equal to (in absolute value) all other eigenvalues, and there is a positive eigenvector *w* corresponding to that eigenvalue, and that eigen value is a simple root (matrix Frobenius root) of the characteristic equation(Alanso, Lamata,2006, p 446)

$$A\,w = \lambda_{\max}\,w$$

Table 3.1 Scale of Relative Importance (Yaralıoğlu,Köksal, 2006)

| **Intensity of Relative Importance** | **Definition** | **Explanation** |
|---|---|---|
| 1 | Equal Importance | Two activities contribute equally to the objective |
| 3 | Moderate Importance | Experience and judgement another slightly favour one activity over |
| 5 | Essential or Strong | Experience or judgement strongly favours one activity over another |
| 7 | Importance Demonstrated | An activity is strongly favoured and its dominance is demonstrated in practice |
| 9 | Extreme (Absolute) | The evidence favouring one activity over another is of the highest possible order of affirmation |
| 2,4,6,8 | Intermediate values | When compromise is needed |

The matrix of pair wise comparisons represents the intensities of the factors in a logical way. By the help of the column vector of the comparison matrix the weightings of the factor can be formed (which is B column vector with has n pieces with n components )

For the calculation of B column vector the below formula is useful. Sum of B column vector will always be 1.

$$B_i = \begin{bmatrix} b_{11} \\ b_{21} \\ . \\ . \\ . \\ b_{n1} \end{bmatrix} \qquad b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}$$

By repeating the steps described above other evaluation factors B column vectors for each factor will be obtained.

By putting together these B column vectors (n units) in a matrix format we generate the matrix C

$$C = \begin{bmatrix} c_{11} & c_{12} & \dots & c_{1n} \\ c_{21} & c_{22} & \dots & c_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ c_{n1} & c_{n2} & \dots & c_{nn} \end{bmatrix}$$

While generating C matrix $c_{ij}$ will be $b_{ij}$.

By the help of C matrix, weights of factors f can be achieved. In order to do this (as shown in he formula below) the arithmetical mean of each line has to calculated. And priority vector, W column vector) can be achieved

$$w_i = \frac{\sum_{j=1}^{n} c_{ij}}{n} \qquad W = \begin{bmatrix} w_1 \\ w_2 \\ . \\ . \\ . \\ w_n \end{bmatrix}$$

*3.2.1.1 Consistency*

Although AHP has a consistent systematic, results are affected with the decision makers consistency for the pair wise comparisons. AHP suggests a process to measure the consistency of these comparisons with the help of consistency ratio. (CR)

In this exceptional case, the two different matrices of judgements (*A*) and weights (*W*) are equal. However, it would be unrealistic to require these relations to hold in the general case. For instance, it is known that the number of totally consistent different matrices (using the Saaty scale) for n=3 is 13 or only 4 depending on whether the indifference in the relation of preference is accepted or not, for n=4 these values are 13 and 1, respectively, for n=5 is 14 and none, and so on. Otherwise, if the referee is not absolutely consistent then $\lambda max > n$, and we need to measure this level of inconsistency. For this purpose, Saaty defined the consistency ratio (CR) asCR = CI / RI . Where RI is the average value of CI for random matrices using the Saaty scale tained by Forman and Saaty only accepts a matrix as a consistent one if CR < 0.1. (Alanso, Lamata,2006, p 446)

If (and only if) the decision-makers generate "perfect" judgements (absolutely consistent judgements) for arbitrary *i, j* and *k*, $a$ij. $a_{jk} = a_{ik}$ ($i, j, k=1,\ldots, n$), the comparison matrix determinant is null , the matrix Frobenius root ($\lambda max$) is always equal to *n,* and the remaining eigenvalues are all 0 for any $a$ij . Thus, the eigenvector corresponding to the Frobenius root is always non-negative, and each element of the eigenvector standardized by normalization can be interpreted as the degree of importance of each alternative. In this situation, the comparison matrix obviously satisfies the transitivity property for all pairwise comparisons. (Alanso, Lamata,2006, p 452)

Unfortunately, decision-makers do not normally make "perfect" judgements, and therefore the Frobenius root of such an inconsistent pairwise comparison matrix is always greater than *n*, and the difference between the root and *n* is equal to the sum of the remaining eigenvalues (Aupetit and Genest, 1993).

Consequently, the smaller the difference, the more consistent the decision maker's judgement would be (Murphy, 1993).

Saaty (1980) defined the consistency index (CI) and consistency ratio(CR) as follows:

$$CR = \frac{CI}{RI} \qquad CI = \frac{\lambda_{max} - n}{n - 1}$$

As RI is an coefficient which we know we need to find $\lambda$ (eigen value) for the solution.

*3.2.1.1.1 Eigen Value Calculation.* To calculate eigen value:

1. We will use D column vector by multiplying matrix A with priority vector W.

$$D = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} x \begin{bmatrix} w_1 \\ w_2 \\ . \\ . \\ . \\ w_n \end{bmatrix}$$

2. After forming D column vector we can evaluate main value E by dividing elements of D column vector by elements of W priority vector

$$E_i = \frac{d_i}{w_i} \qquad (i = 1,2,...,n)$$

3. We can evaluate $\lambda$ (eigen value) by the arithmetical mean of main values

$$\lambda = \frac{\sum_{i=1}^{n} E_i}{n}$$

4. With the help of eigen value we can calculate consistency index (CI)

5. At the last step by just dividing the CI by RI ( which we get from the table below) we can calculate CR

$$CR = \frac{CI}{RI} \qquad \left( CI = \frac{\lambda - n}{n-1} \right)$$

*3.2.1.1.2 Random Index. (RI)*A historical study of several RIs used and a way of estimating this index can be seen in Alonso and Lamata. The main idea is that the CR is a normalized value since it is divided by an arithmetic mean of random matrix consistency indexes (RI). Various authors have computed and obtained different RIs depending on the simulation method and the number of generated matrices involved in the process. Saaty (at Wharton) and Uppuluri (at Oak Ridge) simulated the experiment with 500 and 100 runs, respectively. Lane and Verdini (1989), Golden and Wang (1990), and Noble (1990) carried out 2500, 1000, and 5000 simulation runs. Forman (1990) also provided values for matrices of size 3 through 7 using examples from 17672 to 77487 matrices. Tumala and Wan (1994) subsequently performed the experiment with samples ranging from 4600 to 470000, and they obtained the values shown in (Alanso, Lamata,2006, p 450)

Table 3.2 RI differences (Alanso, Lamata,2006, p 450)

| | Oak Ridge | Wharton | Golden Wang | Lane, Verdini | Forman | Noble | Tumala, Wan | Aguaron et al | Alonso, Lamata |
|---|---|---|---|---|---|---|---|---|---|
| | 100 | 500 | 1000 | 2500 | | 500 | | 100000 | 100000 |
| 3 | 0,382 | 0,58 | 0,5799 | 0,52 | 0,5233 | 0,49 | 0,500 | 0,525 | 0,5245 |
| 4 | 0,946 | 0,90 | 0,8921 | 0,87 | 0,8860 | 0,82 | 0,834 | 0,882 | 0,8815 |
| 5 | 1,220 | 1,12 | 1,1159 | 1,10 | 1,1098 | 1,03 | 1,046 | 1,115 | 1,1086 |
| 6 | 1,032 | 1,24 | 1,2358 | 1,25 | 1,2539 | 1,16 | 1,178 | 1,252 | 1,2479 |
| 7 | 1,468 | 1,32 | 1,3322 | 1,34 | 1,3451 | 1,25 | 1,267 | 1,341 | 1,3417 |
| 8 | 1,402 | 1,41 | 1,3952 | 1,40 | | 1,31 | 1,326 | 1,404 | 1,4056 |
| 9 | 1,350 | 1,45 | 1,4537 | 1,45 | | 1,36 | 1,369 | 1,452 | 1,4499 |
| 10 | 1,464 | 1,49 | 1,4882 | 1,49 | | 1,39 | 1,406 | 1,484 | 1,4854 |
| 11 | 1,576 | 1,51 | 1,5117 | | | 1,42 | 1,433 | 1,513 | 1,5141 |
| 12 | 1,476 | | 1,5356 | 1,54 | | 1,44 | 1,456 | 1,535 | 1,5365 |
| 13 | 1,564 | | 1,5571 | | | 1,46 | 1,474 | 1,555 | 1,5551 |
| 14 | 1,568 | | 1,5714 | 1,57 | | 1,48 | 1,491 | 1,570 | 1,5713 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 15 | 1,586 | | 1,5831 | | | 1,49 | 1,501 | 1,583 | 1,5838 |

We will use in this thesis RI index as Wharton's which is :

Table 3.3 Wharton's RI table (Alanso, Lamata,2006, p 451)

| N | RI | N | RI |
|---|---|---|---|
| 1 | 0 | 8 | 1,41 |
| 2 | 0 | 9 | 1,45 |
| 3 | 0,58 | 10 | 1,49 |
| 4 | 0,90 | 11 | 1,51 |
| 5 | 1,12 | 12 | 1,48 |
| 6 | 1,24 | 13 | 1,56 |

Saaty (1980) only accepts a matrix as a consistent one if CR < 0.1

*3.2.1.1.3 Finding The Percentage Importance Distribution In m Decision Points For Every Factor.* In this stage, the percentage of importance distribution related to every factor is determined. In other words, pair-wise comparisons and matrix operations as are repeated as many times as the number of factors. However, this time the dimensions of comparison matrices to be used in decision points for every factor will become m x m. After every comparison operation, S column vectors with m x 1 dimensions and showing percentage distribution of every evaluated factor to the decision points are obtained (Teck,1997).

$$S_i = \begin{bmatrix} s_{11} \\ s_{21} \\ . \\ . \\ . \\ s_{m1} \end{bmatrix}$$

Reaching the result distribution in the decision points In this stage, *n* times *S* column vectors are all brought together. Thus, a matrix with *m* x *n* dimensions is obtained.(Matrix K).

$$K = \begin{bmatrix} s_{11} & s_{12} & \dots & s_{1n} \\ s_{21} & s_{22} & \dots & s_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ s_{m1} & s_{m2} & \dots & s_{mn} \end{bmatrix}$$

When this matrix K is multiplied with the *W* priority vector we obtain L column vector which is the percentage distribution of decision points (alternatives) (Yaralıoğlu,Köksal, 2006).

$$L = \begin{bmatrix} s_{11} & s_{12} & \dots & s_{1n} \\ s_{21} & s_{22} & \dots & s_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ s_{m1} & s_{m2} & \dots & s_{mn} \end{bmatrix} x \begin{bmatrix} w_1 \\ w_2 \\ . \\ . \\ . \\ w_n \end{bmatrix} = \begin{bmatrix} l_{11} \\ l_{21} \\ . \\ . \\ . \\ l_{m1} \end{bmatrix}$$

### 3.3 Questionnaire; Deciding the Weightings

This questionnaire aims to find out the weightings of issues and criterion of the assessment model.

Table 3.4 Scale of Relative Importance (Yaralıoğlu,Köksal, 2006)

| Intensity of Relative Importance | Definition | Explanation |
|---|---|---|
| 1 | Equal Importance | Two activities contribute equally to the objective |
| 3 | Moderate Importance | Experience and judgement another slightly favour one activity over |
| 5 | Essential or Strong | Experience or judgement strongly favours one activity over another |
| 7 | Importance Demonstrated | An activity is strongly favoured and its dominance is demonstrated in practice |
| 9 | Extreme (Absolute) | The evidence favouring one activity over another is of the highest possible order of affirmation |
| 2,4,6,8 | Intermediate values | When compromise is needed |

### *3.3.1 Sustainable Sites*

In order to compare to topic with each other ( pair wise comparison) underline the topic which important and decide about the intensity of relative importance according to the table.

Table 3.5 Tables for sustainable site criterion

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Provision of public transport | | | | | | | | | | Proximity to amenities |
| Provision of public transport | | | | | | | | | | Enough green areas |
| Provision of public transport | | | | | | | | | | Distance to earthquake faults |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to amenities | | | | | | | | | | Enough green areas |
| Proximity to amenities | | | | | | | | | | Distance to earthquake faults |

Table 3.5 Tables for sustainable site criterion continues

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Enough green areas | | | | | | | | | | Distance to earthquake faults |

### *3.3.2 Water Efficiency*

In order to compare to topic with each other (pair wise comparison) underline the topic which important and decide about the intensity of relative importance according to the table.

Table 3.6 Tables for water efficiency criterion

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Usage of water efficient equipment | | | | | | | | | | Rain water collectors |
| Usage of water efficient equipment | | | | | | | | | | Grey water usage |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Rain water collectors | | | | | | | | | | Grey water usage |

### *3.3.3 Energy and Resources*

In order to compare to topic with each other ( pair wise comparison) underline the topic which important and decide about the intensity of relative importance according to the table.

Table 3.7 Tables for energy and resources criterion

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| LCA results for selected details | | | | | | | | | | Greenhouse gas emission class on energy identity Certificate |
| LCA results for selected details | | | | | | | | | | Heating energy class on energy identity Certificate |
| LCA results for selected details | | | | | | | | | | Cooling energy class on energy identity Certificate |
| LCA results for selected details | | | | | | | | | | Hot water energy class on energy identity Certificate |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| LCA results for selected details | | | | | | | | | | Renewable energy usage ratio on energy identity Certificate |

Table 3.7 Tables for energy and resources criterion continues

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Greenhouse gas emission class on energy identity Certificate | | | | | | | | | | Heating energy class on energy identity Certificate |
| Greenhouse gas emission class on energy identity Certificate | | | | | | | | | | Cooling energy class on energy identity Certificate |
| Greenhouse gas emission class on energy identity Certificate | | | | | | | | | | Hot water energy class on energy identity Certificate |
| Greenhouse gas emission class on energy identity Certificate | | | | | | | | | | Renewable energy usage ratio on energy identity Certificate |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Heating energy class on energy identity Certificate | | | | | | | | | | Cooling energy class on energy identity Certificate |
| Heating energy class on energy identity Certificate | | | | | | | | | | Hot water energy class on energy identity Certificate |
| Heating energy class on energy identity Certificate | | | | | | | | | | Renewable energy usage ratio on energy identity Certificate |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cooling energy class on energy identity Certificate | | | | | | | | | | Hot water energy class on energy identity Certificate |
| Cooling energy class on energy identity Certificate | | | | | | | | | | Renewable energy usage ratio on energy identity Certificate |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|

| Hot water energy class on energy identity Certificate | | | | | | | | | | Renewable energy usage ratio on energy identity Certificate |
|---|---|---|---|---|---|---|---|---|---|---|

Table 3.7 Tables for energy and resources criterion continues

### *3.3.4 Health and Wellbeing*

In order to compare to topic with each other ( pair wise comparison) underline the topic which important and decide about the intensity of relative importance according to the table.

Table 3.8 Tables for health and resources criterion

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Daylight performance | | | | | | | | | | Natural ventilation performance |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Noise control | | | | | | | | | | Daylight performance |
| Noise control | | | | | | | | | | Natural ventilation performance |

### *3.3.5 Main Topics*

In order to compare to topic with each other ( pair wise comparison) underline the topic which important and decide about the intensity of relative importance according to the table.

Table 3.9 Tables for main topics

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sustainable Sites | | | | | | | | | | Water Efficiency |
| Sustainable Sites | | | | | | | | | | Energy and Resources |
| Sustainable Sites | | | | | | | | | | Health and Wellbeing |

Table 3.8 Tables for main topics continues

PROVISION OF PUBLIC TRANSPORT

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Water Efficiency | | | | | | | | | | Energy and Resources |
| Water Efficiency | | | | | | | | | | Health and Wellbeing |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Energy and Resources | | | | | | | | | | Health and Wellbeing |

## 3.4 Pair Wise Comparison Results

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1\9 | 1\8 | 1\7 | 1\6 | 1\5 | 1\4 | 1\3 | 1\2 |
| PROV. PUBLIC TRANSPORT | 84 | | | | | | | | | | | | | | | | |
| PROXIMITY TO AMENITIES | 6 | 1 | 5 | | 3 | 4 | 12 | | | 1 | | 14 | 5 | 25 | 6 | 2 | |
| GREEN AREAS | 3 | | 4 | 2 | 14 | 2 | 6 | | 1 | 1 | | 2 | 7 | 12 | 9 | 21 | |
| DIS. TO E.QUAKE FAULTS | 12 | | | | 5 | 13 | 28 | | 15 | | | | 2 | | 8 | 1 | |

| | PROXIMITY TO AMENITIES | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1\9 | 1\8 | 1\7 | 1\6 | 1\5 | 1\4 | 1\3 | 1\2 |
| PROV. PUBLIC TRANSPORT | 6 | | 2 | 6 | 25 | 5 | 14 | | 1 | | | 12 | 4 | 3 | | 5 | 1 |
| PROXIMITY TO AMENITIES | 84 | | | | | | | | | | | | | | | | |
| GREEN AREAS | 17 | | 3 | 1 | 3 | 6 | 12 | | 1 | 2 | | 3 | 14 | 22 | | | |
| DIS. TO E.QUAKE FAULTS | 2 | | | 8 | 6 | 12 | 21 | 6 | 12 | | 1 | | 1 | 2 | 12 | | 1 |

| | GREEN AREAS | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1\9 | 1\8 | 1\7 | 1\6 | 1\5 | 1\4 | 1\3 | 1\2 |
| PROV. PUBLIC TRANSPORT | 3 | | 21 | 9 | 12 | 7 | 2 | | 1 | 1 | | 6 | 2 | 14 | 2 | 4 | |
| PROXIMITY TO AMENITIES | 17 | | | | 22 | 14 | 3 | | 2 | 1 | | 12 | 6 | 3 | 1 | 3 | |
| GREEN AREAS | 84 | | | | | | | | | | | | | | | | |
| DIS. TO E.QUAKE FAULTS | 2 | 7 | 3 | 1 | 17 | 14 | | 7 | 12 | | | 1 | 2 | 6 | 5 | | 7 |

| | DISTANCE TO EARTHQUAKE FAULTS | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1\9 | 1\8 | 1\7 | 1\6 | 1\5 | 1\4 | 1\3 | 1\2 |
| PROV. PUBLIC TRANSPORT | 12 | | 1 | 8 | | 2 | | | | 15 | | 28 | 13 | 5 | | | |
| PROXIMITY TO AMENITIES | 2 | 1 | | 12 | 2 | 1 | | 1 | | 12 | 6 | 21 | 12 | 6 | 8 | | |
| GREEN AREAS | 2 | 7 | | 5 | 6 | 2 | 1 | | | 12 | 7 | | 14 | 17 | 1 | 3 | 7 |
| DIS. TO E.QUAKE FAULTS | 84 | | | | | | | | | | | | | | | | |

### *3.4.1 Pair Wise Comparison Results About Sustainable Site Criterion*

Table 3.10 Pair wise comparison results about sustainable site criterion table

### *3.4.2 Pair Wise Comparison Results About Water Efficiency Criterion*

Table 3.11 Pair wise comparison results about water efficiency criterion table

| | WATER EFFICIENT EQUIPMENT USAGE | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1\9 | 1\8 | 1\7 | 1\6 | 1\5 | 1\4 | 1\3 | 1\2 |
| WATER EFFICIENT EQUIP. | 84 | | | | | | | | | | | | | | | | |
| RAIN WATER COLLECTOR | 14 | 1 | 8 | 2 | 7 | 1 | | | 1 | 1 | 12 | 7 | 3 | 23 | 2 | 1 | 1 |
| GREY WATER USE | 14 | | | 10 | 11 | 5 | | | 1 | 3 | 3 | 5 | 4 | 18 | 3 | 1 | 6 |

| | RAIN WATER COLLECTOR | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1\9 | 1\8 | 1\7 | 1\6 | 1\5 | 1\4 | 1\3 | 1\2 |
| WATER EFFICIENT EQUIP. | 14 | 1 | 1 | 2 | 23 | 3 | 7 | 12 | 1 | 1 | | | 1 | 7 | 2 | 8 | 1 |
| RAIN WATER COLLECTOR | 84 | | | | | | | | | | | | | | | | |
| GREY WATER USE | 5 | 7 | 6 | 5 | 4 | 1 | | | 1 | | | 1 | 1 | 3 | 3 | 13 | 34 |

| | GREY WATER USE | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1\9 | 1\8 | 1\7 | 1\6 | 1\5 | 1\4 | 1\3 | 1\2 |
| WATER EFFICIENT EQUIP. | 14 | 6 | 1 | 3 | 18 | 4 | 5 | 3 | 3 | 1 | | | 5 | 11 | 10 | | |
| RAIN WATER COLLECTOR | 5 | 34 | 13 | 3 | 3 | 1 | 1 | | | 1 | | | 1 | 4 | 5 | 6 | 7 |
| GREY WATER USE | 84 | | | | | | | | | | | | | | | | |

### *3.4.3 Pair Wise Comparison Results About Energy And Resources Criterion*

Table 3.12 Pair wise comparison results about energy and resources criterion table

| | LCA RESULTS OF DETAILS | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1\9 | 1\8 | 1\7 | 1\6 | 1\5 | 1\4 | 1\3 | 1\2 |
| LCA RESULTS OF DETAILS | 84 | | | | | | | | | | | | | | | | |
| GHG EMISSIONS ON EIC | 12 | | 13 | 1 | 1 | | 4 | | 3 | 1 | | 9 | 9 | 7 | 6 | 18 | |
| HEATING CLASS ON EIC | 10 | 2 | 12 | | 2 | | | 1 | 1 | | 2 | 6 | 6 | 19 | 8 | 3 | 12 |
| COOLING CLASS ON EIC | 11 | | 13 | 5 | 6 | 4 | | 2 | 2 | 1 | 1 | 22 | 1 | 6 | 4 | 4 | 2 |
| HOT WATER CLASS ON EIC | 6 | | | | 4 | 6 | 4 | | 1 | 2 | 14 | 31 | 1 | 2 | 2 | 3 | 8 |
| RENEWABLE EN. CL. ON EIC | 14 | 4 | 2 | 2 | 1 | 12 | 14 | 3 | | 1 | 2 | | 2 | 18 | 6 | 3 | |

| | GHG EMISSIONS ON EIC | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1\9 | 1\8 | 1\7 | 1\6 | 1\5 | 1\4 | 1\3 | 1\2 |
| LCA RESULTS OF | 12 | | 18 | 6 | 7 | 9 | 9 | | 1 | 3 | | 4 | | 1 | 1 | 13 | |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DETAILS | | | | | | | | | | | | | | | | | |
| HG EMISSIONS ON EIC | 84 | | | | | | | | | | | | | | | | |
| HEATING CLASS ON EIC | 24 | 7 | 1 | 2 | 5 | 5 | 3 | | 1 | 3 | | 10 | | 2 | 4 | 4 | 13 |
| COOLING CLASS ON EIC | 2 | 10 | 3 | 2 | | 1 | 1 | | | 8 | 4 | 1 | 2 | 23 | 6 | 14 | 7 |
| HOT WATER CLASS ON EIC | 5 | 12 | 2 | 6 | 2 | 1 | 2 | 1 | 1 | | 25 | | 3 | 2 | 13 | 4 | 5 |
| RENEWABLE EN. CL. ON EIC | 7 | 11 | 5 | 4 | 2 | 2 | | 1 | | | 3 | 1 | 4 | 1 | 3 | 33 | 7 |

| | HEATING CLASS ON EIC | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1\9 | 1\8 | 1\7 | 1\6 | 1\5 | 1\4 | 1\3 | 1\2 |
| LCA RESULTS OF DETAILS | 10 | 12 | 3 | 8 | 19 | 6 | 6 | 2 | | 1 | 1 | | | 2 | | 12 | 2 |
| GHG EMISSIONS ON EIC | 24 | 13 | 4 | 4 | 2 | | 10 | | 3 | 1 | | 3 | 5 | 5 | 2 | 1 | 7 |
| HEATING CLASS ON EIC | 84 | | | | | | | | | | | | | | | | |
| COOLING CLASS ON EIC | 12 | 13 | 7 | 4 | 4 | 1 | 2 | 2 | | | 1 | 3 | | 2 | 6 | 8 | 19 |
| HOT WATER CLASS ON EIC | 4 | 12 | 3 | 3 | 2 | | 1 | 4 | | 1 | 1 | 16 | | 8 | 4 | 4 | 21 |
| RENEWABLE EN. CL. ON EIC | 6 | 12 | 8 | 6 | 4 | 4 | 3 | | | | | | 1 | 2 | 19 | 5 | 14 |

| | COOLING CLASS ON EIC | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1\9 | 1\8 | 1\7 | 1\6 | 1\5 | 1\4 | 1\3 | 1\2 |
| LCA RESULTS OF DETAILS | 11 | 2 | 4 | 4 | 6 | 1 | 22 | 1 | 1 | 2 | 2 | | 4 | 6 | 5 | 13 | |
| GHG EMISSIONS ON EIC | 2 | 7 | 14 | 6 | 23 | 2 | 1 | 4 | 8 | | | 1 | 1 | | 2 | 3 | 10 |
| HEATING CLASS ON EIC | 12 | 19 | 8 | 6 | 2 | | 3 | 1 | | | 2 | 2 | 1 | 4 | 4 | 7 | 13 |
| COOLING CLASS ON EIC | 84 | | | | | | | | | | | | | | | | |
| HOT WATER CLASS ON EIC | 8 | 8 | 8 | 5 | 7 | | 1 | | 1 | | 1 | 1 | 2 | 2 | 4 | 24 | 12 |
| RENEWABLE EN. CL. ON EIC | 8 | 20 | 12 | 1 | 2 | 8 | 3 | 2 | 3 | 1 | | 3 | | 3 | 3 | 6 | 9 |

| | HOT WATER CLASS ON EIC | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1\9 | 1\8 | 1\7 | 1\6 | 1\5 | 1\4 | 1\3 | 1\2 |
| LCA RESULTS OF DETAILS | 6 | 8 | 3 | 2 | 2 | 1 | 31 | 14 | 2 | 1 | | 4 | 6 | 4 | | | |
| GHG EMISSIONS ON EIC | 5 | 5 | 4 | 13 | 2 | 3 | | 25 | | 1 | 1 | 2 | 1 | 2 | 6 | 2 | 12 |
| HEATING CLASS ON EIC | 4 | 21 | 4 | 4 | 8 | | 16 | 1 | 1 | | 4 | 1 | | 2 | 3 | 3 | 12 |
| COOLING CLASS ON EIC | 8 | 12 | 24 | 4 | 2 | 2 | 1 | 1 | | 1 | | 1 | | 7 | 5 | 8 | 8 |
| HOT WATER CLASS ON EIC | 84 | | | | | | | | | | | | | | | | |
| RENEWABLE EN. CL. ON EIC | 6 | 10 | 7 | 6 | 23 | 1 | 3 | 1 | 2 | 1 | | 4 | 1 | 3 | 3 | 5 | 8 |

| | RENEWABLE EN. CLASS ON EIC | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1\9 | 1\8 | 1\7 | 1\6 | 1\5 | 1\4 | 1\3 | 1\2 |
| LCA RESULTS OF | 14 | | 3 | 6 | 18 | 2 | | 2 | 1 | | 3 | 14 | 12 | 1 | 2 | 2 | 4 |

| DETAILS | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GHG EMISSIONS ON EIC | 7 | 7 | 33 | 3 | 1 | 4 | 1 | 3 | | | 1 | | 2 | 2 | 4 | 5 | 11 |
| HEATING CLASS ON EIC | 6 | 14 | 5 | 19 | 2 | 1 | | | | | | 3 | 4 | 4 | 6 | 8 | 12 |
| COOLING CLASS ON EIC | 8 | 9 | 6 | 3 | 3 | | 3 | | 1 | 3 | 2 | 3 | 8 | 2 | 1 | 12 | 20 |
| HOT WATER CLASS ON EIC | 6 | 8 | 5 | 3 | 3 | 1 | 4 | | 1 | 2 | 1 | 3 | 1 | 23 | 6 | 7 | 10 |
| RENEWABLE EN. CL. ON EIC | 84 | | | | | | | | | | | | | | | | |

### *3.4.4 Pair Wise Comparison Results about Health And Wellbeing Criterion*

Table 3.13 Pair wise comparison results about health and wellbeing criterion table

| | NOİSE CONTROL | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1\9 | 1\8 | 1\7 | 1\6 | 1\5 | 1\4 | 1\3 | 1\2 |
| NOİSE CONTROL | 84 | | | | | | | | | | | | | | | | |
| DAYLIGHT PERFORMANCE | 6 | 9 | 12 | 3 | 6 | 8 | 19 | 1 | | 1 | | 3 | 3 | 1 | 2 | 4 | 6 |
| NATURAL VENT. PERFOR. | 3 | 9 | 6 | 4 | 6 | 18 | 8 | 1 | 3 | 1 | 2 | 6 | 3 | 4 | 3 | 4 | 3 |

| | DAYLIGHT PERFORMANCE | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1\9 | 1\8 | 1\7 | 1\6 | 1\5 | 1\4 | 1\3 | 1\2 |
| NOİSE CONTROL | 6 | 6 | 4 | 2 | 1 | 3 | 3 | | 1 | | 1 | 19 | 8 | 6 | 3 | 12 | 9 |
| DAYLIGHT PERFORMANCE | 84 | | | | | | | | | | | | | | | | |
| NATURAL VENT. PERFOR. | 23 | 12 | 5 | 2 | 6 | 4 | 7 | 1 | | | 2 | | 8 | | 3 | 1 | 10 |

| | NATURAL VENTILATION PERFORMANCE | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1\9 | 1\8 | 1\7 | 1\6 | 1\5 | 1\4 | 1\3 | 1\2 |
| NOİSE CONTROL | 3 | 3 | 4 | 3 | 4 | 3 | 6 | 2 | 1 | 3 | 1 | 8 | 18 | 6 | 4 | 6 | 9 |
| DAYLIGHT PERFORMANCE | 23 | 10 | 1 | 3 | | 8 | | 2 | | | 1 | 7 | 4 | 6 | 2 | 5 | 12 |
| NATURAL VENT. PERFOR. | 84 | | | | | | | | | | | | | | | | |

### *3.4.5 Pair Wise Comparison Results About Main Issues*

Table 3.14 Pair wise comparison results about main issues table

| | SUSTAINABLE SITES | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1\9 | 1\8 | 1\7 | 1\6 | 1\5 | 1\4 | 1\3 | 1\2 |
| SUSTAINABLE SITES | 84 | | | | | | | | | | | | | | | | |
| WATER EFFICIENCY | 3 | 11 | 5 | 1 | 3 | 1 | 5 | 4 | | 1 | 4 | 3 | 3 | 19 | 5 | 12 | 4 |
| ENERGY AND RESOURCES | 7 | 20 | 23 | 8 | 2 | 3 | 4 | | 2 | 1 | 1 | | 2 | 4 | 2 | 2 | 3 |
| HEALTH AND WELL BEING | 24 | 12 | 1 | 2 | 6 | 6 | 2 | | 3 | 3 | 4 | | 2 | 5 | | 6 | 8 |

| | WATER EFFICIENCY | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1\9 | 1\8 | 1\7 | 1\6 | 1\5 | 1\4 | 1\3 | 1\2 |
| SUSTAINABLE SITES | 3 | 4 | 12 | 5 | 19 | 3 | 3 | 4 | 1 | | 4 | 5 | 1 | 3 | 1 | 5 | 11 |
| WATER EFFICIENCY | 84 | | | | | | | | | | | | | | | | |
| ENERGY AND RESOURCES | 12 | 9 | 4 | 8 | 19 | 2 | 2 | 4 | 4 | | | 1 | 7 | 2 | 5 | 2 | 3 |
| HEALTH AND WELL BEING | 8 | 12 | 3 | 4 | 6 | 18 | 5 | 5 | | 2 | | | 6 | 3 | 2 | 2 | 8 |

| | ENERGY AND RESOURCES | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1\9 | 1\8 | 1\7 | 1\6 | 1\5 | 1\4 | 1\3 | 1\2 |
| SUSTAINABLE SITES | 7 | 3 | 2 | 2 | 4 | 2 | | 1 | 1 | 2 | | 4 | 3 | 2 | 8 | 23 | 20 |
| WATER EFFICIENCY | 12 | 3 | 2 | 5 | 2 | 7 | 1 | | | 4 | 4 | 2 | 2 | 19 | 8 | 4 | 9 |
| ENERGY AND RESOURCES | 84 | | | | | | | | | | | | | | | | |
| HEALTH AND WELL BEING | 8 | 9 | 12 | 5 | 4 | 3 | | 1 | | | 1 | 3 | 2 | 2 | 1 | 21 | 12 |

| | HEALTH AND WELL BEING | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1\9 | 1\8 | 1\7 | 1\6 | 1\5 | 1\4 | 1\3 | 1\2 |
| SUSTAINABLE SITES | 24 | 8 | 6 | | 5 | 2 | | 4 | 3 | 3 | | 2 | 6 | 6 | 2 | 1 | 12 |
| WATER EFFICIENCY | 8 | 8 | 2 | 2 | 3 | 6 | | | 2 | | 5 | 5 | 18 | 6 | 4 | 3 | 12 |
| ENERGY AND RESOURCES | 8 | 12 | 21 | 1 | 2 | 2 | 3 | 1 | | | 1 | | 3 | 4 | 5 | 12 | 9 |
| HEALTH AND WELL BEING | 84 | | | | | | | | | | | | | | | | |

## 3.5 AHP Results of Questionnaires

### *3.5.1 AHP Results for Sustainable Site Criterion*

The matrix A is evaluated by the arithmetical mean ratios of pair wise comparisons

Table 3.15 AHP results for sustainable site criterion table

**MATRIX A**

| SUSTAINABLE SITES | PROVISION OF PUBLIC TRANSPORT | PROXIMITY TO AMENITIES | GREEN AREAS | DISTANCE TO EARTHQUAKE FAULTS |
|---|---|---|---|---|
| PROVISION OF PUBLIC TRANSPORT | **1** | **1,94187** | **1,3765742** | **0,1511887** |
| PROXIMITY TO AMENITIES | **0,5149673** | **1** | **1,4040666** | **0,1946863** |
| GREEN AREAS | **0,7264411** | **0,71222** | **1** | **0,2651594** |
| DISTANCE TO EARTHQUAKE FAULTS | **6,6142506** | **5,13647** | **3,7713165** | **1** |
| TOTAL | 8,855658981 | 8,790556788 | 7,551957232 | 1,611034377 |

**MATRIX C**

| | | | | TOTAL |
|---|---|---|---|---|
| 0,112922144 | 0,220904195 | 0,18228045 | 0,093845736 | 0,609952525 |
| 0,058151212 | 0,113758437 | 0,18592089 | 0,120845511 | 0,47867605 |
| 0,082031283 | 0,081020684 | 0,132416004 | 0,164589534 | 0,460057505 |
| 0,746895361 | 0,584316685 | 0,499382656 | 0,620719219 | 2,451313921 |
| 1 | 1 | 1 | 1 | |

$$w_i = \frac{\sum_{j=1}^{n} c_{ij}}{n}$$

PRIORITY VECTOR (W) =

| |
|---|
| **0,152488131** |
| **0,119669012** |
| **0,115014376** |
| **0,61282848** |

matrix A x matrix W= vector d

| | | | | vector d |
|---|---|---|---|---|
| 0,152488131 | 0,232381769 | 0,158325818 | 0,092652746 | 0,635848464 |
| 0,078526401 | 0,119669012 | 0,161487846 | 0,119309292 | 0,478992552 |

| | | | | |
|---|---|---|---|---|
| 0,110773641 | 0,085230296 | 0,115014376 | 0,162497231 | 0,473515543 |
| 1,008594716 | 0,614676172 | 0,43375561 | 0,61282848 | 2,669854978 |

| Eigen Value (Ei ) |
|---|
| 4,169822656 |
| 4,002644809 |
| 4,117011792 |
| 4,356610478 |

16,64608974 TOTAL

$$E_i = \frac{d_i}{w_i} \quad (i = 1,2,...,n)$$

$$\lambda = \frac{\sum_{i=1}^{n} E_i}{n} = 16,64608974 /4= \quad 4,161522434$$

$$CI = \frac{\lambda - n}{n-1}$$ => CI = (4,161522434 -4 ) / 3 =0,053840811

CR = CI / RI

We will use in this thesis RI index as Wharton's which is :

(Alanso, Lamata,2006, p 451)

| N | RI | N | RI |
|---|---|---|---|
| 1 | 0 | 8 | 1,41 |
| 2 | 0 | 9 | 1,45 |
| 3 | 0,58 | 10 | 1,49 |
| 4 | 0,90 | 11 | 1,51 |
| 5 | 1,12 | 12 | 1,48 |
| 6 | 1,24 | 13 | 1,56 |

CR = 0,053840811/ 0.90 = 0,0598231 < 0.1 consistent matrix

We have only one decision point so W column vector is S column vector at the same time

Table 3.16 Weightings of sustainable sites section

| SUSTAINABLE SITES | WEIGHTINGS |
|---|---|
| PROVISION OF PUBLIC TRANSPORT | **15.3%** |
| PROXIMITY TO AMENITIES | **12%** |
| GREEN AREAS | **11.5%** |
| DISTANCE TO EARTHQUAKE FAULTS | **61,2%** |

### *3.5.2 AHP Results for Water Efficiency Criterion*

The matrix A is evaluated by the arithmetical mean ratios of pair wise comparisons.

Table 3.17 AHP results for water efficiency criterion table

**MATRIX A**

| **WATER EFFICIENCY** | WATER EFFICIENT EQUIPMENT USAGE | RAIN WATER COLLECTOR | GREY WATER USE |
|---|---|---|---|
| WATER EFFICIENT EQUIPMENT USAGE | **1** | **2,98329** | **1,5632906** |
| RAIN WATER COLLECTOR | **0,3352006** | **1** | **1,3898931** |
| GREY WATER USE | **0,6396764** | **0,71948** | **1** |
| TOTAL | 1,974876939 | 4,702768151 | 3,953183642 |

**MATRIX C**

| | | | TOTAL |
|---|---|---|---|
| 0,506360665 | 0,63436858 | 0,395451032 | 1,536180277 |
| 0,169732391 | 0,212640719 | 0,351588294 | 0,733961404 |
| 0,323906944 | 0,152990701 | 0,252960674 | 0,72985832 |

$$w_i = \frac{\sum_{j=1}^{n} c_{ij}}{n}$$

PRIORITY VECTOR (W) =

| |
|---|
| **0,512060092** |
| **0,244653801** |
| **0,243286107** |

matrix A x matrix W= vector d

| | | | |
|---|---|---|---|
| 0,512060092 | 0,729872836 | 0,380326871 | 1,622259799 |

| | | | |
|---|---|---|---|
| 0,171642842 | 0,244653801 | 0,338141679 | 0,754438322 |
| 0,327552733 | 0,176023467 | 0,243286107 | 0,746862307 |

| Eigen Value (Ei ) |
|---|
| 3,168104338 |
| 3,08369753 |
| 3,069892964 |
| 9,321694832 TOTAL |

$$E_i = \frac{d_i}{w_i} \quad (i = 1,2,\ldots,n)$$

$$\lambda = \frac{\sum_{i=1}^{n} E_i}{n} = 9{,}321694832/3 = 3{,}059895092$$

$$CI = \frac{\lambda - n}{n - 1} \quad => \quad CI = (3{,}059895092 - 3) / 2 = 0{,}053615805$$

CR = CI / RI

We will use in this thesis RI index as Wharton's which is :

| N | RI | N | RI |
|---|---|---|---|
| 1 | 0 | 8 | 1,41 |
| 2 | 0 | 9 | 1,45 |
| 3 | 0,58 | 10 | 1,49 |
| 4 | 0,90 | 11 | 1,51 |
| 5 | 1,12 | 12 | 1,48 |
| 6 | 1,24 | 13 | 1,56 |

CR = 0,053615805/ 0.58 = 0,092441 < 0.1 consistent matrix

We have only one decision point so W column vector is S column vector at the same time

Table 3.18 Weightings of water efficiency section

| WATER EFFICIENCY | WEIGHTINGS |
|---|---|
| WATER EFFICIENT EQUIPMENT USAGE | **51.2%** |
| RAIN WATER COLLECTOR | **24.5 %** |
| GREY WATER USE | **24.3 %** |

### *3.5.3 AHP Results For Energy And Resources Criterion*

The matrix A is evaluated by the arithmetical mean ratios of pair wise comparisons.

Table 3.19 AHP results for energy and resources criterion table

**MATRIX A**

| ENERGY AND RESOURCES | LCA RESULTS OF DETAILS | GHG EMISSIONS ON EIC | HEATING CLASS ON EIC | COOLING CLASS ON EIC | HOT WATER CLASS ON EIC | RENEWABLE EN. CLASS ON EIC |
|---|---|---|---|---|---|---|
| LCA RESULTS OF DETAILS | **1** | **2,0244** | **2,9337884** | **1,5530095** | **3,62870508** | **0,75163707** |
| GHG EMISSIONS ON EIC | **0,49397236** | **1** | **1,3221562** | **4,796729** | **2,70053505** | **1,88517745** |
| HEATING CLASS ON EIC | **0,34085621** | **0,75634** | **1** | **1,0186477** | **2,19035718** | **0,9750201** |
| COOLING CLASS ON EIC | **0,64391105** | **0,20848** | **0,9816937** | **1** | **1,23384567** | **0,54029676** |
| HOT WATER CLASS ON EIC | **0,2755804** | **0,3703** | **0,4565465** | **0,8104741** | **1** | **0,49166696** |
| RENEWABLE EN. CLASS ON EIC | **1,33042933** | **0,53045** | **1,0256199** | **1,8508347** | **2,03389709** | **1** |
| TOTAL | 4,084749356 | 4,889971481 | 7,719804733 | 11,02969507 | 12,78734007 | 5,643798337 |

**MATRIX C**

| | | | | | | TOTAL |
|---|---|---|---|---|---|---|
| 0,244813063 | 0,413991115 | 0,380034019 | 0,140802582 | 0,283773252 | 0,133179292 | 1,596593 |
| 0,120930887 | 0,20450017 | 0,171268085 | 0,434892261 | 0,211188178 | 0,334026367 | 1,476806 |
| 0,083446053 | 0,154671721 | 0,129536955 | 0,092355015 | 0,171291071 | 0,172759556 | 0,80406 |
| 0,157637836 | 0,042633255 | 0,127165615 | 0,090664338 | 0,096489627 | 0,095732825 | 0,610323 |
| 0,067465682 | 0,075725797 | 0,059139649 | 0,0734811 | 0,078202347 | 0,087116323 | 0,441131 |
| 0,32570648 | 0,108477942 | 0,132855677 | 0,167804704 | 0,159055525 | 0,177185636 | 1,071086 |
| 1 | 1 | 1 | 1 | 1 | 1 | |

$$w_i = \frac{\sum_{j=1}^{n} c_{ij}}{n}$$

PRIORITY VECTOR (W) =

| |
|---|
| **0,266098887** |
| **0,246134325** |
| **0,134010062** |
| **0,101720583** |
| **0,073521816** |
| **0,178514327** |

| |
|---|
| 1,716471559 |

matrix A x matrix W = vector d

| | | | | | |
|---|---|---|---|---|---|
| 0,266098887 | 0,498275495 | 0,393157167 | 0,157973035 | 0,266788989 | 0,134177985 |
| 0,131445497 | 0,246134325 | 0,177182231 | 0,487926071 | 0,198548242 | 0,336531185 |
| 0,090701458 | 0,18616131 | 0,134010062 | 0,103617433 | 0,161039039 | 0,174055057 |
| 0,171344013 | 0,051312952 | 0,131556835 | 0,101720583 | 0,073521816 | 0,087769597 |
| 0,073331638 | 0,0911428 | 0,061181831 | 0,082441901 | 0,073521816 | 0,087769597 |
| 0,354025765 | 0,130562947 | 0,137443384 | 0,188267985 | 0,149535808 | 0,178514327 |

| |
|---|
| 1,57776755 |
| 0,849584358 |
| 0,617225796 |
| 0,469389582 |
| 1,138350218 |

| Eigen Value (Ei ) |
|---|
| 6,450502585 |
| 6,410189036 |
| 6,339705734 |
| 6,067855497 |
| 6,384357793 |
| 6,376800309 |

38,02941095 TOTAL

$$E_i = \frac{d_i}{w_i} \quad (i = 1,2,...,n)$$

$$\lambda = \frac{\sum_{i=1}^{n} E_i}{n}$$ = 38,02941095 /6 =6,338235159

$$CI = \frac{\lambda - n}{n-1}$$ => CI = (6,338235159-6 ) / 2 = 0,053615805 CR = CI / RI

We will use in this thesis RI index as Wharton's which is :

| N | RI | N | RI |
|---|---|---|---|
| 1 | 0 | 8 | 1,41 |
| 2 | 0 | 9 | 1,45 |
| 3 | 0,58 | 10 | 1,49 |
| 4 | 0,90 | 11 | 1,51 |
| 5 | 1,12 | 12 | 1,48 |
| 6 | 1,24 | 13 | 1,56 |

CR = 0,053615805/ 1.24 = 0,0545541 < 0.1 consistent matrix

We have only one decision point so W column vector is S column vector at the same time

Table 3.20 Weightings of energy and resources section

| ENERGY AND RESOURCES | WEIGHTINGS |
|---|---|
| LCA RESULTS OF DETAILS | **27%** |
| GHG EMISSIONS ON EIC | **25%** |
| HEATING GRADE ON EIC | **13 %** |
| COOLING GRADE ON EIC | **10%** |
| HOT WATER GRADE ON EIC | **7.2%** |
| RENEWABLE EN. RATIO ON EIC | **17.8%** |

### *3.5.4 AHP Results for Health And Wellbeing Criterion*

The matrix A is evaluated by the arithmetical mean ratios of pair wise comparisons.

Table 3.21 AHP results for health and wellbeing criterion table

**MATRIX A**

| HEALTH AND WELL BEING | NOİSE CONTROL | DAYLIGHT PERFORMANCE | NATURAL VENT. PERFOR. |
|---|---|---|---|
| NOISE CONTROL | **1** | **0,35554** | **0,5215455** |
| DAYLIGHT PERFORMANCE | **2,81258899** | **1** | **0,7057862** |
| NATURAL VENT. PERFOR. | **1,91737809** | **1,41686** | **1** |
| TOTAL | 5,729967082 | 2,772403934 | 2,227331764 |

**MATRIX C**

| | | | TOTAL |
|---|---|---|---|
| 0,174521072 | 0,128244049 | 0,234157099 | 0,53692222 |
| 0,490856047 | 0,3606978 | 0,316875209 | 1,168429057 |
| 0,33462288 | 0,511058151 | 0,448967691 | 1,294648723 |
| 1 | 1 | 1 | |

$$w_i = \frac{\sum_{j=1}^{n} c_{ij}}{n}$$

PRIORITY VECTOR (W) =

| |
|---|
| **0,178974073** |
| **0,389476352** |
| **0,431549574** |

matris A x matris W = vector d

| | | | |
|---|---|---|---|
| 0,178974073 | 0,138476099 | 0,225072758 | 0,54252293 |
| 0,503380509 | 0,389476352 | 0,304581742 | 1,197438604 |
| 0,343160967 | 0,55183332 | 0,431549574 | 1,326543861 |

Eigen Value (Ei )

| |
|---|
| 3,031293415 |
| 3,074483462 |
| 3,073908399 |

9,179685276

$$E_i = \frac{d_i}{w_i} \quad (i = 1,2,...,n)$$

$$\lambda = \frac{\sum_{i=1}^{n} E_i}{n} = 9,179685276 / 3 = 3,059895092$$

$$CI = \frac{\lambda - n}{n-1} \quad => \quad CI = (3,059895092-3) / 2 = 0,029947546$$

We will use in this thesis RI index as Wharton's which is :

(Alanso, Lamata,2006, p 451)

| N | RI | N | RI |
|---|---|---|---|
| 1 | 0 | 8 | 1,41 |
| 2 | 0 | 9 | 1,45 |
| 3 | 0,58 | 10 | 1,49 |
| 4 | 0,90 | 11 | 1,51 |
| 5 | 1,12 | 12 | 1,48 |
| 6 | 1,24 | 13 | 1,56 |

CR = CI / RI

CR = 0,029947546 / 0.58 = 0,0516337 < 0.1 consistent matrix

We have only one decision point so W column vector is S column vector at the same time.

Table 3.22 Weightings of health and wellbeing section

| HEALTH AND WELLBEING CRITERION | WEIGHTINGS |
|---|---|
| NOISE CONTROL | 17.9 % |
| DAYLIGHT PERFORMANCE | 39 % |
| NATURAL VENTILATION PERFORMANCE | 43.1% |

### *3.5.5 AHP Results For Assessment Model Core Version Main Issues*

The matrix A is evaluated by the arithmetical mean ratios of pair wise comparisons.

Table 3.23 AHP results for assessment model core version main issues table

**MATRIX A**

| CORE VERSION MAIN ISUES | SUSTAINABLE SITES | WATER EFFICIENCY | ENERGY AND RESOURCES | HEALTH AND WELL BEING |
|---|---|---|---|---|
| SUSTAINABLE SITES | **1** | **1,7387** | **0,430729** | **0,9396309** |
| WATER EFFICIENCY | **0,5751434** | **1** | **0,4333662** | **0,4351773** |
| ENERGY AND RESOURCES | **2,32164517** | **2,30752** | **1** | **1,1307598** |
| HEALTH AND WELL BEING | **1,06424768** | **2,29791** | **0,8843611** | **1** |
| TOTAL | 4,961036257 | 7,34412796 | 2,748456358 | 3,505568014 |

**MATRIX C**

| | | | | TOTAL |
|---|---|---|---|---|
| 0,20157079 | 0,236746529 | 0,156716711 | 0,268039556 | 0,863073587 |
| 0,115932111 | 0,136163205 | 0,157676213 | 0,124138893 | 0,533910421 |
| 0,467975853 | 0,314198957 | 0,363840596 | 0,322561075 | 1,468576481 |
| 0,214521246 | 0,312891308 | 0,32176648 | 0,285260476 | 1,13443951 |
| 1 | 1 | 1 | 1 | |

PRIORITY VECTOR (W) =

| |
|---|
| **0,215768397** |
| **0,133477605** |
| **0,36714412** |
| **0,283609878** |

$$w_i = \frac{\sum_{j=1}^{n} c_{ij}}{n}$$

matris A x matris W = vector d

| | | | | |
|---|---|---|---|---|
| 0,215768397 | 0,232077086 | 0,158139635 | 0,266488603 | 0,872473721 |
| 0,12409777 | 0,133477605 | 0,159107848 | 0,12342059 | 0,540103814 |
| 0,500937657 | 0,30800189 | 0,36714412 | 0,320694645 | 1,496778312 |
| 0,229631016 | 0,306720032 | 0,324687988 | 0,283609878 | 1,144648914 |

| Eigen Value (Ei ) |
|---|
| 4,04356585 |
| 4,046400239 |
| 4,07681406 |
| 4,035998052 |

16,2027782

$$E_i = \frac{d_i}{w_i} \qquad (i = 1,2,...,n)$$

$$\lambda = \frac{\sum_{i=1}^{n} E_i}{n}$$ = 16,2027782/ 4 =4,05069455

$$CI = \frac{\lambda - n}{n-1}$$ = > CI = (4,05069455-c4 ) / 3 = 0,016898183

We will use in this thesis RI index as Wharton's which is :

(Alanso, Lamata,2006, p 451)

| N | RI | N | RI |
|---|---|---|---|
| 1 | 0 | 8 | 1,41 |
| 2 | 0 | 9 | 1,45 |
| 3 | 0,58 | 10 | 1,49 |
| 4 | 0,90 | 11 | 1,51 |
| 5 | 1,12 | 12 | 1,48 |
| 6 | 1,24 | 13 | 1,56 |

CR = CI / RI

CR = 0,016898183/ 0.90 = 0,0187758 < 0.1 consistent matrix

We have only one decision point so W column vector is S column vector at the same time.

Table 3.24 Weightings of assessment model core version main issues

| **CORE VERSION MAIN ISSUES** | **WEIGHTINGS** |
|---|---|
| SUSTAINABLE SITES | 21.6 % |
| WATER EFFICIENCY | 13.4 % |
| ENERGY AND RESOURCES | 37 % |
| HEALTH AND WELL BEING | 28.3 % |

Table 3.25 Weightings of assessment model core version main issues and criterion

| | TOTAL WEIGHTING % |
|---|---|
| SUSTAINABLE SITES | 21,6 |
| WATER EFFICIENCY | 13,4 |
| ENERGY AND RESOURCES | 37 |
| HEALTH AND WELL BEING | 28,3 |

| PROVISION OF PUBLIC TRANSPORT | PROXIMITY TO AMENITIES | GREEN AREAS | DISTANCE TO EARTHQUAKE FAULTS |
|---|---|---|---|
| 3,3048 | 2,592 | 2,48 | 13,219 |

| WATER EFFICIENT EQUIPMENT USAGE | RAIN WATER COLLECTOR | GREY WATER USE |
|---|---|---|
| 6,8608 | 3,283 | 3,26 |

| LCA RESULTS OF DETAILS | GHG EMISSIONS ON EIC | HEATING CLASS ON EIC | COOLING CLASS ON EIC | HOT WATER CLASS ON EIC | RENEWABLE EN. CLASS ON EIC |
|---|---|---|---|---|---|
| 9,99 | 9,25 | 4,81 | 3,7 | 2,7 | 6,6 |

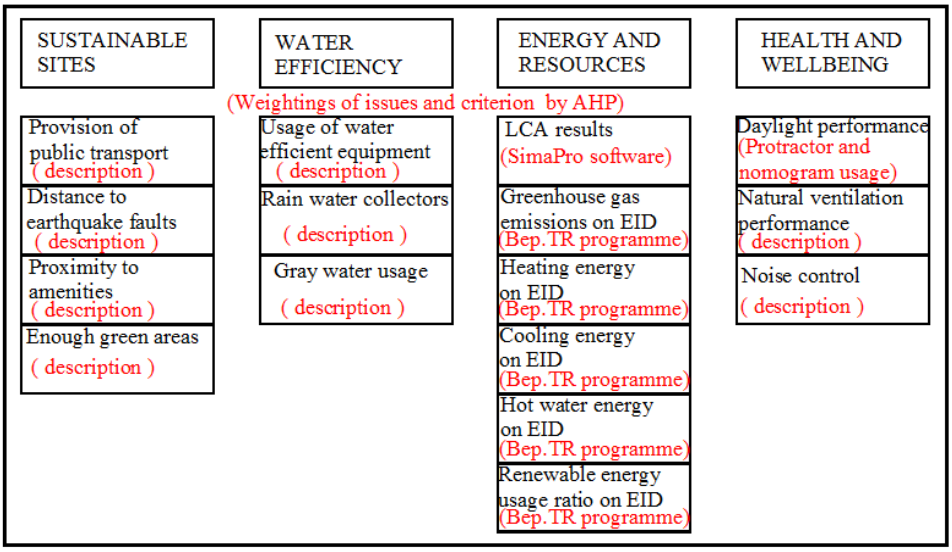
| NOISE CONTROL | DAYLIGHT CONTROL | NATURAL VENTILATION PER. |
|---|---|---|
| 5,0657 | 11,04 | 12,2 |

# CHAPTER FOUR

# ISSUE, CRITERION EXPLANATION OF THE CORE VERSION

## 4.1 Sustainable Sites

Table 4.1 Flow Diagram of care version calculation methodology




### *4.1.1 Provision Of Public Transport (3,3048 points)*

Collect the data below;

a. The distance (m) from the main building entrance to each compliant public transport node

b. The public transport type serving the compliant node e.g. bus, rail, sea travel or minibus routes.

c. The average number of services stopping per hour at each compliant node during the standard operating hours of the building for a typical day

Use these data for assessment of the criteria.

<u>If accessibility Index is > 2 this will be enough to get 3,3048 points</u>

#### *4.1.1.1 Calculation Method*

The first stage in calculation is to calculate the walking distance from the site (known as the point of interest (POI) to the nearest bus stops and rail stations.

These stops and stations are known as service access points (SAPs)'. Only SAPs within a certain distance of the POI are included (640m for bus stops and 1000m for rail stations, which correspond to a walking time of 8 minutes and 12 minutes respectively at the standard assumed walking speed of 80m/min)

The next stage is to determine the service level during the morning peak for each route serving a SAP. Where service levels differ in each direction on a route, the highest frequency is taken.

A total access time for each route is then calculated by adding together the walking time from the POI to the SAP and the average waiting time for services on the route (i.e. half the headway). This is converted to an equivalent doorstep frequency (EDF) by dividing 30 (minutes) by the total access time, which is intended to convert total access time to a "notional average waiting time, as though the route were available at the doorstep of the POI".

Reliability factor for buses 8 minutes, for trains 2 minutes, for minibus 5 minutes

Scheduled waiting time = SWT

Equivalent Doorstep Frequency ( EDF)

EDF = 30 / Total access time ( minutes )

AImode = EDFmax + (0.5 x  All other EDFs)

AIpoi = Σ(AImode1 + AImode1 + AImode2 + AImode3 … AImode n )

#### *4.1.2 Proximity To Amenities (2,592 points)*

If the  building is within 800m of

- Grocery shop and/or food outlet

and

If the building is within 3000m of the following amenities:

- Schools
- Play grounds  for children

<u>These  will be enough to get 2,592 points</u>

### *4.1.3 Distance To Earthquake Fault (13,2192 points)*

- The building will get 4,4064 points if the distance to fault is between 1km - 2km
- The building will get 8,8128 points if the distance to fault is between 2km - 3km
- The building will get 13,2192 points if the distance to fault is more than 3 km

### *4.1.4 Enough Green Areas (2,484 points)*

The building gets 1,242 points  if,

During the performance period, have in place native or adapted vegetation covering a minimum of 25% of the total site area (excluding the building footprint) or 5% of the total site area (including the building footprint), whichever is greater.

The building gets another 1,242 points  if;

The building is within 3000 m of of the following green areas

- City parks
- Sea site walking routes
- Bicycle routes

## 4.2 Water Efficiency

### *4.2.1 Usage Of Water Efficient Equipment (6,8608 points)*

In order to get 6,8608 points, building has to proof that all faucets and toilet flushers are water efficient. Such as faucets with photocell, thermostatic faucets, faucets with perlators etc.

The average water flow of the taps and shower heads excluding bath tub taps, kitchen taps and filling stations has to be 9 litres/minute or less.

WC's have to consumes 6 litres per full flush or less.

### *4.2.2 Rain Water Collectors (3,283points)*

In order to get point, building has to have a rain water collector at least 300 litres. The building also has to have a rain water collection scenario which shows the tank's cleaning and maintenance period. This scenario also has to show the responsible staff and has to proof that rainwater is collected and used for non-sanitary and non-drinking purposes.

### *4.2.3 Grey Water Usage (3,26 points)*

In order to get point, building has to have a grey water collection tank. Building can get a point only if it is using grey water for gardening OR toilet flushing activities.

For both gardening and toilet flushing activities building owners has to show that they can receive at least % 40 of their need from these sources.

## 4.3 Energy and Resources

### *4.3.1 Energy Identity Document*

In 2007 Turkish Government published " 5627 – Energy Efficiency Law ". Afterwards, in 2008 " Energy Performance Regulations for Buildings " has been published. This regulation described "Energy Identity Document". According to the regulation buildings which got a temporary permit after 01.01.2011 has to have an energy identity document in order have a permanent permit. And also the whole building stock has to have this document till May,02.2017.

For energy issues this document investigates the building under 5 main topics:

1. Heating
2. Water Heating
3. Cooling
4. Ventilation
5. Lighting

According to the scores taken from these issues a total score is generated.

#### *4.3.1.1 Description of BEP.TR*

BEP.TR is a web-based program in which an expert can form an energy identity document. The address is www.bep.gov.tr.

*4.3.1.1.1 Brief Explanation Section.* First of all the questions in five sections have to be fulfilled. . These sections are:

1. General Information
2. Data Type
3. Floor geometry and dimensions

4. Floors
5. Thermal bridges

*4.3.1.1.1.1 General Information.* At this section an expert will give general information about the project. Such as building type (masonry, reinforced concrete...), dimensions of the beams and altitude of ground floor

*4.3.1.1.1.2 Data Type.* At this section the expert will give details about the difference between ground and upper floor plans.

*4.3.1.1.1.3 Floor Geometry and Dimension.* BEP.TR describes 17 different plans. The expert has to simplify his project according to these 17 plans. And he /she has to redraw the existing plan according to this plan types.

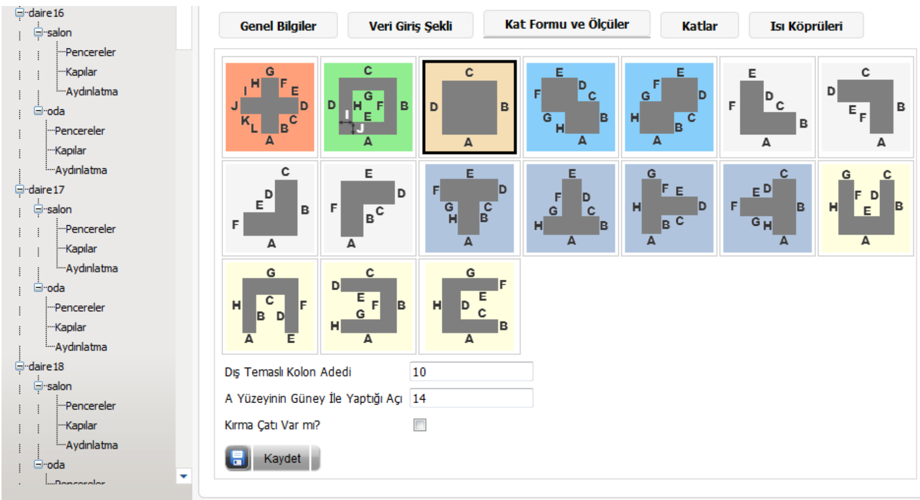


Figure 4.1 Building plans according to BEP.TR

*4.3.1.1.1.4 Floors.* At this section expert has to decide about the floors of the project. Basement, roofs, and floors have different type of questions. The chosen floors are linked to the geometry section of the program. An expert can any time copy a floor plan with all properties of it.

*4.3.1.1.1.5 Thermal Bridges.* The expert has to choose the details used in the project from the given details. The thermal bridges will be at roofs, balconies, columns, walls, corners, slabs, window and door openings.

*4.3.1.1.2 Geometry Section.* At this section the expert will describe the site plan. By entering information about the buildings and other elements which has a shadow effect on the building. After this information the expert will choose the floor plan of each floor from the given 17 plans and will give the dimension s of these plans.

According to BEP.TR the different spaces has different heating and cooling properties. According to the type of spaces the expert will decide about the zones of these spaces. If it is an apartment building every house at the same floor will named as  different zones and also the staircase will be another zone.

For an office building the first par which is 6 meters away from the window area will be the first zone part and the rest will be the second.

For the rest of the building types the whole floor area will be one zone

After creating zones the expert has to  describe the walls, ceiling, slab and also the rooms which creates these zones.

The expert will give very detailed information about the materials which creates the building such as the materials for walls.

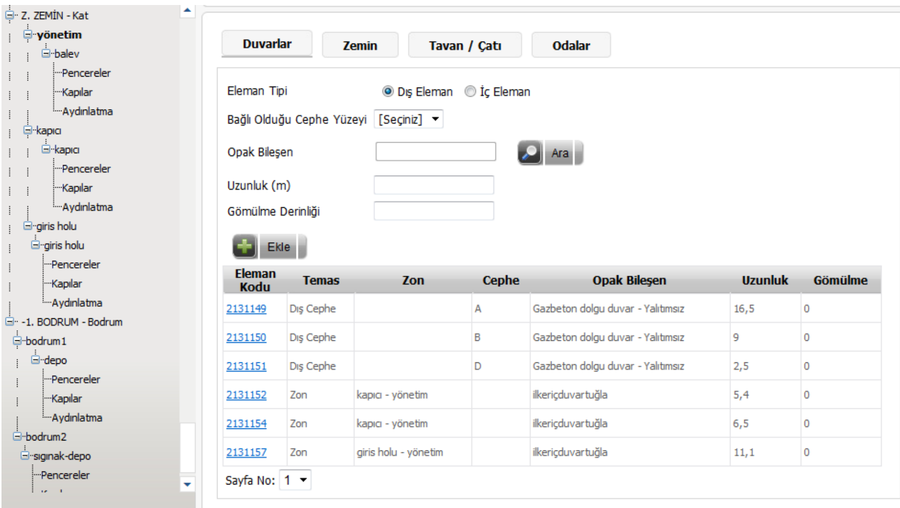



Figure 4.2 Zone properties Building plans according to BEP.TR

*4.3.1.1.2.1 Room Details.* After creating the rooms we will give detailed information about rooms. The expert has to choose the rooms geometry from the given 17 plans.

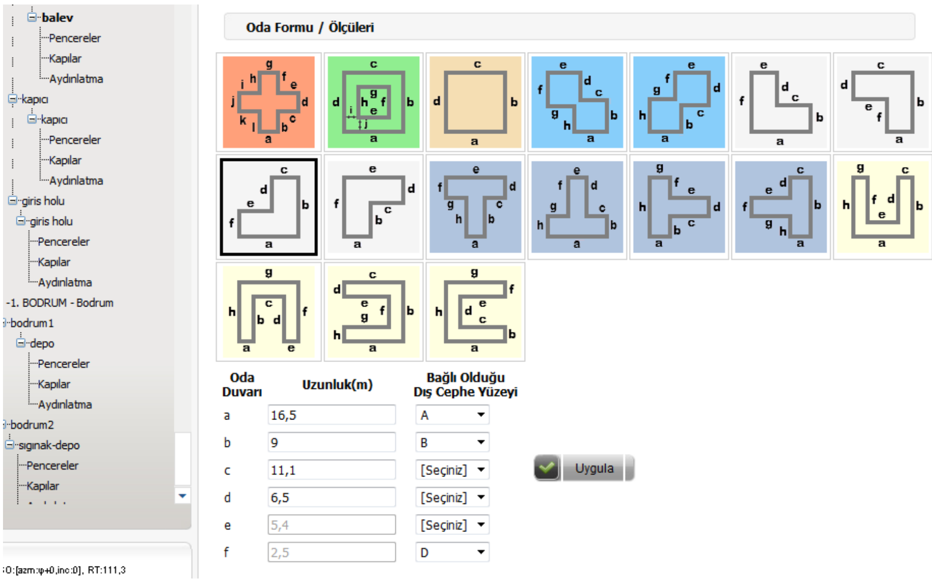



Figure 4.3 Room plans according to BEP.TR

*4.3.1.1.2.2 Window – Door – Lighting Details.* Under all rooms we will give window, door and lighting details. This details will be about the materials ( PVC, Aluminium etc. ), the dimensions, and the location of the window- door and lighting equipments.

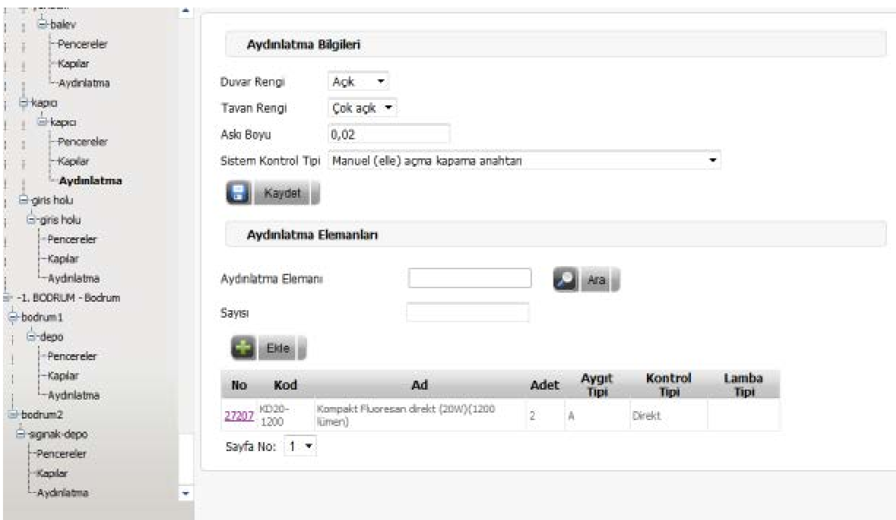



Figure 4.4 Lighting equipment sections

*4.3.1.1.3 Mechanical Properties.* At this section the expert will give answers to the questions about heating, cooling, ventilation and hot water achieving equipments.

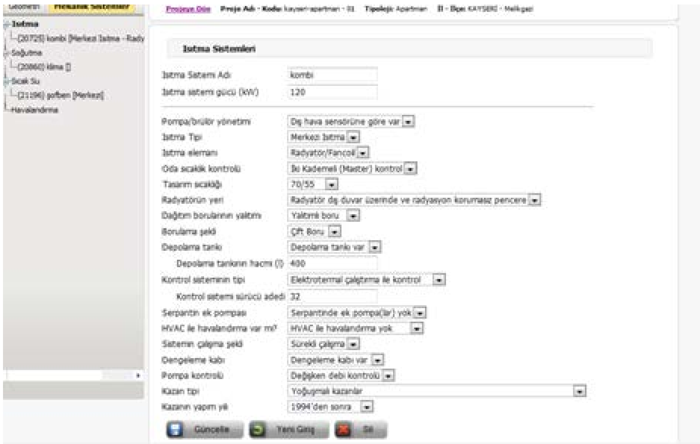
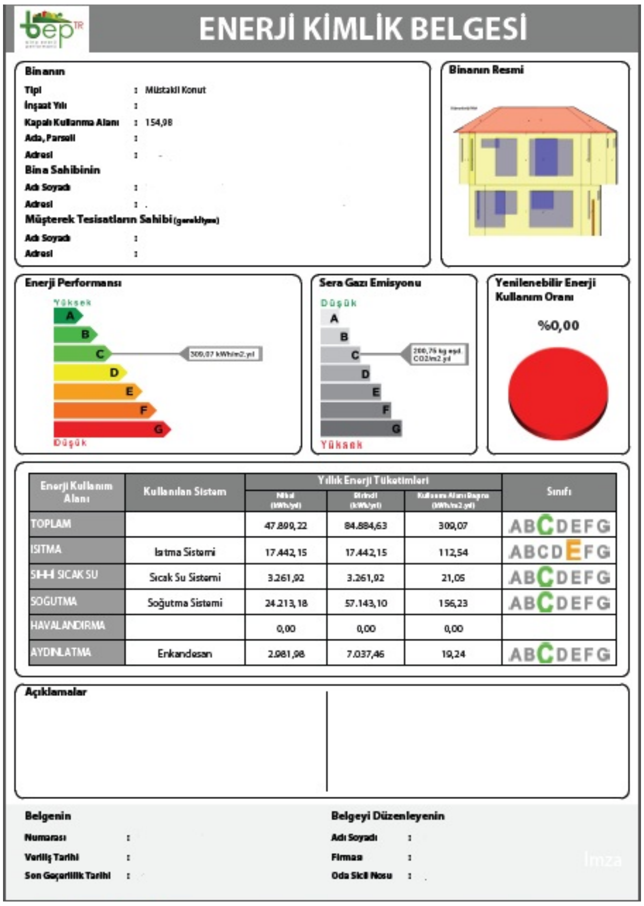



Figure 4.5 Mechanical properties sections



**ENERJİ KİMLİK BELGESİ**

**Binanın**
Tipi : Müstakil Konut
İnşaat Yılı :
Kapalı Kullanma Alanı : 154,98
Ada, Parseli :
Adresi :
**Bina Sahibinin**
Adı Soyadı :
Adresi :
**Müşterek Tesisatların Sahibi** (gerekliyse)
Adı Soyadı :
Adresi :

**Binanın Resmi**

**Enerji Performansı**
Yüksek
A B C D E F G
309,07 kWh/m2.yıl
Düşük

**Sera Gazı Emisyonu**
Düşük
A B C D E F G
Yüksek

**Yenilenebilir Enerji Kullanım Oranı**
%0,00

| Enerji Kullanım Alanı | Kullanılan Sistem | Yıllık Enerji Tüketimleri | | | Sınıfı |
|---|---|---|---|---|---|
| | | Nihai (kWh/yıl) | Birincil (kWh/yıl) | Kullanım Alanı Başına (kWh/m2.yıl) | |
| TOPLAM | | 47.899,22 | 84.884,63 | 309,07 | ABCDEFG |
| ISITMA | Isıtma Sistemi | 17.442,15 | 17.442,15 | 112,54 | ABCDEFG |
| SIHHİ SICAK SU | Sıcak Su Sistemi | 3.261,92 | 3.261,92 | 21,05 | ABCDEFG |
| SOĞUTMA | Soğutma Sistemi | 24.213,18 | 57.143,10 | 156,23 | ABCDEFG |
| HAVALANDIRMA | | 0,00 | 0,00 | 0,00 | |
| AYDINLATMA | Enkandesan | 2.981,98 | 7.037,46 | 19,24 | ABCDEFG |

**Açıklamalar**

**Belgenin**
Numarası :
Veriliş Tarihi :
Son Geçerlilik Tarihi :

**Belgeyi Düzenleyenin**
Adı Soyadı :
Firması :
Oda Sicil Nosu :
İmza

Figure 4.6 Energy identity document example

*4.3.1.2 Points Obtained From Energy Identity Document*

*4.3.1.2.1 Greenhouse Gas Emission Grade On Energy Identity Document (9,25 points)*

- The building will get 9.25 points if it has a grade “A,B or C”

*4.3.1.2.2 Heating Energy Grade On Energy Identity Document (4,81 points)*

- The building will get 4,81 points if it has a grade “A, B or C”

*4.3.1.2.3 Cooling Energy Grade On Energy Identity Document (3,7 points)*

- The building will get 3.7 points if it has a grade “A,B or C”

*4.3.1.2.4 Hot Water Energy Grade On Energy Identity Document (2,7 points)*

- The building will get 2.7 points if it has a grade “A,B or C”

*4.3.1.2.5 Renewable Energy Usage Ratio On Energy Identity Document (6.6 points)*

- The building will get 6.6 points if the ratio is between 100%- 66%

### *4.3.2 LCA of Selected Details*

Life cycle assessment (LCA) is a methodology for assessing the environmental aspects. It is a “cradle-to-grave” approach for assessing systems. “Cradle-to-grave” begins with the gathering of raw materials from the earth to form a product and ends at the point when all materials are returned to the earth.

LCA enables the estimation of the cumulative environmental impacts resulting from all stages in the product life cycle, often including impacts not considered in more traditional analyses (e.g., raw material extraction, material transportation, ultimate product disposal, etc.) (Sustainableabc,2007).

By including the impacts throughout the product life cycle, LCA provides a comprehensive view of the environmental aspects of the product or process and a more accurate picture of the true environmental trade-offs in product and process selection.

There are two ISO standards specifically designed for LCA application: ISO 14040: Principles and Framework and ISO 14044: Requirements and Guidelines. The new 14044 standard replaces the 14041, 14042 and 14043, but there have been no major changes in the contents (Goedkoop, Schryver, Oele, Durksz & Roest, 2010).

The LCA process is a systematic, phased approach and consists of four components:

1. Goal Definition and Scoping - Define and describe the product, process or activity. Establish the context in which the assessment is to be made and identify the boundaries and environmental effects to be reviewed for the assessment.
2. Inventory Analysis - Identify and quantify energy, water and materials usage and environmental releases (e.g., air emissions, solid waste disposal, waste water discharges).

3. Impact Assessment - Assess the potential human and ecological effects of energy, water, and material usage and the environmental releases identified in the inventory analysis.

4. Interpretation - Evaluate the results of the inventory analysis and impact assessment to select the preferred product, process or service with a clear understanding (Ecobilan,2008 ).

*4.3.2.1 SimaPro software for LCA studies*

SimaPro, is a LCA tool, which is helpful for putting metrics behind sustainable product development, sustainability goals, or research. Based on these metrics, solid decisions can made to positively change a product's lifecycle. The software is used by industry, consultancies, and research institutes in more than 80 countries.

*4.3.2.1.1 Description of SimaPro Software*

*4.3.2.1.1.1 Goal and Scope.* Libraries are used in SimaPro as resources where you store standard data and standard impact assessment methodologies. You can select which libraries you consider to be in line with the requirements for a study.

*4.3.2.1.1.2 Inventory.* This section provides access to processes and product stages; the two main data types in SimaPro System descriptions are used as additional documentation in some processes.

*4.3.2.1.1.3 Impact assessment.*This section provides access to impact assessment methods. In the calculation setup section which life cycles, processes and assemblies need to be repeatedly analysed and compared can be defined. The benefit of using a calculation set-up is that all life cycles or assemblies always appear in the same order, with the same colours and the same scale (Goedkoop,2006).

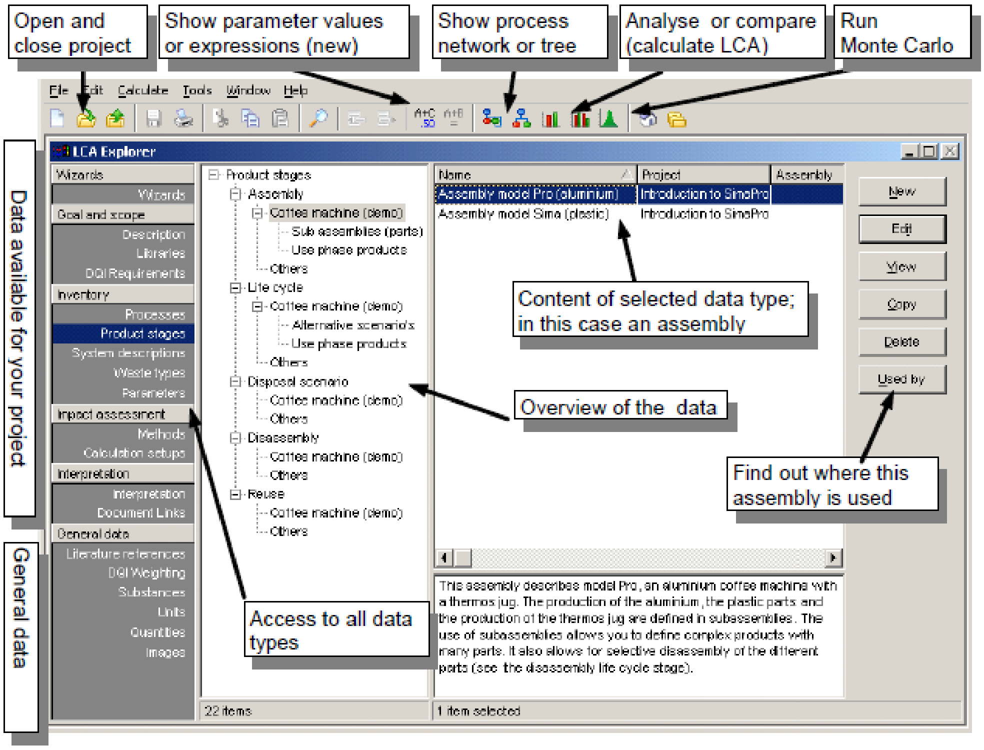



Figure 4.7 Starting with SimaPro (Goedkoop, Schryver, Oele, Durksz & Roest, 2010)

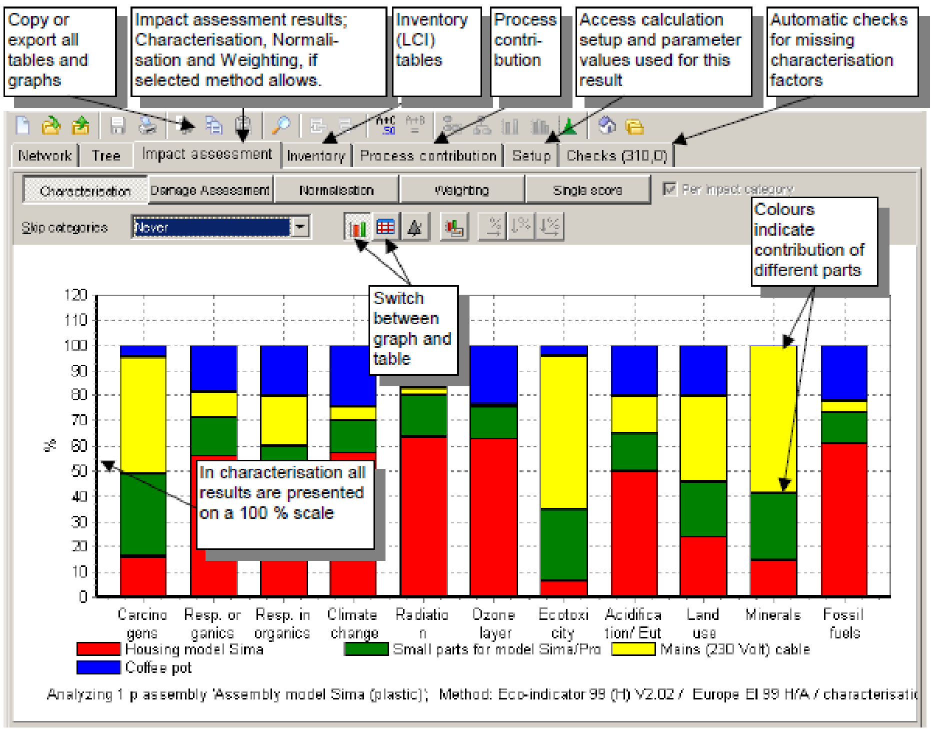



Figure 4.8 Characterisation results (Goedkoop, Schryver, Oele, Durksz & Roest, 2010)

Figure 4.2 shows the characterisation results. As all impact categories have different units, they are plotted on a percent scale. The colours indicate the relative contribution for different parts of the product, in this case the 4 sub-assemblies. This screen has many possibilities.

A network presentation of the SimaPro model can be generated. Different figures can be achieved according to indicators.

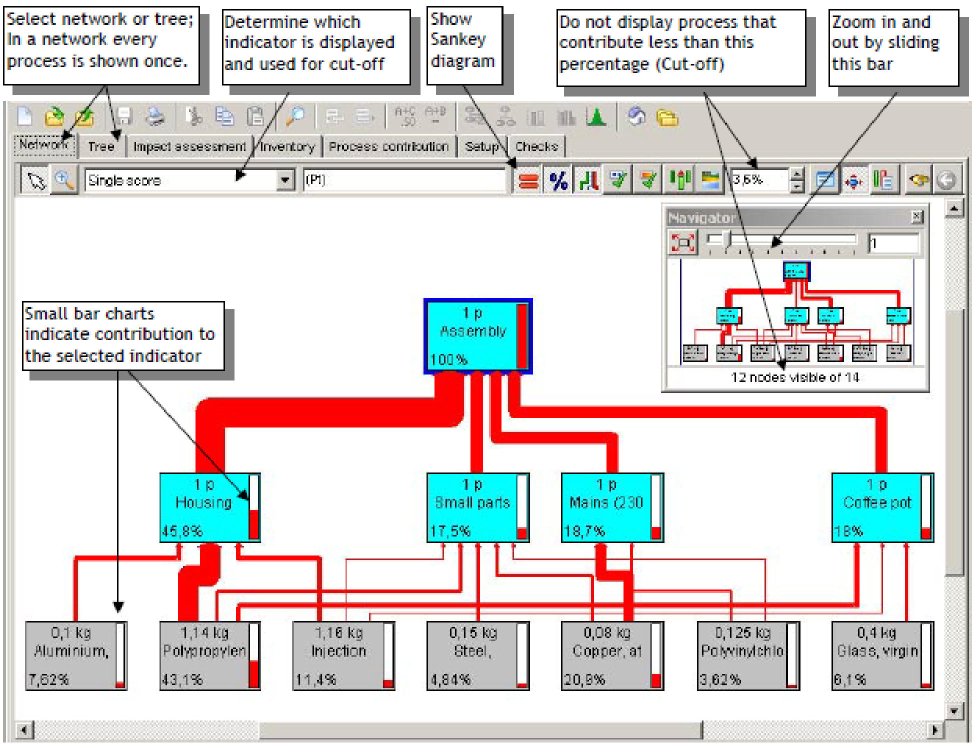



Figure 4.9 Network presentation (Goedkoop, Schryver, Oele, Durksz & Roest, 2010)

At Figure 4.3 each grey box represents a process, each blue box represents a (sub)assembly. The small red bar charts (or thermometers) indicate the environmental load generated in each process and its upstream processes. This is a very useful feature, as you can trace the origins of the environmental load and identify hotspots.

*4.3.2.2 The SimaPro method used in thesis*

For getting results with SimaPro calculation, result, product, method, indicator types have to be decided.

This thesis used the configuration below to compare the results.

Table 4.2 SimaPro configuration used in thesis

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weighting |

*4.3.2.2.1 Eco-indicator 99* .The development of the Eco-indicator 99 methodology started with the design of the weighting procedure. Traditionally in LCA the emissions and resource extractions are expressed as 10 or more different impact categories, like acidification, ozone layer depletion, ecotoxicity and resource extraction. For a panel of experts or non-experts it is very difficult to give meaningful weighting factors for such a large number and rather abstract impact categories. It was concluded that the panel should not be asked to weight the impact categories but the different types of damage that are caused by these impact categories (Goedkoop, Schryver, Oele, Durksz & Roest, 2010).

*4.3.2.2.1.1 Characterization*

*4.3.2.2.1.1.1 Emissions.* Characterization factors are calculated at end-point level (damage). The damage model for emissions includes fate analysis, exposure, effects analysis and damage analysis. This model is applied for the following impact categories (Goedkoop,2006).

- **Carcinogens :** Carcinogenic affects due to emissions of carcinogenic substances to air, water and soil. Damage is expressed in Disability adjusted Life Years (DALY) / kg emission.
- **Respiratory organics** : Respiratory effects resulting from summer smog, due to emissions of organic substances to air, causing respiratory effects. Damage is expressed in Disability adjusted Life Years (DALY) / kg emission.
- **Respiratory inorganics**: Respiratory effects resulting from winter smog caused by emissions of dust, sulphur and nitrogen oxides to air. Damage is expressed in Disability adjusted Life Years (DALY) / kg emission.
- **Climate change** : Damage, expressed in DALY/kg emission, resulting from an increase of diseases and death caused by climate change.
- **Radiation**: Damage, expressed in DALY/kg emission, resulting from radioactive radiation
- **Ozone layer**: Damage, expressed in DALY/kg emission, due to increased UV radiation as a result of emission of ozone depleting substances to air.
- **Ecotoxicity**: Damage to ecosystem quality, as a result of emission of ecotoxic substances to air, water and soil. Damage is expressed in Potentially Affected Fraction (PAF) m2 x year/kg emission.
- **Acidification/ Eutrophication**: Damage to ecosystem quality, as a result of emission of acidifying substances to air. Damage is expressed in Potentially Disappeared Fraction (PDF) m2 x year/kg emission (Goedkoop, Schryver, Oele, Durksz & Roest, 2010, p 7).

*4.3.2.2.1.1.2 Land use.* Land use (in manmade systems) has impact on species diversity. Based on field observations, a scale is developed expressing species diversity per type of land use. Species diversity depends on the type of land use and the size of the area. Both regional effects and local effects are taken into account in the impact category (Goedkoop, Schryver, Oele, Durksz & Roest, 2010, p 7).

- Land use : Damage as a result of either conversion of land or occupation of land. Damage is expressed in Potentially Disappeared Fraction (PDF)

*4.3.2.2.1.1.3 Resource depletion.* Mankind will always extract the best resources first, leaving the lower quality resources for future extraction. The damage of resources will be experienced by future generations, as they will have to use more effort to extract remaining resources. This extra effort is expressed as by "surplus energy".

• Minerals. Surplus energy per kg mineral or ore, as a result of decreasing ore grades. (Goedkoop, Schryver, Oele, Durksz & Roest, 2010, p 8)

*4.3.2.3 Detail Selection and Investigation:*

While deciding about the details, six main parts of a building has been considered. These parts are roofs, outer walls, slabs, foundations, windows.

After selecting main parts, sub issues have been formed. During the decision of sub issues the main criteria was choosing the most common details for Turkish construction market. These are

- Roofs

  - Flat roofs with ceramic on top
  - Flat roofs with gravel on top
  - Sloped roof with shingle
  - Sloped roof with roofing tile

- Outer Walls

  - Sandwich brick walls
  - Brick walls with exterior thermal insulation
  - Autoclaved aerated concrete block
  - Pumice block

- Slabs

- Reinforced concrete slabs with ceramic on top
- Reinforced concrete slabs with laminated flooring on top
- Reinforced concrete slabs with solid parquet on top

- Foundations

- Ground foundation ceramic on top
- Ground foundation laminated flooring on top
- Ground foundation solid parquet on top
- Basement foundation ceramic on top
- Basement foundation laminated flooring on top

- Windows

- Aluminium windows
- Wood windows
- PVC windows

The details of each type have been drawn with different materials. Totally 241 details have been drawn. These are:

- 68 different details for roof types
- 51 different details for slab types
- 37 different details for outer wall types
- 85 details for foundation types

By using 241 different details, the materials used in one square meter of each detail have been calculated. The results of these calculations were used for the SimaPro 7.4 software in order to obtain LCA results of each detail.

241 environmental impact categories per product and subassemblies (which show the results according to the method Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I and with indicator “weighting”. ) and 241 characterisation tables have been achieved.

In order to have a brief document these 241 environmental impacts categories per product and subassemblies and 241 characterisation tables are not printed.

Instead of printing these 241 environmental impact categories per product and subassemblies the total impacts of each detail has been collected and printed. According to the total impacts of each detail a value has been calculated

Two characterisation tables are given as an example for these details.

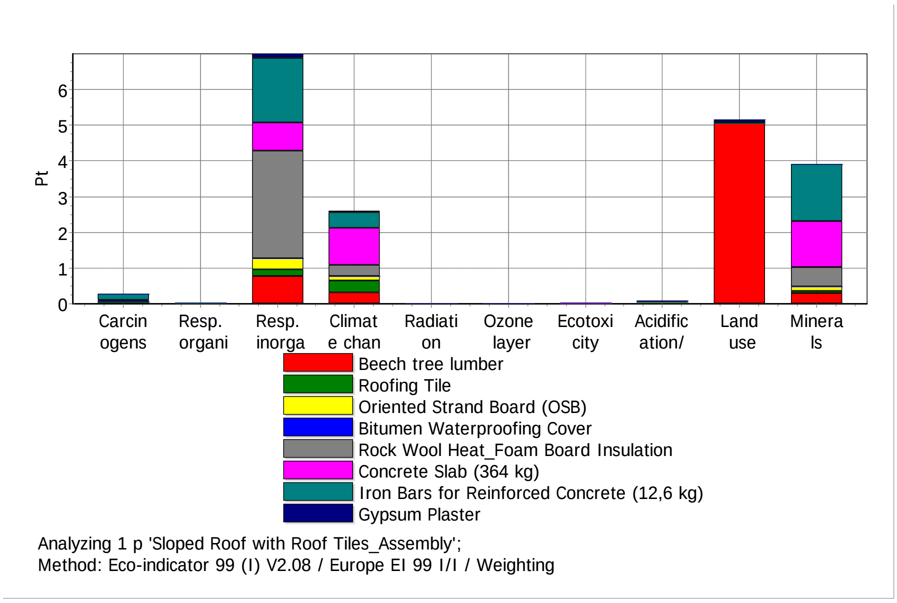



Figure 4.14 Characterisation of sloped roof with roof tiles detail which uses 8 cm rockwool as thermal insulation. ( Figure 4-10 detail 11-C )

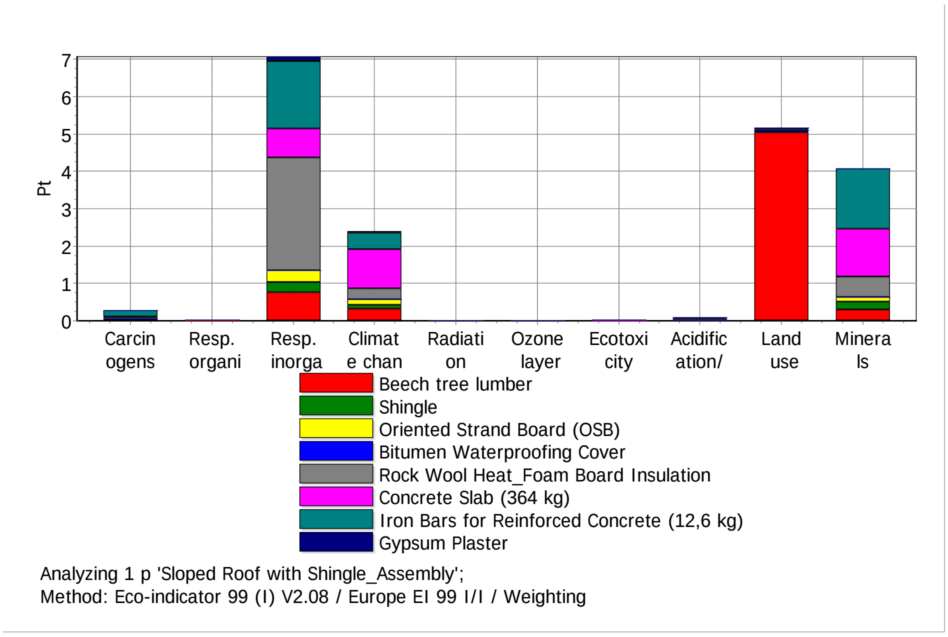



Figure 4.15 Characterisation of sloped roof with shingle detail which uses 8 cm rockwool as thermal insulation. ( Figure 4-10 detail 11-D )

For window frame types the database of the SimaPro software has been used. For that reason there is not any detail for window types. But the characterisation tables of each window types have been declared.

The unit “**Pt**” (point) is just a reference unit and must only be used for comparison between solutions.

Table 4.2 Environmental impact categories per product and subassemblies for the detail flat roofs with ceramic on top – The ingredients of the detail except the insulation - **According to Figure 4.10**

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Flat Roof Ceramic On Top** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weighting |

| Impact category | Unit | TOTAL | Ceramic Tile(12kg) | Cement Based Ceramic Adhesive Mortar(2kg) | Geotextile Felt(0.1kg) | Polymeric Modified Bituminous Waterproofing 0.8kg) |
|---|---|---|---|---|---|---|
| Total | Pt | 16,23123 | 7,36753 | 0,0154747 | 0,035158 | 0,07293 |
| Carcinogens | Pt | 0,260208 | 0,05187 | 0,0001445 | 0,0017353 | 0,00162 |
| Resp. organics | Pt | 0,0056 | 0,00052 | 1,53E-05 | 5,79E-05 | 0,00024 |
| Resp. inorganics | Pt | 9,689347 | 6,57676 | 0,0042609 | 0,0120093 | 0,02916 |
| Climate change | Pt | 2,59068 | 0,22049 | 0,0089925 | 0,0118141 | 0,01548 |
| Radiation | Pt | 0,001773 | 0,00024 | 7,64E-06 | 9,46E-06 | 2,25E-05 |
| Ozone layer | Pt | 0,000514 | 0,0001 | 1,63E-06 | 5,90E-06 | 2,53E-05 |
| Ecotoxicity | Pt | 0,014689 | 0,00381 | 1,90E-05 | 9,54E-05 | 9,98E-05 |
| Acidification/ Eutrophication | Pt | 0,06064 | 0,00555 | 0,0001798 | 0,0002832 | 0,00056 |
| Land use | Pt | 0,059407 | 0,01355 | 0,0003213 | 0,0001155 | 0,00097 |
| Minerals | Pt | 3,548375 | 0,49465 | 0,0015323 | 0,0090318 | 0,02475 |

| Impact category | Unit | Plaster for incline purposes coating ceiling(154.14kg) | Concrete Slab (364 kg) | Iron Bars for Reinforced Concrete (12,6 kg) | Gypsum Plaster(5kg) |
|---|---|---|---|---|---|
| Total | Pt | 1,316473 | 3,19929 | 4,0514817 | 0,172895 |
| Carcinogens | Pt | 0,008531 | 0,0326 | 0,1619623 | 0,0017415 |
| Resp. organics | Pt | 0,001185 | 0,00195 | 0,0014905 | 0,000143 |
| Resp. inorganics | Pt | 0,350789 | 0,78096 | 1,819896 | 0,1155205 |
| Climate change | Pt | 0,813898 | 1,04074 | 0,4375217 | 0,0417369 |
| Radiation | Pt | 0,000614 | 0,00056 | 0,0002837 | 3,20E-05 |
| Ozone layer | Pt | 0,00013 | 0,00016 | 7,10E-05 | 1,96E-05 |
| Ecotoxicity | Pt | 0,0012 | 0,00291 | 0,0062278 | 0,0003278 |
| Acidification/ Eutrophication | Pt | 0,015552 | 0,0255 | 0,0116859 | 0,0013345 |
| Land use | Pt | 0,005432 | 0,02766 | 0,008998 | 0,002363 |
| Minerals | Pt | 0,119142 | 1,28625 | 1,6033447 | 0,0096762 |

Table 4.3 Total impacts of the flat roof with ceramic on top detail

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Flat Roof Ceramic On Top** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weighting |

| Impact category | Unit | A1 | A2 | A3 | A4 | A5 | A6 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 16,2312 | 16,406 | 16,511 | 16,58099 | 16,65094 | 16,347818 |
| Carcinogens | Pt | 0,26021 | 0,2622 | 0,26333 | 0,264112 | 0,264893 | 0,2615094 |
| Resp. organics | Pt | 0,0056 | 0,0065 | 0,00711 | 0,007484 | 0,007861 | 0,0062279 |
| Resp. inorganics | Pt | 9,68935 | 9,7601 | 9,80259 | 9,830904 | 9,859215 | 9,7365325 |
| Climate change | Pt | 2,59068 | 2,684 | 2,73993 | 2,777237 | 2,814548 | 2,6528655 |
| Radiation | Pt | 0,00177 | 0,0018 | 0,00177 | 0,001774 | 0,001774 | 0,0017732 |
| Ozone layer | Pt | 0,00051 | 0,0005 | 0,00052 | 0,000525 | 0,000527 | 0,0005173 |
| Ecotoxicity | Pt | 0,01469 | 0,015 | 0,01514 | 0,015251 | 0,015363 | 0,0148765 |
| Acidification/ Eutrophication | Pt | 0,06064 | 0,0625 | 0,06366 | 0,06441 | 0,065163 | 0,0618968 |
| Land use | Pt | 0,05941 | 0,0594 | 0,05942 | 0,059429 | 0,059434 | 0,0594142 |
| Minerals | Pt | 3,54837 | 3,5541 | 3,55757 | 3,559864 | 3,562162 | 3,5522045 |

| Impact category | Unit | A7 | A8 | A9 | A10 | A11 | A12 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 16,4178 | 16,464 | 16,511 | 18,66149 | 20,11964 | 21,091742 |
| Carcinogens | Pt | 0,26229 | 0,2628 | 0,26333 | 0,267462 | 0,271815 | 0,2747166 |
| Resp. organics | Pt | 0,0066 | 0,0069 | 0,00711 | 0,0068 | 0,00752 | 0,0080005 |
| Resp. inorganics | Pt | 9,76484 | 9,7837 | 9,80259 | 11,56948 | 12,69756 | 13,449612 |
| Climate change | Pt | 2,69018 | 2,7151 | 2,73993 | 2,775073 | 2,885709 | 2,9594668 |
| Radiation | Pt | 0,00177 | 0,0018 | 0,00177 | 0,00197 | 0,002088 | 0,0021663 |
| Ozone layer | Pt | 0,00052 | 0,0005 | 0,00052 | 0,000549 | 0,00057 | 0,000584 |
| Ecotoxicity | Pt | 0,01499 | 0,0151 | 0,01514 | 0,015246 | 0,015581 | 0,0158034 |
| Acidification/ Eutrophication | Pt | 0,06265 | 0,0632 | 0,06366 | 0,069575 | 0,074936 | 0,0785104 |
| Land use | Pt | 0,05942 | 0,0594 | 0,05942 | 0,074423 | 0,083433 | 0,0894395 |
| Minerals | Pt | 3,5545 | 3,556 | 3,55757 | 3,880908 | 4,080428 | 4,2134417 |

| Impact category | Unit | A13 | A14 | A15 | A16 | A17 |
|---|---|---|---|---|---|---|
| Total | Pt | 22,0638 | 16,347 | 16,4169 | 16,5098 | 16,5098018 |
| Carcinogens | Pt | 0,27762 | 0,2638 | 0,26597 | 0,268852 | 0,26885182 |
| Resp. organics | Pt | 0,00848 | 0,0058 | 0,00598 | 0,006175 | 0,00617473 |
| Resp. inorganics | Pt | 14,2017 | 9,7328 | 9,75882 | 9,793561 | 9,79356135 |
| Climate change | Pt | 3,03322 | 2,6223 | 2,64123 | 2,666506 | 2,66650613 |
| Radiation | Pt | 0,00224 | 0,0019 | 0,00203 | 0,002158 | 0,00215783 |
| Ozone layer | Pt | 0,0006 | 0,0005 | 0,00055 | 0,000561 | 0,0005614 |
| Ecotoxicity | Pt | 0,01603 | 0,0148 | 0,0149 | 0,014999 | 0,01499922 |
| Acidification/ Eutrophication | Pt | 0,08208 | 0,0624 | 0,06338 | 0,064756 | 0,06475639 |
| Land use | Pt | 0,09545 | 0,0603 | 0,06077 | 0,061453 | 0,0614525 |
| Minerals | Pt | 4,34646 | 3,5827 | 3,60331 | 3,63078 | 3,63078034 |

Table 4.4 Environmental impact categories per product and subassemblies for the detail flat roofs with gravel on top -The ingredients of the detail except the insulation - **According to Figure 4.10**

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Flat Roof Gravel on Top** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weighting |

| Impact category | Unit | TOTAL | Gravel(90kg) | Geotextile Felt(0.1kg) | Polymeric Modified Bituminous Waterproofing 0,8kg |
|---|---|---|---|---|---|
| Total | Pt | 8,886930286 | 0,038699673 | 0,035157957 | 0,072931956 |
| Carcinogens | Pt | 0,2087595 | 0,000566841 | 0,001735302 | 0,001624394 |
| Resp. organics | Pt | 0,005107773 | 4,07E-05 | 5,79E-05 | 0,000241975 |
| Resp. inorganics | Pt | 3,124955887 | 0,01662582 | 0,012009331 | 0,029156126 |
| Climate change | Pt | 2,367188952 | 0,005994399 | 0,011814059 | 0,015481451 |
| Radiation | Pt | 0,001552269 | 2,77E-05 | 9,46E-06 | 2,25E-05 |
| Ozone layer | Pt | 0,000414541 | 2,87E-06 | 5,90E-06 | 2,53E-05 |
| Ecotoxicity | Pt | 0,010916421 | 5,59E-05 | 9,54E-05 | 9,98E-05 |
| Acidification/ Eutrophication | Pt | 0,055414481 | 0,000501945 | 0,000283249 | 0,000555139 |
| Land use | Pt | 0,046082392 | 0,00054271 | 0,000115514 | 0,000971806 |
| Minerals | Pt | 3,066538025 | 0,014340687 | 0,009031827 | 0,024753481 |

| Impact category | Unit | Plaster for incline purposes coating ceiling (154,14 kg) | Concrete Slab (364 kg) | Iron Bars for Reinforced Concrete (12,6 kg) | Gypsum Plaster(5kg) |
|---|---|---|---|---|---|
| Total | Pt | 1,3164726 | 3,1992914 | 4,0514817 | 0,172895 |
| Carcinogens | Pt | 0,008530628 | 0,03259851 | 0,16196229 | 0,001741535 |
| Resp. organics | Pt | 0,001185363 | 0,001948238 | 0,001490518 | 0,000143043 |
| Resp. inorganics | Pt | 0,3507889 | 0,78095922 | 1,819896 | 0,11552049 |
| Climate change | Pt | 0,81389818 | 1,0407423 | 0,43752169 | 0,041736873 |
| Radiation | Pt | 0,000613826 | 0,000563049 | 0,000283712 | 3,20E-05 |
| Ozone layer | Pt | 0,000129536 | 0,000160335 | 7,10E-05 | 1,96E-05 |
| Ecotoxicity | Pt | 0,001200037 | 0,002909656 | 0,006227831 | 0,000327781 |
| Acidification/ Eutrophication | Pt | 0,015552259 | 0,025501532 | 0,011685875 | 0,001334481 |
| Land use | Pt | 0,005431694 | 0,027659624 | 0,008998029 | 0,002363015 |
| Minerals | Pt | 0,11914222 | 1,2862489 | 1,6033447 | 0,009676209 |

Table 4.5 Total impacts of the flat roof with gravel on top detail

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Flat Roof Gravel on Top** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weighting |

| Impact category | Unit | B1 | B2 | B3 | B4 | B5 | B6 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 8,886930286 | 9,06180833 | 9,16673515 | 9,236686366 | 9,30663758 | 9,003515646 |
| Carcinogens | Pt | 0,2087595 | 0,21071167 | 0,21188298 | 0,212663844 | 0,21344471 | 0,210060948 |
| Resp. organics | Pt | 0,005107773 | 0,00604967 | 0,00661482 | 0,006991577 | 0,00736834 | 0,005735708 |
| Resp. inorganics | Pt | 3,124955887 | 3,19573424 | 3,23820125 | 3,266512585 | 3,29482392 | 3,172141453 |
| Climate change | Pt | 2,367188952 | 2,46046744 | 2,51643454 | 2,553745938 | 2,59105734 | 2,429374614 |
| Radiation | Pt | 0,001552269 | 0,00155264 | 0,00155286 | 0,001553004 | 0,00155315 | 0,001552514 |
| Ozone layer | Pt | 0,000414541 | 0,00042016 | 0,00042353 | 0,000425771 | 0,00042802 | 0,000418285 |
| Ecotoxicity | Pt | 0,010916421 | 0,01119719 | 0,01136564 | 0,011477951 | 0,01159026 | 0,011103598 |
| Acidification/ Eutrophication | Pt | 0,055414481 | 0,057299 | 0,05842971 | 0,059183513 | 0,05993732 | 0,056670825 |
| Land use | Pt | 0,046082392 | 0,04609357 | 0,04610027 | 0,046104743 | 0,04610921 | 0,046089843 |
| Minerals | Pt | 3,066538025 | 3,07228271 | 3,07572952 | 3,078027399 | 3,08032527 | 3,070367816 |

| Impact category | Unit | B7 | B8 | B9 | B10 | B11 | B12 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 9,073466862 | 9,120101006 | 9,16673515 | 11,31718479 | 12,7753375 | 13,7474393 |
| Carcinogens | Pt | 0,210841817 | 0,211362396 | 0,211882975 | 0,216013831 | 0,22036643 | 0,22326816 |
| Resp. organics | Pt | 0,006112468 | 0,006363642 | 0,006614816 | 0,00630801 | 0,00702815 | 0,00750825 |
| Resp. inorganics | Pt | 3,200452793 | 3,219327019 | 3,238201245 | 5,005088637 | 6,13316829 | 6,88522139 |
| Climate change | Pt | 2,466686011 | 2,491560276 | 2,516434541 | 2,551582433 | 2,66221852 | 2,73597591 |
| Radiation | Pt | 0,001552661 | 0,001552759 | 0,001552857 | 0,001748947 | 0,00186695 | 0,00194563 |
| Ozone layer | Pt | 0,000420531 | 0,000422028 | 0,000423525 | 0,000449738 | 0,00047086 | 0,00048494 |
| Ecotoxicity | Pt | 0,011215904 | 0,011290774 | 0,011365645 | 0,011473469 | 0,0118077 | 0,01203052 |
| Acidification/ Eutrophication | Pt | 0,057424632 | 0,057927169 | 0,058429707 | 0,06434943 | 0,0697104 | 0,07328438 |
| Land use | Pt | 0,046094313 | 0,046097293 | 0,046100273 | 0,061098736 | 0,07010854 | 0,07611508 |
| Minerals | Pt | 3,072665691 | 3,074197608 | 3,075729524 | 3,399071518 | 3,59859161 | 3,73160501 |

| Impact category | Unit | B13 | B14 | B15 | B16 | B17 |
|---|---|---|---|---|---|---|
| Total | Pt | 14,71954109 | 9,00300075 | 9,07264302 | 9,119071206 | 9,16549939 |
| Carcinogens | Pt | 0,226169894 | 0,21236111 | 0,21452208 | 0,215962722 | 0,21740337 |
| Resp. organics | Pt | 0,007988341 | 0,00534724 | 0,00549093 | 0,005586713 | 0,0056825 |
| Resp. inorganics | Pt | 7,637274487 | 3,16837854 | 3,19443213 | 3,211801195 | 3,22917026 |
| Climate change | Pt | 2,809733307 | 2,39878323 | 2,4177398 | 2,430377516 | 2,44301523 |
| Radiation | Pt | 0,002024297 | 0,00171265 | 0,00180888 | 0,001873033 | 0,00193719 |
| Ozone layer | Pt | 0,000499014 | 0,00043446 | 0,00044641 | 0,000454373 | 0,00046234 |
| Ecotoxicity | Pt | 0,012253336 | 0,01104554 | 0,01112301 | 0,011174654 | 0,0112263 |
| Acidification/ Eutrophication | Pt | 0,07685836 | 0,05712944 | 0,05815842 | 0,058844399 | 0,05953038 |
| Land use | Pt | 0,082121619 | 0,04693478 | 0,04744622 | 0,047787173 | 0,04812813 |
| Minerals | Pt | 3,86461841 | 3,1008737 | 3,1214751 | 3,135209375 | 3,14894364 |

Table 4.6 Environmental impact categories per product and subassemblies for the detail sloped roof with roof tiles detail - The ingredients of the detail except the insulation- **According to Figure 4.10**

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Roof - Sloped Roof with Roof Tiles** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weighting |

| Impact category | Unit | TOTAL | Beech tree lumber(124 kg) | Roofing Tile(39 kg) | Oriented Strand Board (OSB-10.8kg) |
|---|---|---|---|---|---|
| Total | Pt | 15,16469252 | 6,4744883 | 0,60929896 | 0,61798297 |
| Carcinogens | Pt | 0,25816611 | 0,03905984 | 0,008269483 | 0,014016987 |
| Resp. organics | Pt | 0,014950038 | 0,008314703 | 0,001220838 | 0,001739941 |
| Resp. inorganics | Pt | 3,990964858 | 0,76570002 | 0,1968032 | 0,29636073 |
| Climate change | Pt | 2,298383132 | 0,30727096 | 0,32886301 | 0,13193332 |
| Radiation | Pt | 0,001811709 | 0,000604895 | 0,000139507 | 0,000184547 |
| Ozone layer | Pt | 0,000493324 | 0,000112033 | 9,12E-05 | 2,63E-05 |
| Ecotoxicity | Pt | 0,013530071 | 0,002604857 | 0,000289689 | 0,001105654 |
| Acidification/ Eutrophication | Pt | 0,071111397 | 0,019989165 | 0,007194585 | 0,005067628 |
| Land use | Pt | 5,136936911 | 5,0416231 | 0,004868628 | 0,050719246 |
| Minerals | Pt | 3,378345037 | 0,28920877 | 0,061558778 | 0,11682858 |

| Impact category | Unit | Bitumen Waterproofing Cover(0.4kg) | Concrete Slab (364 kg) | Iron Bars for Reinforced Concrete (12,6 kg) | Gypsum Plaster(5kg) |
|---|---|---|---|---|---|
| Total | Pt | 0,039254694 | 3,1992913 | 4,0514813 | 0,172895 |
| Carcinogens | Pt | 0,000517478 | 0,032598508 | 0,16196228 | 0,001741535 |
| Resp. organics | Pt | 9,28E-05 | 0,001948238 | 0,001490518 | 0,000143043 |
| Resp. inorganics | Pt | 0,015725228 | 0,78095919 | 1,819896 | 0,11552049 |
| Climate change | Pt | 0,010314989 | 1,0407423 | 0,43752168 | 0,041736873 |
| Radiation | Pt | 4,04E-06 | 0,000563049 | 0,000283712 | 3,20E-05 |
| Ozone layer | Pt | 1,28E-05 | 0,000160335 | 7,10E-05 | 1,96E-05 |
| Ecotoxicity | Pt | 6,46E-05 | 0,002909656 | 0,00622783 | 0,000327781 |
| Acidification/ Eutrophication | Pt | 0,000338133 | 0,025501531 | 0,011685874 | 0,001334481 |
| Land use | Pt | 0,000705311 | 0,02765964 | 0,008997971 | 0,002363015 |
| Minerals | Pt | 0,0114794 | 1,2862488 | 1,6033445 | 0,009676209 |

Table 4.7 Total impacts of the sloped roof with roof tiles detail

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Roof- Sloped Roof with Roof Tiles** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weightings |

| Impact category | Unit | C1 | C2 | C3 | C4 | C5 | C6 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 15,164693 | 15,3395706 | 15,4444974 | 15,5144486 | 15,58439982 | 15,281278 |
| Carcinogens | Pt | 0,2581661 | 0,26011828 | 0,26128959 | 0,262070454 | 0,262851323 | 0,2594676 |
| Resp. organics | Pt | 0,01495 | 0,01589194 | 0,01645708 | 0,016833841 | 0,017210602 | 0,015578 |
| Resp. inorganics | Pt | 3,9909649 | 4,06174321 | 4,10421022 | 4,132521556 | 4,160832896 | 4,0381504 |
| Climate change | Pt | 2,2983831 | 2,39166163 | 2,44762872 | 2,484940118 | 2,522251515 | 2,3605688 |
| Radiation | Pt | 0,0018117 | 0,00181208 | 0,0018123 | 0,001812444 | 0,00181259 | 0,001812 |
| Ozone layer | Pt | 0,0004933 | 0,00049894 | 0,00050231 | 0,000504554 | 0,0005068 | 0,0004971 |
| Ecotoxicity | Pt | 0,0135301 | 0,01381084 | 0,01397929 | 0,0140916 | 0,014203906 | 0,0137172 |
| Acidification/ Eutrophication | Pt | 0,0711114 | 0,07299591 | 0,07412662 | 0,074880429 | 0,075634236 | 0,0723677 |
| Land use | Pt | 5,1369369 | 5,13694809 | 5,13695479 | 5,136959262 | 5,136963733 | 5,1369444 |
| Minerals | Pt | 3,378345 | 3,38408972 | 3,38753654 | 3,389834411 | 3,392132286 | 3,3821748 |

| Impact category | Unit | C7 | C8 | C9 | C10 | C11 | C12 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 15,351229 | 15,3978632 | 15,4444974 | 17,59494702 | 19,05309972 | 20,025202 |
| Carcinogens | Pt | 0,2602484 | 0,26076901 | 0,26128959 | 0,265420441 | 0,269773039 | 0,2726748 |
| Resp. organics | Pt | 0,0159547 | 0,01620591 | 0,01645708 | 0,016150274 | 0,016870416 | 0,0173505 |
| Resp. inorganics | Pt | 4,0664618 | 4,08533599 | 4,10421022 | 5,871097608 | 6,999177258 | 7,7512304 |
| Climate change | Pt | 2,3978802 | 2,42275446 | 2,44762872 | 2,482776613 | 2,593412702 | 2,6671701 |
| Radiation | Pt | 0,0018121 | 0,0018122 | 0,0018123 | 0,002008387 | 0,002126394 | 0,0022051 |
| Ozone layer | Pt | 0,0004993 | 0,00050081 | 0,00050231 | 0,000528521 | 0,000549639 | 0,0005637 |
| Ecotoxicity | Pt | 0,0138296 | 0,01390442 | 0,01397929 | 0,014087119 | 0,014421348 | 0,0146442 |
| Acidification/ Eutrophication | Pt | 0,0731215 | 0,07362409 | 0,07412662 | 0,080046347 | 0,085407316 | 0,0889813 |
| Land use | Pt | 5,1369488 | 5,13695181 | 5,13695479 | 5,151953255 | 5,160963062 | 5,1669696 |
| Minerals | Pt | 3,3844727 | 3,38600462 | 3,38753654 | 3,71087853 | 3,910398627 | 4,043412 |

| Impact category | Unit | C13 | C14 | C15 | C16 | C17 |
|---|---|---|---|---|---|---|
| Total | Pt | 20,997303 | 15,280763 | 15,3504053 | 15,39683344 | 15,44326163 |
| Carcinogens | Pt | 0,2755765 | 0,26176772 | 0,26392869 | 0,265369333 | 0,266809977 |
| Resp. organics | Pt | 0,0178306 | 0,01518951 | 0,01533319 | 0,015428977 | 0,015524765 |
| Resp. inorganics | Pt | 8,5032835 | 4,03438751 | 4,0604411 | 4,077810166 | 4,095179228 |
| Climate change | Pt | 2,7409275 | 2,32997741 | 2,34893398 | 2,361571696 | 2,374209409 |
| Radiation | Pt | 0,0022837 | 0,00197209 | 0,00206832 | 0,002132473 | 0,002196625 |
| Ozone layer | Pt | 0,0005778 | 0,00051324 | 0,00052519 | 0,000533156 | 0,000541123 |
| Ecotoxicity | Pt | 0,014867 | 0,01365919 | 0,01373666 | 0,013788303 | 0,01383995 |
| Acidification/ Eutrophication | Pt | 0,0925553 | 0,07282636 | 0,07385533 | 0,074541315 | 0,075227299 |
| Land use | Pt | 5,1729761 | 5,1377893 | 5,13830074 | 5,138641692 | 5,138982648 |
| Minerals | Pt | 4,1764254 | 3,41268071 | 3,43328212 | 3,447016387 | 3,460750657 |

Table 4.8 Environmental impact categories per product and subassemblies for the detail sloped roof with shingle detail- The ingredients of the detail except the insulation- **According to Figure 4.10**

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Sloped Roof with Shingle** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weighting |

| Impact category | Unit | TOTAL | Beech tree lumber | Shingle | Oriented Strand Board (OSB) |
|---|---|---|---|---|---|
| Total | Pt | 15,2074 | 6,4744883 | 0,65200865 | 0,61798297 |
| Carcinogens | Pt | 0,266165 | 0,03905984 | 0,01626831 | 0,014016987 |
| Resp. organics | Pt | 0,016128 | 0,0083147 | 0,00239854 | 0,001739941 |
| Resp. inorganics | Pt | 4,065056 | 0,76570002 | 0,27089385 | 0,29636073 |
| Climate change | Pt | 2,092378 | 0,30727097 | 0,12285781 | 0,13193332 |
| Radiation | Pt | 0,001874 | 0,0006049 | 0,00020219 | 0,000184547 |
| Ozone layer | Pt | 0,00067 | 0,00011203 | 0,00026813 | 2,63E-05 |
| Ecotoxicity | Pt | 0,014265 | 0,00260486 | 0,00102436 | 0,001105654 |
| Acidification/ Eutrophication | Pt | 0,069194 | 0,01998917 | 0,00527713 | 0,005067628 |
| Land use | Pt | 5,142501 | 5,041623 | 0,01043307 | 0,050719247 |
| Minerals | Pt | 3,539172 | 0,28920877 | 0,22238525 | 0,11682858 |

| Impact category | Unit | Bitumen Waterproofing Cover | Concrete Slab (364 kg) | Iron Bars for Reinforced Concrete (12,6 kg) | Gypsum Plaster |
|---|---|---|---|---|---|
| Total | Pt | 0,039255 | 3,199292 | 4,0514817 | 0,172895 |
| Carcinogens | Pt | 0,000517 | 0,03259852 | 0,16196229 | 0,001741535 |
| Resp. organics | Pt | 9,28E-05 | 0,00194824 | 0,00149052 | 0,000143043 |
| Resp. inorganics | Pt | 0,015725 | 0,78095929 | 1,819896 | 0,11552049 |
| Climate change | Pt | 0,010315 | 1,0407424 | 0,43752169 | 0,041736873 |
| Radiation | Pt | 4,04E-06 | 0,00056305 | 0,00028371 | 3,20E-05 |
| Ozone layer | Pt | 1,28E-05 | 0,00016033 | 7,10E-05 | 1,96E-05 |
| Ecotoxicity | Pt | 6,46E-05 | 0,00290966 | 0,00622783 | 0,000327781 |
| Acidification/ Eutrophication | Pt | 0,000338 | 0,02550153 | 0,01168588 | 0,001334481 |
| Land use | Pt | 0,000705 | 0,02765968 | 0,00899804 | 0,002363015 |
| Minerals | Pt | 0,011479 | 1,2862494 | 1,6033447 | 0,009676209 |

Table 4.9 Total impacts of the sloped roof with shingle detail

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Sloped Roof with Shingle** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weighting |

| Impact category | Unit | D1 | D2 | D3 | D4 | D5 | D6 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 15,2074 | 15,3822814 | 15,4872082 | 15,5571594 | 15,6271106 | 15,3239887 |
| Carcinogens | Pt | 0,266165 | 0,26811713 | 0,26928843 | 0,270069302 | 0,27085017 | 0,26746641 |
| Resp. organics | Pt | 0,016128 | 0,01706964 | 0,01763478 | 0,018011542 | 0,0183883 | 0,01675567 |
| Resp. inorganics | Pt | 4,065056 | 4,13583396 | 4,17830097 | 4,206612306 | 4,23492365 | 4,11224117 |
| Climate change | Pt | 2,092378 | 2,18565655 | 2,24162364 | 2,278935038 | 2,31624644 | 2,15456371 |
| Radiation | Pt | 0,001874 | 0,00187476 | 0,00187498 | 0,001875123 | 0,00187527 | 0,00187463 |
| Ozone layer | Pt | 0,00067 | 0,00067582 | 0,00067919 | 0,000681432 | 0,00068368 | 0,00067395 |
| Ecotoxicity | Pt | 0,014265 | 0,01454551 | 0,01471397 | 0,014826278 | 0,01493858 | 0,01445192 |
| Acidification/ Eutrophication | Pt | 0,069194 | 0,07107846 | 0,07220917 | 0,072962981 | 0,07371679 | 0,07045029 |
| Land use | Pt | 5,142501 | 5,14251254 | 5,14251924 | 5,142523714 | 5,14252818 | 5,14250881 |
| Minerals | Pt | 3,539172 | 3,544917 | 3,54836381 | 3,550661684 | 3,55295956 | 3,5430021 |

| Impact category | Unit | D7 | D8 | D9 | D10 | D11 | D12 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 15,39394 | 15,440574 | 15,4872082 | 17,63765782 | 19,0958105 | 20,0679123 |
| Carcinogens | Pt | 0,268247 | 0,26876785 | 0,26928843 | 0,273419288 | 0,27777189 | 0,28067362 |
| Resp. organics | Pt | 0,017132 | 0,01738361 | 0,01763478 | 0,017327975 | 0,01804812 | 0,01852821 |
| Resp. inorganics | Pt | 4,140553 | 4,15942674 | 4,17830097 | 5,945188358 | 7,07326801 | 7,82532111 |
| Climate change | Pt | 2,191875 | 2,21674938 | 2,24162364 | 2,276771533 | 2,38740762 | 2,46116501 |
| Radiation | Pt | 0,001875 | 0,00187488 | 0,00187498 | 0,002071066 | 0,00218907 | 0,00226774 |
| Ozone layer | Pt | 0,000676 | 0,00067769 | 0,00067919 | 0,000705399 | 0,00072652 | 0,0007406 |
| Ecotoxicity | Pt | 0,014564 | 0,0146391 | 0,01471397 | 0,014821796 | 0,01515602 | 0,01537884 |
| Acidification/ Eutrophication | Pt | 0,071204 | 0,07170664 | 0,07220917 | 0,078128898 | 0,08348987 | 0,08706385 |
| Land use | Pt | 5,142513 | 5,14251626 | 5,14251924 | 5,157517707 | 5,16652751 | 5,17253405 |
| Minerals | Pt | 3,5453 | 3,54683189 | 3,54836381 | 3,871705803 | 4,0712259 | 4,2042393 |

| Impact category | Unit | D13 | D14 | D15 | D16 | D17 |
|---|---|---|---|---|---|---|
| Total | Pt | 21,04001 | 15,3234738 | 15,3931161 | 15,43954424 | 15,4859724 |
| Carcinogens | Pt | 0,283575 | 0,26976657 | 0,27192754 | 0,27336818 | 0,27480882 |
| Resp. organics | Pt | 0,019008 | 0,01636721 | 0,01651089 | 0,016606678 | 0,01670247 |
| Resp. inorganics | Pt | 8,577374 | 4,10847826 | 4,13453185 | 4,151900916 | 4,16926998 |
| Climate change | Pt | 2,534922 | 2,12397233 | 2,1429289 | 2,155566616 | 2,16820433 |
| Radiation | Pt | 0,002346 | 0,00203477 | 0,002131 | 0,002195152 | 0,0022593 |
| Ozone layer | Pt | 0,000755 | 0,00069012 | 0,00070207 | 0,000710034 | 0,000718 |
| Ecotoxicity | Pt | 0,015602 | 0,01439386 | 0,01447133 | 0,014522981 | 0,01457463 |
| Acidification/ Eutrophication | Pt | 0,090638 | 0,07090891 | 0,07193788 | 0,072623867 | 0,07330985 |
| Land use | Pt | 5,178541 | 5,14335375 | 5,14386519 | 5,144206143 | 5,1445471 |
| Minerals | Pt | 4,337253 | 3,57350798 | 3,59410939 | 3,607843659 | 3,62157793 |

Table 4.10 Environmental impact categories per product and subassemblies for the detail slab with ceramic on top detail- The ingredients of the detail except the insulation- **According to Figure 4.12**

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Slab with ceramic on top** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weighting |

| Impact category | Unit | TOTAL | Ceramic Tile(12kg) | Cement Based Ceramic Adhesive Mortar (2kg) | Geotextile Felt(0.1kg) |
|---|---|---|---|---|---|
| Total | Pt | 15,14145348 | 7,3675273 | 0,015474698 | 0,035157956 |
| Carcinogens | Pt | 0,249621003 | 0,051870817 | 0,000144477 | 0,001735302 |
| Resp. organics | Pt | 0,004628939 | 0,000517713 | 1,53E-05 | 5,79E-05 |
| Resp. inorganics | Pt | 9,403546055 | 6,576756 | 0,004260914 | 0,012009331 |
| Climate change | Pt | 2,133979587 | 0,22049285 | 0,008992455 | 0,011814059 |
| Radiation | Pt | 0,001461998 | 0,000240735 | 7,64E-06 | 9,46E-06 |
| Ozone layer | Pt | 0,000419168 | 0,000100309 | 1,63E-06 | 5,90E-06 |
| Ecotoxicity | Pt | 0,013663982 | 0,003809848 | 1,90E-05 | 9,54E-05 |
| Acidification/ Eutrophication | Pt | 0,050531451 | 0,005548162 | 0,000179791 | 0,000283249 |
| Land use | Pt | 0,051347675 | 0,013545808 | 0,000321275 | 0,000115514 |
| Minerals | Pt | 3,232253693 | 0,49464512 | 0,00153226 | 0,009031827 |

| Impact category | Unit | Plaster for Coating Slab (110 kg) | Concrete Slab (291.2 kg) | Iron Bars for Reinforced Concrete (12.6 kg) | Gypsum Plaster(5kg) |
|---|---|---|---|---|---|
| Total | Pt | 0,93948355 | 2,55943328 | 4,0514817 | 0,172895 |
| Carcinogens | Pt | 0,006087772 | 0,02607881 | 0,16196229 | 0,001741535 |
| Resp. organics | Pt | 0,000845919 | 0,00155859 | 0,001490518 | 0,000143043 |
| Resp. inorganics | Pt | 0,25033592 | 0,6247674 | 1,819896 | 0,11552049 |
| Climate change | Pt | 0,58082782 | 0,83259384 | 0,43752169 | 0,041736873 |
| Radiation | Pt | 0,000438049 | 0,000450439 | 0,000283712 | 3,20E-05 |
| Ozone layer | Pt | 9,24E-05 | 0,000128268 | 7,10E-05 | 1,96E-05 |
| Ecotoxicity | Pt | 0,000856391 | 0,002327725 | 0,006227831 | 0,000327781 |
| Acidification/ Eutrophication | Pt | 0,011098667 | 0,020401226 | 0,011685875 | 0,001334481 |
| Land use | Pt | 0,003876275 | 0,022127705 | 0,008998083 | 0,002363016 |
| Minerals | Pt | 0,085024297 | 1,02899928 | 1,6033447 | 0,009676209 |

Table 4.11 Total impacts of the slab with ceramic on top detail

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Slab with ceramic on top** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Single score |

| Impact category | Unit | A1 | A2 | A3 | A4 | A5 | A6 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 15,141453 | 15,24638 | 15,316332 | 15,351307 | 15,38628 | 15,2114 |
| Carcinogens | Pt | 0,249621 | 0,250792 | 0,2515732 | 0,2519636 | 0,252354 | 0,250402 |
| Resp. organics | Pt | 0,0046289 | 0,005194 | 0,0055708 | 0,0057592 | 0,005948 | 0,005006 |
| Resp. inorganics | Pt | 9,4035461 | 9,446013 | 9,4743244 | 9,4884801 | 9,502636 | 9,431857 |
| Climate change | Pt | 2,1339796 | 2,189947 | 2,2272581 | 2,2459138 | 2,264569 | 2,171291 |
| Radiation | Pt | 0,001462 | 0,001462 | 0,0014624 | 0,0014624 | 0,001463 | 0,001462 |
| Ozone layer | Pt | 0,0004192 | 0,000423 | 0,0004248 | 0,0004259 | 0,000427 | 0,000421 |
| Ecotoxicity | Pt | 0,013664 | 0,013832 | 0,0139447 | 0,0140009 | 0,014057 | 0,013776 |
| Acidification/ Eutrophication | Pt | 0,0505315 | 0,051662 | 0,052416 | 0,0527929 | 0,05317 | 0,051285 |
| Land use | Pt | 0,0513477 | 0,051354 | 0,0513589 | 0,0513611 | 0,051363 | 0,051352 |
| Minerals | Pt | 3,2322537 | 3,235701 | 3,2379984 | 3,2391473 | 3,240296 | 3,234552 |

| Impact category | Unit | A7 | A8 | A9 | A10 | A11 | A12 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 15,258039 | 15,28136 | 15,304673 | 16,599606 | 17,57171 | 18,05776 |
| Carcinogens | Pt | 6 | 0,251183 | 0,251443 | 0,2539736 | 0,256875 | 0,258326 |
| Resp. organics | Pt | 0,0052569 | 0,005382 | 0,005508 | 0,0053491 | 0,005829 | 0,006069 |
| Resp. inorganics | Pt | 9,4507316 | 9,460169 | 9,4696058 | 10,531626 | 11,28368 | 11,65971 |
| Climate change | Pt | 2,1961652 | 2,208602 | 2,2210395 | 2,2446157 | 2,318373 | 2,355252 |
| Radiation | Pt | 0,0014622 | 0,001462 | 0,0014623 | 0,00158 | 0,001659 | 0,001698 |
| Ozone layer | Pt | 0,0004229 | 0,000424 | 0,0004244 | 0,0004403 | 0,000454 | 0,000461 |
| Ecotoxicity | Pt | 0,0138512 | 0,013889 | 0,013926 | 0,0139982 | 0,014221 | 0,014332 |
| Acidification/ Eutrophication | Pt | 0,0517878 | 0,052039 | 0,0522903 | 0,0558924 | 0,059466 | 0,061253 |
| Land use | Pt | 0,0513551 | 0,051357 | 0,0513581 | 0,0603575 | 0,066364 | 0,069367 |
| Minerals | Pt | 3,2360835 | 3,236849 | 3,2376154 | 3,4317738 | 3,564787 | 3,631294 |

| Impact category | Unit | A13 | A14 | A15 | A16 | A17 |
|---|---|---|---|---|---|---|
| Total | Pt | 18,54381 | 15,2111 | 15,257524 | 15,280738 | 15,30395 |
| Carcinogens | Pt | 0,2597771 | 0,251782 | 0,2532226 | 0,2539429 | 0,254663 |
| Resp. organics | Pt | 0,0063093 | 0,004773 | 0,0048684 | 0,0049163 | 0,004964 |
| Resp. inorganics | Pt | 12,035732 | 9,4296 | 9,4469687 | 9,4556532 | 9,464338 |
| Climate change | Pt | 2,3921305 | 2,152936 | 2,1655739 | 2,1718927 | 2,178212 |
| Radiation | Pt | 0,0017373 | 0,001558 | 0,0016224 | 0,0016545 | 0,001687 |
| Ozone layer | Pt | 0,0004684 | 0,000431 | 0,0004391 | 0,0004431 | 0,000447 |
| Ecotoxicity | Pt | 0,0144438 | 0,013741 | 0,0137931 | 0,0138189 | 0,013845 |
| Acidification/ Eutrophication | Pt | 0,0630404 | 0,05156 | 0,0522464 | 0,0525894 | 0,052932 |
| Land use | Pt | 0,0723706 | 0,051859 | 0,0522001 | 0,0523705 | 0,052541 |
| Minerals | Pt | 3,6978006 | 3,252855 | 3,2665894 | 3,2734565 | 3,280324 |

Table 4.12 Environmental impact categories per product and subassemblies for the detail slab with laminated flooring on top detail- The ingredients of the detail except the insulation- **According to Figure 4.12**

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Slab with laminated flooring on top** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Single score |

| Impact category | Unit | TOTAL | Laminated Flooring | Foam Underlayment | Geotextile Felt |
|---|---|---|---|---|---|
| Total | Pt | 8,4214881 | 0,65142952 | 0,01160705 | 0,03515796 |
| Carcinogens | Pt | 0,2068888 | 0,00892289 | 0,00036016 | 0,0017353 |
| Resp. organics | Pt | 0,0057939 | 0,00167403 | 2,3947E-05 | 5,79E-05 |
| Resp. inorganics | Pt | 3,0068799 | 0,1800085 | 0,00434227 | 0,01200933 |
| Climate change | Pt | 1,9800802 | 0,07242645 | 0,00315943 | 0,01181406 |
| Radiation | Pt | 0,0013768 | 0,00014718 | 1,6038E-05 | 9,46E-06 |
| Ozone layer | Pt | 0,0003445 | 2,53E-05 | 1,99E-06 | 5,90E-06 |
| Ecotoxicity | Pt | 0,0103268 | 0,00047879 | 1,2912E-05 | 9,54E-05 |
| Acidification/ Eutrophication | Pt | 0,0494144 | 0,00443944 | 0,0001715 | 0,00028325 |
| Land use | Pt | 0,3731348 | 0,33556901 | 8,5239E-05 | 0,00011551 |
| Minerals | Pt | 2,7872479 | 0,04773798 | 0,00343357 | 0,00903183 |

| Impact category | Unit | Plaster for Coating Slab (110 kg) | Concrete Slab (291,2 kg) | Iron Bars for Reinforced Concrete (12,6 kg) | Gypsum Plaster |
|---|---|---|---|---|---|
| Total | Pt | 0,9394836 | 2,55943328 | 4,0514817 | 0,172895 |
| Carcinogens | Pt | 0,0060878 | 0,02607881 | 0,16196229 | 0,00174153 |
| Resp. organics | Pt | 0,0008459 | 0,00155859 | 0,00149052 | 0,00014304 |
| Resp. inorganics | Pt | 0,2503359 | 0,6247674 | 1,819896 | 0,11552049 |
| Climate change | Pt | 0,5808278 | 0,83259384 | 0,43752169 | 0,04173687 |
| Radiation | Pt | 0,000438 | 0,00045044 | 0,00028371 | 3,20E-05 |
| Ozone layer | Pt | 9,24E-05 | 0,00012827 | 7,10E-05 | 1,96E-05 |
| Ecotoxicity | Pt | 0,0008564 | 0,00232772 | 0,00622783 | 0,00032778 |
| Acidification/ Eutrophication | Pt | 0,0110987 | 0,02040123 | 0,01168588 | 0,00133448 |
| Land use | Pt | 0,0038763 | 0,0221277 | 0,00899808 | 0,00236302 |
| Minerals | Pt | 0,0850243 | 1,02899928 | 1,6033447 | 0,00967621 |

Table 4.13 Total impacts of the slab with laminated flooring on top detail

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Slab with laminated flooring on top** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weighting |

| Impact category | Unit | B1 | B2 | B3 | B4 | B5 | B6 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 8,4214881 | 8,52641488 | 8,59636609 | 8,6313417 | 8,6663173 | 8,6080246 |
| Carcinogens | Pt | 0,2068888 | 0,20806006 | 0,20884093 | 0,2092314 | 0,2096218 | 0,2081902 |
| Resp. organics | Pt | 0,0057939 | 0,00635907 | 0,00673583 | 0,0069242 | 0,0071126 | 0,0064219 |
| Resp. inorganics | Pt | 3,0068799 | 3,04934692 | 3,07765826 | 3,0918139 | 3,1059696 | 3,0540655 |
| Climate change | Pt | 1,9800802 | 2,03604725 | 2,07335865 | 2,0920143 | 2,11067 | 2,0422658 |
| Radiation | Pt | 0,0013768 | 0,00137706 | 0,00137721 | 0,0013773 | 0,0013774 | 0,0013771 |
| Ozone layer | Pt | 0,0003445 | 0,00034786 | 0,0003501 | 0,0003512 | 0,0003523 | 0,0003482 |
| Ecotoxicity | Pt | 0,0103268 | 0,01049531 | 0,01060761 | 0,0106638 | 0,0107199 | 0,010514 |
| Acidification/ Eutrophication | Pt | 0,0494144 | 0,05054514 | 0,05129895 | 0,0516759 | 0,0520528 | 0,0506708 |
| Land use | Pt | 0,3731348 | 0,37314155 | 0,37314602 | 0,3731483 | 0,3731505 | 0,3731423 |
| Minerals | Pt | 2,7872479 | 2,79069467 | 2,79299254 | 2,7941415 | 2,7952904 | 2,7910776 |

| Impact category | Unit | B7 | B8 | B9 | B10 | B11 | B12 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 8,5380734 | 8,56139048 | 8,58470756 | 9,8796408 | 10,851743 | 11,337793 |
| Carcinogens | Pt | 0,2081902 | 0,2084505 | 0,20871078 | 0,2112414 | 0,2141431 | 0,215594 |
| Resp. organics | Pt | 0,0064219 | 0,00654745 | 0,00667304 | 0,0065141 | 0,0069942 | 0,0072342 |
| Resp. inorganics | Pt | 3,0540655 | 3,06350259 | 3,0729397 | 4,1349596 | 4,8870127 | 5,2630392 |
| Climate change | Pt | 2,0422658 | 2,05470295 | 2,06714008 | 2,0907162 | 2,1644736 | 2,2013523 |
| Radiation | Pt | 0,0013771 | 0,00137714 | 0,00137719 | 0,0014948 | 0,0015735 | 0,0016129 |
| Ozone layer | Pt | 0,0003482 | 0,00034898 | 0,00034973 | 0,0003656 | 0,0003797 | 0,0003867 |
| Ecotoxicity | Pt | 0,010514 | 0,01055146 | 0,0105889 | 0,0106611 | 0,0108839 | 0,0109953 |
| Acidification/ Eutrophication | Pt | 0,0506708 | 0,05092204 | 0,05117331 | 0,0547754 | 0,0583494 | 0,0601364 |
| Land use | Pt | 0,3731423 | 0,37314378 | 0,37314527 | 0,3821446 | 0,3881512 | 0,3911545 |
| Minerals | Pt | 2,7910776 | 2,79184361 | 2,79260957 | 2,986768 | 3,1197814 | 3,1862881 |

| Impact category | Unit | B13 | B14 | B15 | B16 | B17 |
|---|---|---|---|---|---|---|
| Total | Pt | 11,823844 | 8,49143927 | 8,53807341 | 8,5613905 | 8,5847076 |
| Carcinogens | Pt | 0,2170448 | 0,20766963 | 0,20819021 | 0,2084505 | 0,2087108 |
| Resp. organics | Pt | 0,0074743 | 0,00617069 | 0,00642187 | 0,0065475 | 0,006673 |
| Resp. inorganics | Pt | 5,6390658 | 3,03519125 | 3,05406547 | 3,0635026 | 3,0729397 |
| Climate change | Pt | 2,238231 | 2,01739155 | 2,04226582 | 2,0547029 | 2,0671401 |
| Radiation | Pt | 0,0016522 | 0,00137699 | 0,00137709 | 0,0013771 | 0,0013772 |
| Ozone layer | Pt | 0,0003938 | 0,00034673 | 0,00034823 | 0,000349 | 0,0003497 |
| Ecotoxicity | Pt | 0,0111067 | 0,01043915 | 0,01051403 | 0,0105515 | 0,0105889 |
| Acidification/ Eutrophication | Pt | 0,0619234 | 0,05016824 | 0,05067078 | 0,050922 | 0,0511733 |
| Land use | Pt | 0,3941577 | 0,37313931 | 0,37314229 | 0,3731438 | 0,3731453 |
| Minerals | Pt | 3,2527947 | 2,78954573 | 2,79107765 | 2,7918436 | 2,7926096 |

Table 4.14 Environmental impact categories per product and subassemblies for the detail slab with solid parquet on top detail- The ingredients of the detail except the insulation- **According to Figure 4.12**

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Slab with solid parquet on top** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weighting |

| Impact category | Unit | TOTAL | Solid Parquet ( 9kg) | Adhesive(1kg) | Geotextile Felt (0.1kg) |
|---|---|---|---|---|---|
| Total | Pt | 8,68132 | 0,76141113 | 0,16146107 | 0,035158 |
| Carcinogens | Pt | 0,21216 | 0,01042935 | 0,00412506 | 0,0017353 |
| Resp. organics | Pt | 0,00661 | 0,00195665 | 0,00055327 | 5,79E-05 |
| Resp. inorganics | Pt | 3,08325 | 0,21039954 | 0,05031732 | 0,0120093 |
| Climate change | Pt | 2,03726 | 0,08465429 | 0,04810898 | 0,0118141 |
| Radiation | Pt | 0,00145 | 0,00017203 | 6,36E-05 | 9,46E-06 |
| Ozone layer | Pt | 0,00037 | 2,95E-05 | 2,16E-05 | 5,90E-06 |
| Ecotoxicity | Pt | 0,01058 | 0,00055962 | 0,00018523 | 9,54E-05 |
| Acidification/ Eutrophication | Pt | 0,05111 | 0,00518895 | 0,00111611 | 0,0002832 |
| Land use | Pt | 0,43074 | 0,39222352 | 0,00103445 | 0,0001155 |
| Minerals | Pt | 2,84781 | 0,05579764 | 0,05593545 | 0,0090318 |

| Impact category | Unit | Plaster for Coating Slab (110 kg) | Concrete Slab (291,2 kg) | Iron Bars for Reinforced Concrete (12,6 kg) | Gypsum Plaster (5kg) |
|---|---|---|---|---|---|
| Total | Pt | 0,93948 | 2,55943328 | 4,0514817 | 0,172895 |
| Carcinogens | Pt | 0,00609 | 0,02607881 | 0,16196229 | 0,0017415 |
| Resp. organics | Pt | 0,00085 | 0,00155859 | 0,00149052 | 0,000143 |
| Resp. inorganics | Pt | 0,25034 | 0,6247674 | 1,819896 | 0,1155205 |
| Climate change | Pt | 0,58083 | 0,83259384 | 0,43752169 | 0,0417369 |
| Radiation | Pt | 0,00044 | 0,00045044 | 0,00028371 | 3,20E-05 |
| Ozone layer | Pt | 9,24E-05 | 0,00012827 | 7,10E-05 | 1,96E-05 |
| Ecotoxicity | Pt | 0,00086 | 0,00232772 | 0,00622783 | 0,0003278 |
| Acidification/ Eutrophication | Pt | 0,0111 | 0,02040123 | 0,01168588 | 0,0013345 |
| Land use | Pt | 0,00388 | 0,0221277 | 0,00899808 | 0,002363 |
| Minerals | Pt | 0,08502 | 1,02899928 | 1,6033447 | 0,0096762 |

Table 4.15 Total impacts of the slab with solid parquet on top detail

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Slab with solid parquet on top** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weighting |

| Impact category | Unit | C1 | C2 | C3 | C4 | C5 | C6 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 8,6813237 | 8,78625051 | 8,8562017 | 8,8911773 | 8,926153 | 8,7512749 |
| Carcinogens | Pt | 0,2121601 | 0,21333143 | 0,2141123 | 0,2145027 | 0,214893 | 0,212941 |
| Resp. organics | Pt | 0,0066059 | 0,00717103 | 0,0075478 | 0,0077362 | 0,007925 | 0,0069826 |
| Resp. inorganics | Pt | 3,083246 | 3,12571301 | 3,1540244 | 3,16818 | 3,182336 | 3,1115573 |
| Climate change | Pt | 2,0372575 | 2,09322464 | 2,130536 | 2,1491917 | 2,167847 | 2,0745689 |
| Radiation | Pt | 0,0014492 | 0,00144944 | 0,0014496 | 0,0014497 | 0,00145 | 0,0014494 |
| Ozone layer | Pt | 0,0003684 | 0,00037177 | 0,000374 | 0,0003751 | 0,000376 | 0,0003706 |
| Ecotoxicity | Pt | 0,01058 | 0,01074846 | 0,0108608 | 0,0109169 | 0,010973 | 0,0106923 |
| Acidification/ Eutrophication | Pt | 0,0511086 | 0,05223927 | 0,0529931 | 0,05337 | 0,053747 | 0,0518624 |
| Land use | Pt | 0,4307386 | 0,43074526 | 0,4307497 | 0,430752 | 0,430754 | 0,430743 |
| Minerals | Pt | 2,8478094 | 2,85125621 | 2,8535541 | 2,854703 | 2,855852 | 2,8501073 |

| Impact category | | C7 | C8 | C9 | C10 | C11 | C12 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 8,797909 | 8,82122612 | 8,8445432 | 10,139476 | 11,11158 | 11,597629 |
| Carcinogens | Pt | 0,2134616 | 0,21372186 | 0,2139821 | 0,2165127 | 0,219414 | 0,2208653 |
| Resp. organics | Pt | 0,0072338 | 0,00735941 | 0,007485 | 0,007326 | 0,007806 | 0,0080462 |
| Resp. inorganics | Pt | 3,1304316 | 3,13986868 | 3,1493058 | 4,2113257 | 4,963379 | 5,3394053 |
| Climate change | Pt | 2,0994432 | 2,11188034 | 2,1243175 | 2,1478936 | 2,221651 | 2,2585297 |
| Radiation | Pt | 0,0014495 | 0,00144952 | 0,0014496 | 0,0015672 | 0,001646 | 0,0016852 |
| Ozone layer | Pt | 0,0003721 | 0,00037289 | 0,0003736 | 0,0003895 | 0,000404 | 0,0004106 |
| Ecotoxicity | Pt | 0,0107672 | 0,01080462 | 0,0108421 | 0,0109142 | 0,011137 | 0,0112485 |
| Acidification/ Eutrophication | Pt | 0,0523649 | 0,05261617 | 0,0528674 | 0,0564695 | 0,060044 | 0,0618305 |
| Land use | Pt | 0,430746 | 0,4307475 | 0,430749 | 0,4397484 | 0,445755 | 0,4487582 |
| Minerals | Pt | 2,8516392 | 2,85240515 | 2,8531711 | 3,0473295 | 3,180343 | 3,2468496 |

| Impact category | it | C13 | C14 | C15 | C16 | C17 |
|---|---|---|---|---|---|---|
| Total | Pt | 12,08368 | 8,75096596 | 8,7973941 | 8,8206082 | 8,843822 |
| Carcinogens | Pt | 0,2223162 | 0,21432109 | 0,2157617 | 0,2164821 | 0,217202 |
| Resp. organics | Pt | 0,0082862 | 0,00674957 | 0,0068454 | 0,0068932 | 0,006941 |
| Resp. inorganics | Pt | 5,7154319 | 3,10929959 | 3,1266687 | 3,1353532 | 3,144038 |
| Climate change | Pt | 2,2954084 | 2,05621411 | 2,0688518 | 2,0751707 | 2,08149 |
| Radiation | Pt | 0,0017246 | 0,00154545 | 0,0016096 | 0,0016417 | 0,001674 |
| Ozone layer | Pt | 0,0004177 | 0,00038035 | 0,0003883 | 0,0003923 | 0,000396 |
| Ecotoxicity | Pt | 0,0113599 | 0,01065747 | 0,0107091 | 0,0107349 | 0,010761 |
| Acidification/ Eutrophication | Pt | 0,0636175 | 0,05213754 | 0,0528235 | 0,0531665 | 0,05351 |
| Land use | Pt | 0,4517614 | 0,43124999 | 0,4315909 | 0,4317614 | 0,431932 |
| Minerals | Pt | 3,3133563 | 2,8684108 | 2,8821451 | 2,8890122 | 2,895879 |

Table 4.16 Environmental impact categories per product and subassemblies for the detail brick sandwich wall detail- The ingredients of the detail except the insulation- **According to Figure 4.13**

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Brick Sandwich Wall** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weighting |

| Impact category | Unit | TOTAL | Alkyd Paint | Plaster 3cm(66kg) | brick, at plant/DE U 70 kg | brick, at plant/DE U 46.25 kg | Plaster 2 cm(44 | Alkyd Paint |
|---|---|---|---|---|---|---|---|---|
| Total | Pt | 2,52153151 | 0,03855974 | 0,56369013 | 0,90619349 | 0,598734984 | 0,37579342 | 0,038559741 |
| Carcinogens | Pt | 0,18606365 | 0,00106558 | 0,003652663 | 0,10708929 | 0,070755424 | 0,002435109 | 0,00106558 |
| Resp. organics | Pt | 0,00201289 | 4,26E-05 | 0,000507551 | 0,000651352 | 0,000430357 | 0,000338368 | 4,26E-05 |
| Resp. inorganics | Pt | 0,54194268 | 0,01678617 | 0,150201552 | 0,15537557 | 0,102658859 | 0,100134368 | 0,016786167 |
| Climate change | Pt | 1,04043296 | 0,00861539 | 0,348496692 | 0,26637596 | 0,175998402 | 0,232331128 | 0,00861539 |
| Radiation | Pt | 0,00052554 | 7,15E-06 | 0,00026283 | 4,41E-05 | 2,91221E-05 | 0,00017522 | 7,15E-06 |
| Ozone layer | Pt | 0,00031261 | 5,00E-06 | 5,55E-05 | 0,000126551 | 8,36138E-05 | 3,69765E-05 | 5,00E-06 |
| Ecotoxicity | Pt | 0,00209175 | 4,20E-05 | 0,000513834 | 0,000693297 | 0,000458071 | 0,000342556 | 4,20E-05 |
| Acidification/ Eutrophication | Pt | 0,02247434 | 0,00033187 | 0,0066592 | 0,006450197 | 0,004261737 | 0,004439467 | 0,000331869 |
| Land use | Pt | 0,2486275 | 0,0037586 | 0,002325765 | 0,1428506 | 0,094383432 | 0,00155051 | 0,003758597 |
| Minerals | Pt | 0,47704758 | 0,00790536 | 0,051014578 | 0,2265366 | 0,149675968 | 0,034009719 | 0,007905359 |

Table 4.17 Total impacts of the brick sandwich wall detail

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Brick Sandwich Wall** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weighting |

| Impact category | Unit | A3 | A4 | A5 | A6 | A7 | A8 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 2,63E+00 | 2,69640955 | 2,731385154 | 2,77E+00 | 2,591482722 | 2,638116866 |
| Carcinogens | Pt | 1,87E-01 | 0,18801582 | 0,188406252 | 1,89E-01 | 0,186844515 | 0,187365094 |
| Resp. organics | Pt | 2,58E-03 | 0,0029548 | 0,003143175 | 3,33E-03 | 0,002389654 | 0,002640828 |
| Resp. inorganics | Pt | 5,84E-01 | 0,61272103 | 0,626876702 | 6,41E-01 | 0,570254022 | 0,589128249 |
| Climate change | Pt | 1,10E+00 | 1,13371145 | 1,152367154 | 1,17E+00 | 1,077744359 | 1,102618624 |
| Radiation | Pt | 5,26E-04 | 0,00052591 | 0,000525982 | 5,26E-04 | 0,000525688 | 0,000525786 |
| Ozone layer | Pt | 3,16E-04 | 0,00031823 | 0,000319353 | 3,20E-04 | 0,000314861 | 0,000316358 |
| Ecotoxicity | Pt | 2,26E-03 | 0,00237251 | 0,002428665 | 2,48E-03 | 0,002204054 | 0,002278924 |
| Acidification/ Eutrophication | Pt | 2,36E-02 | 0,02435885 | 0,024735757 | 2,51E-02 | 0,023228144 | 0,023730682 |
| Land use | Pt | 2,49E-01 | 0,24863868 | 0,248640912 | 2,49E-01 | 0,248631971 | 0,248634951 |
| Minerals | Pt | 4,80E-01 | 0,48279227 | 0,483941208 | 4,85E-01 | 0,479345459 | 0,480877375 |

| Impact category | Unit | A9 | A10 | A11 | A12 | A13 | A14 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 2,66143394 | 2,684751 | 3,979684206 | 4,951786006 | 5,437836906 | 5,923887806 |
| Carcinogens | Pt | 0,18762538 | 0,187886 | 0,190416244 | 0,193317977 | 0,194768843 | 0,196219709 |
| Resp. organics | Pt | 0,00276641 | 0,002892 | 0,002733035 | 0,00321313 | 0,003453177 | 0,003693224 |
| Resp. inorganics | Pt | 0,59856536 | 0,608002 | 1,670022333 | 2,422075433 | 2,798101983 | 3,174128533 |
| Climate change | Pt | 1,11505576 | 1,127493 | 1,151069051 | 1,224826443 | 1,261705139 | 1,298583836 |
| Radiation | Pt | 0,00052584 | 0,000526 | 0,000643548 | 0,00072222 | 0,000761555 | 0,000800891 |
| Ozone layer | Pt | 0,00031711 | 0,000318 | 0,000333733 | 0,000347812 | 0,000354851 | 0,00036189 |
| Ecotoxicity | Pt | 0,00231636 | 0,002354 | 0,002425977 | 0,002648796 | 0,002760205 | 0,002871615 |
| Acidification/ Eutrophication | Pt | 0,02398195 | 0,02423322 | 0,027835308 | 0,031409287 | 0,033196277 | 0,034983267 |
| Land use | Pt | 0,24863644 | 0,24863793 | 0,257637308 | 0,263643845 | 0,266647114 | 0,269650383 |
| Minerals | Pt | 0,48164333 | 0,48240929 | 0,67656768 | 0,809581077 | 0,876087776 | 0,942594475 |
| | | 0 | | | | | |

| Impact category | Unit | A15 | A16 | A17 | A18 |
|---|---|---|---|---|---|
| Total | Pt | 2,59117378 | 2,637602 | 2,660816058 | 2,68403 |
| Carcinogens | Pt | 0,18822461 | 0,1896653 | 0,190385579 | 0,191106 |
| Resp. organics | Pt | 0,00215658 | 0,0022524 | 0,002300257 | 0,002348 |
| Resp. inorganics | Pt | 0,56799628 | 0,5853653 | 0,594049868 | 0,602734 |
| Climate change | Pt | 1,05938953 | 1,0720272 | 1,0783461 | 1,084665 |
| Radiation | Pt | 0,00062177 | 0,0006859 | 0,000718 | 0,00075 |
| Ozone layer | Pt | 0,00032456 | 0,0003325 | 0,000336514 | 0,00034 |
| Ecotoxicity | Pt | 0,00216922 | 0,0022209 | 0,002246687 | 0,002273 |
| Acidification/ Eutrophication | Pt | 0,02350331 | 0,0241893 | 0,024532289 | 0,024875 |
| Land use | Pt | 0,24913894 | 0,2494799 | 0,24965037 | 0,249821 |
| Minerals | Pt | 0,49764899 | 0,5113833 | 0,518250394 | 0,525118 |

Table 4.18 Environmental impact categories per product and subassemblies for the detail brick wall exterior thermal insulation- The ingredients of the detail except the insulation- **According to Figure 4.13**

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Brick Wall Exterior Thermal Insulation** |
| Method: Indicator: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I Weighting |

| Impact category | Unit | Total | Alkyd Paint | Plaster 3cm(66kg) | brick, at plant/DE U 98.5 kg | Plaster 2 cm | Alkyd Paint |
|---|---|---|---|---|---|---|---|
| Total | Pt | 2,291747 | 0,03856 | 0,56369 | 1,275144 | 0,375793 | 0,03856 |
| Carcinogens | Pt | 0,158909 | 0,001066 | 0,003653 | 0,15069 | 0,002435 | 0,001066 |
| Resp. organics | Pt | 0,001848 | 4,26E-05 | 0,000508 | 0,000917 | 0,000338 | 4,26E-05 |
| Resp. inorganics | Pt | 0,502544 | 0,016786 | 0,150202 | 0,218636 | 0,100134 | 0,016786 |
| Climate change | Pt | 0,972888 | 0,008615 | 0,348497 | 0,374829 | 0,232331 | 0,008615 |
| Radiation | Pt | 0,000514 | 7,15E-06 | 0,000263 | 6,2E-05 | 0,000175 | 7,15E-06 |
| Ozone layer | Pt | 0,000281 | 5,00E-06 | 5,55E-05 | 0,000178 | 3,7E-05 | 5,00E-06 |
| Ecotoxicity | Pt | 0,001916 | 4,20E-05 | 0,000514 | 0,000976 | 0,000343 | 4,20E-05 |
| Acidification/ Eutrophication | Pt | 0,020839 | 0,000332 | 0,006659 | 0,009076 | 0,004439 | 0,000332 |
| Land use | Pt | 0,212405 | 0,003759 | 0,002326 | 0,201011 | 0,001551 | 0,003759 |
| Minerals | Pt | 0,419604 | 0,007905 | 0,051015 | 0,318769 | 0,03401 | 0,007905 |

Table 4.19 Total impacts of the brick wall with exterior thermal insulation

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Brick Wall With exterior Heat Panel** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weightings |

| Impact category | Unit | B3 | B4 | B5 | B6 | B7 | B8 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 1,59E+00 | 1,28778473 | 1,322760342 | 1,36E+00 | 1,18285791 | 1,229492054 |
| Carcinogens | Pt | 1,55E-01 | 0,11202564 | 0,112416074 | 1,13E-01 | 0,110854336 | 0,111374915 |
| Resp. organics | Pt | 1,68E-03 | 0,00179561 | 0,001983987 | 2,17E-03 | 0,001230465 | 0,001481639 |
| Resp. inorganics | Pt | 3,29E-01 | 0,2942992 | 0,308454874 | 3,23E-01 | 0,251832195 | 0,270706422 |
| Climate change | Pt | 5,28E-01 | 0,45683307 | 0,475488768 | 4,94E-01 | 0,400865974 | 0,425740238 |
| Radiation | Pt | 1,37E-04 | 0,00011929 | 0,000119364 | 1,19E-04 | 0,000119071 | 0,000119169 |
| Ozone layer | Pt | 2,04E-04 | 0,00015496 | 0,000156081 | 1,57E-04 | 0,000151589 | 0,000153086 |
| Ecotoxicity | Pt | 1,35E-03 | 0,00117765 | 0,0012338 | 1,29E-03 | 0,001009188 | 0,001084058 |
| Acidification/ Eutrophication | Pt | 1,24E-02 | 0,01052851 | 0,010905413 | 1,13E-02 | 0,0093978 | 0,009900338 |
| Land use | Pt | 2,09E-01 | 0,1509909 | 0,150993132 | 1,51E-01 | 0,150984191 | 0,150987172 |
| Minerals | Pt | 3,50E-01 | 0,25985992 | 0,261008853 | 2,62E-01 | 0,256413103 | 0,25794502 |

| Impact category | Unit | B9 | B10 | B11 | B12 | B13 | B14 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 1,25280913 | 1,2761262 | 2,571059394 | 3,543161194 | 4,029212094 | 5,329795231 |
| Carcinogens | Pt | 0,11163521 | 0,11189549 | 0,114426066 | 0,117327798 | 0,118778664 | 0,125507628 |
| Resp. organics | Pt | 0,00160723 | 0,00173281 | 0,001573847 | 0,002053941 | 0,002293988 | 0,003267447 |
| Resp. inorganics | Pt | 0,28014353 | 0,28958065 | 1,351600506 | 2,103653606 | 2,479680156 | 3,072747948 |
| Climate change | Pt | 0,43817737 | 0,4506145 | 0,474190665 | 0,547948058 | 0,584826754 | 1,12528317 |
| Radiation | Pt | 0,00011922 | 0,00011927 | 0,000236931 | 0,000315602 | 0,000354938 | 0,000774062 |
| Ozone layer | Pt | 0,00015383 | 0,00015458 | 0,000170461 | 0,00018454 | 0,000191579 | 0,000278765 |
| Ecotoxicity | Pt | 0,00112149 | 0,00115893 | 0,001231111 | 0,00145393 | 0,001565339 | 0,00241924 |
| Acidification/ Eutrophication | Pt | 0,01015161 | 0,01040288 | 0,014004963 | 0,017578943 | 0,019365933 | 0,030775467 |
| Land use | Pt | 0,15098866 | 0,15099015 | 0,159989528 | 0,165996066 | 0,168999334 | 0,175363333 |
| Minerals | Pt | 0,25871098 | 0,25947694 | 0,453635325 | 0,586648722 | 0,653155421 | 0,793378185 |

| Impact category | Unit | B15 | B16 | B17 | B18 | B1 |
|---|---|---|---|---|---|---|
| Total | Pt | 1,18285791 | 1,22949205 | 1,252809126 | 1,276126198 | 2,291747 |
| Carcinogens | Pt | 0,11085434 | 0,11137492 | 0,111635205 | 0,111895495 | 0,158909 |
| Resp. organics | Pt | 0,00123047 | 0,00148164 | 0,001607226 | 0,001732813 | 0,001848 |
| Resp. inorganics | Pt | 0,2518322 | 0,27070642 | 0,280143535 | 0,289580648 | 0,502544 |
| Climate change | Pt | 0,40086597 | 0,42574024 | 0,438177371 | 0,450614503 | 0,972888 |
| Radiation | Pt | 0,00011907 | 0,00011917 | 0,000119217 | 0,000119266 | 0,000514 |
| Ozone layer | Pt | 0,00015159 | 0,00015309 | 0,000153835 | 0,000154584 | 0,000281 |
| Ecotoxicity | Pt | 0,00100919 | 0,00108406 | 0,001121494 | 0,001158929 | 0,001916 |
| Acidification/ Eutrophication | Pt | 0,0093978 | 0,00990034 | 0,010151607 | 0,010402875 | 0,020839 |
| Land use | Pt | 0,15098419 | 0,15098717 | 0,150988662 | 0,150990152 | 0,212405 |
| Minerals | Pt | 0,2564131 | 0,25794502 | 0,258710978 | 0,259476936 | 0,419604 |

Table 4.20 Environmental impact categories per product and subassemblies for the detail autoclaved aerated concrete block- The ingredients of the detail except the insulation- **According to Figure 4.13**

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Autoclaved Aerated Concrete Block, At Plant/Ch U** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weightings |

| Impact category | Unit | TOTAL | Alkyd Paint | Plaster 1cm(22kg) |
|---|---|---|---|---|
| Total | Pt | 2,06134 | 0,03856 | 0,187897 |
| Carcinogens | Pt | 0,02349 | 0,001066 | 0,001218 |
| Resp. organics | Pt | 0,00179 | 4,26E-05 | 0,000169 |
| Resp. inorganics | Pt | 0,60813 | 0,016786 | 0,050067 |
| Climate change | Pt | 1,02578 | 0,008615 | 0,116166 |
| Radiation | Pt | 0,00062 | 7,15E-06 | 8,76E-05 |
| Ozone layer | Pt | 0,00022 | 5,00E-06 | 1,85E-05 |
| Ecotoxicity | Pt | 0,00142 | 4,20E-05 | 0,000171 |
| Acidification/ Eutrophication | Pt | 0,01827 | 0,000332 | 0,00222 |
| Land use | Pt | 0,01973 | 0,003759 | 0,000775 |
| Minerals | Pt | 0,3619 | 0,007905 | 0,017005 |

| Impact category | Unit | Autoclaved aerated concrete block, at plant/CH U 20 cm 80 kg | Plaster 1cm(22kg) | Alkyd Paint |
|---|---|---|---|---|
| Total | Pt | 1,60843 | 0,187897 | 0,03856 |
| Carcinogens | Pt | 0,01892 | 0,001218 | 0,001066 |
| Resp. organics | Pt | 0,00137 | 0,000169 | 4,26E-05 |
| Resp. inorganics | Pt | 0,47442 | 0,050067 | 0,016786 |
| Climate change | Pt | 0,77622 | 0,116166 | 0,008615 |
| Radiation | Pt | 0,00043 | 8,76E-05 | 7,15E-06 |
| Ozone layer | Pt | 0,00018 | 1,85E-05 | 5,00E-06 |
| Ecotoxicity | Pt | 0,00099 | 0,000171 | 4,20E-05 |
| Acidification/ Eutrophication | Pt | 0,01317 | 0,00222 | 0,000332 |
| Land use | Pt | 0,01066 | 0,000775 | 0,003759 |
| Minerals | Pt | 0,31208 | 0,017005 | 0,007905 |

Table 4.21 Total impacts of the autoclaved aerated concrete block detail

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Autoclaved Aerated Concrete Block, At Plant/Ch U** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weightings |

| Impact category | Unit | C1 | C2 |
|---|---|---|---|
| Total | Pt | 2,0613384 | 2,46344478 |
| Carcinogens | Pt | 0,02348733 | 0,02821759 |
| Resp. organics | Pt | 0,00179064 | 0,0021324 |
| Resp. inorganics | Pt | 0,60812943 | 0,72673511 |
| Climate change | Pt | 1,02577935 | 1,21983371 |
| Radiation | Pt | 0,00061579 | 0,00072236 |
| Ozone layer | Pt | 0,00022313 | 0,00026717 |
| Ecotoxicity | Pt | 0,00141651 | 0,001664 |
| Acidification/ Eutrophication | Pt | 0,01827226 | 0,02156453 |
| Land use | Pt | 0,01972794 | 0,022393 |
| Minerals | Pt | 0,36189598 | 0,43991486 |

Table 4.22 Total impacts of the pumice block detail

| Impact category | Unit | D1 | D2 |
|---|---|---|---|
| Total | Pt | 0,91067745 | 1,02511859 |
| Carcinogens | Pt | 0,00840488 | 0,00936453 |
| Resp. organics | Pt | 0,00071584 | 0,00078889 |
| Resp. inorganics | Pt | 0,30382743 | 0,34635761 |
| Climate change | Pt | 0,40159391 | 0,43960191 |
| Radiation | Pt | 0,00026316 | 0,00028157 |
| Ozone layer | Pt | 7,3148E-05 | 7,9688E-05 |
| Ecotoxicity | Pt | 0,00079043 | 0,00088141 |
| Acidification/ Eutrophication | Pt | 0,00891064 | 0,0098625 |
| Land use | Pt | 0,02966922 | 0,0348196 |
| Minerals | Pt | 0,15642881 | 0,1830809 |

Table 4.23 Environmental impact categories per product and subassemblies for the detail pumice block- The ingredients of the detail except the insulation- **According to Figure 4.13**

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Pumice Block** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weightings |

| Impact category | Unit | TOTAL | Alkyd Paint | Plaster 1cm(22kg) |
|---|---|---|---|---|
| Total | Pt | 0,91067745 | 0,03856 | 0,187897 |
| Carcinogens | Pt | 0,00840488 | 0,001066 | 0,001218 |
| Resp. organics | Pt | 0,00071584 | 4,26E-05 | 0,000169 |
| Resp. inorganics | Pt | 0,30382743 | 0,016786 | 0,050067 |
| Climate change | Pt | 0,40159391 | 0,008615 | 0,116166 |
| Radiation | Pt | 0,00026316 | 7,15E-06 | 8,76E-05 |
| Ozone layer | Pt | 7,3148E-05 | 5,00E-06 | 1,85E-05 |
| Ecotoxicity | Pt | 0,00079043 | 4,20E-05 | 0,000171 |
| Acidification/ Eutrophication | Pt | 0,00891064 | 0,000332 | 0,00222 |
| Land use | Pt | 0,02966922 | 0,003759 | 0,000775 |
| Minerals | Pt | 0,15642881 | 0,007905 | 0,017005 |

| Impact category | Unit | Lightweight concrete block, pumice, at plant/DE U 20 cm (30 kg) | Plaster 1cm(22kg) | Alkyd Paint |
|---|---|---|---|---|
| Total | Pt | 0,45776455 | 0,187897 | 0,03856 |
| Carcinogens | Pt | 0,00383861 | 0,001218 | 0,001066 |
| Resp. organics | Pt | 0,0002922 | 0,000169 | 4,26E-05 |
| Resp. inorganics | Pt | 0,17012073 | 0,050067 | 0,016786 |
| Climate change | Pt | 0,152032 | 0,116166 | 0,008615 |
| Radiation | Pt | 7,36E-05 | 8,76E-05 | 7,15E-06 |
| Ozone layer | Pt | 2,62E-05 | 1,85E-05 | 5,00E-06 |
| Ecotoxicity | Pt | 0,00036389 | 0,000171 | 4,20E-05 |
| Acidification/ Eutrophication | Pt | 0,00380743 | 0,00222 | 0,000332 |
| Land use | Pt | 0,02060152 | 0,000775 | 0,003759 |
| Minerals | Pt | 0,10660837 | 0,017005 | 0,007905 |

Table 4.24 Environmental impact categories per product and subassemblies for ground foundation ceramic on top- The ingredients of the detail except the insulation- **According to Figure 4.11**

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Ground Foundation( Ceramic On Top)** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weighting |

| Impact category | Unit | TOTAL | Ceramic Tile(12 kg) | Cement Based Ceramic Adhesive Mortar(2kg) | Plaster(66kg) | Polymeric Modified Bituminous Water proofing 0,8kg | Plaster for Coating Slab (220 kg) |
|---|---|---|---|---|---|---|---|
| Total | Pt | 9,898591 | 7,3675274 | 0,0154747 | 0,5636901 | 0,072932 | 1,878967 |
| Carcinogens | Pt | 0,069468 | 0,0518708 | 0,0001445 | 0,0036527 | 0,001624 | 0,012176 |
| Resp. organics | Pt | 0,002974 | 0,0005177 | 1,53E-05 | 0,0005076 | 0,000242 | 0,001692 |
| Resp. inorganics | Pt | 7,261046 | 6,576756 | 0,0042609 | 0,1502016 | 0,029156 | 0,500672 |
| Climate change | Pt | 1,755119 | 0,2204929 | 0,0089925 | 0,3484967 | 0,015481 | 1,161656 |
| Radiation | Pt | 0,00141 | 0,0002407 | 7,64E-06 | 0,0002628 | 2,25E-05 | 0,000876 |
| Ozone layer | Pt | 0,000368 | 0,0001003 | 1,63E-06 | 5,546E-05 | 2,53E-05 | 1,85E-04 |
| Ecotoxicity | Pt | 0,006155 | 0,0038098 | 1,90E-05 | 0,0005138 | 9,98E-05 | 0,001713 |
| Acidification/ Eutrophication | Pt | 0,03514 | 0,0055482 | 0,0001798 | 0,0066592 | 0,000555 | 0,022197 |
| Land use | Pt | 0,024917 | 0,0135458 | 0,0003213 | 0,0023258 | 0,000972 | 0,007753 |
| Minerals | Pt | 0,741994 | 0,4946451 | 0,0015323 | 0,0510146 | 0,024753 | 0,170049 |

Table 4.25 Environmental impact categories per product and subassemblies for ground foundation laminated flooring on top

| Impact category | Unit | TOTAL | Laminated flooring (7,7kg) | Foam underlayment (0,09kg) | Plaster (66kg) | Polymeric Modified Bituminous Waterproofing 0,8kg | Plaster for Coating Slab (220 kg) |
|---|---|---|---|---|---|---|---|
| Total | Pt | 3,178625752 | 0,65143 | 0,011607046 | 0,56369013 | 0,07293196 | 1,8789671 |
| Carcinogens | Pt | 0,026735649 | 0,008923 | 0,000360161 | 0,003652663 | 0,00162439 | 0,01217554 |
| Resp. organics | Pt | 0,004139337 | 0,001674 | 2,3947E-05 | 0,000507551 | 0,00024198 | 0,00169184 |
| Resp. inorganics | Pt | 0,864380283 | 0,180009 | 0,004342265 | 0,150201552 | 0,02915613 | 0,50067184 |
| Climate change | Pt | 1,601219656 | 0,072426 | 0,003159428 | 0,348496692 | 0,01548145 | 1,16165564 |
| Radiation | Pt | 0,001324677 | 0,000147 | 1,60382E-05 | 0,00026283 | 2,25E-05 | 0,0008761 |
| Ozone layer | Pt | 0,000292879 | 2,53E-05 | 1,99E-06 | 5,54648E-05 | 2,53E-05 | 1,85E-04 |
| Ecotoxicity | Pt | 0,0028181 | 0,000479 | 1,29116E-05 | 0,000513834 | 9,98E-05 | 0,00171278 |
| Acidification/ Eutrophication | Pt | 0,034022607 | 0,004439 | 0,000171496 | 0,0066592 | 0,00055514 | 0,02219733 |
| Land use | Pt | 0,346704369 | 0,335569 | 8,5239E-05 | 0,002325765 | 0,00097181 | 0,00775255 |
| Minerals | Pt | 0,296988198 | 0,047738 | 0,003433568 | 0,051014578 | 0,02475348 | 0,17004859 |

Table 4.26 Total impacts of the ground foundation ceramic on top detail

Calculation: Analyze
Results: Impact assessment
Product: **Ground Foundation( Ceramic On Top)**
Method: Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I
Indicator: Weighting

| Impact category | Unit | A1 | A2 | A3 | A4 | A5 | A6 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 9,898591 | 9,4749859 | 9,544937 | 9,57991 | 9,6149 | 9,44001 |
| Carcinogens | Pt | 0,069468 | 0,0687218 | 0,069503 | 0,06989 | 0,0703 | 0,06833 |
| Resp. organics | Pt | 0,002974 | 0,0030898 | 0,003467 | 0,00365 | 0,0038 | 0,0029 |
| Resp. inorganics | Pt | 7,261046 | 7,1653212 | 7,193633 | 7,20779 | 7,2219 | 7,15117 |
| Climate change | Pt | 1,755119 | 1,4744036 | 1,511715 | 1,53037 | 1,549 | 1,45575 |
| Radiation | Pt | 0,00141 | 0,0011567 | 0,001157 | 0,00116 | 0,0012 | 0,00116 |
| Ozone layer | Pt | 0,000368 | 0,0003214 | 0,000324 | 0,00032 | 0,0003 | 0,00032 |
| Ecotoxicity | Pt | 0,006155 | 0,0059053 | 0,006018 | 0,00607 | 0,0061 | 0,00585 |
| Acidification/ Eutrophication | Pt | 0,03514 | 0,0298944 | 0,030648 | 0,03103 | 0,0314 | 0,02952 |
| Land use | Pt | 0,024917 | 0,0227137 | 0,022718 | 0,02272 | 0,0227 | 0,02271 |
| Minerals | Pt | 0,741994 | 0,7034581 | 0,705756 | 0,7069 | 0,7081 | 0,70231 |

| Impact category | Unit | A7 | A8 | A9 | A10 | A11 | A12 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 9,486644 | 9,5099615 | 9,533279 | 10,8282 | 11,8 | 12,2864 |
| Carcinogens | Pt | 0,068852 | 0,0691123 | 0,069373 | 0,0719 | 0,0748 | 0,07626 |
| Resp. organics | Pt | 0,003153 | 0,0032782 | 0,003404 | 0,00324 | 0,0037 | 0,00396 |
| Resp. inorganics | Pt | 7,17004 | 7,1794769 | 7,188914 | 8,25093 | 9,003 | 9,37901 |
| Climate change | Pt | 1,480622 | 1,4930592 | 1,505496 | 1,52907 | 1,6028 | 1,63971 |
| Radiation | Pt | 0,001157 | 0,0011568 | 0,001157 | 0,00127 | 0,0014 | 0,00139 |
| Ozone layer | Pt | 0,000322 | 0,0003225 | 0,000323 | 0,00034 | 0,0004 | 0,00036 |
| Ecotoxicity | Pt | 0,005924 | 0,0059614 | 0,005999 | 0,00607 | 0,0063 | 0,00641 |
| Acidification/ Eutrophication | Pt | 0,03002 | 0,0302713 | 0,030523 | 0,03412 | 0,0377 | 0,03949 |
| Land use | Pt | 0,022714 | 0,0227159 | 0,022717 | 0,03172 | 0,0377 | 0,04073 |
| Minerals | Pt | 0,703841 | 0,704607 | 0,705373 | 0,89953 | 1,0325 | 1,09905 |

| Impact category | Unit | A13 | A14 | A15 | A16 | A17 |
|---|---|---|---|---|---|---|
| Total | Pt | 12,77242 | 9,4397014 | 9,48613 | 9,50934 | 9,5326 |
| Carcinogens | Pt | 0,077707 | 0,0697115 | 0,071152 | 0,07187 | 0,0726 |
| Resp. organics | Pt | 0,004205 | 0,0026684 | 0,002764 | 0,00281 | 0,0029 |
| Resp. inorganics | Pt | 9,75504 | 7,1489078 | 7,166277 | 7,17496 | 7,1836 |
| Climate change | Pt | 1,676587 | 1,437393 | 1,450031 | 1,45635 | 1,4627 |
| Radiation | Pt | 0,001432 | 0,0012527 | 0,001317 | 0,00135 | 0,0014 |
| Ozone layer | Pt | 0,000367 | 0,0003299 | 0,000338 | 0,00034 | 0,0003 |
| Ecotoxicity | Pt | 0,006517 | 0,0058143 | 0,005866 | 0,00589 | 0,0059 |
| Acidification/ Eutrophication | Pt | 0,041273 | 0,0297927 | 0,030479 | 0,03082 | 0,0312 |
| Land use | Pt | 0,04373 | 0,0232184 | 0,023559 | 0,02373 | 0,0239 |
| Minerals | Pt | 1,165558 | 0,7206127 | 0,734347 | 0,74121 | 0,7481 |

Table 4.27 Total impacts of the ground foundation laminated flooring on top detail- **According to Figure 4.11**

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Ground Foundation( Laminated Flooring On Top)** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weighting |

| Impact category | Unit | B1 | B2 | B3 | B4 | B5 | B6 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 3,178625752 | 2,75502 | 2,824971619 | 2,85994723 | 2,89492284 | 2,7200448 |
| Carcinogens | Pt | 0,026735649 | 0,02599 | 0,026770461 | 0,0271609 | 0,02755133 | 0,02559916 |
| Resp. organics | Pt | 0,004139337 | 0,004255 | 0,004631576 | 0,00481996 | 0,00500834 | 0,00406643 |
| Resp. inorganics | Pt | 0,864380283 | 0,768655 | 0,796966411 | 0,81112208 | 0,82527775 | 0,7544994 |
| Climate change | Pt | 1,601219656 | 1,320504 | 1,357815516 | 1,37647121 | 1,39512691 | 1,30184842 |
| Radiation | Pt | 0,001324677 | 0,001072 | 0,001071677 | 0,00107175 | 0,00107182 | 0,00107146 |
| Ozone layer | Pt | 0,000292879 | 0,000247 | 0,000248932 | 0,00025006 | 0,00025118 | 0,00024556 |
| Ecotoxicity | Pt | 0,0028181 | 0,002568 | 0,00268045 | 0,0027366 | 0,00279276 | 0,00251199 |
| Acidification/ Eutrophication | Pt | 0,034022607 | 0,028777 | 0,029531172 | 0,02990808 | 0,03028498 | 0,02840046 |
| Land use | Pt | 0,346704369 | 0,344501 | 0,344505294 | 0,34450753 | 0,34450976 | 0,34449859 |
| Minerals | Pt | 0,296988198 | 0,258452 | 0,260750134 | 0,26189907 | 0,26304801 | 0,25730332 |

| Impact category | Unit | B7 | B8 | B9 | B10 | B11 | B12 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 2,766678939 | 2,789996 | 2,813313083 | 4,10824628 | 5,08034808 | 5,56639898 |
| Carcinogens | Pt | 0,026119737 | 0,02638 | 0,026640316 | 0,02917089 | 0,03207262 | 0,03352349 |
| Resp. organics | Pt | 0,004317609 | 0,004443 | 0,004568783 | 0,00440982 | 0,00488991 | 0,00512996 |
| Resp. inorganics | Pt | 0,773373628 | 0,782811 | 0,792247855 | 1,85426771 | 2,60632081 | 2,98234736 |
| Climate change | Pt | 1,326722685 | 1,33916 | 1,35159695 | 1,37517311 | 1,4489305 | 1,4858092 |
| Radiation | Pt | 0,001071555 | 0,001072 | 0,001071652 | 0,00118932 | 0,00126799 | 0,00130732 |
| Ozone layer | Pt | 0,000247061 | 0,000248 | 0,000248558 | 0,00026444 | 0,00027851 | 0,00028555 |
| Ecotoxicity | Pt | 0,002586862 | 0,002624 | 0,002661732 | 0,00273391 | 0,00295673 | 0,00306814 |
| Acidification/ Eutrophication | Pt | 0,028903 | 0,029154 | 0,029405538 | 0,03300763 | 0,03658161 | 0,0383686 |
| Land use | Pt | 0,344501569 | 0,344503 | 0,344504549 | 0,35350393 | 0,35951046 | 0,36251373 |
| Minerals | Pt | 0,258835238 | 0,259601 | 0,260367155 | 0,45452554 | 0,58753894 | 0,65404564 |

| Impact category | Unit | B13 | B14 | B15 | B16 | B17 |
|---|---|---|---|---|---|---|
| Total | Pt | 6,052449879 | 2,719736 | 2,766164039 | 2,78937813 | 2,81259222 |
| Carcinogens | Pt | 0,034974352 | 0,026979 | 0,0284199 | 0,02914022 | 0,02986054 |
| Resp. organics | Pt | 0,005370005 | 0,003833 | 0,003929144 | 0,00397704 | 0,00402493 |
| Resp. inorganics | Pt | 3,358373912 | 0,752242 | 0,769610716 | 0,77829525 | 0,78697978 |
| Climate change | Pt | 1,522687897 | 1,283494 | 1,296131305 | 1,30245016 | 1,30876902 |
| Radiation | Pt | 0,001346659 | 0,001168 | 0,001231692 | 0,00126377 | 0,00129584 |
| Ozone layer | Pt | 0,000292593 | 0,000255 | 0,000263233 | 0,00026722 | 0,0002712 |
| Ecotoxicity | Pt | 0,003179552 | 0,002477 | 0,002528801 | 0,00255462 | 0,00258045 |
| Acidification/ Eutrophication | Pt | 0,040155585 | 0,028676 | 0,029361615 | 0,02970461 | 0,0300476 |
| Land use | Pt | 0,365517001 | 0,345006 | 0,345346509 | 0,34551699 | 0,34568747 |
| Minerals | Pt | 0,720552338 | 0,275607 | 0,289341122 | 0,29620826 | 0,30307539 |

Table 4.28 Environmental impact categories per product and subassemblies for ground foundation solid parquet on top- The ingredients of the detail except the insulation- **According to Figure 4.11**

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Ground Foundation( Solid Parquet On Top)** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weighting |

| Impact category | Unit | Total | Solid Parquet (9kg) | Adhesive (1kg) | Plaster ( 66 kg) | Polymeric Modified Bituminous Waterproofing 0,8kg |
|---|---|---|---|---|---|---|
| Total | Pt | 3,438461386 | 0,76141113 | 0,16146107 | 0,56369013 | 0,072931956 |
| Carcinogens | Pt | 0,032007014 | 0,01042935 | 0,004125064 | 0,003652663 | 0,001624394 |
| Resp. organics | Pt | 0,004951291 | 0,001956654 | 0,000553273 | 0,000507551 | 0,000241975 |
| Resp. inorganics | Pt | 0,940746378 | 0,21039954 | 0,05031732 | 0,150201552 | 0,029156126 |
| Climate change | Pt | 1,658397045 | 0,084654286 | 0,048108976 | 0,348496692 | 0,015481451 |
| Radiation | Pt | 0,001397058 | 0,000172033 | 6,36E-05 | 0,00026283 | 2,25E-05 |
| Ozone layer | Pt | 0,00031679 | 2,95E-05 | 2,16E-05 | 5,54648E-05 | 2,53E-05 |
| Ecotoxicity | Pt | 0,003071255 | 0,000559624 | 0,000185232 | 0,000513834 | 9,98E-05 |
| Acidification/ Eutrophication | Pt | 0,035716738 | 0,005188953 | 0,001116111 | 0,0066592 | 0,000555139 |
| Land use | Pt | 0,404308086 | 0,39222352 | 0,001034446 | 0,002325765 | 0,000971806 |
| Minerals | Pt | 0,357549737 | 0,055797638 | 0,055935446 | 0,051014578 | 0,024753481 |

Table 4.29 Total impacts of the ground foundation solid parquet on top detail

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Ground Foundation( Solid Parquet On Top)** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weighting |

| Impact category | Unit | C1 | C2 | C3 | C4 | C5 | C6 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 3,4384614 | 3,01485604 | 3,084807253 | 3,11978286 | 3,154758469 | 2,97988043 |
| Carcinogens | Pt | 0,032007 | 0,03126096 | 0,032041826 | 0,03243226 | 0,032822694 | 0,03087052 |
| Resp. organics | Pt | 0,0049513 | 0,00506677 | 0,00544353 | 0,00563191 | 0,00582029 | 0,00487839 |
| Resp. inorganics | Pt | 0,9407464 | 0,84502117 | 0,873332506 | 0,88748818 | 0,901643846 | 0,8308655 |
| Climate change | Pt | 1,658397 | 1,37768151 | 1,414992905 | 1,4336486 | 1,452304302 | 1,35902581 |
| Radiation | Pt | 0,0013971 | 0,00114391 | 0,001144057 | 0,00114413 | 0,001144204 | 0,00114384 |
| Ozone layer | Pt | 0,0003168 | 0,0002706 | 0,000272843 | 0,00027397 | 0,000275089 | 0,00026947 |
| Ecotoxicity | Pt | 0,0030713 | 0,0028213 | 0,002933606 | 0,00298976 | 0,003045911 | 0,00276515 |
| Acidification/ Eutrophication | Pt | 0,0357167 | 0,0304715 | 0,031225302 | 0,03160221 | 0,031979109 | 0,03009459 |
| Land use | Pt | 0,4043081 | 0,40210454 | 0,402109011 | 0,40211125 | 0,402113481 | 0,40210231 |
| Minerals | Pt | 0,3575497 | 0,3190138 | 0,321311674 | 0,32246061 | 0,323609548 | 0,31786486 |

| Impact category | Unit | C7 | C8 | C9 | C10 | C11 | C12 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 3,0265146 | 3,04983165 | 3,073148717 | 4,36808191 | 5,340183713 | 5,82623461 |
| Carcinogens | Pt | 0,0313911 | 0,03165139 | 0,031911681 | 0,03444225 | 0,037343984 | 0,03879485 |
| Resp. organics | Pt | 0,0051296 | 0,00525515 | 0,005380736 | 0,00522177 | 0,005701864 | 0,00594191 |
| Resp. inorganics | Pt | 0,8497397 | 0,85917684 | 0,868613949 | 1,93063381 | 2,682686907 | 3,05871346 |
| Climate change | Pt | 1,3839001 | 1,39633721 | 1,408774339 | 1,4323505 | 1,506107893 | 1,54298659 |
| Radiation | Pt | 0,0011439 | 0,00114398 | 0,001144033 | 0,0012617 | 0,001340368 | 0,0013797 |
| Ozone layer | Pt | 0,000271 | 0,00027172 | 0,000272469 | 0,00028835 | 0,000302425 | 0,00030946 |
| Ecotoxicity | Pt | 0,00284 | 0,00287745 | 0,002914888 | 0,00298707 | 0,003209889 | 0,0033213 |
| Acidification/ Eutrophication | Pt | 0,0305971 | 0,0308484 | 0,031099668 | 0,03470176 | 0,038275736 | 0,04006273 |
| Land use | Pt | 0,4021053 | 0,40210678 | 0,402108266 | 0,41110764 | 0,417114179 | 0,42011745 |
| Minerals | Pt | 0,3193968 | 0,32016274 | 0,320928694 | 0,51508708 | 0,64810048 | 0,71460718 |

| Impact category | Unit | C13 | C14 | C15 | C16 | C17 |
|---|---|---|---|---|---|---|
| Total | Pt | 6,3122855 | 2,97957149 | 3,025999673 | 3,04921377 | 3,072427857 |
| Carcinogens | Pt | 0,0402457 | 0,03225062 | 0,033691265 | 0,03441159 | 0,035131909 |
| Resp. organics | Pt | 0,006182 | 0,00464531 | 0,004741098 | 0,00478899 | 0,004836886 |
| Resp. inorganics | Pt | 3,43474 | 0,82860775 | 0,845976811 | 0,85466134 | 0,863345873 |
| Climate change | Pt | 1,5798653 | 1,34067098 | 1,353308694 | 1,35962755 | 1,365946407 |
| Radiation | Pt | 0,001419 | 0,00123992 | 0,001304072 | 0,00133615 | 0,001368225 |
| Ozone layer | Pt | 0,0003165 | 0,00027918 | 0,000287144 | 0,00029113 | 0,000295111 |
| Ecotoxicity | Pt | 0,0034327 | 0,00273031 | 0,002781957 | 0,00280778 | 0,002833603 |
| Acidification/ Eutrophication | Pt | 0,0418497 | 0,03036976 | 0,031055745 | 0,03139874 | 0,031741729 |
| Land use | Pt | 0,4231207 | 0,40260927 | 0,402950226 | 0,4031207 | 0,403291182 |
| Minerals | Pt | 0,7811139 | 0,33616839 | 0,349902661 | 0,3567698 | 0,363636931 |

Table 4.30 Environmental impact categories per product and subassemblies for basement foundation ceramic on top- The ingredients of the detail except the insulation- **According to Figure 4.11**

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Basement Foundations (Ceramic On Top)** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weighting |

| Impact category | Unit | Total | Ceramic Tile | Cement Based Ceramic Adhesive Mortar | Plaster for Coating Slab (110 kg) | Concrete Slab (1699 kg) |
|---|---|---|---|---|---|---|
| Total | Pt | 45,462258 | 7,3675274 | 0,015474697 | 0,93948352 | 14,932957 |
| Carcinogens | Pt | 1,0010289 | 0,051870817 | 0,000144477 | 0,006087772 | 0,15215623 |
| Resp. organics | Pt | 0,019734059 | 0,000517713 | 1,53E-05 | 0,000845919 | 0,00909356 |
| Resp. inorganics | Pt | 19,79194 | 6,576756 | 0,004260914 | 0,25033592 | 3,6451915 |
| Climate change | Pt | 8,770937 | 0,22049285 | 0,008992455 | 0,58082782 | 4,8577506 |
| Radiation | Pt | 0,005233788 | 0,000240735 | 7,64E-06 | 0,000438049 | 0,002628079 |
| Ozone layer | Pt | 0,0014719 | 0,000100309 | 1,63E-06 | 9,24E-05 | 0,000748376 |
| Ecotoxicity | Pt | 0,050380828 | 0,003809848 | 1,90E-05 | 0,000856391 | 0,013581058 |
| Acidification/ Eutrophication | Pt | 0,21665539 | 0,005548162 | 0,000179791 | 0,011098667 | 0,1190305 |
| Land use | Pt | 0,2178799 | 0,013545807 | 0,000321274 | 0,003876259 | 0,12910426 |
| Minerals | Pt | 15,386995 | 0,49464512 | 0,00153226 | 0,085024286 | 6,003673 |

| Impact category | Unit | Irons Bars for Reinforced Concrete (58,8 kg) | Protection Concrete Slab | Polymeric Modified Bituminous Waterprfing 1,2kg | Concrete Slab (242kg) |
|---|---|---|---|---|---|
| Total | Pt | 18,906915 | 1,0635008 | 0,10939793 | 2,1270015 |
| Carcinogens | Pt | 0,75582401 | 0,010836318 | 0,002436591 | 0,021672636 |
| Resp. organics | Pt | 0,006955751 | 0,000647628 | 0,000362963 | 0,001295257 |
| Resp. inorganics | Pt | 8,4928481 | 0,25960457 | 0,043734188 | 0,51920915 |
| Climate change | Pt | 2,0417679 | 0,34596105 | 0,023222177 | 0,6919221 |
| Radiation | Pt | 0,00132399 | 0,000187167 | 3,38E-05 | 0,000374335 |
| Ozone layer | Pt | 0,000331338 | 5,33E-05 | 3,79E-05 | 0,000106596 |
| Ecotoxicity | Pt | 0,029063209 | 0,000967221 | 0,000149673 | 0,001934442 |
| Acidification/ Eutrophication | Pt | 0,054534084 | 0,008477158 | 0,000832709 | 0,016954315 |
| Land use | Pt | 0,041990879 | 0,009194571 | 0,001457709 | 0,018389142 |
| Minerals | Pt | 7,4822753 | 0,42757177 | 0,037130221 | 0,85514353 |

Table 4.31 Total impacts of the basement foundation ceramic on top detail

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Basement Foundations (Ceramic On Top)** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weighting |

| Impact category | Unit | D1 | D2 | D3 | D4 | D5 | D6 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 45,462258 | 45,5671847 | 45,637136 | 45,6721115 | 45,707087 | 45,5322091 |
| Carcinogens | Pt | 1,0010289 | 1,00220015 | 1,002981 | 1,00337146 | 1,0037619 | 1,00180972 |
| Resp. organics | Pt | 0,01973406 | 0,0202992 | 0,020676 | 0,02086434 | 0,0210527 | 0,02011082 |
| Resp. inorganics | Pt | 19,79194 | 19,8344074 | 19,862719 | 19,8768744 | 19,89103 | 19,8202517 |
| Climate change | Pt | 8,770937 | 8,82690405 | 8,8642154 | 8,88287114 | 8,9015268 | 8,80824835 |
| Radiation | Pt | 0,00523379 | 0,00523401 | 0,0052342 | 0,00523423 | 0,0052343 | 0,00523394 |
| Ozone layer | Pt | 0,0014719 | 0,00147527 | 0,0014775 | 0,00147864 | 0,0014798 | 0,00147415 |
| Ecotoxicity | Pt | 0,05038083 | 0,05054929 | 0,0506616 | 0,05071775 | 0,0507739 | 0,05049313 |
| Acidification/ Eutrophication | Pt | 0,21665539 | 0,2177861 | 0,2185399 | 0,2189168 | 0,2192937 | 0,21740919 |
| Land use | Pt | 0,2178799 | 0,21788661 | 0,2178911 | 0,21789331 | 0,2178955 | 0,21788437 |
| Minerals | Pt | 15,386995 | 15,3904423 | 15,39274 | 15,3938891 | 15,395038 | 15,3892934 |

| Impact category | Unit | D7 | D8 | D9 | D10 | D11 | D12 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 45,5788432 | 45,6021603 | 45,625477 | 46,9204105 | 47,892512 | 48,3785632 |
| Carcinogens | Pt | 1,0023303 | 1,00259059 | 1,0028509 | 1,00538145 | 1,0082832 | 1,00973405 |
| Resp. organics | Pt | 0,02036199 | 0,02048758 | 0,0206132 | 0,0204542 | 0,0209343 | 0,02117434 |
| Resp. inorganics | Pt | 19,8391259 | 19,848563 | 19,858 | 20,92002 | 21,672073 | 22,0480996 |
| Climate change | Pt | 8,83312261 | 8,84555975 | 8,8579969 | 8,88157304 | 8,9553304 | 8,99220913 |
| Radiation | Pt | 0,00523403 | 0,00523408 | 0,0052341 | 0,0053518 | 0,0054305 | 0,0054698 |
| Ozone layer | Pt | 0,00147564 | 0,00147639 | 0,0014771 | 0,00149302 | 0,0015071 | 0,00151414 |
| Ecotoxicity | Pt | 0,050568 | 0,05060544 | 0,0506429 | 0,05071506 | 0,0509379 | 0,05104929 |
| Acidification/ Eutrophication | Pt | 0,21791173 | 0,218163 | 0,2184143 | 0,22201636 | 0,2255903 | 0,22737732 |
| Land use | Pt | 0,21788735 | 0,21788884 | 0,2178903 | 0,22688971 | 0,2328962 | 0,23589951 |
| Minerals | Pt | 15,3908253 | 15,3915912 | 15,392357 | 15,5865156 | 15,719529 | 15,7860357 |

| Impact category | Unit | D13 | D14 | D15 | D16 | D17 |
|---|---|---|---|---|---|---|
| Total | Pt | 48,8646141 | 45,5319001 | 45,578328 | 45,6015424 | 45,624756 |
| Carcinogens | Pt | 1,01118491 | 1,00318982 | 1,0046305 | 1,00535078 | 1,0060711 |
| Resp. organics | Pt | 0,02141439 | 0,01987774 | 0,0199735 | 0,02002142 | 0,0200693 |
| Resp. inorganics | Pt | 22,4241262 | 19,8179939 | 19,835363 | 19,8440475 | 19,852732 |
| Climate change | Pt | 9,02908783 | 8,78989352 | 8,8025312 | 8,80885009 | 8,8151689 |
| Radiation | Pt | 0,00550914 | 0,00533002 | 0,0053942 | 0,00542625 | 0,0054583 |
| Ozone layer | Pt | 0,00152118 | 0,00148385 | 0,0014918 | 0,0014958 | 0,0014998 |
| Ecotoxicity | Pt | 0,05116069 | 0,0504583 | 0,0505099 | 0,05053577 | 0,0505616 |
| Acidification/ Eutrophication | Pt | 0,22916431 | 0,21768436 | 0,2183703 | 0,21871334 | 0,2190563 |
| Land use | Pt | 0,23890278 | 0,21839134 | 0,2187323 | 0,21890277 | 0,2190732 |
| Minerals | Pt | 15,8525424 | 15,4075969 | 15,421331 | 15,4281983 | 15,435065 |

Table 4.32 Environmental impact categories per product and subassemblies for basement foundation laminated flooring on top- The ingredients of the detail except the insulation- **According to Figure 4.11**

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Basement Foundation ( Laminated Floor On Top)** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weighting |

| Impact category | Unit | TOTAL | Laminated Floorıng | Foam Underlayment | Plaster for Coating Slab (110 kg) | Concrete Slab (1699 kg) |
|---|---|---|---|---|---|---|
| Total | Pt | 38,74229232 | 0,65142952 | 0,011607046 | 0,93948352 | 14,932957 |
| Carcinogens | Pt | 0,958296606 | 0,008922888 | 0,000360161 | 0,006087772 | 0,15215623 |
| Resp. organics | Pt | 0,020899051 | 0,001674026 | 2,3947E-05 | 0,000845919 | 0,00909356 |
| Resp. inorganics | Pt | 13,39527419 | 0,1800085 | 0,004342265 | 0,25033592 | 3,6451915 |
| Climate change | Pt | 8,61703752 | 0,072426445 | 0,003159428 | 0,58082782 | 4,8577506 |
| Radiation | Pt | 0,005148633 | 0,000147184 | 1,60382E-05 | 0,000438049 | 0,002628079 |
| Ozone layer | Pt | 0,001397219 | 2,53E-05 | 1,99E-06 | 9,24E-05 | 0,000748376 |
| Ecotoxicity | Pt | 0,047043695 | 0,00047879 | 1,29116E-05 | 0,000856391 | 0,013581058 |
| Acidification/ Eutrophication | Pt | 0,215538366 | 0,004439438 | 0,000171496 | 0,011098667 | 0,1190305 |
| Land use | Pt | 0,539667069 | 0,33556901 | 8,5239E-05 | 0,003876259 | 0,12910426 |
| Minerals | Pt | 14,94198965 | 0,047737977 | 0,003433568 | 0,085024286 | 6,003673 |

| Impact category | Unit | Irons Bars for Reinforced Concrete (58,8 kg) | Protection Concrete Slab | Polymeric Modified Bituminous Waterprfing 1,2kg | Concrete Slab (242kg) |
|---|---|---|---|---|---|
| Total | Pt | 18,906915 | 1,0635008 | 0,10939793 | 2,1270015 |
| Carcinogens | Pt | 0,75582401 | 0,010836318 | 0,002436591 | 0,021672636 |
| Resp. organics | Pt | 0,006955751 | 0,000647628 | 0,000362963 | 0,001295257 |
| Resp. inorganics | Pt | 8,4928481 | 0,25960457 | 0,043734188 | 0,51920915 |
| Climate change | Pt | 2,0417679 | 0,34596105 | 0,023222177 | 0,6919221 |
| Radiation | Pt | 0,00132399 | 0,000187167 | 3,38E-05 | 0,000374335 |
| Ozone layer | Pt | 0,000331338 | 5,33E-05 | 3,79E-05 | 0,000106596 |
| Ecotoxicity | Pt | 0,029063209 | 0,000967221 | 0,000149673 | 0,001934442 |
| Acidification/ Eutrophication | Pt | 0,054534084 | 0,008477158 | 0,000832709 | 0,016954315 |
| Land use | Pt | 0,041990879 | 0,009194571 | 0,001457709 | 0,018389142 |
| Minerals | Pt | 7,4822753 | 0,42757177 | 0,037130221 | 0,85514353 |

Table 4.33 Total impacts of the basement foundation laminated flooring on top detail

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **Basement Foundation ( Laminated Flooring On Top)** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weighting |

| Impact category | Unit | E1 | E2 | E3 | E4 | E5 | E6 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 38,74229232 | 38,8472191 | 38,91717 | 38,95214596 | 38,9871216 | 38,81224353 |
| Carcinogens | Pt | 0,958296606 | 0,95946791 | 0,9602488 | 0,960639212 | 0,96102965 | 0,959077475 |
| Resp. organics | Pt | 0,020899051 | 0,02146419 | 0,021841 | 0,022029333 | 0,02221771 | 0,021275812 |
| Resp. inorganics | Pt | 13,39527419 | 13,4377412 | 13,466053 | 13,48020821 | 13,4943639 | 13,42358553 |
| Climate change | Pt | 8,61703752 | 8,67300462 | 8,710316 | 8,728971712 | 8,74762741 | 8,654348917 |
| Radiation | Pt | 0,005148633 | 0,00514885 | 0,005149 | 0,005149074 | 0,00514915 | 0,00514878 |
| Ozone layer | Pt | 0,001397219 | 0,00140059 | 0,0014028 | 0,001403957 | 0,00140508 | 0,001399465 |
| Ecotoxicity | Pt | 0,047043695 | 0,04721215 | 0,0473245 | 0,047380612 | 0,04743677 | 0,047156001 |
| Acidification/ Eutrophication | Pt | 0,215538366 | 0,21666908 | 0,2174229 | 0,217799785 | 0,21817669 | 0,216292173 |
| Land use | Pt | 0,539667069 | 0,53967377 | 0,5396782 | 0,539680479 | 0,53968271 | 0,539671539 |
| Minerals | Pt | 14,94198965 | 14,9454365 | 14,947734 | 14,94888328 | 14,9500322 | 14,94428753 |

| Impact category | Unit | E7 | E8 | E9 | E10 | E11 | E12 |
|---|---|---|---|---|---|---|---|
| Total | Pt | 38,85887768 | 38,8821947 | 38,905512 | 40,20044502 | 41,1725468 | 41,65859772 |
| Carcinogens | Pt | 0,959598054 | 0,95985834 | 0,9601186 | 0,962649204 | 0,96555094 | 0,967001803 |
| Resp. organics | Pt | 0,021526986 | 0,02165257 | 0,0217782 | 0,021619193 | 0,02209929 | 0,022339335 |
| Resp. inorganics | Pt | 13,44245976 | 13,4518969 | 13,461334 | 14,52335384 | 15,2754069 | 15,65143349 |
| Climate change | Pt | 8,679223182 | 8,69166031 | 8,7040974 | 8,727673609 | 8,801431 | 8,838309698 |
| Radiation | Pt | 0,005148878 | 0,00514893 | 0,005149 | 0,00526664 | 0,00534531 | 0,005384647 |
| Ozone layer | Pt | 0,001400962 | 0,00140171 | 0,0014025 | 0,001418337 | 0,00143242 | 0,001439455 |
| Ecotoxicity | Pt | 0,047230871 | 0,04726831 | 0,0473057 | 0,047377923 | 0,04760074 | 0,047712152 |
| Acidification/ Eutrophication | Pt | 0,21679471 | 0,21704598 | 0,2172972 | 0,220899336 | 0,22447332 | 0,226260305 |
| Land use | Pt | 0,539674519 | 0,53967601 | 0,5396775 | 0,548676875 | 0,55468341 | 0,557686682 |
| Minerals | Pt | 14,94581944 | 14,9465854 | 14,947351 | 15,14150975 | 15,2745231 | 15,34102984 |

| Impact category | Unit | E13 | E14 | E15 | E16 | E17 |
|---|---|---|---|---|---|---|
| Total | Pt | 42,14464862 | 38,8119346 | 38,858363 | 38,88157687 | 38,8119346 |
| Carcinogens | Pt | 0,968452669 | 0,96045757 | 0,9618982 | 0,962618539 | 0,96045757 |
| Resp. organics | Pt | 0,022579382 | 0,02104273 | 0,0211385 | 0,021186415 | 0,02104273 |
| Resp. inorganics | Pt | 16,02746004 | 13,4213278 | 13,438697 | 13,44738138 | 13,4213278 |
| Climate change | Pt | 8,875188394 | 8,63599409 | 8,6486318 | 8,654950659 | 8,63599409 |
| Radiation | Pt | 0,005423982 | 0,00524486 | 0,005309 | 0,005341091 | 0,00524486 |
| Ozone layer | Pt | 0,001446495 | 0,00140917 | 0,0014171 | 0,001421118 | 0,00140917 |
| Ecotoxicity | Pt | 0,047823562 | 0,04712116 | 0,0471728 | 0,047198634 | 0,04712116 |
| Acidification/ Eutrophication | Pt | 0,228047295 | 0,21656734 | 0,2172533 | 0,217596317 | 0,21656734 |
| Land use | Pt | 0,560689951 | 0,5401785 | 0,5405195 | 0,540689937 | 0,5401785 |
| Minerals | Pt | 15,40753654 | 14,9625911 | 14,976325 | 14,98319246 | 14,9625911 |

Table 4.34 Environmental impact categories per product for wooden window frame (According to SimaPro software database)

| | | |
|---|---|---|
| Calculation: | Analyze | |
| Results: | Impact assessment | |
| Product: | **1p Wood window frame (1 m2)** | |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I | |
| Indicator: | Weighting | |
| Impact category | Unit | Window frame, wood, U=1.5 W/m2K, at plant/RER U |
| Total | Pt | 23,97825 |
| Carcinogens | Pt | 0,975971 |
| Resp. organics | Pt | 0,023024 |
| Resp. inorganics | Pt | 7,173578 |
| Climate change | Pt | 3,096996 |
| Radiation | Pt | 0,005157 |
| Ozone layer | Pt | 0,001043 |
| Ecotoxicity | Pt | 0,084814 |
| Acidification/ Eutrophication | Pt | 0,126223 |
| Land use | Pt | 3,377881 |
| Minerals | Pt | 9,113567 |

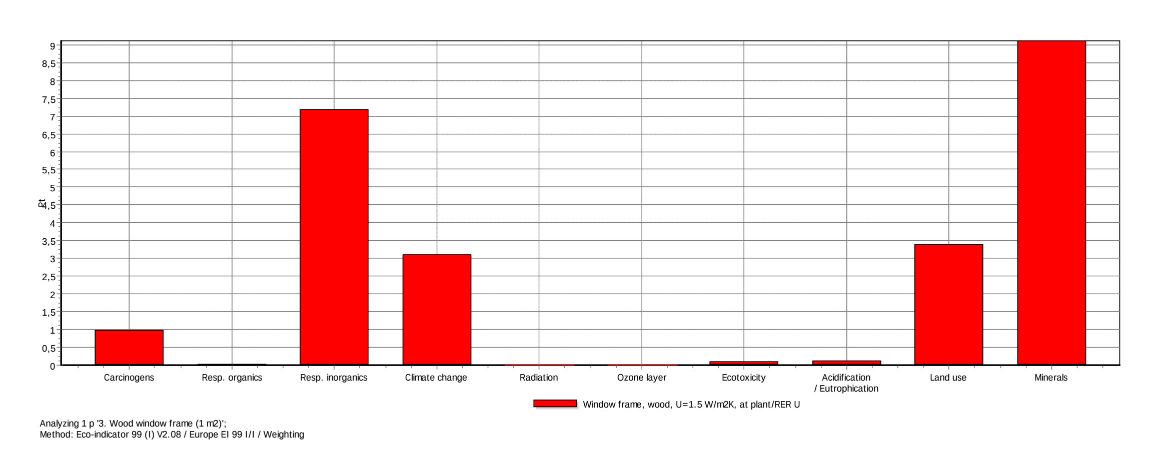



Figure 4.16 Characterisation of wooden window frame

Table 4.35 Environmental impact categories per product for aluminium window frame ( According to SimaPro software database)

| | | |
|---|---|---|
| Calculation: | Analyze | |
| Results: | Impact assessment | |
| Product: | **1 p Aluminium window frame (1 m2)** | |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I | |
| Indicator: | Weighting | |
| | | |
| Impact category | Unit | Window frame, aluminium, U=1.6 W/m2K, at plant/RER U |
| Total | Pt | 96,01602 |
| Carcinogens | Pt | 5,265319 |
| Resp. organics | Pt | 0,025401 |
| Resp. inorganics | Pt | 24,08342 |
| Climate change | Pt | 11,44698 |
| Radiation | Pt | 0,011979 |
| Ozone layer | Pt | 0,003368 |
| Ecotoxicity | Pt | 0,077639 |
| Acidification/ Eutrophication | Pt | 0,276814 |
| Land use | Pt | 0,244217 |
| Minerals | Pt | 54,58088 |

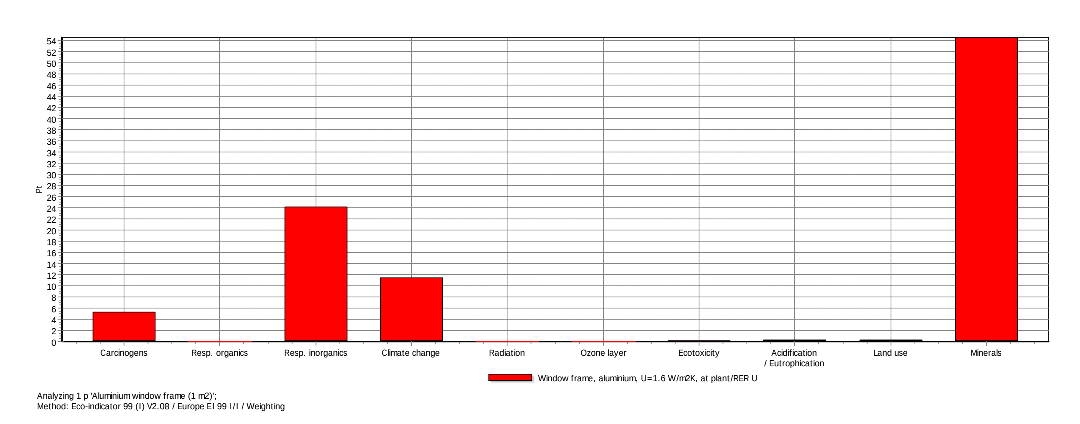



Figure 4.17 Characterisation of aluminium window frame

Table 4.36 Environmental impact categories per product for PVC window frame ( According to SimaPro software database)

| | |
|---|---|
| Calculation: | Analyze |
| Results: | Impact assessment |
| Product: | **1 p PVC Window frame (1 m2)** |
| Method: | Eco-indicator 99 (I) V2.08 / Europe EI 99 I/I |
| Indicator: | Weighting |

| Impact category | Unit | Window frame, plastic (PVC), U=1.6 W/m2K, at plant/RER U |
|---|---|---|
| Total | Pt | 46,56107 |
| Carcinogens | Pt | 1,194129 |
| Resp. organics | Pt | 0,056237 |
| Resp. inorganics | Pt | 13,86737 |
| Climate change | Pt | 5,788706 |
| Radiation | Pt | 0,003684 |
| Ozone layer | Pt | 0,00107 |
| Ecotoxicity | Pt | 0,201951 |
| Acidification/ Eutrophication | Pt | 0,334088 |
| Land use | Pt | 0,197956 |
| Minerals | Pt | 24,91588 |

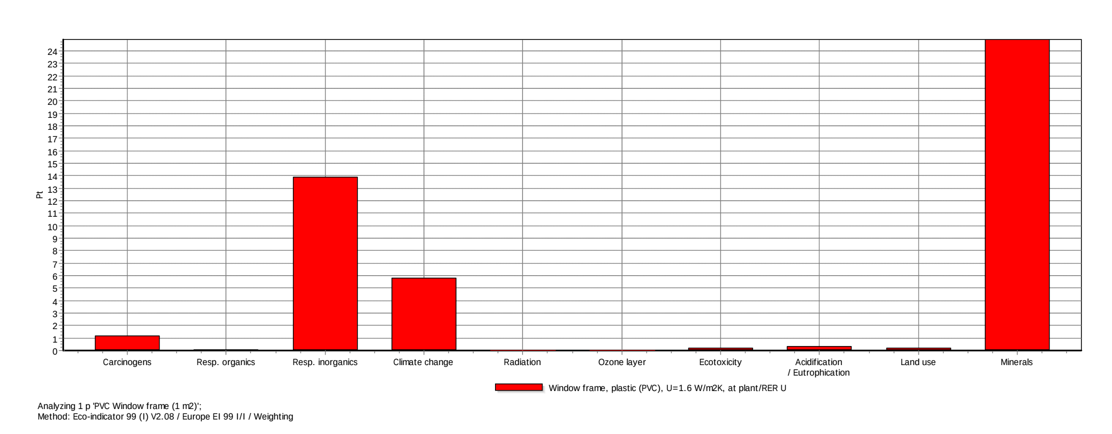



Figure 4.18 Characterisation of PVC window frame

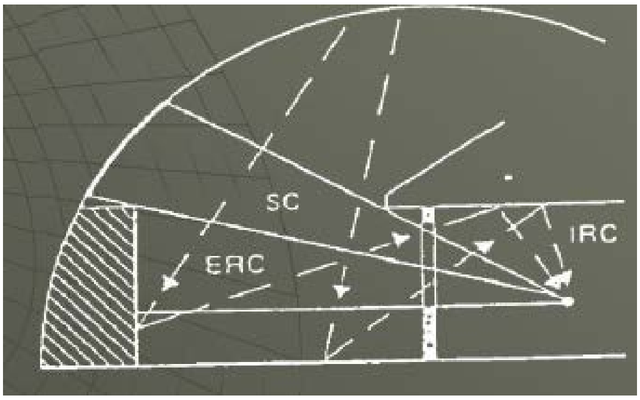
## 4.3 Health And Wellbeing

### *4.4.1 Daylight*

An average daylight factor of 2% or more is needed (excluding staircases and circulation areas at common spaces)

#### *4.4.1.1 Average Daylight Factor*

The average daylight factor is the average indoor illuminance (from daylight) on the working plane within a room, expressed as a percentage of the simultaneous outdoor illuminance on a horizontal plane under an unobstructed CIE Standard Overcast Sky.




DF = SC + ERC + IRC

DF : Daylighting Factor

SC : Sky Component

ERC: External Reflected Component

IRC : Internal Reflected Component

Figure 4.19 Daylight factor (IEA,2000)

*4.4.1.1.1 Sky Component :* In order to calculate the Sky Component we will use protractor. Different protractors are available for different glazing.

Table 4.38 Protractor properties (Szokolay,1980)

| | Uniform Sky Protractor No | CIE sky Protractor No |
|---|---|---|
| Vertical windows | 1 | 2 |
| Horizontal glazing | 3 | 4 |
| 30oC glazing | 5 | 6 |
| 60$^{o}$C glazing | 7 | 8 |
| Unglazed apertures | 9 | 10 |

We will evaluate apartment buildings and houses; they usually have vertical windows so we are going to use Protractor 2 CIE sky.

*4.4.1.1.1.1 CIE Overcast Sky Protractor*

*4.4.1.1.1.1.1 Calculating Sky Component.* Sky Component = Initial Sky Component x Correction Factor

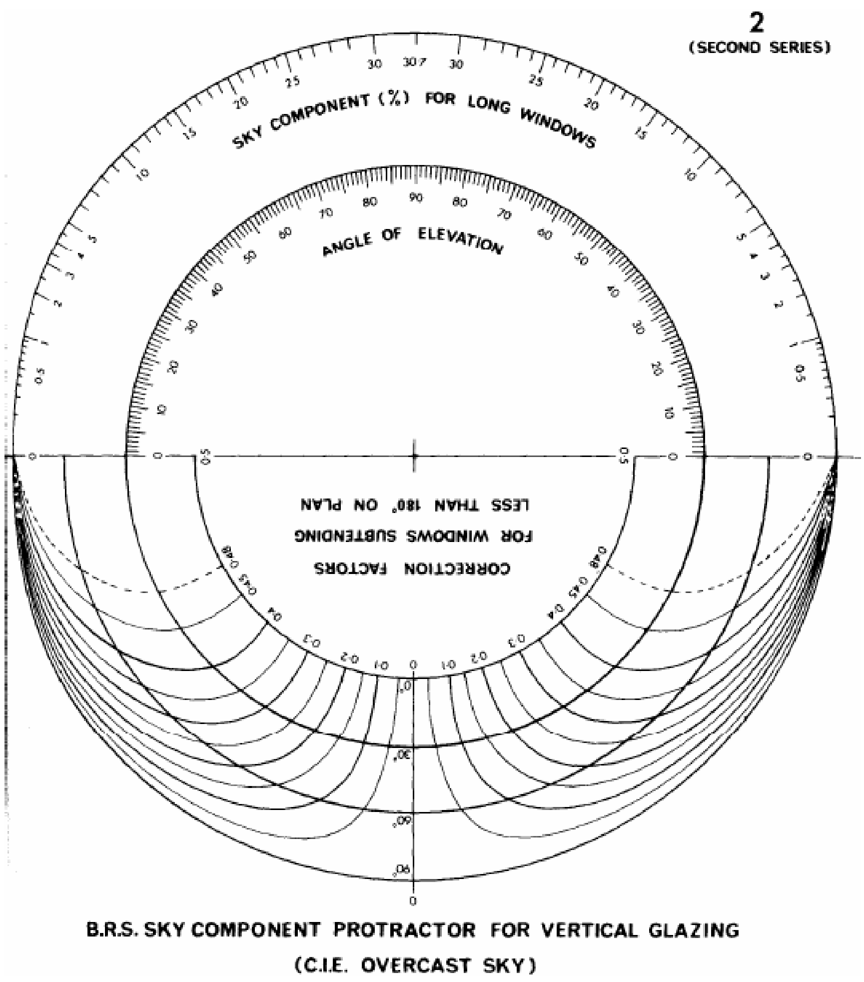



Figure 4.20 CIE protractor for vertical glazing (Szokolay,1980)

In order to calculate the sky component we will calculate initial sky component first by using protractor.

1. Take a section of the room, draw the working plane and on it the point to be considered (O).

2. Connect the limits of aperture (or edges of obstruction) to point O, i.e., lines PO and RO.

3. Place the protractor with scale A uppermost, base line on the working plane with the centre on point O.

4. Read the values where lines PO and RO intersect the perimeter scale: the difference of the two values is the initial SC.

5. Read the altitude angles where lines OP and RO intersect the 'angle of elevation' scale and take the average of the two readings.

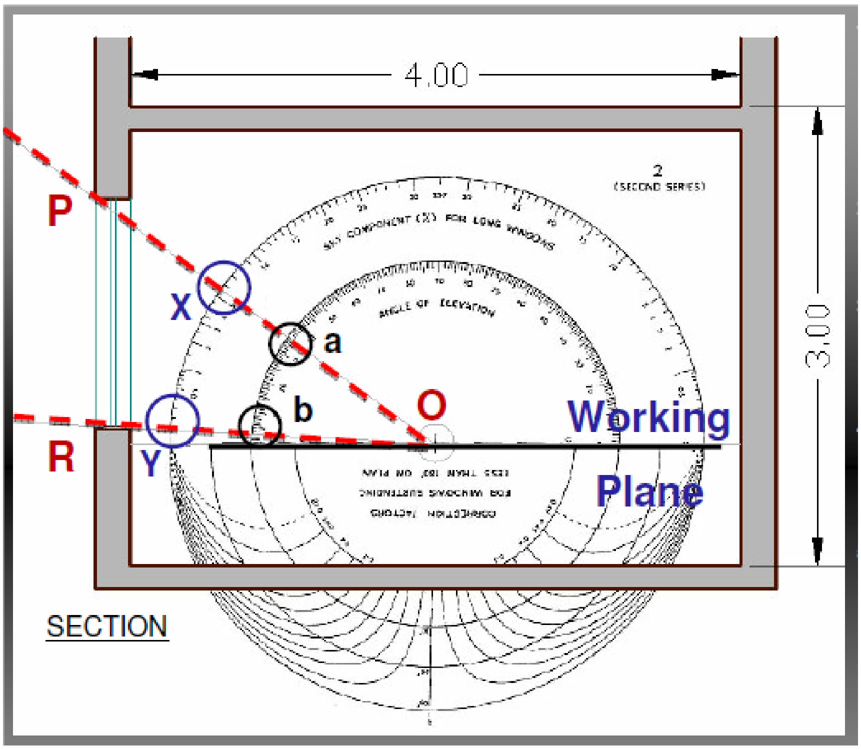



Figure 4.21 Usage of protractor (Szokolay,1980)

*4.4.1.1.1.1.2 Calculating Correction Factor.*

1. Take the room plan and mark position of the point to be considered (O).

2. Connect the limits of aperture with point O, i.e., lines MO and NO.

3. Place the protractor with scale B towards the window, base line parallel to the window with the centre on point O.

4. Four concentric semicircles are marked on the protractor 0 deg, 30 deg, 60 deg and 90 deg. Select the one according to the corresponding elevation angle obtained in step 5, if necessary interpolating an imaginary semi-circle. Unless the reference point is very close to the window, this will normally be well below 30 deg and will not have much effect.

5. Where Lines MO and NO intersect this semicircle read the values along the short curves on the scale of the inner semicircle.

6. If the two intersection points are on either side of the centre line, add the two values obtained: if they are on the same side, take the difference of the two values. This will be a correction factor.

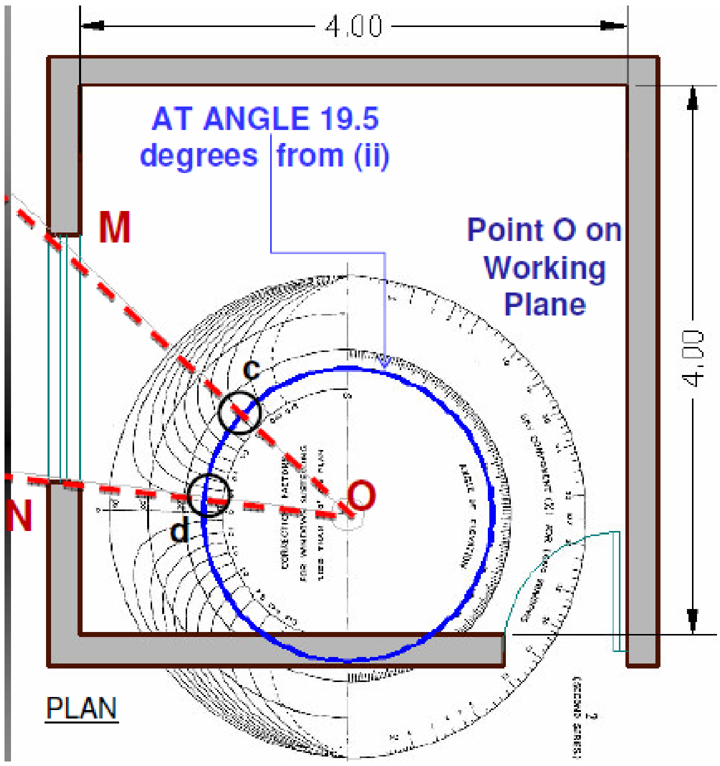



Figure 4.22 Correction factor (Szokolay,1980)

*4.4.1.1.1.1.3 External Reflected Component.* If there are no obstructions outside the window, there will be no ERC.

As we are using Protractor series 2 we can multiply the Final sky component by 0.2 as prescribed in order to obtain the externally reflected component

*4.4.1.1.1.1.4 Internal Reflected Component.* Much of the light entering through the window will reach the point considered only after reflection from the walls, ceiling and other surfaces inside the room.

The magnitude of this contribution to the day lighting of the point considered is expressed by the IRC. This will normally be fairly uniform throughout the room, thus for most problems it is sufficient to find the average IRC value. The simplest method uses the nomogram.

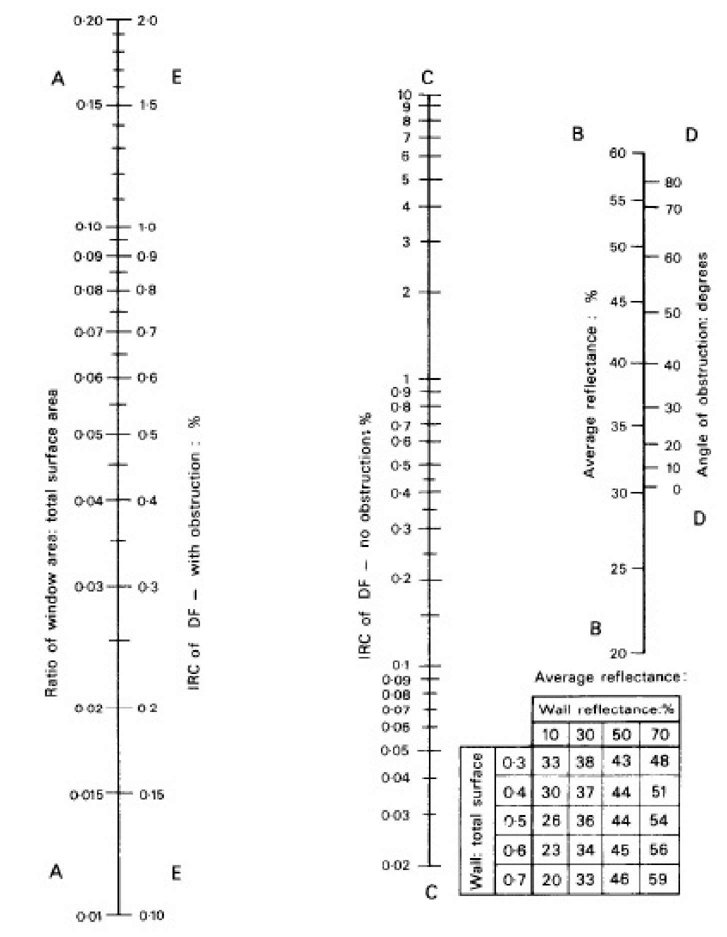



Figure 4.23 Nomogram (Szokolay,1980)

1. Find the window area and find the total room surface area (floor,ceiling and walls, including windows) and calculate the ratio of window to total surface area. Locate this value on scale A of the nomogram.

2. Find the area of all the walls and calculate the ratio of wall to total surface area. Locate this value in the first column of the small table (alongside the nomogram).

3. Locate the wall reflectance value across the top of this table and read the average reflectance at the intersection of column and line (interpolating, if necessary, both vertically and horizontally). Or calculate an area-weighted mean reflectance (assume glass reflectance is 20%).

4. Locate the average reflectance value on scale B and lay a straightedge from this point across to scale A (to value obtained in step iii).

5. Where this intersects scale C, read the value which gives the average IRC if there is no external obstruction.

6. If there is an external obstruction, locate its angle from the horizontal, measured at the centre of window, on scale D.

7. Lay the straight-edge from this point on scale D through the point on scale C and read the average IRC value on scale E.

#### ***4.4.2 Potential for Natural Ventilation***

*4.4.2.1 Occupied Spaces*: of the building are designed to be capable of providing fresh air entirely via :

a. The openable window area in each occupied space is equivalent to 5% of the gross internal floor area of that room/floor plate. For room/floor plates between 7m-

15m depth, the openable window area is on opposite sides and evenly distributed across the area to promote adequate cross-ventilation.

*4.4.2.2 Naturally-Ventilated Buildings*

Where openable windows/ventilators are over 10m from sources of external pollution.

The distance requirement does not necessarily mean the plan distance, but the three dimensional distance around and over objects; e.g. on plan the air intakes may be less than 20m from a source of external pollution, but the intake may be on the roof of a 10 storey building and therefore over 20m from the source of pollution

*4.4.2.2.1 Sources of External Pollution* This includes the following:

- Highways and the main access roads on the assessed site.
- Car parks and delivery/vehicle waiting bays

### ***4.4.3 Noise Control***

In order to get point from this criteria the building slabs must have a plaster on it which does not touch the slab directly as a noise barrier.( Floating Slab)

## 4.5 Rating Scores of Core Version (Proposed assessment method)

In order to decide about the rating scores of the proposed assessment method LEED, BREEAM and DGNB and HQE tools has been investigated.

*Table 4.39 Rating scores of assessment tools*

| | |
|---|---|
| <u>LEED Rating Scores</u><br>Unclassified <40<br>Certified 40–49 points<br>Silver 50–59 points<br>Gold 60–79 points<br>Platinum 80 points and above | <u>BREEAM Rating Scores</u><br>Unclassified <30<br>Pass ≥30<br>Good ≥45<br>Very good ≥55<br>Excellent ≥70<br>Outstanding ≥85 |
| <u>DGNB Rating Scores</u><br>Bronze ≥ if the total performance index is %50<br>Silver ≥ if the total performance index is %65<br>Gold ≥ if the total performance index is %80 | <u>HQE</u><br>Good 1-4 stars<br>Very good 5-8 stars<br>Excellent 9-12 stars<br>Exceptional 12-16 stars |

**Proposed Assessment Method's proposed scores**

Bronze ≥ 50

Silver ≥ 65

Gold ≥ 80

CHAPTER FIVE

# TESTING THE PROPOSED MODEL (CORE VERSION)

## 5.1 Project Details

Project is a residential building with 4 floors. Ground floor area is 316 $m^2$, normal floor area is 321 $m^2$.

Location is İzmir- Menemen / Kasımpaşa district.

There are two entrances and also two separate staircases, 3 flats at each floor which have 3 rooms and a living room.

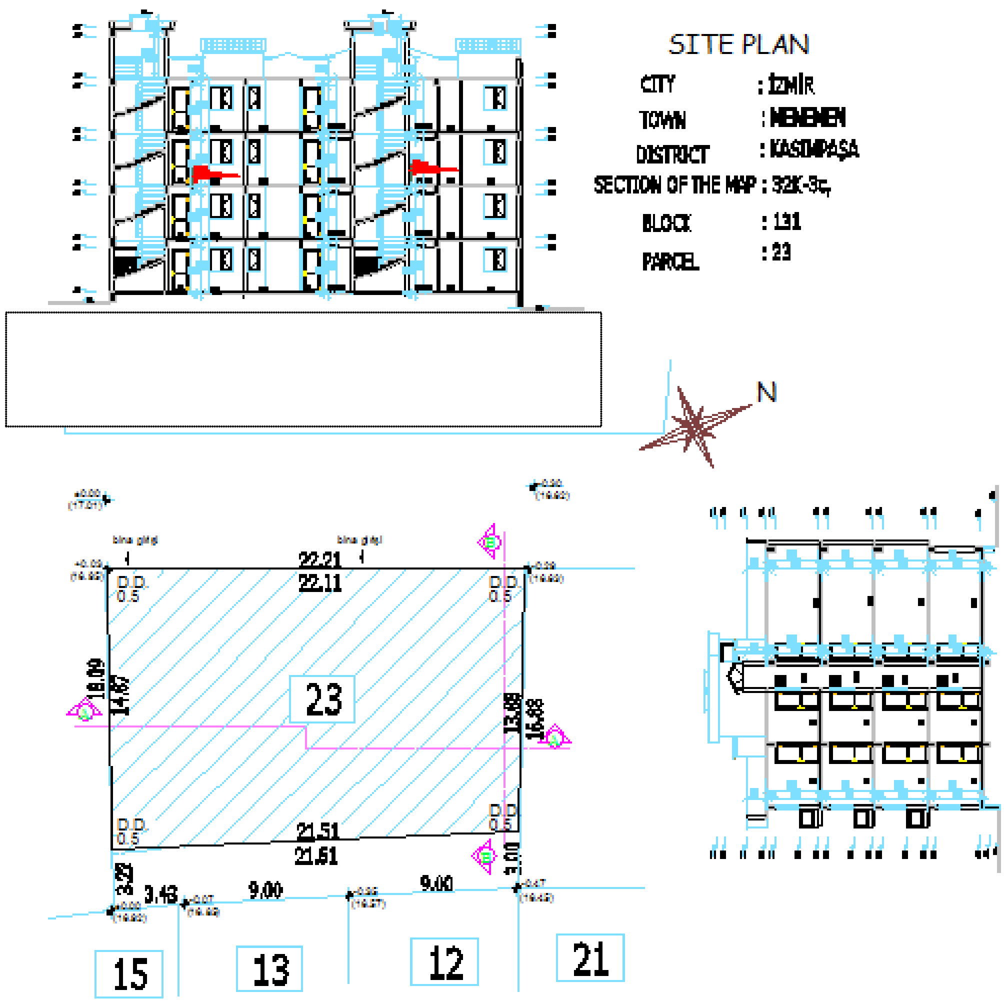



Figure 5.1 Site plan

## 5.2 Score Of The Project

### *5.2.1 Sustainable Site Results*

*5.2.1.1 Provision Of Public Transport Results*

If accessibility Index is > 2 this will be enough to get 3,3048 points

*5.2.1.1.1 Calculation Of Accessibility Index For Menemen Project*

*5.2.1.1.1 .1 Bus Schedules*

- Bus Number 747 : Emiralem transfer at every 30 minutes

11 minutes walking time

SWT = 0,5 x 60 / frequency = 15 minutes

Avarage waiting time ( total access time ) : 11 + 15 + 8( Reliability factor) = 34 minutes

EDF = 30 / 34 = 0,88

- Bus Number 748 Ulukent transfer at every 40 minutes(11 minutes)

11 minutes walking time

SWT = 0,5 x 60 / frequency = 15 minutes

Average waiting time ( total access time ) : 11 + 20+ 8 = 39 minutes

EDF = 30 / 39 = 0,77

- Bus Number 749 Ulukent transfer at every 30 minutes (11 minutes)

11 minutes walking time

SWT = 0,5 x 60 / frequency = 15 minutes

Average waiting time ( total access time ) : 11 + 15 + 8( Reliability factor) = 34 minutes

EDF = 30 / 34 = 0,88

- Bus Number 754 Bozalan transfer once a day ( 9 minutes )

Because of being just once a day, the passengers of this route knows the exact time so the assumed SWT is = 15 minutes

TAT = 9 + 15 + 8 = 32 minutes

EDF : 30 / 32 = 0,94

- Bus Number 755 Görece transfer once a day ( 9 minutes )

Because of being just once a day, the passengers of this route knows the exact time so the assumed SWT is = 15 minutes

TAT = 9 + 15 + 8 = 32 minutes

EDF : 30 / 32 = 0,94

AImode = EDFmax + (0.5 x All other EDFs)

AIpoi = Σ(AImode1 + AImode1 + AImode2 + AImode3 … AImode n )

$AI_{bus}$= 0,88 + (0,5 x ( 0,77 + 0,88 + 0,94 + 0,94 ))

= 0,88 + 1,765 = > 2,645

*5.2.1.1.1.2 IZBAN Schedules.*

Cumalı ova- Menemen = at every 22 minutes

Menemen - Aliağa = at every 22 minutes

TAT = 5 minutes walk + 11 minutes wait + 2 minutes Reliability factor

TAT = 18 minutes

EDF = 30 / 18 = 1,66

$AI_{train}$ = 1,66 + (0,5 x 1,66 ) = 2,49

*5.2.1.1.1.3 Minibus Schedules.* At every 40 minutes to Otogar. ( Bus Station)

Tat = 11 minutes walk + 20 minutes wait + 5 minutes Reliability factor

EDF = 30 / 36 = 0,83

$AI_{minibus}$ = 0,83

$AI_{poi}$ = 0,83 + 2,49 + 2,65 = 5,97

AI = 5,97 > 2 = > **3,3048 points**

*5.2.1.2 Proximity to Amenities (2,592 points).*

If the building is within 800m of

- Grocery shop and/or food outlet

And

If the building is within 3000m of the following amenities:

- Schools
- Play grounds for children

These will be enough to get 2,592 points

*5.2.1.2.1 Calculation*

- Grocery shop - 200 meter to the project site

Figure 5.6 Distance to Grocery shop

- Schools and play grounds – 1500 meters



Figure 5.7 Distance to schools

Because of accomplishing the necessities: **2,592 points**

*5.2.1.3 Distance To Earthquake Fault (13,2192 points)*

- The building will get 13,2192 points if the distance to fault is more than 3 km

*5.2.1.3.1 Calculation :* The location of the faults has been determine by using Figure 5.8 In order to determine the location of the project Google Erath program has been used. After deciding about the location of both faults and the project the distance to faults has been determined.

The distance to the fault is 8.127 km > 3 km = > **13,2192 points**

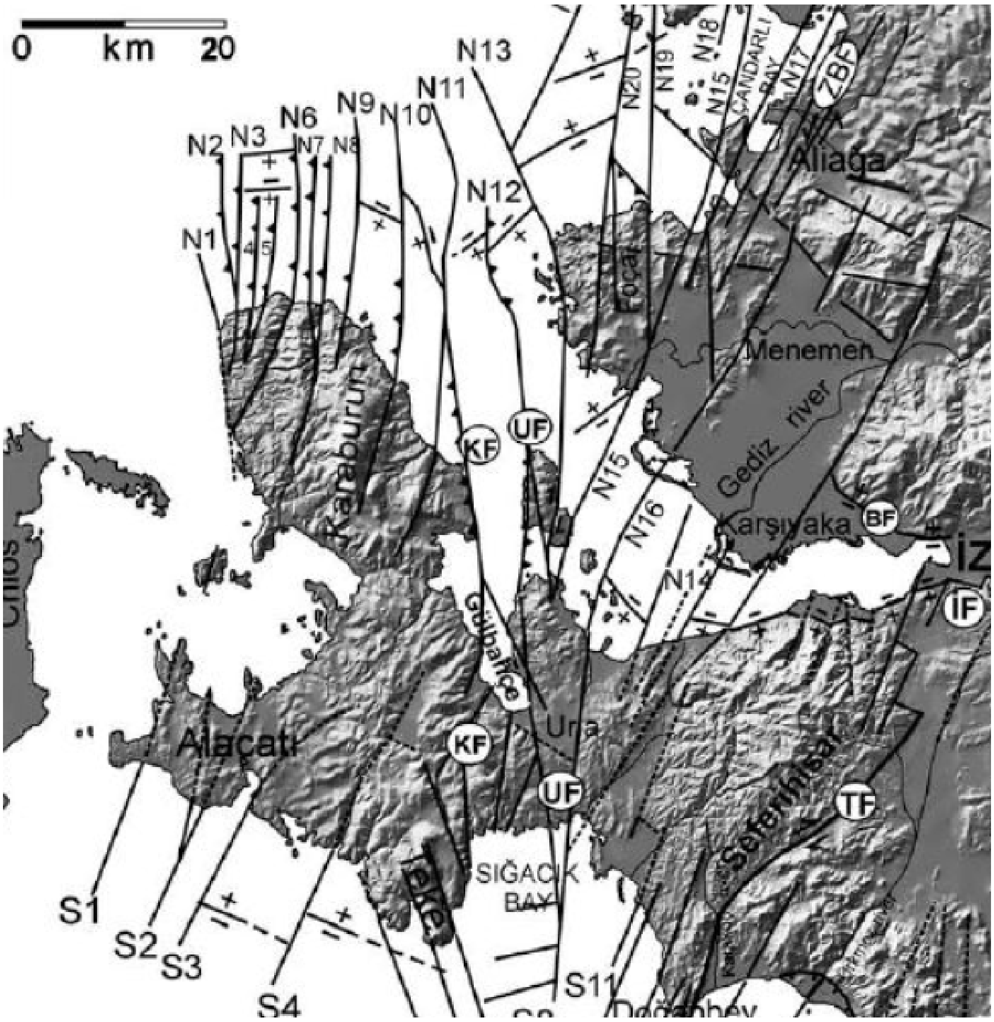



Figure 5.8 Faults at İzmir, Aliağa, Karaburun, Alaçatı, Doğanbey & Kuşadası, (Ocakoğlu, N., Demirbağ, E. ve Kuşçu, İ., 2005)

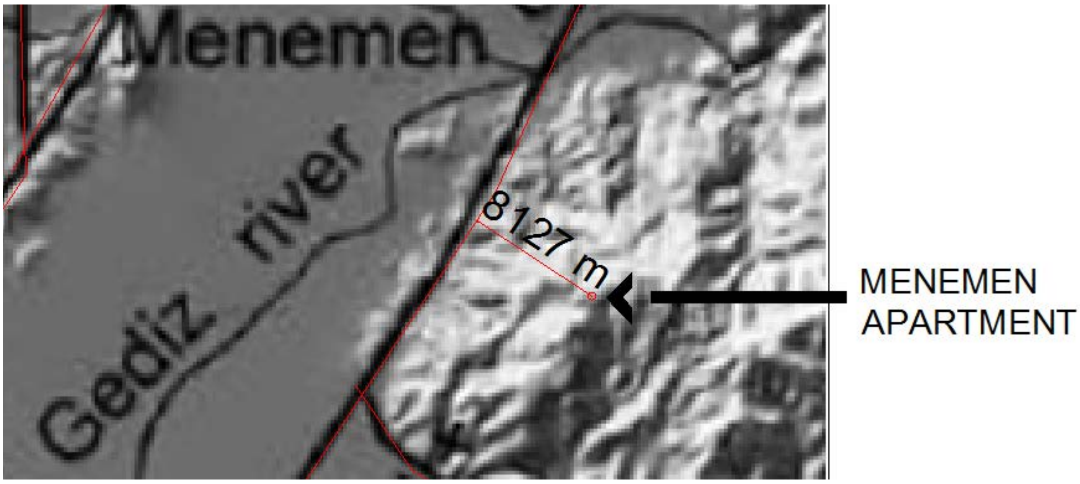



Figure 5.9 Distance to fault from project location

*5.2.1.4 Enough Green Areas (2,484 points)*

The building gets *2,484* points if,

During the performance period, have in place native or adapted vegetation covering a minimum of 25% of the total site area (excluding the building footprint) or 5% of the total site area (including the building footprint), whichever is greater.

And

The building is within 3000 m to at least one of the following green areas

- City parks
- Sea site walking routes
- Bicycle routes

*5.2.1.4.1 Calculation*

381 $m^2$ total area, 316 $m^2$ building footprint, 65$m^2$.

381 x 0,05 = 19,05 $m^2$

65$m^2$ > 19,05 $m^2$ and

Menemen city park is within 1800 m = > **2,484 points**

Figure 5.10 Menemen City Park

### *5.2.2 Water Efficiency Results*

*5.2.2.1 Usage Of Water Efficient Equipment (6,8608 points)*

In order to get 6,8608 points, building has to proof that all faucets and toilet flushers are water efficient. Such as faucets with photocell, thermostatic faucets, faucets with perlators etc.

The average water flow of the taps and shower heads excluding bath tub taps, kitchen taps and filling stations has to be 9 litres/minute or less.

WCs have to consume 6 litres per full flush or less.

*5.2.2.1.1 Calculation*

There is no proof for these kind of equipment = > **0 points**

*5.2.2.2 Rain Water Collectors (3,283points)*

In order to get point, building has to have a rain water collector at least 300 litres. The building also has to have a rain water collection scenario which shows the tank’s cleaning and maintenance period. This scenario also has to show the responsible staff and has to proof that rainwater is collected and used for non-sanitary and non-drinking purposes.

*5.2.2.2.1 Calculation:* There is no drawn detail for rain water collectors = > **0 points**

*5.2.2.3 Grey Water Usage (3,26 points)*

In order to get point, building has to have a grey water collection tank. Building can get a point only if it is using grey water for gardening OR toilet flushing activities.

For both gardening and toilet flushing activities building owners has to show that they can receive at least % 40 of their need from these sources.

*5.2.2.3.1 Calculation.* There is no drawn detail for grey water usage detail = > **0 points**

### *5.2.3 Energy And Resources Results*

*5.2.3.1 Greenhouse Gas Emission Grade On Energy Identity Document (9, 25 points).*

- The building will get 9,25 points if it has a grade "A,B or C "
- Menemen project will get **9,25** points by having grade "C"

*5.2.3.2 Heating Energy Grade On Energy Identity Document (4,81 points)*

- The building will get 4,81 points if it has a grade "A,B or C"
- Menemen project will get **4,81** points by having grade "C"

*5.2.3.3 Cooling Energy Grade On Energy Identity Document (3,7 points)*

- The building will get 3.7 points if it has a grade "A,B or C"
- Menemen project will get 3,7 points by having grade "C"

*5.2.3.4 Hot Water Energy Grade On Energy Identity Document (2,7 points)*

- The building will get 2.7 points if it has a grade "A,B or C"
- Menemen project will get "0 points " from this section

*5.2.3.5 Renewable Energy Usage Ratio On Energy Identity Document (6.6 points)*

- The building will get 6.6 points if the ratio is between 100%- 66%
- Menemen project will get "0 points " from this section

ENERJİ KİMLİK BELGESİ
HESAPLAMA SONUÇ FORMU

**Proje Kodu : 27459**

Proje Adı : tez 01
Kapalı Kullanım Alanı : 1.084,10
Ada/Pafta/Parsel : 131/32k3c/23
Adres : menemen
İl : İZMİR
İlçe : Menemen
Belediye : Menemen
Bina Yapılış Tarihi :
Bina Yenileme Tarihi :
Bina Tipi : Apartman
Bina Sahibinin Adı :
Bina Sahibinin Adresi :

**SORUMLU FİRMANIN**

Firma Kodu : F06R7851
Ünvanı : TMMOB Mimarlar Odası İzmir Şubesi
Adresi : TMMOB Mimarlar Odası İzmir Şubesi
Şehir : ANKARA
Telefon / Faks : 05337640934
Vergi dairesi : Çankaya
Vergi numarası : 6210044800

**SORUMLU EKB UZMANININ**

Adı Soyadı : İlker Kahraman
Uzman sertifika no'su : EĞT-0184
Sertifika veriliş tarihi : 11.12.2011
Adresi : TMMOB Mimarlar Odası İzmir Şb. 1456 Sk. No:8/10 Alsancak
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**ENERJİ KİMLİK BELGESİ DEĞERLERİ**

| Enerji kullanım alanı | Kullanılan sistem | Nihai tüketim (kWh/yıl) | Birincil tüketim (kWh/yıl) | $m^2$ başına tüketim | SINIFI |
|---|---|---|---|---|---|
| TOPLAM | | 770.621,97 | 1.338.154,94 | 710.84 | C |
| Isıtma | Isıtma Sistemi | 214.826,23 | 214.826,23 | 198.16 | C |
| Sıhhi Sıcak Su | Sıcak Su Sistemi | 138.492,10 | 138.492,10 | 127.75 | D |
| Soğutma | Soğutma Sistemi | 411.586,06 | 971.343,10 | 379,66 | C |
| Havalandırma | | 0.00 | 0.00 | 0,00 | |
| Aydınlatma | Kompakt fluoresan | 5.717,59 | 13.493,51 | 5,27 | B |
| Sera Gazı Emisyonu | | | | 300.83 | C |

| Yenilenebilir Enerji Kullanım Oranı | %0,00 |
|---|---|

Figure 5.11 Energy identity document for Menemen project

### *5.2.4 Health and Wellbeing Results*

*5.2.4.5 Daylight (11,04 points)*

An average daylight factor of 2% or more is needed.

*5.2.4.5.1 Calculation*

DF = SC + ERC + IRC

DF : Daylighting Factor

SC : Sky Component

ERC: External Reflected Component = 0,2 x SC

IRC : Internal Reflected Component

*According to colour light reflectance value is : 88*

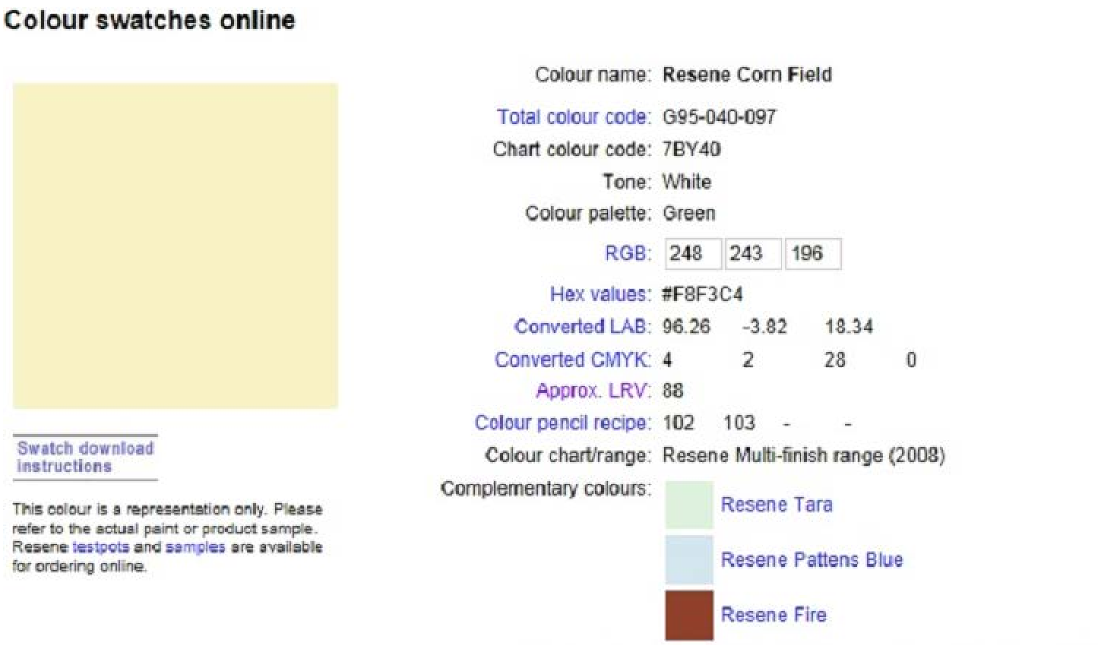


Figure 5.12 Colour reflectance value http://www.resene.co.nz/swatches/reflectance.htm

*5.2.4.1.1.1 Calculation of SC.* In order to calculate SC Protractor series 2 has been used. For every space at the building a SC is calculated ( for the centre of each room at a height of 90 cm). You can find an example for the calculation process.

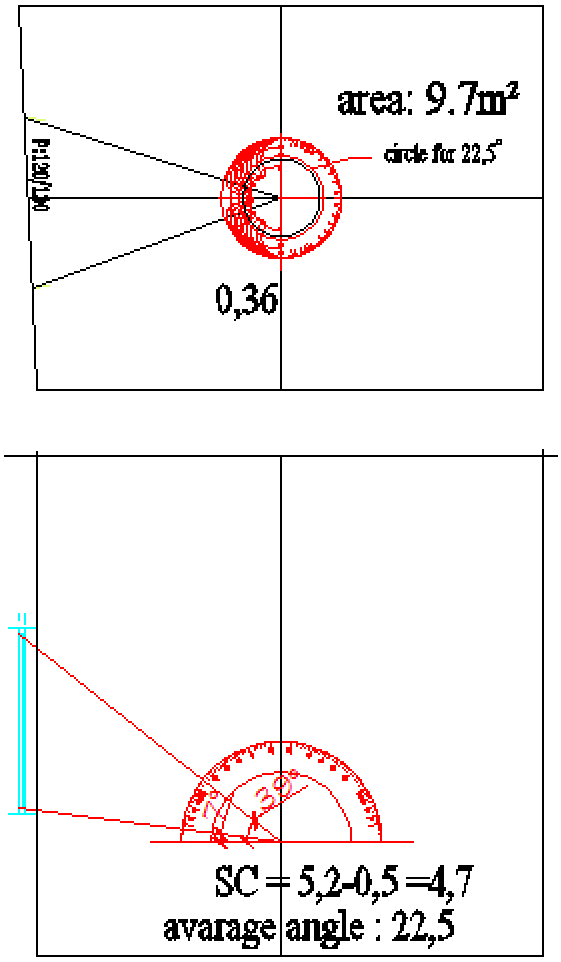


Figure 5.13 Calculation Of SC

The total SC  for 21 rooms ( including bathrooms and toilets) = 53

The total space at the building (including corridors) = 27

Average SC= 53 / 27 = 1,96

*5.2.4.1.1.2 Calculation of ERC*

$ERC_{average} = 0{,}2 \times SC_{average} = 0{,}392$

*5.2.4.1.1.3 Calculation of IRC*

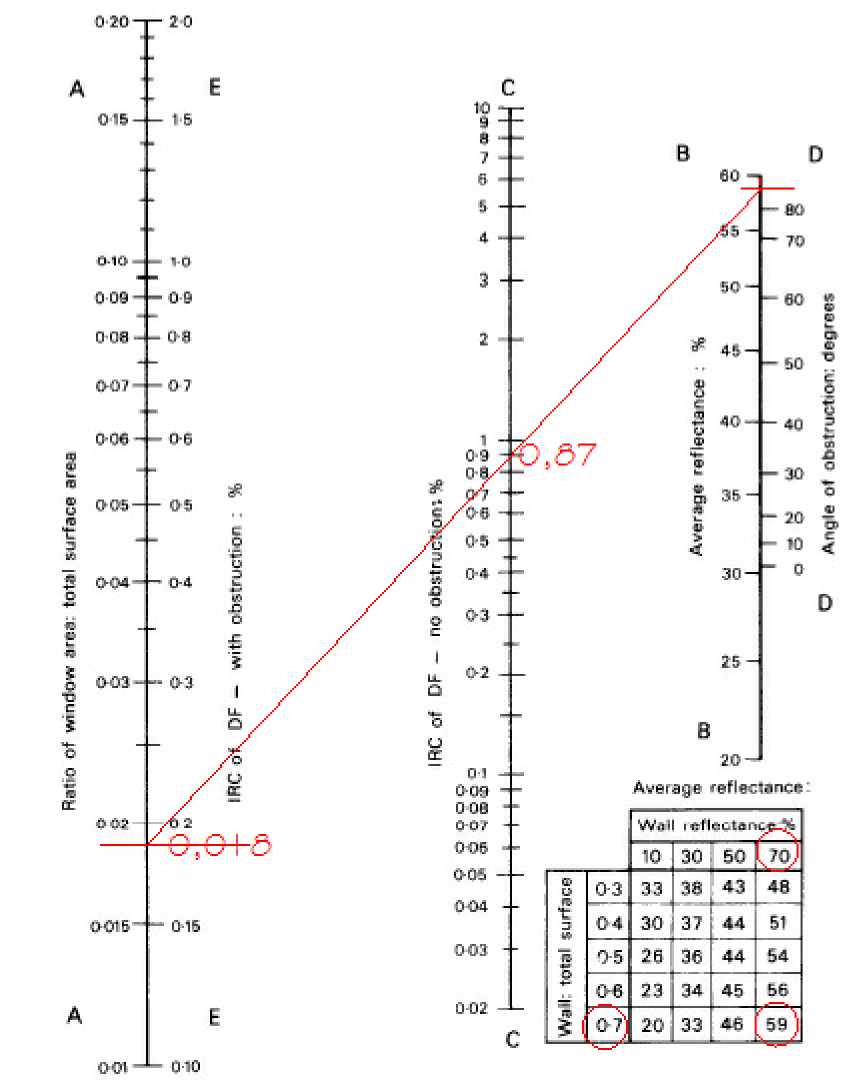


Figure 5.13 Calculation of IRC

Window / total surface= 0,018

Wall / total surface = 0,71

Wall reflectance value is 88 %

$IRC_{kitchen}$ = 0,87 ( as an example for kitchen areas)

**IRC average =** Total IRC / 27 spaces = 15,66 / 27 = 0,58

**DF** $_{\textbf{average}}$ = SC $_{average}$ + ERC $_{average}$ + IRC $_{average}$

**DF** $_{\textbf{average}}$ = 1,96 + 0,392 + 0,58 = 2,932

**DF** $_{\textbf{average}}$ =2,932 >2

- Menemen project will get **11,04 points** from daylight section

*5.2.4.6 Potential for Natural Ventilation Results (12,2 points)*

The openable window area in each occupied space is bigger than 5% of the gross internal floor area, openable windows are over 70m from the main access roads . The distance to delivery/vehicle waiting bays is 100m.

*5.2.4.2.1 Calculation.* Menemen project will get "12,2 points " from this section

*5.2.4.7 Noise Control (5,0657 points)*

In order to get point from this criteria the building slabs must have a plaster on it which does not touch the slab directly as a noise barrier.( Floating Plaster)

*5.2.4.3.1 Calculation:* There is no noise barrier detail for this project

Menemen project will get "0 points " from this section

Table 5.1Assessment Score of  Menemen Project

| | TOTAL SCORE | PROVISION OF PUBLIC TRANSPORT | PROXIMITY TO AMENITIES | GREEN AREAS | DISTANCE TO EARTHQUAKE FAULTS |
|---|---|---|---|---|---|
| SUSTAINABLE SITES | 21,6 | 3,3048 | 2,592 | 2,48 | 13,219 |

| | | WATER EFFICIENT EQUIPMENT USAGE | RAIN WATER COLLECTOR | GREY WATER USE |
|---|---|---|---|---|
| WATER EFFICIENCY | 0 | 0 | 0 | 0 |

| | | LCA RESULTS OF DETAILS | GHG EMISSIONS ON EIC | HEATING CLASS ON EIC | COOLING CLASS ON EIC | HOT WATER CLASS ON EIC | RENEWABLE EN. CLASS ON EIC |
|---|---|---|---|---|---|---|---|
| ENERGY AND RESOURCES | 22,9221 | 5,1621 | 9,25 | 4,81 | 3,7 | 0 | 0 |

| | | NOISE CONTROL | DAYLIGHT CONTROL | NATURAL VENTILATION PER. |
|---|---|---|---|---|
| HEALTH AND WELL BEING | 23,24 | 0 | 11,04 | 12,2 |

| | |
|---|---|
| **TOTAL SCORE** | **67,7621** |

80 > silver certificate ≥ 65 = > **Menemen Project gets “Silver” certificate**

# CHAPTER SIX
# CONCLUSION

As being one of the largest end users of environmental resources and one of the largest polluters of manmade and natural environments, construction sector is the key sector for the destiny of our world.

This thesis is a kind of yardstick for measuring environmental performance of buildings and developed according to the need for reducing environmental impacts of buildings. It is impossible to have zero impact but we can always decrease the ratio.

In order to decrease the ratio of these impacts firstly we have to know the current situation and find out the impacts in different scenarios.

Till this time Turkey did not have a rating system or a model to assess sustainable performance of buildings. The rating systems which are famous in other countries are getting famous in our country but they are not tailored for our needs. In order to evaluate some criterion we have to be sure that we are ready to do so. For example, encouraging bicycle usage is important if the country has extra lanes for bicycles. If you can arrange enough parking areas for bicycles in a building people will start to use their bicycles and this activity reduces the $CO_2$ emissions. The conditions for bicycle usage in Turkey are not similar with the developed countries. We don't have bicycle lanes so if you decide to have bicycle parking areas more than enough in it will be only an energy and material consumption.

Minibuses are good opportunities for us as a public transport vehicle. But it is hard to find details about minibus usage in a building assessment tools because it is not common for developed counties.

Turkey has a new Building Energy Performance regulations. This new regulations introduced us energy identity cards. New buildings have to have C,B or A certificate in order to get a permit by using a internet based computer program BEP.TR. This new regulation caused awareness for insulation usage and we have more energy efficient buildings than before.

Using thick insulation layers causes a better heating or cooling performance but from the sustainable point of view what about the manufacturing process of those materials. How to compare the environmental impacts of different construction materials?

Life cycle assessment processes are very useful for these calculations. But end users do not have an idea about LCA process usually. You can choose lots of different details for your construction but for choosing the right details with less environmental impact you have to be a LCA expert.

Our new regulations encourage us to use insulation materials. But the problem is the manufacturing process of an insulation material which's U value is higher than the similar ones can produce harmful greenhouse gases or can produce more waste than others. So before using a detail in a construction site we have to evaluate the materials.

This thesis introduces the environmental impacts of 241 common details which are very common for Turkish construction market. The environmental impacts of these details are calculated by using well known databases of SimaPro software.

For achieving a sustainable building the end user can decide the details needed by taking into consideration of each details U values and environmental impacts.

In this thesis the current environmental building assessment methods and rating systems used in different countries in terms of their characteristics and limitations in assessing building sustainability has been clarified and categorised; by criticising them a new model for the assessment of new residential buildings according to sustainability issues has been developed.

The weightings of the developed method’s issues and categories have been investigated by the help of a questionnaire and the real importance of these issues and criterion have been formed by Turkish experts.

Achieving the weightings of issues and criterion according to Turkish experts is one of the core parts of this thesis. The assessment tools which are popular in Turkey uses their own weightings according to their own country needs and other societies necessities are not familiar with ours. So a criteria can be important for them but not for us. Such as proximity to post offices is an important issue in USA but not in Turkey.

This method will be helpful for comparing buildings according to sustainable assessment approach. A labelling can be formed according to the scores of buildings.

The construction market can adapt sustainable issues to design process for getting a high score. The adapted issues will be the ones which are identified and tailored for various needs.

In this thesis three versions of the method have been formed but only the core version has been investigated. Future researchers can deal with the mid and full versions of this method and also the weightings of issues and criterion can be diversified according to different necessities.

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# APPENDICES

## ABBREVIATIONS

AHP Analytic Hierarchy Process

APAT Italian National Agency for the Environment and for Technical Services

BEP.TR Web based Turkish Building Energy Performance tool,

BRE: Building Research Establishment

BREEAM: BRE Environmental Assessment Method

CEN: European Committee for Standardisation

CASBEE: Comprehensive Assessment System for Building Environmental Efficiency

ÇEDBİK: Turkish Green Building Council

CI Consistency Index

CR Consistency Ratio

DALY Disability adjusted Life Years

DGNB : Deutsche Gesellschaft für Nachhaltiges Bauen

DEU Dokuz Eylül University

EDF Equivalent Doorstep Frequency

EKB Energy Identity Document

ERC External Reflected Component

EU European Union

GBC : Green Building Challenge

GHG: Greenhouse Gases

iiSBE: International Initiative for a Sustainable Built Environment

IBEC: Institute for Building Environment and Energy Conservation

IRC Internal Reflected Component

ISO: International Organization for Standardisation

ISPRA Italian Institute for Environmental Protection and Research

İTU Istanbul Teknik University

LCA Life Cycle Assessment

LCC Life Cycle Costing

LEnSE Label for Environmental, Social and Economic Buildings

LEED Leadership in Energy and Environmental Design

MCDM Multi-Criteria Decision-Making

OPEN HOUSE Benchmarking and mainstreaming building sustainability in the EU based on transparency and openness (open source and availability) from model to implementation.

PAF Potentially Affected Fraction

PDF Potentially Disappeared Fraction

POI Point of interest

RI Random Index Study

SAP Service Access Point

SB Alliance Sustainable Building Alliance

SC Subcommittee

SC Sky Component

SuPerBuildings : Sustainability and Performance assessment and Benchmarking of Buildings – SuPerBuildings (Project of FP7 from the EC)

SMEs, small and medium-sized businesses

SÜRYAD Sustainable Buildings and Materials Association

TC Technical Committee

USGBC:  United States Green Building Council