UNIVERSITÉ DE GENÈVE
Faculté des sciences

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Master en sciences naturelles de l'environnement

Life Cycle Assessment of 21 buildings: analysis of the different life phases and highlighting of the main causes of their impact on the environment

Mémoire présenté par

Cecilia Matasci
Licenciée en biologie

Sous la direction des Professeurs Susanne Kytzia (EPFZ), Christina Seyler (EPFZ), Walter Wildi (UNIGE) et Bernard Lachal (UNIGE)

Mémoire No 128

2006

Acknowledgement

Without the help of many people, this work would not have been possible. I would particularly like to thank:

Dr. Christina Seyler-Jahn for her help, for having assisted me all along the work and for having introduced me to a new and interesting subject;

Prof. Susanne Kytzia, for her supervision and her interesting observations;

Prof. Walter Wildi and Prof. Bernard Lachal for directing my work;

Beat Meier, Dipl. Arch. ETH/SIA, for supplying me with all the plans and information on the house and for being always kindly disposed to answer questions on architecture;

Dr. Stefan Rubli and Hans-Jörg Althaus for their useful information and their explanations on the actual situation of dismantling in the canton of Zürich and in Switzerland;

Peter Gallinelli, Dipl. Arch. (CUEPE), for his explanations and tips on the EnerCAD program;

Annick Lalive d'Epinay, Dipl. Arch. ETH, for hers clarifications;

Yves Loerincik, ETH Lausanne, for his elucidations on LCA;

Laurent Vorlet, Ing. Env. ETHZ, and Claude Willemin, Dipl. Arch., for their precious information;

Prof. Emanuel Castella for his kind and prompt help for statistical analysis;

My sister Caterina Matasci and Jolanda Hofschreuder for their reviewing of the work;

My thanks go also to Martin Streicher-Porte for sharing the office and for the joggings in the forests of Hönggerberg, to Ronny Haase for always being here when I needed help and to all the co-worker in the IRL institute and to all my flat mates for the great time that we had together in Zürich.

Cecilia Matasci

Abstract

Nowadays, buildings are increasingly seen as a pressing environmental problem. By their very nature, they affect and transform the land on which they are built by changing and destroying habitats and causing loss of biological diversity. On a macro level, buildings contribute to deforestation, natural resources depletion, the risk of global warming, stratospheric ozone depletion, overuse of water and acid rain by their enormous materials and energy consumption. In order to effectively improve the ecological performance of buildings, it is important to know in which life phase (the construction, the use, the refurbishment or the disposal) which environmental impacts occur and why.

The aim of this work was to perform a Life Cycle Assessment (LCA) on a set of buildings obtained from the BKI -the German “centre for construction costs”- to assess which life phases and elements require particular attention during the effort of reducing the environmental impacts in the building and construction sectors. The LCA method allows a holistic assessment, considering the whole life cycle of a building. This avoids problems in shifting from on phase to another.

The following questions were posed: “Which are the variations in environmental impact between buildings of different shapes, materials and functions and why do they exist?”; “How is the environmental impact generally divided between the life phases and why?” and “Which elements inside each phase determine the impact on the environment? For which reason?”. The large size of the sample data utilised, 21 different constructions, allowed to make sound statements and constitutes the validity of this work. Effectively, very rarely such a high number of existing buildings was compared within a unique study and therefore on an equivalent basis.

This work consists of two parts: a practical part in which a case study house in canton Zürich is inventoried before and after renovation and a more theoretical part in which a group of houses obtained from a database are compared. The database also forms a basis for phase and materials impact assessment and for recommendations for further impact reduction of buildings. The practical part was accomplished with architectural plans and with site visits. The recent renovation allowed to answer the following questions: “How big are the consequences of renovation on the environment?; “During which life phases,

the environmental impact is higher?" and "Do the gains in terms of energy outweight the losses?".

Results generated from the analysis of set of buildings interestingly outlined the importance of the refurbishment phase. This phase was hardly ever taken into consideration in previous studies or it was generally included in the use phase. In the present study it appeared that the most environmentally impacting phase was in almost all the cases the use one (responsible of 38-70% of the total impact), this was followed by the refurbishment (16-40%) phase. The construction (11-25%) and the disposal phases came after. For this last phase, the impact was fairly small in comparison (2-6%). The biggest portion of impact appeared undoubtly to be caused by heating during the use phase. Many architectural and construction factors played a role in determining the low or high consuming of a building, in particular compactness and window surface. Also the replacement of materials, in particular of metals, wood and of insulating ones appeared to have its relevance on the total impact of the building. Materials appearing in a small quantity but with very high environmental score (as for example metals as zinc or lead) did also emerge. In addition, materials present in the original construction appeared to contribute to the overall impact, but in a minor way. They were in this case structural ones as steel and wood, but also insulating materials. Transport, disposal and lighting played comparably a very small role. A significant distinction between the four classes of buildings considered (single occupancy and apartment houses, service and manufacturing buildings) did not emerge. Nonetheless, results appeared rather constant in between the single occupancy class and became more and more variable within the apartment, the service and the manufacturing classes. If summed up, the total impact brought by materials appears to be equal to the one brought by heating. It also appeared that apartment buildings are a better solution than single occupancy ones.

Concerning the renovation of the single occupancy house, it appeared that it results in big environmental improvements. In the case study, it allowed a reduction of the impact on the environment of 38%. The principal phases affected appeared to be refurbishment and use. From an energetic point of view, benefits were bigger than losses by a factor of twelve. Moreover, renovation appeared, on a very simple comparison, to perform slightly better than reconstruction.

Resumé

De nos jours, les bâtiments représentent une menace sérieuse et pressante pour l'environnement. À partir du moment où ils sont bâtis, ils affectent et ils transforment le territoire où ils sont construits en altérant et détruisant son habitat et en réduisant la diversité biologique. À un plus large niveau, à cause de leur énorme consommation de matériaux et d'énergie, ils sont coresponsables de la déforestation, du pillage des ressources naturelles, de l'effet de serre, de la destruction de la couche d'ozone, de la surconsommation d'eau et des pluies acides. Pour améliorer la performance écologique des bâtiments, il est important de connaître dans quelle phase de leur vie (la construction, l'utilisation, la rénovation ou la démolition) ils ont un impact sur l'environnement, et quelle en est la cause. Pour disposer d'une vue intégrée du phénomène et pour éviter de déplacer le problème d'une phase de la vie à l'autre, il est important de prendre en considération l'entier du cycle de vie du bâtiment. Ceci peut être réalisé grâce à l'Analyse du Cycle de Vie (ACV ou LCA en anglais).

Le but de ce travail est précisément de réaliser une LCA sur un groupe de bâtiments obtenus du BKI, le centre allemand des coûts de construction. Ceci pour définir quelle phase de vie et quels éléments nécessitent une attention et une considération particulières pendant l'effort de réduction de l'impact que ce secteur a sur l'environnement. Les questions suivantes ont été posées : « Quelles sont les variations en impact parmi des bâtiments qui possèdent des formes, des matériaux et des fonctions différents et à quoi sont-elles dues ? », « Comment est généralement réparti le poids sur l'environnement parmi les phases et pourquoi ? », « Quelles phases dominent généralement ? » et « Quels éléments à l'intérieur de chaque phase déterminent l'impact sur l'environnement ? Pour quelle raison ?». La taille importante de l'échantillon utilisé, 21 constructions de fonction, architecture et matériaux différents, donne de la force aux affirmations et constitue la robustesse de ce travail. Effectivement, très rarement un si grand nombre de bâtiments a été comparé dans une même étude et donc sur une base comparable.

Une LCA d'une maison unifamiliale édifiée dans le région zuriquoise (Suisse) a été également menée. Ceci parce que pour le groupe de bâtiments il n'a pas été nécessaire d'inventorier les matériaux de construction ainsi que leur quantité, et parce que le besoin de développer des modèles pour compléter des informations utiles s'est fait sentir. Par exemple des modèles concernant la quantité d'énergie consommée pour le chauffage et

pour l'éclairage pendant la phase d'utilisation, le taux de rénovation et les différentes voies d'élimination du matériel de démolition ont été crées. L'inventaire, qui a permis d'effectuer du travail pratique, a été accompli grâce à des plans architecturaux et à des visites du site. Du fait que cette maison a récemment été rénovée, les questions suivantes ont aussi pu être éclaircies: « De quelle ampleur sont les conséquences de la rénovation sur l'environnement ? », « Quelles phases de la vie du bâtiment sont les plus influencées ? », « Les gains en terme d'énergie sont-ils plus grands que les pertes ? ».

Les résultats générés par l'analyse du groupe de bâtiments ont de manière intéressante mis en évidence l'importance de la phase de rénovation. Cette phase a rarement été prise en considération dans des études précédentes et, si elle l'a été, elle était généralement incluse dans la phase d'utilisation. Cette étude montre que, pour la quasi totalité des bâtiments, la phase à plus fort impact est l'utilisation (responsable de 38-70% de l'impact total), suivie par la rénovation (16-40%). La construction (11-25%) et la démolition viennent après. L'impact de cette dernière est particulièrement petit en comparaison (2-6%). La plus grande tranche de l'impact est clairement causée par le chauffage pendant la phase d'utilisation. Plusieurs facteurs architecturaux et de construction jouent un rôle, en particulier la compacité du bâtiment et la surface occupée par des fenêtres. Le remplacement de matériaux pendant la rénovation, en particulier de métaux, de bois et de produits isolants à démontré être capable d'influencer le score total du bâtiment. Des matériaux présent en faible quantité mais possédant un très grand effet négatif sur l'environnement (par exemple des métaux comme le zinc ou le plomb) jouent aussi un rôle important. Des matériaux présents dans la construction originale contribuent en plus faible partie à l'impact total. Les matériaux critiques résultent être dans ce cas les constituants du squelette du bâtiment, comme l'acier et le bois, et les matériaux d'isolation. Le transport, la démolition et l'énergie nécessaire pour l'éclairage ne jouent qu'un rôle très mineur. Une distinction significative entre les quatre catégories de bâtiments (les maisons unifamiliales, les appartements, les bâtiments de service et ceux de production) n'est pas apparue. Une certaine constance dans les résultats pour la première catégorie a tout de même émergé, mais elle devient de plus en plus faible dans les suivantes et les résultats de plus en plus hétèrogènes. Pour la catégorie des bâtiments de construction, la constance est pratiquement inexistante. Si additionné, l'impact amené par les matériaux se montre égal à celui amené par la consommation d'énergie pour le chauffage. Il est aussi apparu que les appartements sont une solution meilleure du point de vue environnementale que les maisons unifamiliales et ceci d'autant plus si l'unité fonctionnelle considérée est l'habitant et non la surface.

En relation avec la rénovation de la maison unifamiliale, une possibilité de diminuer fortement l'impact sur l'environnement est apparue. Dans le cas étudié, cette intervention a permis une réduction de l'impact de 38%. Les principales phases affectées sont la rénovation et l'utilisation. Du point de vue énergétique, les bénéfices sont douze fois plus grands que les pertes. De plus, la rénovation est, dans une très simple comparaison, légèrement meilleure que la reconstruction.

TABLE OF CONTENTS

1 Introduction

1.1 Background - Environmental impact of the built environment

Buildings are major consumers of energy and natural resources. Furthermore, they generate emissions and diminish landfilling capacities. In 2002 for instance, housing accounted for the consumption of 28% of the 853'670 terajoules of energy exploited in Switzerland (OFEN 2004). Heating and production of hot water in residential housing are responsible for about 60% of the total Swiss combustible consumption, i.e. fuel oil and natural gas. In addition, 32% of the total Swiss electricity utilization is generally utilized by this sector (BFE 2005). However, this reflects only the use phase of the lifecycle of a occupancy house; other types of buildings and the amount of energy required during the production of building materials, construction, maintenance, renovation and disposal of an edifice are not considered. Data on those subjects is more difficult to estimate.

An additional impact on the environment caused by buildings, is natural resources depletion. This could easily be imagined if we picture that in Switzerland, annually, the construction sector is responsible for approximately the consumption of 75 millions of tons of material (BFE 2000), of which the greatest part is virgin material. Every day, 11 hectares of arable land disappear. This means approximately 1.3 square metres each second. Around two thirds of this land, especially on the plateau, become housing and infrastructure areas. Nationally, around 15'000 new housing buildings rise every year. Of them, approximately 75% are single occupancy and 25% apartment houses (OFS 2004). Roughly, 500 new service buildings are also built in this lapse of time (calculated after BFS [1]).

The amount of waste produced by the construction sector is enormous. Roughly half of the land filled waste derives from the building stock (and in general two thirds from the

[1] http://www.bfs.admin.ch/bfs/portal/fr/index/infothek/lexikon/bienvenue___login/blank/zugang_lexikon.Document.21130.html

entire construction sector). In 1997, 11.1 millions tons of construction waste (considering all types of constructions) were generated (BUWAL 2002). Of them an estimated 1.7 millions went finally to landfills, mainly concrete.

Buildings are not the main pollutants emitters. Nevertheless, housing accounts for more than 20% of the SO_2 and CO_2 emissions for Switzerland[2]. Additionally, they are accountable for 10% of the CO, dioxins and furans freed in the country. Once again data considers only the use phase and housing buildings. Emissions here are generated principally by heating systems (oil and wood combustion) or by the illegal combustion of housing waste. To this data should be added emissions caused during construction, disposal and renovation and by other types of buildings.

Important progresses to lower the environmental impact of buildings have been made. Labels such as Minergie and Minergie-P, conceived in the last years, want to bring energy consumption during the building's use phase to more sustainable levels (OFS 2000) are beginning to gain success in the country[3]. Their weakness is, however, that they focus principally on the use phase and on the energy consumption for heating, omitting other important environmental aspects[4].

1.2 Aim of this study

In order to effectively improve the ecological performance of buildings, it is important to know where exactly and why environmental impacts occur. To have an integrated view on the problem and to avoid problem shifting from one stage to the other it is important to take into account the whole life cycle of a building. This can be done by carrying out a Life Cycle Assessment (LCA).

A sufficient large sample of buildings is necessary to make sound statements on their environmental impact. Carrying out a LCA on a building is a time consuming task. This is the reason why in literature no large sample of buildings' LCA is found. Results published are usually not comparable among each other as the bases of the studies are not the same (for example, they use different system boundaries). The particularity of this study resides precisely in the size of the set of elements studied: very rarely, such an

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[2] http://www.umwelt-schweiz.ch/buwal/fr/fachgebiete/fg_luft/quellen/haushalte/
[3] http://www.minergie.ch
[4] A new label, Minergie-eco is going to be launched soon.

elevated number of existing and real buildings has been compared within a unique study and therefore on an equivalent basis.

The goal of this work is to analyse and compare this set of buildings, 20 constructions of different architectural and material characteristics and that have different functions, to specifically assess which life phases and factors require particular attention and consideration during the effort of reducing the environmental impact of this sector.

1.3 Similar studies

There are other studies dealing with the environmental impact caused by buildings during their entire life. The majority of them considers generally one, maximum five buildings. Three different essays, done respectively by Hebel (1995, in Pulli 1998), Blanchard and Reppe (1998) and Dinesen and Traberg-Borup (1994), describe the energy use in single occupancy houses. Hebel, by studying a singular house, found a predominance of the use phase. So did Blanchard and Reppe by examining a house in Michigan. Dinesen and Traberg-Borup analysed the energy flow of three houses with different energy consumption levels. They found a dominance of the use phase as well for the standard and the low-energy consumption houses. On the contrary, for the experimental house, they determined that the biggest burden was carried by the construction phase. Kohler (1994) considered a larger spectrum of impacts for a set of 100 simulated houses. He found a dominance of the use phase for the environmental impacts caused by water and energy consumption, greenhouse effect, the critical air and water volumes, UBP[5], acidification, photochemical oxidation potential and external costs. The refurbishment phase dominated for the waste production and the financial costs. Scholz *et al.* (1995) observed a dominance of the use phase for all the categories considered: radioactivity, abiotic resources consumption, human toxicology, greenhouse effect, ozone layer depletion, ecotoxicology, acidification, eutrophication and photochemical oxidation potential.

In relation to apartment houses, three studies show the impact that these buildings have on the environment. Adalberth (1999) found a dominance of the use phase for global warming potential, acidification, eutrophication, photochemical ozone depletion and human toxicology. The study panel was composed by four houses. Bringolf *et al.* (1997, in Pulli 1998) compared different variants for a double-family house. They found that

[5] Ecological Scarcity (Umwelt Belastung Punkte)

different phases were responsible for different impacts; the use one for energy consumption, the construction for material flow and renovation for the total non-renewable energy and material flow, for ozone depletion, UBP, cleaning and costs. Quack (1998, in Pulli 1998) found a dominance of the renovation phase for UBP, greenhouse effects and waste production in five low-energy consumption houses.

Some studies analysed the impact caused by service buildings, as for example offices. A publication, written by Michiya and Tatsuo (1998), dealt with energy consumption. They found a domination of the use phase but a big variability in results depending on materials and systems used. Junilla (2004) studied a 24’000 m^2 office building finding that the operating electricity caused most of the environmental impact during the life of the buildings for CO_2 emission, acidification, eutrophication and heavy metals emissions. Finally, Sheuer *et al.* (2003), studied a six-story building observing a dominance of the use phase for energy consumption, global warming potential, ozone depletion, acidification, nitrification and solid waste generation. No study was found concerning manufacturing buildings.

1.4 Proceeding

In order to undergo a life cycle assessment data must be collected. A part being already available in the BKI[6] catalogue, inventory was necessary only in one case, as it will be explained hereafter. Other data came from models created ad hoc. With the information gathered and in order to provide a score for the environmental impact of all the stages of the lifecycle, a complete LCA for the 20 buildings was then calculated. The results were the basis to discuss the relevance of the different stages and to identify the critical factors in each one of them.

As it was not necessary to carry out fieldwork on the BKI data, an LCA of a single occupancy house in the region of Zürich (Switzerland) was carried out instead, allowing practical training. The task was accomplished with architectural plans and with site visits. Moreover, it was carried out with the architect on charge. This is rather the “common” way to make an LCA of a building.

[6] The BKI is the the German “centre for construction costs” (Baukosteninformationszentrum Deutscher Architektenkammern).

This field study was aimed firstly at explaining the method and proceeding of an LCA and secondly, to furnish the set with an additional case study. The issue of the different database will be taken into account and discussed. To complete the fieldwork a realistic question was chosen in the discussion of the results. As the case study house recently underwent renovation, the environmental impacts before and after it were assessed.

1.5 Organisation of the study

This work is divided in two parts. In the first (Part A), is more practical and consists of the data collection from the case study house located in Wetzikon (in the canton of Zürich) and its analysis. In the second one (Part B) the set of twenty buildings cited in precedence was analysed and results interpreted.

This work continues the study done by Dr. Christina Seyler (Seyler *et al.* 2004) that focused on the first stage of the life cycle of the same set of buildings, comprehending the production of materials and the building phase.

Part A - Case study: A single occupancy house under renovation

The aim of this section could be expressed as following:

- First; it serves as an example to explain the method and the proceeding of an LCA.
- Second; it allows elaborating and refining models such as the ones allowing to estimate energy consumption for heating and electricity, the refurbishment rate or the disposal paths. These models will be implemented in the second part of this work.
- Third; it allows collecting data of a building that will consequently be added to the set of 20 houses studied successively;
- Forth; it allows to put into practice the theory from literature by means of the selected case study house. As it recently underwent change, the environmental impacts before and after were investigated. Questions concerning the gains and losses from an environmental point of view were settled, in particular: "How big are the consequences of renovation for the environment?", "On which life cycle phases does the renovation show the highest impact?" and "Are the gains in terms of energy bigger than the losses?.

2 Data and method

In the next chapters the following will be discussed:

- The method of LCA, chosen to evaluate the impact of the building on the environment (Chapter 2.1);
- The goals of the LCA in Part A and the definition of the system (Chapter 2.2);
- The Life Cycle Inventory (Chapter 2.3) and the Life Cycle Assessment (Chapter 2.4); two steps which are required to allow the evaluation of the impact.

Thanks to this information, the bases are settled for the analysis of the building.

2.1 Overview of the method of LCA

Life Cycle Assessment (LCA) is a tool developed in order to describe the environmental impact caused by a product "from cradle to grave", meaning that it considers the impacts caused in all the stages of its life cycle, from the extraction of resources until the disposal of waste. This method allows the comparison of different products, allows to outline in which step of an item's life cycle improvement could be achieved and helps to develop new products with smaller impact on the environment.

An LCA can basically be divided into four steps (Figure 2-1). In the first, called "Goals and scope definition", the questions that need to be answered are clarified, the product or service under study is described, the system boundaries are defined, a functional basis for comparison is chosen (the functional unit) and the required level of details, precision and reliability is described (ISO 1997).

This step is followed by the "Inventory of extractions and emissions": for each phase of the product's life cycle information concerning energy and raw material consumption and regarding emissions to atmosphere, water and land will be collected and quantified.

The third stage consists of the impact assessment; the quantification of the effects of the flows mentioned before. Those effects are for example ozone depletion, emissions of global greenhouse gases and so on. Different methods exist that allow quantifying and condensate the results back to only one or a few environmental scores. Those approaches are for example Cumulative Energy Demand (CED) (VDI 1997), Ecological Scarcity 99 (UBP 97) (BUWAL 1998) and Ecoindicator 99 (EI 99) (Goedkoop et Spriensma 1999). Interpretation of the results is performed at all the stages of this assessment method. Ways to reduce the impact of the product are evaluated.

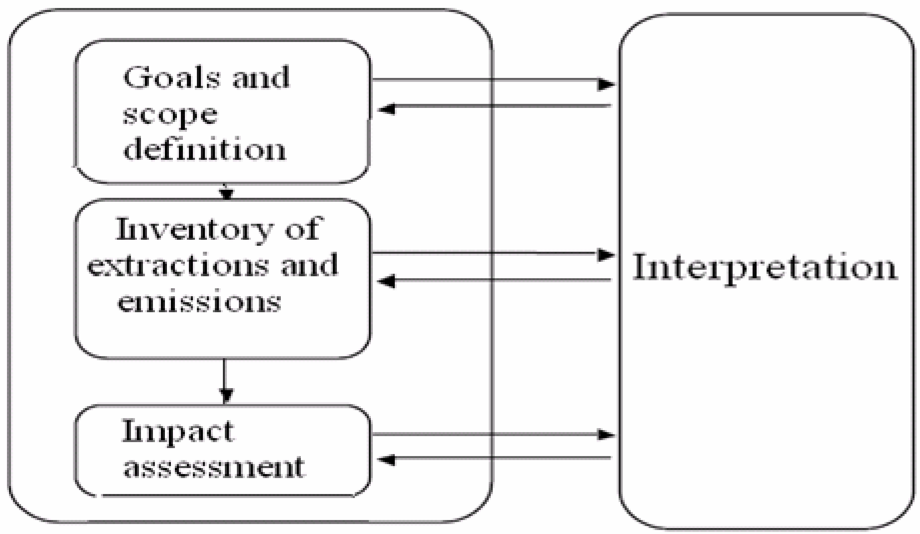

Figure 2-1: Steps of an LCA (after Jolliet et Cretaz 2001, modified).

Life Cycle Assessment has proved to be a valuable tool to evaluate sustainable production and consumption patterns. Its effectiveness has largely been demonstrated (UNEP 1999) and its utilization ranges from a variety of products, between which buildings.

2.2 Goals and scope definition

In this part, the system studied is illustrated, in particular:

- The phases composing the system and its boundaries are delineated (2.2.1);
- The functional unit is settled (2.2.2);
- The assumptions made are described (2.2.3).

2.2.1 The system under study

The system studied is the building during its entire life. This consists of four main phases: the construction, the refurbishment, the use and the disposal. This is illustrated in Figure 2-2, in which also the building boundaries, the internal and the external flows are represented.

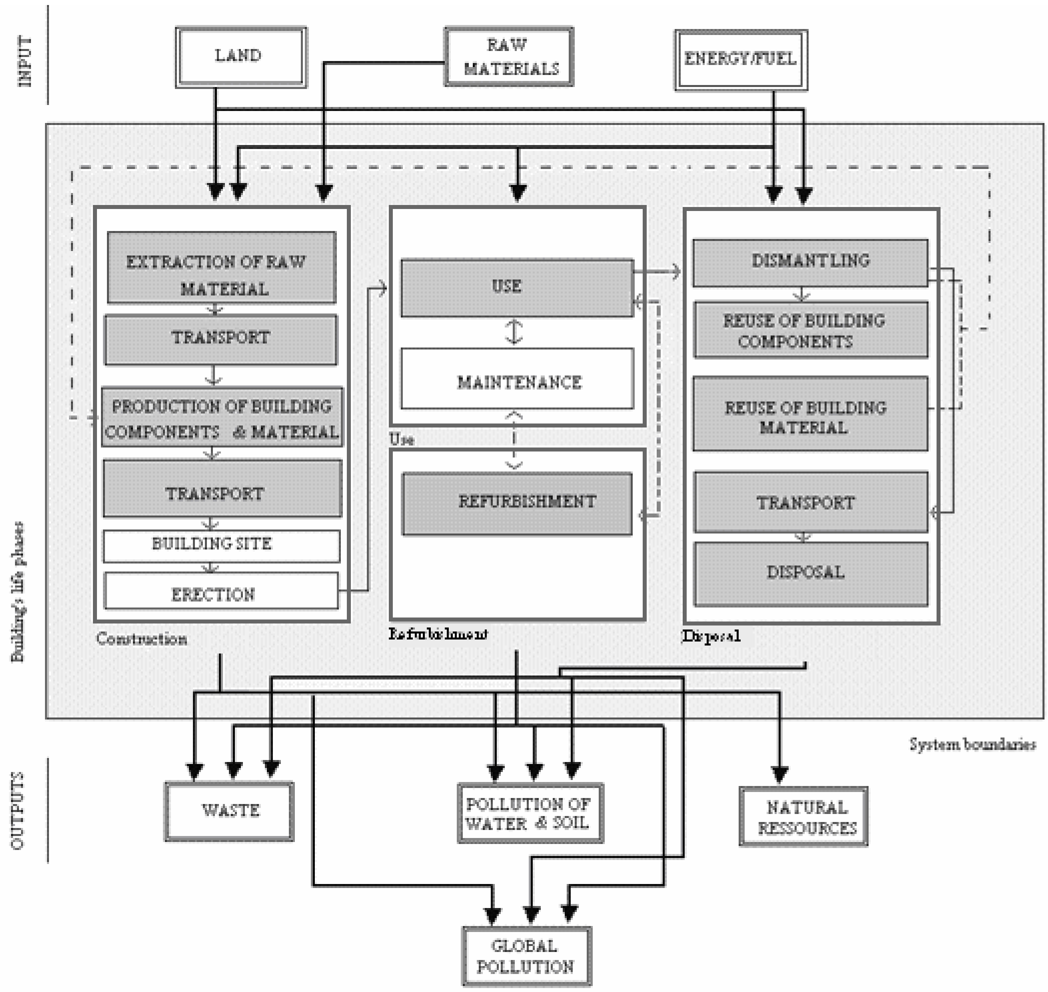

Figure 2-2: The system. In light gray: the system, divided in the four phases (construction, use, refurbishment and disposal). The dull grey inner rectangles represent the processes that are considered. The white ones the ones that are excluded from this study. Lines connect them, dashed lines show different scenarios. The double rectangles represent the inputs and the outputs, the flows are represented with tick arrows.

The **construction** phase includes the extraction of raw material, its transport to the elaboration site, its elaboration and the transport of the finished product to the building site. Losses of construction material are not considered even if for some substances they could reach 10% of the used amount (after GEDEC 2004). In addition, the building site and the erection are not considered. The reason for this exclusion is the assumption that those phases have a relatively little impact on the environment (Kasser et Pöll 1998).

The **use** phase considers the aspects that are strongly linked with the construction characteristics; the use of energy for heating and of electricity for illumination. Because this study focuses on the impact that architectural structures have on the environment, some components, processes and factors that are not related have not been included as for example furniture and electrical appliances. Not included are also all the aspects that strictly depend on inhabitant's behavioural patterns. Therefore, waste produced during use, cleaning materials and energy consumption from other aspects than the ones cited here (as for example cooling and electricity for houseold equipment) are excluded. Also the influence of the inhabitants' behaviour on the amount of heating and electricity consumption has not been taken into account. Indications of their impact for space heating could be found in Haas *et al.* (1998). For simplification, also maintenance was not considered.

The **refurbishment** phase includes materials that are going periodically to replace the ones that need substitution, their transport to and from the house and their disposal.

The **disposal** phase includes the dismantling of the building, the transport of the building material to its following destination and its disposal. The latter can vary depending from the material considered, as illustrated in Chapter 2.3.6.

The **inputs** to the system are the land occupied during the production and the disposal of materials (but not the land occupied by the building), the quantity of raw materials used and the amount of energy and fuel consumed. The **outputs** are the amount of construction waste produced during the life of the building, the pollution of water and soil, the global pollution for example by emissions into air and the depletion of natural resources. In the scheme the flows of those inputs and outputs are illustrated; the life phases touched are designated with thick arrows. Thin arrows indicate the paths linking the processes.

The building is physically delimited by its external walls, its foundations and its roof (after CRB 2000). Therefore, the land on which the propriety lies is not taken into consideration, nor are adjoined constructions.

2.2.2 Definition of the functional unit

The functional unit was chosen in order to allow a comparison between the house before and after renovation, with the German single occupancy house 13EFH presented in Appendix B.1 and with other studies. For this reason, a square meter of gross external floor area (Brutto-Grundfläche, BGF[7]) was chosen and the buildings life span set at 80 years. All the results do consequently refer to a square meter of gross floor area (BGF) on a period of 80 years.

Life expectancy is difficult to determine; a building does not only turn over because of the age of its materials but also and mostly because of evolution of urban plans, changes in lifestyle and the economic situation (BFE 2000). Buildings' lifetimes would be never estimated with precision. For this reason and because this factor could modify significantly the impact of the house (O'Connor 2004), additional life scenarios (lifespan of 50 and 100 years) have been made.

2.2.3 Assumptions

Hereafter, the assumptions made are described in order to provide the study with the required degree of transparency:

- The remote future, in which a big part of the phenomena (as for example the end of life of the building) takes place, is considered to reflect the present situation. Therefore, in the method there are no differences in the future environment compared to the present situation.

In the **construction** phase:

- The building material used has the same characteristic of the average Swiss or European one. Where density or thickness were not at disposition, data found in various literature was used (Appendix A.1);
- Material transport from the production site to the building site was standardized and is represented in Table 2-1. It is considered that lorries do half of the way back empty before being loaded with other materials (after Peuportier 2001). This reflects the standard practice in Europe;

[7] The BGF is the gross external floor area (Brutto Grundfläche) as defined by DIN 277 / 1987. In other parts of the work, this area is definited as GF following the Swiss appellation. Differences range from 0% up to 10%.

Table 2-1: Distances and means of transport of materials from the production to the building site (Lalive d'Epinay 2000).

Materials to the building site	Go	Train [Km]	Lorry 28 t [Km]	Return	Train [Km]	Lorry 28 t [Km]
Concrete (not reinforced), gravel, sand		0	20		0	10
Cement		80	20		0	10
Steel, wood, plastic and other materials		0	100		0	50

- The inputs and outputs during the building site, meant as the excavation of the fundaments and the emissions coming from the machinery during the erection of the building are negligible in comparison to the ones occurring during the rest of the life.

In the **refurbishment** phase:
- Each component is replaced with an identical one.

In the **use** phase:
- No changes in function will occur during the life of the building; from its construction to its disposal it will serve as the same type of house (in this case it will always be a single occupancy house);
- The house is heated at 20°C, it is supposed to be exposed at the same climate as a house in the city of Zürich and has an urban horizon. It is occupied 12 hours per day. On average, a person disposes of 60 m^2 of liveable space and 80 MJ/m^2 of total (lighting plus household appliances) electricity are consumed annually. 0.7 m^3 of air circulate for ventilation per m^2 and per hour;
- Its technical installations are not optimal and not optimally employed. That means that the regulation of the temperature is made manually with thermostatic valves, that the temperature of the radiators is settled at 60°C and the one of the floor heating system at 42°C. Thermal bridges were not considered;
- Electricity supply has different sources; its origins can be hydrological, nuclear, etc. The Swiss mix of year 2000 shown in Appendix A.2 was taken as reference.

In the **disposal** phase:
- When possible, sorting will be done directly on place;
- Dismantling of the house is considered to be done quite roughly. Therefore, a big fraction of materials will be mixed with bricks and cement to create the demolition mix.

2.3 Life Cycle Inventory and models development

The Life Cycle Inventory consists in the collection of data required to perform the life cycle inventory of the house. More precisely, it consists of:

- The inventory of the materials composing the house before and after its renovation. Data was collected about the construction, the refurbishment and the disposal phases (Chapter 2.3.2);

- When data could not be collected, models were developed for the use phase, to establish the refurbishment rate and the disposal paths (Chapters 2.3.4 - 2.3.6).

In the following chapters, the house is described (Chapter 2.3.1), as is a house similar in structure, which was used to validate the inventory (Chapter 2.3.3).

2.3.1 Description of the case study house

The single occupancy house in Wetzikon ($21EFH_{old}$) (Figure 2-3) was built in 1959. In 1967, it underwent a first restructure, consisting mainly of the addition of a new component to the south face. In 2005, new works were undertaken that supplied the house with a better insulation which resulted in a reduction of the energy consumption for heating. A solar collector for the generation of hot water was installed and other structural modifications were also made.

Figure 2-3: The south and the west faces of the single occupancy house during the renovation.

The building is a two-story home with 218 m^2 of floor area and an internal volume of 810 m^3. It has a basement and a tilted roof. As shown in Table 2-2, the main structure is composed by bricks, reinforced concrete and a fraction of wood, all covered in plastic work. The roof is covered by fibre cement corrugated slabs. The interior walls are made of brick, wood, concrete or gypsum cartonboard. The house is heated by light fuel oil, a fireplace is also present.

Table 2-2: The main materials composing the house before renovation and the main modifications done during the renovation.

Components	Before renovation	Modifications with renovation
Ceiling	Reinforced concrete	Plus 6 cm of mineral wool
Ceiling covering	Plaster	
External doors	Wood	
External walls	Reinforced concrete, bricks or wood	Plus 10 cm of Polystyrene
Facade	Old wing: Fibre cement slabs, reinforced concrete, bricks. New wing: bricks, wood, mineral wool, fibre cement slabs and concrete	New wing: fiber cement slabs removed
Floor covering	Parquet, fitted carpet, plastic materials, clay or ceramic tiles	Modifications in some rooms. Mainly plastic materials substituted with parquet
Foundations	Reinforced concrete	
Interior doors	Wood or concrete	
Interior walls	Bricks, wood, concrete or gypsum cartonboard	Modification of the emplacement
Roof	Fibre cement corrugated slabs over a wood and mineral wool structure	Plus insulation layer (synthetic film) and 10 cm of mineral wool
Stairs	Concrete or wood	
Walls covering	Plaster or tapestry	Tapestry removed
Windows	Wood frame, double glass panes. 2.8W/m2K	Glass panes with a U-value of 1.2 W/m^2K

In Table 2-2 the main modifications done in 2005 are shown. The renovation consisted mainly of attaching a 10 centimetres layer of Polystyrene to the external walls, in furnishing the pavement over the underground floor with 6 centimetres and the parapet of 10 centimetres of mineral wool and in adding an insulating layer at the roof structure. Moreover, the ancient windows, constituted of double glass panes located in wood frames with a U-value of approximately 2.8W/m^2K were substituted with better performing ones, IV- glass panes with a U-value of 1.2 W/m^2K. Further works were the closure of the balcony, also difficult to insolate, and the installation of solar panes for warm water generation.

2.3.2 Data collection for the Life Cycle Inventory

Because the method that was used for the inventory of the set of 20 buildings shown in Chapter 5.2.2 could not be applied, other methods had to be developped. The **materials** and their amounts were therefore retraced from the available plans. For each component of the house, its composition was retraced. The volumes and surfaces of materials can consequently be calculated. The passage to masses was performed with standard densities presented in Appendix A.1. The inventory being undertaken during the renovation period, some components were visible and more easily determined in case of doubts. Contacts with the architect responsible of the works allowed discussions and consultations.

2.3.3 Description of the reference house

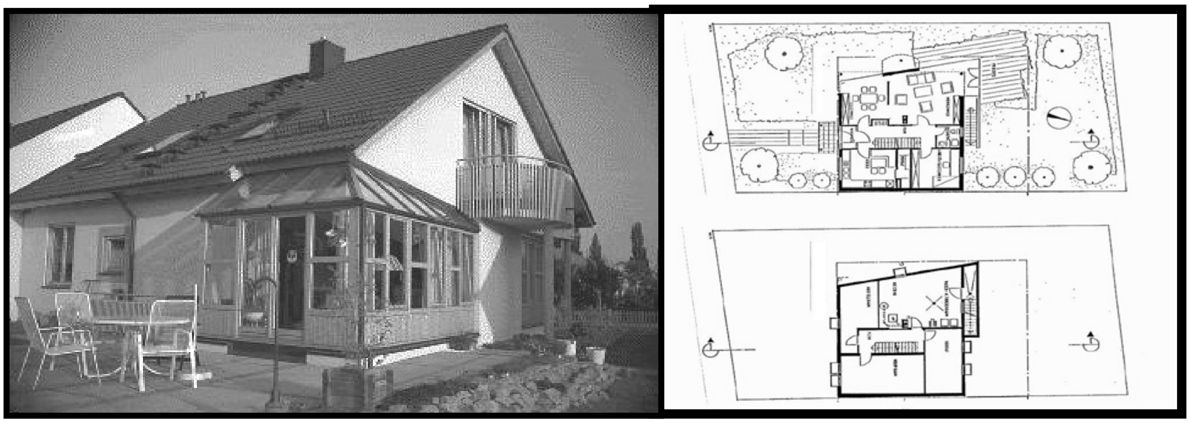

Figure 2-4: House 13EFH; picture and plans (after BKI 2003).

In order to validate the inventory, the results obtained for house 21EFH before its renovation ($21EFH_{old}$) were compared with the ones of a BKI house similar in structure (BKI 2003). House 13EFH (Figure 2-4) was chosen because of its architectural and composition similarities with the case study object. As shown in Table 2-3, their constructed spaces differ only two square metres, their liveable spaces 13 square metres and their volumes only 79 cubic metres. Both have a basement, reinforced concrete foundations and two additional floors, of which the second is directly under roof. Their composition differs by the roof covering (fibre cement corrugated slabs against concrete slabs), the walls (reinforced concrete and bricks against various types of concrete and concrete blocks), and the interior walls (different materials in the one, mainly light concrete in the other). Also the amount of insulation materials varies considerably, the first house ($21EFH_{old}$) lacking greatly of such components.

Table 2-3: Comparison between the characteristics of the single occupancy house in Wetzikon and the German single occupancy house 13EFH.

	Single occupancy house in Wetzikon	Single occupancy house (13EFH)
Constructed space	111 m^2	113 m^3
Liveable space	218 m^2	205 m^2
Internal volume	810 m^3	889 m^3
Floors	A basement, a first floor and a second one directly under the roof	A basement, a first floor and a second one directly under the roof
Roof	Fibre cement corrugated slabs over a wood and mineral wool structure	Concrete slabs over a wood and expanded polystyrene structure
Foundations	Reinforced concrete	Reinforced concrete
Walls	Reinforced concrete, bricks or wood	Concrete, light concrete and concrete blocks
Interior walls	Reinforced concrete, brick, wood or gypsum cartonboard	Light concrete

2.3.4 Heating and lighting models

Some data must be modelled because either impossible to collect (heating, electricity and refurbishment rate) or taking place in the future (disposal paths). Therefore, models were assessed. Data for energy consumption was calculated following the SIA standards (SIA norms 380/1 for heating (SIA 2001) and 380/4 for electricity consumption (SIA 1996)) and can be regarded as the consumption of "average" occupants.

Energy consumption for **heating** during the use phase was calculated with EnerCAD 2004 (CUEPE 2004). A literature review was done to find suitable models but they generally appeared too rough or too old (Kohler 1986, Schweizer Energiefachbuch 2003, OFEN 2004). This software, on the contrary, appeared to be very good. The following parameters are needed:

- Energy-related floor area (m^2 of EFA[8]);
- Location of the building;
- Horizon;
- Kind of building (single occupancy house, office, etc);
- Category of building's weight (from light to very heavy);
- Kind of technical installations (optimal, non-optimal);

[8] The Energy-related Floor Area as defined in SIA 180/4 (1982).

- Surface, orientation, U-value and type of walls, roofs, windows and floors.

The program's output is the annual energy flow for the building.

Electricity consumption for **lighting** during the use phase was calculated considering the subdivision of the house in its main function area (Nutzfläche, NF), the circulation area (Verkehrsfläche, VF) and the ancillary area for services (Funktionsfläche, FF). Each of those areas possesses a SIA 380/4 value pro square metre, as illustrated in Table 2-4. Their multiplication to the respective surfaces, addition and adjustment to the net floor area gave the final value.

Table 2-4: Calculation of energy consumption for lighting.

House			Electricity consumption		
			NF	VF	FF
			[MJ/m²BGFy]	[MJ/m²BGFy]	[MJ/m²BGFy]
21	EFH	Single occupancy houses	60	10	25

2.3.5 Refurbishment model

Materials have different lifespans and require recurring substitution. The frequency of the replacement vary between materials for many reasons and is therefore difficult to estimate. Lists exist in which indications are given, as for example the one published by the AFB, the Swiss Office for Federal Construction Facilities (1997).

Data for the **refurbishment** rate was calculated considering only the house and the materials' lifespan, without considering changing in esthetical or economical aspects. Two models were available. The first one (M I) consideres that elements will be replaced after a period corresponding to their lifespan (AFB 1997). The second one (M II, established in the frame of this study), considers that renovation takes place by steps and that an element can be replaced prematurely if this allows to substitute more elements at the same time. After having tested the two models, the second one was chosen because considered more realistic. The refurbishment, as a result, is considered to take into consideration the interdependence of assemblies that are located in the same structure. That means that if, for example, the life expectancy of a glass pane is 30 years and the one of the wood frame of 25 years, both of them would be replaced after 25 years. This is shown in Table 2-5. Moreover, where possible refurbishment works are grouped; for example the entire roof will be renovated at the same time.

Table 2-5: Refurbishment periods for different components of the building.

Material	Lifespan (M II) [years]	Changing ratio (M I) [years]	Location	Material	Lifespan (M II) [years]	Changing ratio (M I) [years]	Location
Brick	80	80	Structure	Mineral wool	35	35	Walls
Brick, not hollow	80	80	Structure	Moisture barrier	35	35	Roof
Cellular concrete	80	80	Structure	Parquet	40	30	Floor and wall covering **
Cement layer, floor	80	80	Structure	Plaster	35	35	Walls
Ceramic tile	30	30	Floor and wall covering	Polystyrene	35	35	Walls
Clay tile, floor	40	30	Floor and wall covering	Reinforced concrete P175	80	80	Structure
Concrete	80	80	Structure	Reinforced concrete P250	80	80	Structure
Cork	35	35	Walls I	Reinforced concrete P300	80	80	Structure
Detritus	80	80	Structure	Synthetic film, under roof (Isoroof)	35	35	Roof
Fibre cement Corrugated slab	35	35	Roof	Synthetic material (Sucoflex)	35	30	Floor and wall covering
Fibre cement facing tile	45	35	Walls	Synthetic material (Super Walton)	35	30	Floor and wall covering
Fibreboard (Pavatex)	35	35	Walls	Tapestry	15	15	Walls
Fitted carpet	10	10	Floor and wall covering	Wood	30	35*	Various
Glass pane	30	25	Windows	Wood, hardwood	30	30	Various
Gypsum carton Board	40	35	Walls	Wood, softwood	30	30	Various
Insulation, floor	35	30	Floor and wall covering	Wood, window frame	25	25	Windows

* Added five years to the lifespan given in AFB (1997)

** Changed with the other wood components

2.3.6 Disposal model

Materials at the end of their life could follow different disposal paths. However, because for a long time this phase of the life of a building was ignored, only few models are available. On top of that, they are often still rough. The method created by Doka (2003) was finally chosen because referring to the Swiss context and being the most commonly used. However, it still has several imperfections. For example, a big quantity of materials are not yet inventoried. This model consists in the life cycle assessment of the disposal of various common building materials in Switzerland. It heeds energy consumption as well as directly or indirectly emitted pollutants and valuates the consequent impact generated on the environment (Doka 2003). As illustrated hereafter, for each material it consents to choose between three different disposal paths, without however saying which one has generally to be chosen. Consequently, a choice of allocation for the materials' disposal needed to be made.

Disposal paths for materials follow the method developed by Doka (2000) and implemented in ECOINVENT (Doka 2003), which is the most compete public source of data available for the evaluation of the impact of materials and energy sources on the environment (Frischknecht 1995). The scenario is particularly complex. It consists of a description of the dismantling of the building and the different paths the produced waste can follow: direct recycling, recycling after sorting and disposal after recycling. As shown in Figure 2-5, direct recycling (A) is made on site. Only dismantling burdens, consisting of energy consumption and emissions, are taken into account. The transport of the recycled material out of the site is not considered in the system. Therefore, no energy is used and emission made during the dismantling, so the impact is regarded as not-existing. The second path is recycling after sorting (B). This option applies to the building materials that cannot be separated at the building site because they are part of a mix. The result of the sorting can lead to recycling or disposal. The model takes the transport to the sorting plant and to the final disposal into account. As it does with the sorting process and the impact caused by the final disposal. The last path consists in disposal without recycling (C). This applies to all the materials for which recycling is not possible or not yet common practice. The transport to final disposal is considered, and so are the impacts caused by the landfilling or the incineration of the materials.

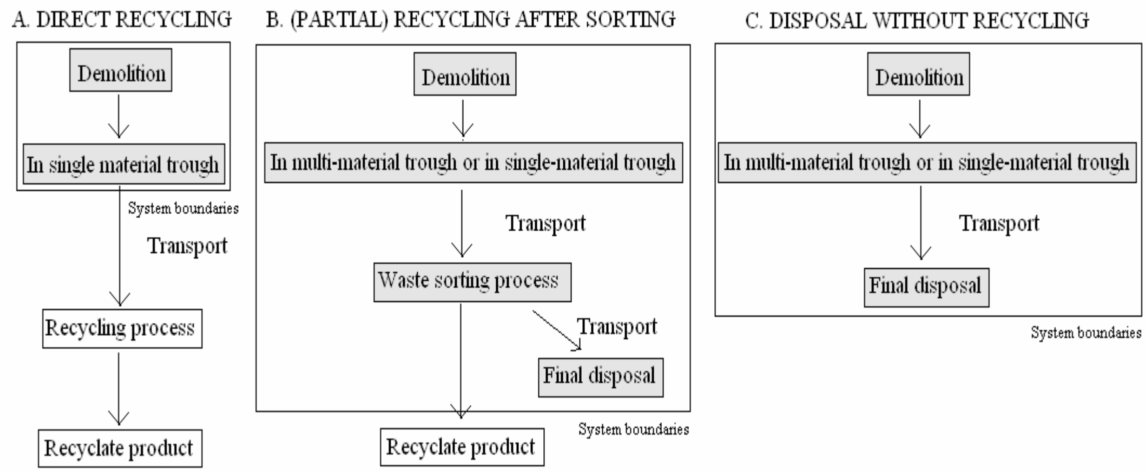

Figure 2-5: System boundaries of the three types of disposal options. All the processes included in the big rectangles are included in the inventory of the building material disposal. Processes outside them must be attributed to the recycled product (cut-off method) (after Doka 2003).

Concerning allocation for the disposal, no bonus or burden compensation is given for recycled material (Doka 2003 after Frischknecht et Faist Emmenegger 2003). Moreover, no partial allocation of burdens from recycling process to the old and the new products is made. Some further considerations can be done:

- Normally, if the size of the building and the location are big enough, sorting will be done directly on place, by using different buckets for the different families of materials (GEDEC 2004b);
- Dismantling of the house can be done quite roughly, in which case a big fraction of materials will be mixed with bricks and cement (demolition mix), or meticulously and then tapestry, plaster plates, etc are sorted separately. Here generally the first scenario was taken;
- Some materials can be recycled if still clean. For example, mineral wool derived from constructing rests is recycled. Because here soiled material is considered, it goes directly to incineration or final disposal. Moreover, because often materials are linked together, it appends that some of them do not follow the way they should. For instance, foam glass when linked with bitumen gets to final disposal even if recycling is possible;
- The building's waste will be treated as the present average building waste in Switzerland is. Suppositions refer to CFS (1990) and GEDEC (2004a). They are shown in Table 2-6;

Table 2-6: Choice of allocation for the materials' disposal.

Materials	To direct recycling	To sorting plant	To final disposal	To municipal incineration	Material	To direct recycling	To sorting plant	To final disposal	To municipal incineration
Brick	X				Mineral wool			X	
Brick, not hollow	X				Moisture barrier				X
Cellular concrete	X				Parquet		X		
Cement layer, floor	X				Plaster	X			
Ceramic tile			X		Polystyrene				X
Clay tile, floor			X		Reinforced concrete P175		X		
Concrete	X				Reinforced concrete P250		X		
Cork		X			Reinforced concrete P300		X		
Detritus	X				Synthetic film, under roof (Isoroof)				X
Fibre cement corrugated Slab (cement asbestos)			X		Synthetic material (Sucoflex)				X
Fibre cement facing tile (cement asbestos)			X		Synthetic material (Super Walton)				X
Fibreboard (Pavatex)			X		Tapestry	X			
Fitted carpet				X	Wood		X		
Glass pane			X		Wood, hardwood		X		
Gypsum carton board			X		Wood, softwood		X		
Insulation, floor			X		Wood, window frame			X	

- The materials' transport to the disposal facilities should recreate the actual situation in Switzerland and was standardized as following (Table 2-7):

Table 2-7: Standard distances for transport to disposal facilities (Doka 2003).

Disposal facilities	Lorry [Km]
Inert material landfill	15
Sanitary landfill	10
Municipal waste incineration	10
Hazardous waste incineration	50

2.4 Life Cycle Impact Assessment

The Life Cycle Impact assessment was undertaken following the European methodology REGENER (REGENER 1997) and the ISO 14040 standards (ISO 1997). It also used the data set ECOINVENT of the Swiss Federal Institute of Technology (2004). Calculations were made on Microsoft Office Excel 2003 (© Microsoft Corporation).

Before assessing the impact of each material and process, data obtained from the inventory needed to be matched to the catalogue of their emissions of pollutants and extraction of natural resources. For this, ECOINVENT v 1.1 (Swiss Centre for Life Cycle Inventories 2004) was used. The method is explained in Chapter 2.4.1. In the following chapter (Chapter 2.4.2) the impact assessment methods retained are shortly described.

2.4.1 Background to the Life Cycle Impact Assessment

The Life Cycle Assessment was completed with the help of ECOINVENT v 1.1, a presentation of this database can be found in Frischknecht et Jungbluth (2004).

Figure 2-6 shows the materials and processes in the house, which were inventoried with help of the developed methods. In the next step, a corresponding object was found in the ECOINVENT database which allowed to attribute a complete list of emissions of pollutants and extractions of natural resources to the inventory list. This was repeated with the different impact assessment methods, which weigh it up and evaluate the relative magnitude of each emission and extraction by giving a score to it. By finally assembling all the obtained scores, it is possible to evaluate the total impact of the house differentiated to its life phases.

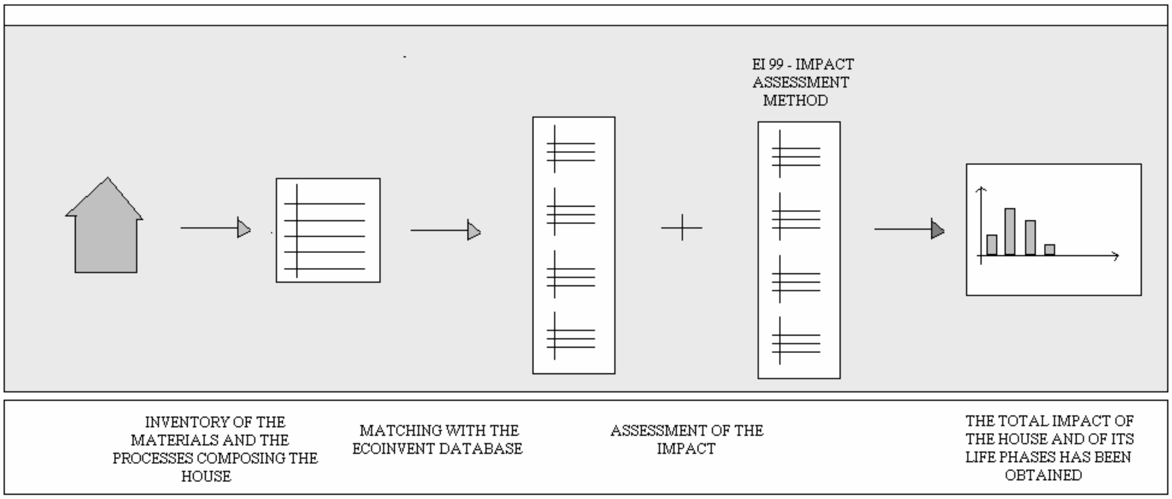

Figure 2-6: Background and the Life Cycle Assessment.

2.4.2 Impact assessment methods

Impact assessment methods weigh up and evaluate the relative magnitude of each emission and extraction by giving a score to it. By doing this, they allow comparison of the results that are not directly comparable. Examples of impact assessment methods are Cumulative Energy Demand (VDI 1997), Ecoindicator 99 (Goedkoop et Spriensma 1999) and Ecological Scarcity (BUWAL 1998). These methods include emissions into the atmosphere, soil and groundwater and the use of non-energetic resources such as for example metal ores.

The aim of the **Cumulative Energy Demand (CED)** method is to calculate the total primary energy input for the generation of a product, taking into account the pertinent front-end process chains (Röhrlich *et al*. 2000). It divides the results, expressed in MJ equivalents, in five categories of primary energy resources: biomass, fossil, nuclear, water and one category containing wind, solar and geothermal resources. More information can be found in VDI (1997).

The **Ecoindicator 99 (EI 99)** is a damage oriented impact assessment method for LCA. For each product, emissions are aggregated in several impact factors (acidification and eutrophication, ecotoxicity, ozone layer depletion, etc) using the best available scientific knowledge. Those are then combined in three main damage categories (human health, ecosystem quality and resources) basing on the "distance to the target" principle[9] and then aggregated to give a final single value. Because the aggregation of the three damage categories does not arise from a scientific base but from a more subjective point of view, three kind of perspectives giving different weight to each of the three category have been created: the EE (egalitarian), the HA (hierarchical) and the II (individualist). In this study only the HA perspective, the more commonly used, is considered and in order to keep the best degree of transparency possible, it should be avoided to present the results in the most aggregated form. A complete explanation of the method is presented in Goedkoop et Spriensma (1999).

The method of **Ecological Scarcity (**Umwelt Belastung Punkte, **UBP)**, developed by BUWAL, allows a comparative weighting and aggregation of various environmental interventions (different emissions into air, water and top soil/ groundwater as well as the use of energy resources) by use of eco-factors; as the Ecoindicator 99 does. A distance to the target approach was chosen to characterize the weighting factors. By comparing between the actual situation (the current flow) and the tolerable burden limit (the critical flows), set in the Swiss environment policy. More information can be found in BUWAL (1998) and in Doka (2000).

It is interesting to consider several impact methods: each one gives different weights to different factors and therefore allows observing the problem from different perspectives. For example, in the CED all the impacts are energy related, other factors as heavy metals pollution do not appear. Their impact however is particularly highlighted in the UBP method.

3 Results

Results are divided into two sections:

- In the first, results concerning the inventory are presented and validated by comparing them with the inventory of a BKI house similar in structure (Chapter 3.1).
- In the second, positive and negative effects of renovation are illustrated (Chapter 3.2).

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[9] The distance to target principle is based on the difference between the total impact in a specific area and the target value.

Only results concerning renovation are discussed, the analysis of the different life phases will be examined in Part B.

3.1 Life Cycle Inventory

3.1.1 Collected and calculated data for the inventory

32 **materials** were found and inventoried. In the following table their amount before and after the renovation is presented, given in volumes or surfaces.

Table 3-8: Volume or surface of the materials composing house 21EFH before and after its renovation, with indication of the difference.

	Before		After		Difference	
Brick	41	m^3	41	m^3	0	m^3
Brick, not hollow	14	m^3	14	m^3	0	m^3
Cellular concrete	4	m^3	4	m^3	0	m^3
Cement layer, floor	1	m^3	1	m^3	0	m^3
Ceramic tile	108	m^2	109	m^2	1	m^2
Clay tile, floor	35	m^2	34	m^2	-1	m^2
Concrete	0	m^3	0	m^3	0	m^3
Cork	1	m^3	1	m^3	0	m^3
Detritus	13	m^3	13	m^3	0	m^3
Fibre cement corrugated slab (cement asbestos)	160	m^2	160	m^2	0	m^2
Fibre cement facing tile (cement asbestos)	61	m^2	31	m^2	-30	m^2
Fibreboard (Pavatex)	1	m^3	0	m^3	-1	m^3
Fitted carpet	26	m^2	0	m^2	-26	m^2
Glass pane	37	m^2	39	m^2	2	m^2
Gypsum carton board	1	m^3	3	m^3	2	m^3
Insulation, floor	3	m^3	3	m^3	0	m^3
Mineral wool	10	m^3	33	m^3	23	m^3
Moisture barrier	0	m^2	105	m^2	105	m^2
Parquet	62	m^2	87	m^2	25	m^2
Plaster	11	m^3	12	m^3	1	m^3
Polystyrene	0	m^3	18	m^3	18	m^3
Reinforced concrete P175	21	m^3	21	m^3	0	m^3
Reinforced concrete P250	25	m^3	25	m^3	0	m^3
Reinforced concrete P300	51	m^3	51	m^3	0	m^3
Synthetic film, under roof (Isoroof)	0	m^2	3	m^2	3	m^2

	Before		After		Difference	
Synthetic material (Sucoflex)	0	m^3	0	m^3	0	m^3
Synthetic material (Super Walton)	40	m^2	40	m^2	0	m^2
Tapestry	147	m^2	0	m^2	-147	m^2
Wood	30	m^2	30	m^2	0	m^2
Wood, hardwood	0	m^3	0	m^3	0	m^3
Wood, softwood	12	m^3	12	m^3	0	m^3
Wood, window frame	16	m^2	17	m^2	1	m^2

Two main differences concerning the material's amount appear with the renovation of the house. This is shown in Table 3-9, where only the materials that undergo change in their amount are presented, ordered by their relative change. The first dissimilarity can be found in insulation substances: there is an adding of 23 m^3 of mineral wool, of 18 m^3 of polystyrene and a certain amount of other insulating materials. The second is the absence of cement asbestos facing tiles on the external walls of the house. Other differences come from the modification of the internal spaces and the consequent creation and removal of walls, floor and wall coverings.

Table 3-9: Materials' surfaces and volumes that have undergone a modification during the renovation of the house, with indication of the difference and the percentage between them.

	Volume – Before		Volume - After		Difference *	
Mineral wool	10.1	m^3	33.1	m^3	2.8	%
Polystyrene	0.0	m^3	17.6	m^3	2.2	%
Plaster	10.6	m^3	12.4	m^3	0.2	%
Gypsum carton board	1.4	m^3	2.8	m^3	0.2	%
Parquet	0.6	m^3	0.9	m^3	0.0	%
Moisture barrier	0.0	m^3	0.1	m^3	0.0	%
Synthetic film, under roof (Isoroof)	0.0	m^3	<0.1	m^3	<0.1	%
Wood, window frame	0.3	m^3	0.3	m^3	<0.1	%
Glass pane	0.6	m^3	0.6	m^3	<0.1	%
Ceramic tile	0.7	m^3	0.7	m^3	<0.1	%
Clay tile, floor	0.7	m^3	0.7	m^3	< -0.1	%
Fitted carpet	0.0	m^3	0.0	m^3	< -0.1	%
Tapestry	0.2	m^3	0.0	m^3	< -0.1	%
Fibre cement facing tile (cement asbestos)	0.3	m^3	0.2	m^3	< -0.1	%

* of the total volume before renovation (810 m^3)

Energy consumption for **heating,** calculated with EnerCAD 2004, is shown in Figure 3-7. The total energy flow before renovation is 809 MJ/m^2 EFA. 81%, or 652 MJ/m^2, of the incoming flow is brought by heating. A minor part comes from solar heat (11%) and from internal heat (7%) produced for example from houseold equipment and lighting. The walls account for the biggest losses (36%); followed by windows (25%), the ceiling (20%), the roof (10%) and the ventilation (9%). After renovation, the total flow decreases to 350 MJ/m^2. 242 MJ/m^2 (69%) of the in coming flow is brought by heating, 16% by internal heat and 15% by solar heat. Also the outflows are modified: windows become the component causing the biggest losses (35%), followed by ventilation (21%), walls (20%), the ceiling (16%) and the roof (9%). With the renovation, heating needs diminish by almost 1/3.

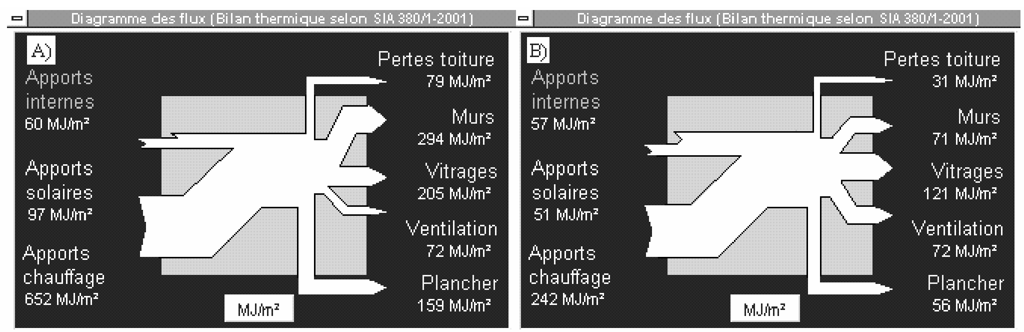


Figure 3-7: Energy flow for the house before A) and after B) renovation.

Electricity consumption for **lighting** during the use phase was found at 60.3 MJ/m^{2}NGF[10]y. Because NF (the main area), VF (the circulation one) and FF (thet ancillary area for services) surfaces do not change substantially with refurbishment, electricity consumption after renovation remains the same.

3.1.2 Validation of the inventory - Comparison with a house similar in structure

In order to test the validity of the inventory, the list of materials inventoried for the house before renovation was compared with the one of house 13EFH. This house, from the BKI set, is particularly similar in structure.

Materials were aggregated in order to form comparable classes between the two lists. For example, all the flooring materials (parquet, tiles, etc) were grouped in a class, even if they are different in thicknesses and density.

[10] The NGF is the net floor area (Netto Grundfläche) as defined in DIN 277 / 1987 (2000).

The comparison, presented in Table 3-10, shows a good equivalence for materials forming the principal structure of the houses. That means concrete taken singularly, bricks, concrete and light concrete summed, glass panes, plaster and in a certain measure steel appear in comparable mesure between the two houses.

Table 3-10: Masses of the main materials composing the single occupancy houses $21EFH_{old}$ and 13EFH.

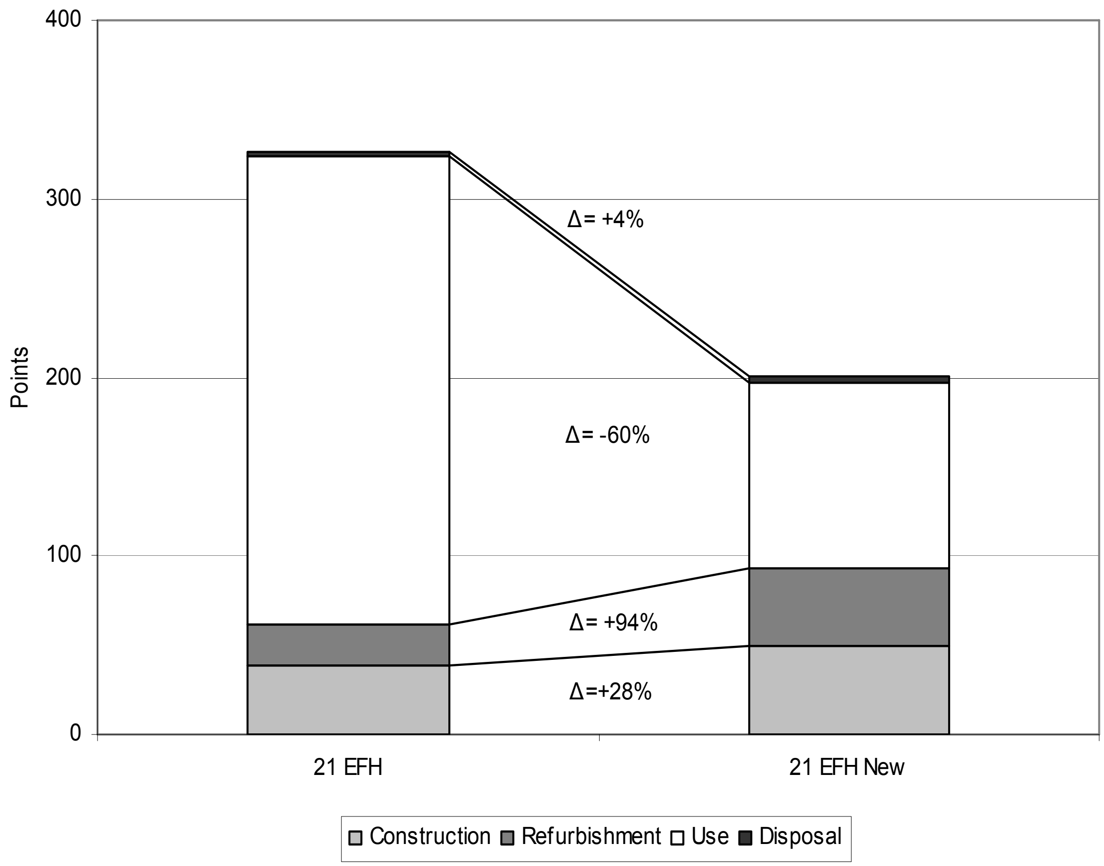
	$21EFH_{old}$		13EFH	
Concrete and concrete block	227197	Kg	220187	Kg
Light concrete	0	Kg	58759	Kg
Plaster	22248	Kg	25786	Kg
Wood	7064	Kg	23345	Kg
Cement	3055	Kg	20114	Kg
Steel	5152	Kg	8381	Kg
Roof slabs	1539	Kg	4383	Kg
Glass pane	1492	Kg	1409	Kg
Brick	72611	Kg	1242	Kg
Flooring materials *	3129	Kg	1066	Kg
Copper	0	Kg	897	Kg
Insulating block	5756	Kg	626	Kg
Natural stone	0	Kg	556	Kg
Gypsum carton board	1363	Kg	307	Kg
Insulating sheet	0	Kg	131	Kg
Bitumen	0	Kg	108	Kg
Aluminium	0	Kg	33	Kg
Brass	0	Kg	11	Kg
Facing tiles	549	Kg	0	Kg
Cork	97	Kg	0	Kg
Concrete, light concrete and bricks summed	299809	Kg	280188	Kg

* Synthetic materials, parquet, tiles and fitted carpet

3.2 Environmental impact of renovation

The inventory of materials and processes of the house before and after its renovation allowed observing advantages and disadvantages brought by it. As illustrated in Figure 3-8; the total impact of the house decreases by 125 EI 99 points, shifting from 326 to 201 points (Appendix C.1). The relative importance for the construction phase changes from 12% to 25% (+11 points), for the refurbishment from 7% to 22% (+ 21 points), for the use from 80% to 52% (-158 points) and for the disposal from 1% to 2% (+<1 points). This corresponds to an increase of 28% of the construction phase, of 94% of the refurbishment phase and respectively a reduction of 60% and an augmentation of 4% for the use and the disposal phases.

A)



B)

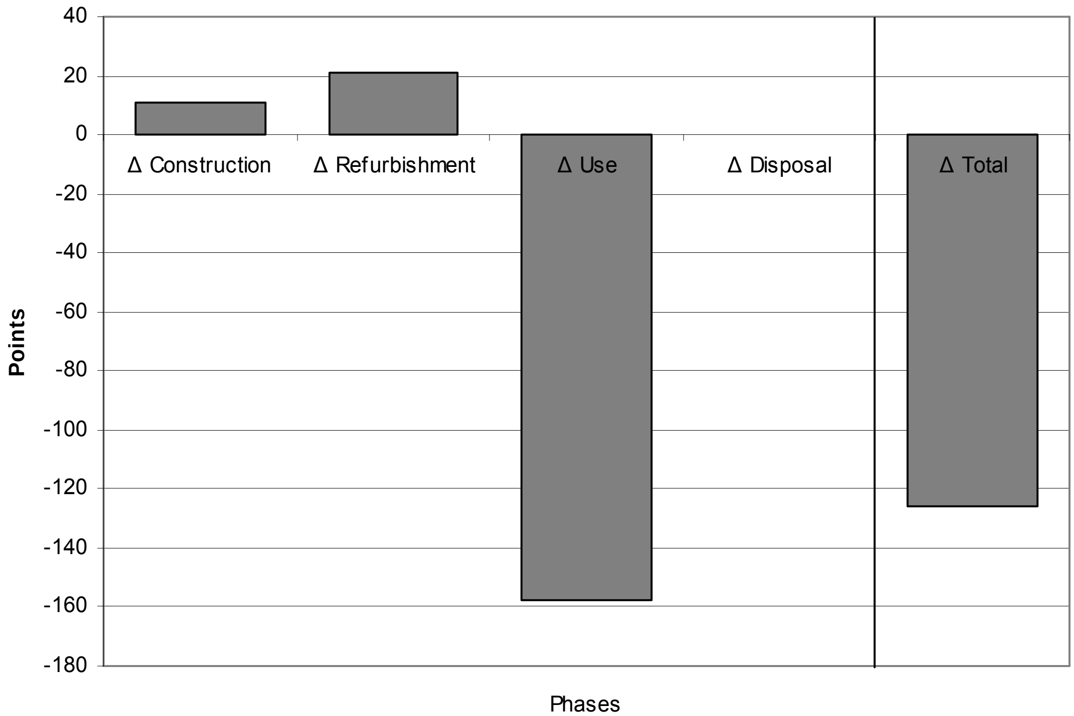


Figure 3-8: Comparison of the impact of the house before ($21EFH_{old}$) and after ($21EFH_{new}$) its renovation, with separation between life phases and indication of the variation of their impact A). Variations of the impact of each life phase and of the total impact of the house given in EI 99 points B).

From an energetic point of view, gains from the renovation are importantly higher than losses, as shown in the figure below (Figure 3-9). Results are presented in MJ equivalents of non-renewable energy (CED- non renewable) and concern the whole life of the building. The score shifts from 39’092 to 3’395 MJ equivalents, corresponding to a reduction of 91%.

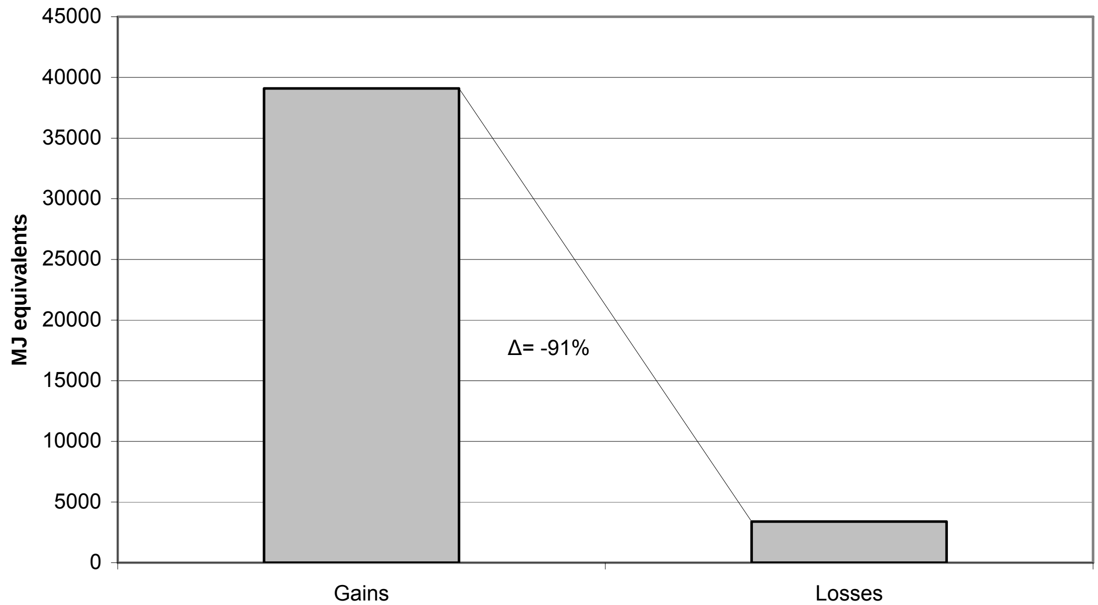


Figure 3-9: Non renewable energy resources (CED fossil and nuclear) savings brought by renovation (Gains) versus the amount of primary energy needed for the production, transport, refurbishment and disposal of insulating materials (Losses).

Insulation helped to reduce energy losses in particular from the walls (-223 MJ/m^2EFAy), the windows (-84 MJ/m^2EFAy) and the roof (-48 MJ/m^2EFAy). Where, on the other hand, it had not been possible to reduce losses by ventilation (which continues to be done manually and without control) and the floor, which could not be insulated properly due to a lack of vertical space. The contribution of fuel oil to the overall heating of the house (considering the contributions of the sun, of people and of electrical equipments as well) changes from 80.6% to 69.2% (Figure 3-7).

Further EI 99 impacts arising from insulation materials (as for example ecotoxicity, emission into water and ozone layer depletion) and their balancing with the benefits brought by energy savings are shown in Appendix C.2.

4 Discussion

In the following discussion, two thematic were treated:

- In the first part the qualitative aspects of the inventory (Chapter 4.1);
- In the second one, the quantitative effects of renovation. Chapter 4.2 looks for an answer to the posed questions. In Chapter 4.3, the characteristics of the house were analysed in order to determine further improvements if possible. In Chapter 4.4 it was analysed whether it were more advisable to renovate a house or to reconstruct it.

4.1 Discussion about the inventory

The aim of the inventory was to collect data on the materials composition of the house. Thanks to the available plans, to visits on site and to contact with the architect, this could be achieved successfully. Moreover, data about the energy consumption of both heating and electricity could be assessed with the help of models and programs. EnerCAD appeared necessary for the estimation of energy needs for heating because simple models lacked the required precision. Results can be regarded as complete; all the information necessary to undertake the LCA was gathered successfully. They are to be considered reliable, as the comparison with house 13EFH shows.

The houses are very similar in the amount of materials of the principal structure of the house as concrete, bricks and lightweight concrete if summed, concrete taken singularly, glass panes and plaster. Other factors permit to confirm the validity of the inventory. One of those is the total heaviness of the houses. House 13EFH weights approximately 367 tonnes; house $21EFH_{old}$ 373 tonnes (without considering the detritus under foundations). Also the number of materials listed can give a rough indication of the good practise of the inventory. House 13EFH is composed of 31 materials, the house in Wetzikon of 32. It is important to note that walls in 13EFH are not made of bricks, but of lightweight concrete blocks (Appendix B.1). The similar density (1600 Kg/m^3 for both materials) can explain the resemblance between the total amounts of those materials.

The quantity of window glass panes is fairly similar (on approximately a ton of materials employed there are only 83 kilograms of difference), this reflects the similitude in the surface occupied by windows (15%) and the fact that both houses have double glass panels.

Dissimilarity appears in secondary materials; as for example aluminium, copper and bitumen. The difference probably has diverse origins; some materials were not present because replaced by others with the same function (gypsum carton board replaced by brick in the internal walls) or being simply a particularity of the house (like the facing tiles, the natural stone or the cork plates). Others, present in a small quantity (as for example bitumen and aluminium), were perhaps present but not inventoried for the reason that they were not noted on plans and they were not directly visible.

Some odd data can nevertheless be discussed: there is a difference in weight for the roof slabs. This can partially be explained by their diversity in thickness and partially by the diverse density of materials used. A certain difference in the quantity of wood is also noticeable. This can result from the fact that in this study a density of 500 kg/m^3 was used for softwood. In the BKI inventory, density of wood is fixed at 720 kg/m^3. For an uncertainty discussion, proceed to Chapter 8.1.

4.2 Discussion about the impact of renovation

The following questions relate to the consequencesof the renovation:

- How big are the consequences on the environment?;
- Which life phases are the most influenced?;
- Are the gains in terms of energy bigger than the losses?.

The obtained results can be considered complete; data could be gathered thanks also to the utilisation of models and programs. As explained in Chapter 4.2; results can be regarded as reliable.

Renovation does have big consequences on the house's burdens on the environment. Thanks to the renovation works, the total impact of the house on the environment was reduced by one third. The principal phases affected were the refurbishment (+94%) and the use (-60%) ones. The first impact roughly doubles, the second one diminishes by two thirds. Differences for construction and disposal are not so consequent. If analysed as a whole, it is clearly the predominant use phase that faced the biggest change. So even if for the construction, the refurbishment and the disposal phases the balance is yet negative, benefits brought by this phase are so large that the final balance results positive. Cutbacks are realised by reducing fuel needs by a better insulation. Increases in the refurbishment phase are caused by the increase of insulating materials' amount during replacement.

Differences in energy consumption are particularly relevant. With renovation, there is a reduction of fuel for heating of 410 MJ pro m^2 of EFA per year. This corresponds approximately to a yearly cutback of 11 litres of light fuel oil per square meter and to 2'528 litres for the whole house. The annual CO_2 emission cutback is approximately 7 tonnes (calculated following Aubé 2001). On the other hand, materials as polystyrene and plastic films used for insulating the house do have an impact on the environment, mainly because of their high energy consumption during production. Because losses in terms of energy are twelve times smaller than gains, it can be said that renovation has proven to be highly effective in allowing energy cutbacks. Gains by a better insulation are remarkable and do clearly outshine the disadvantages of the new materials. It therefore appears evident that interventions during renovation really must focus on fuel consumption reduction. A better insulation of the house and, even better, the application of Minergie and Minergie+ standards are undoubtedly valuable tools allowing a substantial reduction of the environmental burdens.

4.3 Evaluation of the house by its conceptual characteristics

House 21EFH was, before its renovation and for many points of view, not energetically efficient. Renovation works allowed important cutbacks. This chapter investigates if renovation could have been pushed further: were other interventions for energy savings possible? Moreover, which interventions on the contrary should have taken place on the conception stage?

Fraefel (1998) illustrated that actions for efficiency in energy consumption can be taken on 4 points: in the architecture, in the construction, in the installation and by the user. In Table 4-11, the characteristics and the performances of the house in relation to the three first points before and after its renovation are given. Data of a typical building of the 1950-1960s and of a typical new one (Fraefel 1998) are given for reference. The calculations refer to these edifices.

Table 4-11: Characteristics of the house before ($21EFH_{old}$) and after ($21EFH_{new}$) renovation. References are also given.

	$21EFH_{old}$		$21EFH_{new}$		Reference - typical building of the 1950-1960s		Reference - typical new building	
Architecture	**Characteristics**		**Characteristics**		**Characteristics**		**Characteristics**	
Shape (S/EFA)	1.80		1.80		1.75		1.75	
Windows' surface	22% of the EFA surface		22% of the EFA surface		15% of the EFA surface		15% of the EFA surface	
Frame part	30% of the windows' surface		30% of the windows' surface		30% of the windows' surface		30% of the windows' surface	
Openings' orientation	60% West, 19% East, 16% South, 5% North		60% West, 19% East, 16% South, 5% North		50% West, 50% East, 40% South, 10% North		50% West, 50% East, 40% South, 10% North	
Shadow on the south face	Weak		Weak		25%		25%	
Envelop	**Insulation**	**U- Value**	**Insulation**	**U- Value**	**Insulation**	**U- Value**	**Insulation**	**U- Value**
Cellar's ceiling	0 cm	3.1 W/m^2K	6 cm	0.5 W/m^2K	2 cm	1.2 W/m^2K	6 cm	0.5 W/m^2K
External walls	0 cm	1.2 W/m^2K	10 cm	0.3 W/m^2K	2 cm	0.8 W/m^2K	10 cm	0.35 W/m^2K
Roof	6 cm	0.5 W/m^2K	16 cm	0.2 W/m^2K	4 cm	0.7 W/m^2K	12 cm	0.3 W/m^2K
Windows' surface	DV ca. 2 cm	2.8 W/m^2K	IV-glass ca. 28 mm	1.2 W/m^2K	DV or Vi-air	3.0 W/m^2K	superinsulant	1.3 W/m^2K
Installations								
Aeration	From windows, without control		From windows, without control		From infiltrations and from windows		From windows, without control	
Heat production	Light fuel oil boiler		Light fuel oil boiler		Light fuel oil boiler		Light fuel oil or gas boiler	
Heat diffusion	Radiators		Radiators		Heating of floors or radiator		Heating of floors	
Hot water preparation	Boiler		Boiler		Boiler combined with light fuel oil		Winter light fuel oil, summer electricity	
Energy Demand								
Heating	652 MJ/m^2EFAy		242 MJ/m^2EFAy		607 MJ/m^2EFAy		286 MJ/m^2EFAy	
Electricity (380/l)	60 MJ/m^2EFAy		60 MJ/m^2EFAy		80 MJ/m^2EFAy		80 MJ/m^2EFAy	

The comparison between the old and the new buildings shows a very important difference in energy demand (approximately 360 MJ/m^2EFAy for the heating and 20MJ/m^2EFAy for the electricity demand). Compared with Minergie standards[11] for a renovated house, even more. Further reductions of energy consumption can potentially be significant (additional 60% of energy savings only to reach the Minergie limits). For

[11] Minergie limits for *Eth < 320 MJ/m2y for energy (including also energy consumption for ventilation and air-conditioning) against the 741 MJ/m^2 and the 401 MJ/m^2 of the two reference buildings

this reason, hereafter it will be investigated which actions, potential or actuated, bring the highest benefits.

Architectural characteristics can very difficultly be changed. The balcony's closure and the windows' renovation are the only modifications possible during a renovation. Both have been applied to the house; the removal of the thermal bridges caused by the balcony allowed probably for an energy saving of 5%. The windows' substitution allowed a reduction of 84 MJ/m^2EFAy; a saving of 13%. Windows before renovation were not optimal, with a high U-value. However, the loss of energy could have been significantly higher if the south and west windows were in the shadow. The substitution with super insulating ones allowed a reduction of 84 MJ/m^2EFAy. This represents a saving of 13%. However, window frames are the less insulated part of a building. Technically it had been possible to substitute the actual windows (which frames compose around 30% of the window surface (calculated from available data [12])) with others that have less than 20% of their surface occupied by frames (for example windows without a median separation). This action would have allowed an additional gain of 7-8% of the total energy consumption.

From a **construction** point of view, insulation materials allowed big savings (the energy loss by the walls was diminished by a factor of 4, the one from the ceiling cellar by a factor of 3 and the losses by the roof and the windows were halved) lowering the energy consumption for heating from 652 MJ/m^2EFAy to 242 MJ/m^2EFAy. Further improvements however were possible: a super isolated building, as realised nowadays by pioneer architects, could have brought the annual consumption to 170 MJ pro m^2EFA, with additional energy savings of 30%.

Concerning technical **installations**, attention needs to be given to aeration. There are four ways to aerate a building: via unsealed parts of the house and via permanent, intermittent, and soft aerations. The best one, which could not be applied to the house during the renovation for technical reasons, is the soft aeration. If included to new houses, with extaordinarilly performing insulation, potential gains can reach 65%. Improvements related to the heating system can additionally be achieved with a higher boiler's productivity (10% of the gains), the utilization of heating coming from wood or from a heat pump, the own production of electricity (via photovoltaic cells or

[12] Data obtained from T. Schraner, in charge of the windows substitution.

cogeneration) (5-25%) and thermal solar energy (20-50%). Also the production of hot sanitary water carries a certain impact that can be optimized by a combination of several techniques (Fraefel 1998). The installation of solar panels and the substitution of the boiler with a new and better performing one certainly have already reduced the burden.

Other aspects could only have been modified on a conceptual stage. For example, a more compact form (S/EFA of 1.0 instead of 1.8) would have allowed an energy gain of 30%. Also a better orientation could have brought a certain benefit: a North-South direction would have allowed a saving of 5% of energy. Shadow is already rather optimal, as is the windows orientation. There is a small surface at North, a not excessively big one at East (the east side is most exposed to shadow) and a large surface to the west side, which is the most sun- exposed. 60% of windows oriented to the West have the same benefits as 30% of windows exposed to the South. The south side must have a large window surface. Moreover, there are no balconies or eaves that could screen the sun.

It therefore appears that much was done to save energy and that further measures could not apply because of technical and structural limitations. The house could not reach the Minergie standards (Eth[13] ≤320 MJ/m^2y) for two main reasons: it was not possible to equip the house with a soft aeration system and the floor would have needed a better insulation, which was not possible due to the lack of space (Meier, personal communication). There is, nonetheless, still an important margin of improvement for energy cutbacks that can be brought by other interventions.

4.4 Rebuilding versus renovation

In an environmental impacts reduction oriented strategy for buildings, it can be particularly interesting to analyze if it is better to renovate a house or to dismantle it in order to build a better performing one.

In this investigation, three options have been chosen and described in Figure 4-10:
- SI (A): The old house is dismantled after 50 years of life to give place to a more insulated and therefore less energy-consuming one. After extra 50 years, the new building is demolished.

[13] Eth (weighted energetic thermal index) = weighted energetic index for heating, ventilation, air conditioning and for the preparation of hot water.

- SII (B): The house, after 50 years, undergoes renovation that brings it to the same standard of the new house in the option SI. The renewal phase includes the impacts by the disposal of the old materials and of the use of new ones. After further 50 years, the building is dismantled.
- SIII (C): The house does not go through any works and is exploited for a period of 100 years.

The model operates with two levels of efficiency for the house. The first corresponds to the one of the house before renovation and is found in the first part of SI, SII and in the whole SIII. The second correspons to the characteristics of the renewed building and is found in the second part of SI and SII.

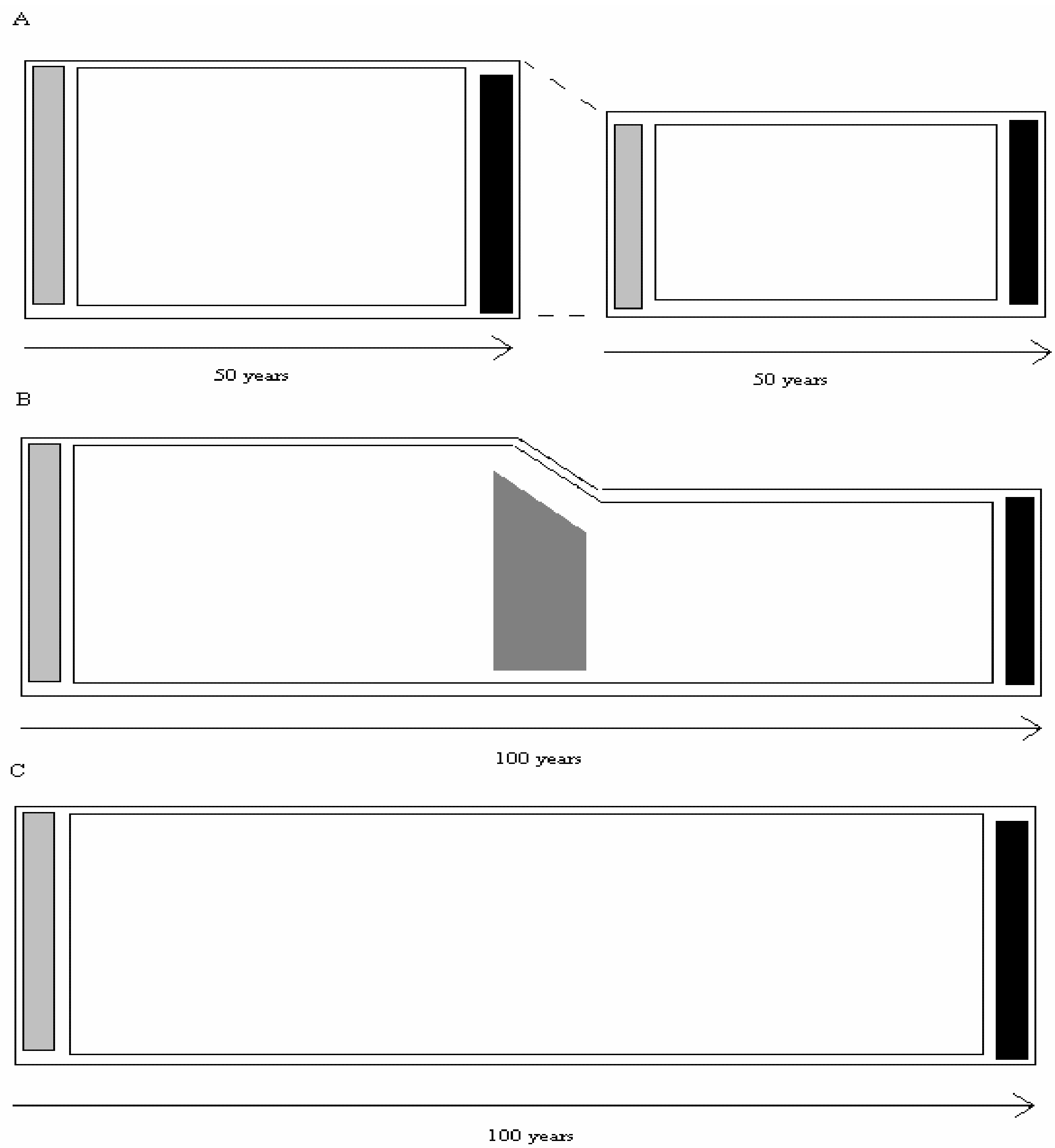


Figure 4-10: Three possible solutions: the house is replaced by a new one with a fewer energy consumption but including insulation materials (SI) A), the house is renovated (SII) and in C the house is kept as it is for the whole period of its life (SIII) B). In pale gray the construction phase, in white the use and refurbishment phases, in gray, the renovation and in black the disposal phases. The arrows under the drawings indicate time.

Results do not differ greatly as Table A-5 indicates. The difference between the first and the last possibility is really subtle and, depending on the impact method used (Appendix C.3), pending for one or the other solution. SIII required a larger amount of fuel, therefore its CED value for fossil energy is bigger that the one of SI. On the other hand, SI has a higher rate for biomass giving the use of new wood and of new floor insulation, materials that both produce unexploited heat. For the other sources of energy, the difference is quite unnoticeable; for EI 99 and for UBP 97 the last option is less interesting, even if again the difference is slightly detectable.

The second option (SII, the renovation of the house) appears to be the best one, and this for almost all the methods used (Appendix C.3). However, it has to be kept in mind than in reality the construction of a new house allows much more improvements that its renovation because of the structural and architectural limitations . Moreover, better performing materials and new knowledge can be implied to lower the environmental impact of the house. In addition with the time a house becomes less performing; at the end of its life its impact is supposedly higher than estimated and this particularly if the lifespan is 100 years. It can therefore be assumed that the impact of SIII is higher. This confirms what found by Erlandsson et Levin (2004).

As discussed, renovation does play an important role in reducing the environmental impact; this is especially true for existing houses for which energy savings were not taken into consideration during the planning phase.

Part B - Analysis of the set of 21 buildings: highlighting of the main causes of their load on the environment

The purpose of this second section is to find an answer to the following questions:
- "Which are the variations in environmental impact between buildings of different shapes, materials and functions and why do they exist?";
- "How is the environmental impact generally divided between the life phases and why?";
- "Which phases generally dominate?" and
- "Which elements determine the impact on the environment? For which reason?".

Those questions are answered by carrying out a life cycle analysis on a set of 21 buildings, very seldom such a large set of buildings can be evaluated on a comparable basis.

In the following chapters first, the assumptions made specifically for this section of the work are listed and the Life Cycle Inventory described (Chapter 5.1). Then, thanks to the definition of those bases, calculations are undertaken. Results are presented in the following Chapter 6 and then discussed in Chapter 7. In Chapter 8, an uncertainty discussion and a sensitivity analysis are done for both Parts A and B.

5 Data and method

In the next chapters the following will be discussed:

- The goals of the LCA of Part B and the assumptions that needed to be established specially for the set of houses studied (Chapter 5.1);
- The Life Cycle Inventory, in which the set is described and the models settled are illustrated (Chapter 5.2).

Thanks to this information, the basis are settled for the analysis of the group of buildings.

5.1 Goals and scope definition

The method utilized retrace the one employed in Part A; the system boundaries, the functional unit and the assumptions are generally the same. Hereafter the assumptions made specifically for the set of 20 houses are presented:

In the **construction** phase:
- Thickness did not need to be estimated and the passage from the volume to the mass of the majority of the elements was done in a precedent study (Seyler *et al.* 2004). Only concrete (density of 2300 kg/m^3) and wood (720 kg/m^3) needed to be assumed.

In the **use** phase:
- The type of heating system does not vary considerably between the buildings. The majority of the buildings are heated by natural gas, only two by oil (6DLG and 19EFH). For three buildings it was not possible to establish the exact system (2DLG heat exchanger; 10EFH and 14DLG external heat supply). For this reason, it was chosen to compare all the houses on a similar basis and to take natural gas as the common heating system. Uncertainties generated by this assumption are discussed in Chapter 8.1.

The lifespan of the building was once again settled at 80 years. This corresponds approximately to reality for the single occupancy and the apartment houses, but it is an overestimation for the service and the manufacturing buildings, which lifespan ranges generally between 26 and 50 years (O'Connor 2004).

5.2 Life Cycle Inventory

5.2.1 Description of the set of houses

The buildings studied were recently erected (1989-1999). They belong to four different categories: single occupancy houses (Einfamilienhäuser, EFH), apartment houses (Mehrfamilienhäuser, MFH), service buildings (Dienstleistung, DLG) as for example offices and training centres and manufacturing buildings (Produktionsgebaud, PRG) as for example warehouses. Some of them were constructed principally in reinforced concrete, others in wood, in bricks (masonry) or in steel. The number of elements inventoried ranges between 12 and 37. For more information, see Appendix B.1.

5.2.2 Data collection for the Life Cycle Inventory

Data concerning the set of houses comes from the Baukosteninformationszentrum Deutscher Architektenkammern (BKI, the German “centre for construction costs”) (BKI 2003). The original idea of the catalogue is to furnish architects with data about the design processes’ influence on costs in terms of space, the quantity of structural elements, technical/mechanical service equipment, and the choice of materials. Data was gathered by sampling the totality of the bills produced during the works.

For each house, the totality of the materials used during the construction was inventoried and recorded by their weight. Data was obtained from the list of materials purchased for the construction of the buildings (EKG 1991). Architectural, construction, an installation attributes are furnished in attachment (Appendix B.1).

5.2.3 Assessment of models for not inventoried data

The same models utilized in Part A apply (Chapters 2.3.4-2.3.6). In the calculation of the energy consumption for **heating** in the use life phase, EnerCAD was once again utilised. Nonetheless, criteria concerning the houses differ from the ones presented previously (Chapter 2.2.3) for the MFH, the DLG and the PRG buildings. They do not only vary between classes but also inside groups (after SIA 2001):

- EFH (1EFH, 10EFH, 11EFH, 12EFH, 13EFH, 19EFH): 20°C of internal temperature; 12 hours of presence/day, 60 m^2EFA/person, 80 MJ/m^2 of total (lighting plus household appliances) electricity use, 0.7 m^3 air for ventilation/m^2h;
- MFH (4MFH, 7MFH, 9MFH, 17MFH, 20MFH): 20°C of internal temperature; 12 hours of presence/ day, 40 m^2 EFA/person, 100 MJ/m^2 of total (lighting plus household appliances) electricity use, 0.7 m^3 air for ventilation/m^2h;
- Administration buildings (2DLG, 6DLG): 20°C of internal temperature; 6 hours of presence/ day, 40 m^2 EFA/person, 80 MJ/m^2 of total (lighting plus household appliances) electricity use, 0.7 m^3 air for ventilation/m^2h;
- Training centres (5DLG, 14DLG,): 20°C of internal temperature; 4 hours of presence/ day, 10 m^2 EFA/person, 40 MJ/m^2 of total (lighting plus household appliances) electricity use, 0.7 m^3 air for ventilation/m^2h;

- Meeting centres (15DLG): internal temperature: 20°C of internal temperature; 3 hours of presence/ day, 5 m^2 EFA/person, 60 MJ/m^2 of total (lighting plus household appliances) electricity use, 1.0 m^3 air for ventilation/m^2h;
- Warehouses (3PRG, 8PRG, 16PRG): 18°C of internal temperature; 6 hours of presence/ day, 100 m^2 EFA/person, 20 MJ/m^2 of total (lighting plus household appliances) electricity use, 0.3 m^3 air for ventilation/m^2h;
- Sport halls (18PRG): 18°C of internal temperature; 6 hours of presence/ day, 20 m^2 EFA/person, 20 MJ/m^2 of total (lighting plus household appliances) electricity use, 0.7 m^3 air for ventilation/m^2h.

The model utilised for calculating the electricity consumption for **lighting** during the use phase was already presented in Chapter 2.3.4. Values for electricity consumption attributed to each area of the different buildings are presented in Table 5-12. They were calculated after SIA (1996).

Table 5-12: Calculation of energy consumption for lighting.

House		Electricity consumption			
		NF	VF	FF	Total/NGF
		[MJ/m²BGFy]	[MJ/m²BGFy]	[MJ/m²BGFy]	[MJ/m²NGFy]
1 EFH	Two single occupancy houses	60	10	25	69.3
10 EFH	Single occupancy house, low energy	60	10	25	65.0
11 EFH	Single occupancy house with double garage	60	10	25	63.8
12 EFH	Half of a double house, wood construction	60	10	25	63.3
13 EFH	Single occupancy house	60	10	25	69.6
19 EFH	Single occupancy house, wood construction	60	10	25	62.2
4 MFH	Apartment house with double garage	60	30	25	62.6
7 MFH	Apartment house (16) with underground garage	60	30	25	51.7
9 MFH	Apartment house (15) with underground garage	60	30	25	58.4
17 MFH	Apartment house (6)	60	30	25	67.3
20 MFH	Apartment house (9) with underground garage	60	30	25	66.3
2 DLG	Offices and commercial building	60	30	25	57.5
5 DLG	Professional training centre	30	30	25	31.5
6 DLG	Administration building	60	30	25	58.7
14 DLG	Training for constructors yard	30	30	25	33.0
15 DLG	Motorway police, personnel building	60	30	25	59.8
3 PRG	Farm machines hall	7	10	25	7.8
8 PRG	Beverages warehouse	7	10	25	9.7
16 PRG	Centre of distribution, warehouse, offices	60	30	25	64.1
18 PRG	Sport hall	25	30	25	27.7

NF: main function area; VF: circulation area; FF: ancillary area for services; BGF: gross external floor area; NGF: net floor area

In the **refurbishment,** the same technique used in Part A was used. Therefore, here too refurbishment is considered to be realised by steps. The periods presented in Table 5-13 were chosen.

Table 5-13: Refurbishment periods for different components of the building.

Material	Changing ratio [years]	Material	Changing ratio [years]	Material	Changing ratio [years]
Aluminium	25	Floor - anhydrite	25	PS – expanded plastic slab	25
Asbestos	25	Floor – cement layer	80	PVC	25
Asphalt- mastic asphalt	25	Floor – mastic asphalt	25	Roof – tile	25
Bitumen	25	Glass	25	Roof – “Frankfurter” tile	25
Bitumen sheet	25	Glass – polished sheet glass	25	Roof – clay brick	25
Brass	25	Glass fibre	25	Roof – clay tile	25
Brick – hollow block	80	Glass fleece	25	Roof - concrete tile	25
Brick HLZ	80	Granit	35	Sand	80
Brick MZ	80	Gypsum carton board	25	Sand – lime brick block	80
Carpet	10	Hartfaser	35	Soil	80
Cartonboard	25	Hollow sand – lime brick	80	Steel, for reinforcement	80
Cast iron	25	Gravel	80	Steel, not for reinforcement	25
Cellular glass	25	Lead	25	Styrodur	25
Clinker	80	Linoleum	25	Tile – floor	25
Concrete - autoclaved aerated concrete	80	Marble	35	Tile – wall	25
Concrete – gas concrete	80	Mineral wool	25	Window – aluminium	25
Concrete – light	80	Mineral wool	25	Window – PVC	25
Concrete - lightweight concrete block	80	Modern insulation	25	Window - PVC glass	25
Concrete - pumice concrete block	80	Mortar	80	Window – wood	25
Concrete B10	80	Mortar – cement mortar	80	Window - wood glass	25
Concrete B15	80	Natural stone	35	Window -aluminium glass	25
Concrete B25	80	PE-film	25	Wood	25
Concrete B5	80	Plaster	25	Wood - laminated beam	25
Concrete-concrete block	80	Plaster – cement plaster	25	Wood - particle board	25
Copper	25	Plaster – gypsum plaster	25	Wood - particle board	35
Cork	35	Plaster – lime cement plaster	25	Wood – plywood	35
Fibre cement corrugated slab	25	Plaster – lime plaster	25	Wood - roof structure	75
Fiberglas	25	Plastics	25	Zink	25
Fleece	35				

For **disposal** paths of materials, the suppositions presented in Table 5-14 were taken. The model is more accurate than the precedent because new inputs became available with the development of the work.

Table 5-14: Choice of allocation for the materials' disposal reflecting the actual situation in the canton of Zürich (Althaus and Rubli, personal communication).

	To direct recycling	To sorting plant	To final disposal	To municipal incineration		To direct recycling	To sorting plant	To final disposal	To municipal incineration
Aluminium		98%	2%		Lead		98%	2%	
Asbestos			100%		Linoleum				100%
Asphalt- mastic asphalt		90%	10%		Marble	7%	50%	43%	
Bitumen				100%	Mineral wool			80%	20%
Bitumen sheet				100%	Mineral wool			80%	20%
Brass		98%	2%		Modern insulation				100%
Brick – hollow block	7%	50%	43%		Mortar	7%	50%	43%	
Brick HLZ	7%	50%	43%		Mortar – cement mortar	7%	50%	43%	
Brick MZ	7%	50%	43%		Natural stone	20%	60%	20%	
Carpet				100%	PE-film				100%
Cartonboard				100%	Plaster	7%	50%	43%	
Cast iron		98%	2%		Plaster – cement plaster	7%	50%	43%	
Cellular glass		10%	90%		Plaster – gypsum plaster	7%	50%	43%	
Clinker	7%	50%	43%		Plaster – lime cement plaster	7%	50%	43%	
Concrete - autoclaved aerated concrete	7%	60%	33%		Plaster – lime plaster	7%	50%	43%	
Concrete – gas concrete	7%	60%	33%		Plastics				100%
Concrete – light	7%	60%	33%		PS – expanded plastic slab				100%
Concrete - lightweight Concrete block	7%	60%	33%		PVC				100%
Concrete - pumice concrete block			100%		Roof – tile	7%	50%	43%	
Concrete B10	7%	60%	33%		Roof – "Frankfurter" tile	7%	50%	43%	
Concrete B15	7%	60%	33%		Roof – clay brick	7%	50%	43%	
Concrete B25	7%	60%	33%		Roof – clay tile	7%	50%	43%	
Concrete B5	7%	60%	33%		Roof - concrete tile	7%	60%	33%	
Concrete-concrete block	7%	60%	33%		Sand	50%	50%		
Copper		98%	2%		Sand – lime brick block	7%	50%	43%	
Cork				100%	Soil	60%	10%	30%	
Fibre cement corrugated slab			100%		Steel		100%		
Fibre cement facing tile			100%		Steel*		100%		
Fiberglas			100%		Styrodur				100%
Fleece				100%	Tile – floor	7%	50%	43%	
Floor – anhydrite		20%	80%		Tile – wall	7%	50%	43%	
Floor – cement layer		20%	80%		Window – aluminium		98%	2%	

	To direct recycling	To sorting plant	To final disposal	To municipal incineration		To direct recycling	To Sorting plant	To final disposal	To municipal incineration
Floor – mastic asphalt		90%	10%		Window - PVC		30%		70%
Glass			100%		Window - PVC glass			100%	
Glass – polished sheet glass			100%		Window - wood		30%		70%
Glass fibre			100%		Window - wood glass			100%	
Glass fleece			100%		Window -aluminium glass			100%	
Granit		10%	90%		Wood		60%		40%
Gypsum carton board			100%		Wood - laminated beam		60%		40%
Hartfaser			100%		Wood - particle board		60%		40%
Hollow sand – lime brick	7%	50%	43%		Wood - plywood		60%		40%
Gravel	50%	50%			Zink		98%	2%	

In this model, it was considered that brick, plaster, a fraction of concrete, of tapestry and of gypsum carton board end in the demolition mix.

5.2.4 Life Cycle Impact Assessment

The same approach that the one shown in Chapter 2.4.1 applies. Nonetheless the Life Cycle Assessment was completed with the more recent version of ECOINVENT, the version v1.2 dating from 2005. The same impact assessment methods, CED, EI 99 and UBP 97, were also utilized.

6 Results

This Chapter is divided in two sections:

- In the first, results concerning the buildings and their impact are presented. Firstly, in Chapter 6.1 the overall impact of the 21 buildings is shown. Then, in Chapter 6.2, the distribution of the impact between the four life phases of the houses is illustrated. Finally, in Chapter 6.3, for each life phase the components predominantly responsible of the impacts are sought.
- In the second, contained in Chapter 6.4, two assessment methods are compared in order to establish if the cumulative energy demand could be taken as an indicator of the total impact of the houses on the environment.

6.1 The overall impact of the 21 buildings

Results were obtained for the three impact assessment methods: Ecoindicator 99 (EI 99), Cumulative Energy Demand (CED), and Ecological Scarcity 97 (UBP 97). Hereafter the total impact of the buildings and of the four different classes studied (EFH, MFH, DLG, PRG) are analysed.

In **EI 99**, total scores of the buildings fluctuate between 71 (3PRG) and 326 ($21EFH_{old}$) points, with an average of 188 points and a standard deviation of 60 (Figure 6-11). EFH buildings have on average the highest score (223 if houses $21EFH_{old}$ and $21EFH_{new}$ are considered, 211 points otherwise), followed by the DLG ones (196 points), the PRG (171 points) and the MFH (139 points). The PRG do have the biggest variance intra group, with a standard deviation of 89, followed by the DLG ($\sigma = 45$), the EFH ($\sigma = 50$ with the additional houses, 31 if they are not considered) and the MFH ($\sigma = 23$) ones. Only the EFH and the DLG classes result to be significantly different (ANOVA p-value < 0.05).

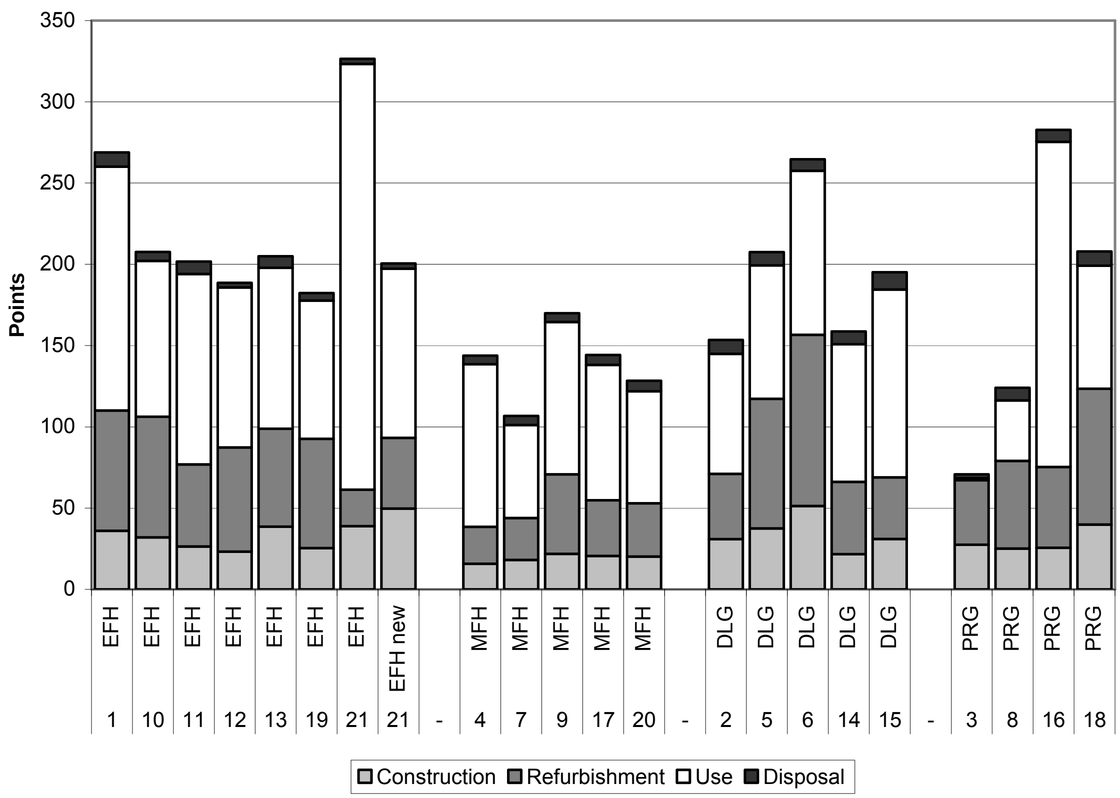


Figure 6-11: Results of the lifecycle of the set of houses with EI 99. The part played by each life phase can be seen.

"CED – non renewable energies" focuses on a single component of the EI 99 assessment method, in effect only the energetic viewpoint is taken into consideration. Results range between 8'400 and 79'700 MJ equivalents. Single occupancy houses posses on average the biggest impact (53'900 MJ eq or 51'300 MJ eq without $21EFH_{old}$ and $21EFH_{new}$), followed by DLG ones (46'000 MJ eq), MFH (38'600 MJ eq) and PLG (36'300 MJ eq) (Figure 6-12). The standard deviation is relatively small for the EFH (σ = 95 or 133 with the additional two houses), the MFH (62) and the DLG (73) buildings. It is, on the other hand, important for the PRG ones (293). The inhomogeneousity in this class is given by the fact that some buildings aren't heated at all (3PRG), that the surface heated is only a small part of the whole construction (8PRG) or that architectural characteristics bring to a lower energy consumption (18PRG). It cannot be said that classes are significantly different (ANOVA p-value > 0.05 between all of them).

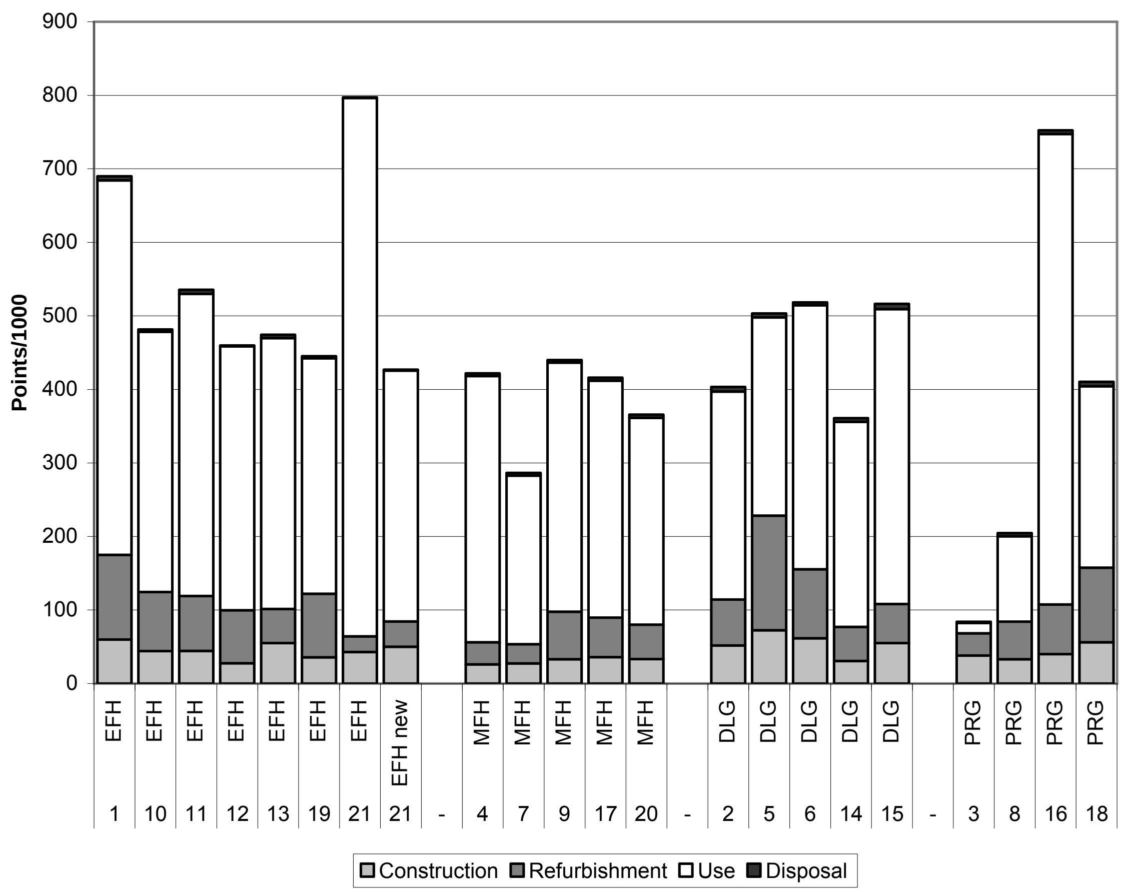


Figure 6-12: Results of the lifecycle of the set of houses with CED – non renewable. The part played by each life phase can be seen.

Finally, in the UBP method, results vary between 9’900 (3PRG) and 38’600 (6DLG) points (Figure 6-13). EFH houses have, on average, the highest impact (274’000, σ = 52 or 276’000 points, σ = 52 without considering the added houses), followed by DLG (289’000 points, σ = 60), PRG (283’000 points, σ = 123) and MFH (215’000 points, σ = 16) ones. The variation inter groups seems to be too small to be significant. Once again, results for the PRG class are inhomogeneous compared to the others. However averages of the different classes are not significantly different (ANOVA p-value > 0.05 for all comparisons).

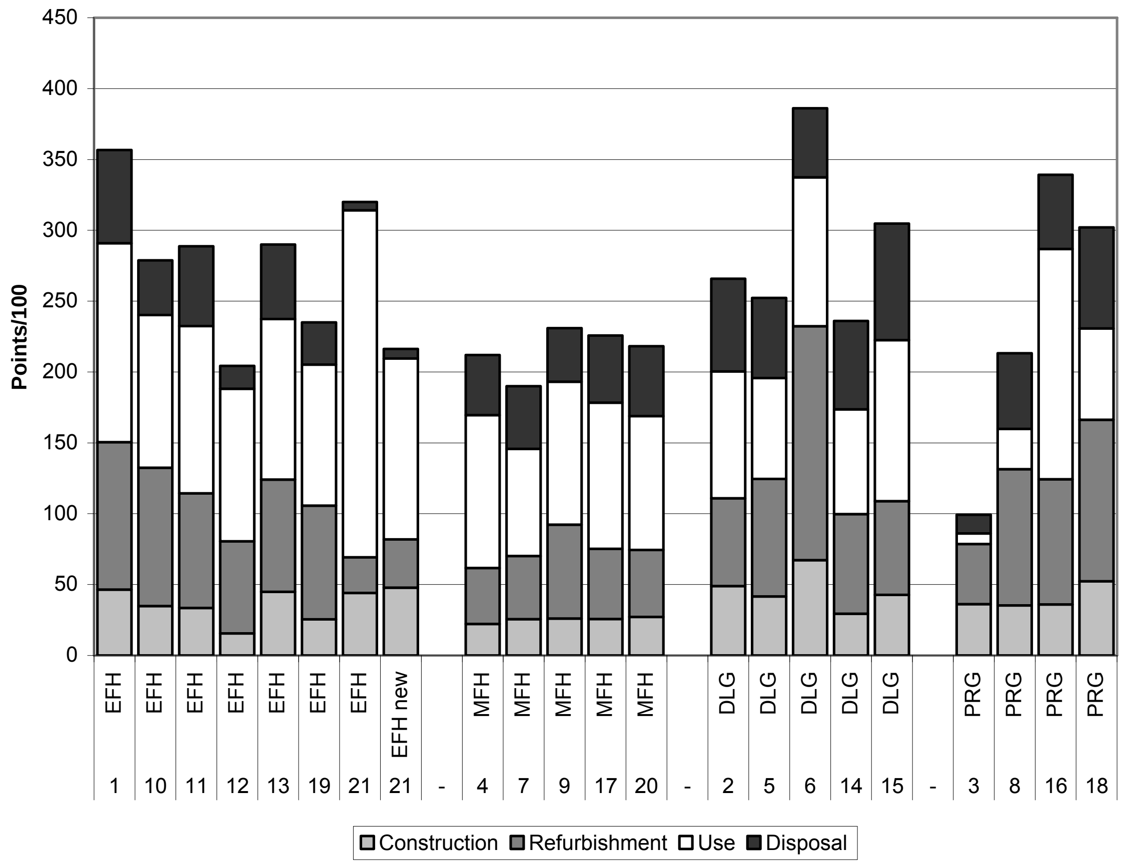


Figure 6-13: Results of the lifecycle of the set of houses with UBP 97. The part played by each life phase can be seen.

6.2 Distribution of the impact between the four life phases

In order to determine which life phases dominate and possess the biggest impact on the environment, their relative importance on the overall impact is presented hereafter for the three assessment methods.

In the **EI 99** method, the use phase is the biggest responsible of the impact of the houses on the environment with the 38-70% of the whole (not considering PRG buildings and house $21EFH_{old}$, which are exceptions at this trend). This phase is followed by the refurbishment (16-40%), the construction (11-25%) and finally the disposal (2-6%) ones. For the first three categories of buildings, differences of the distribution inside the group are slight (Figure 6-14).

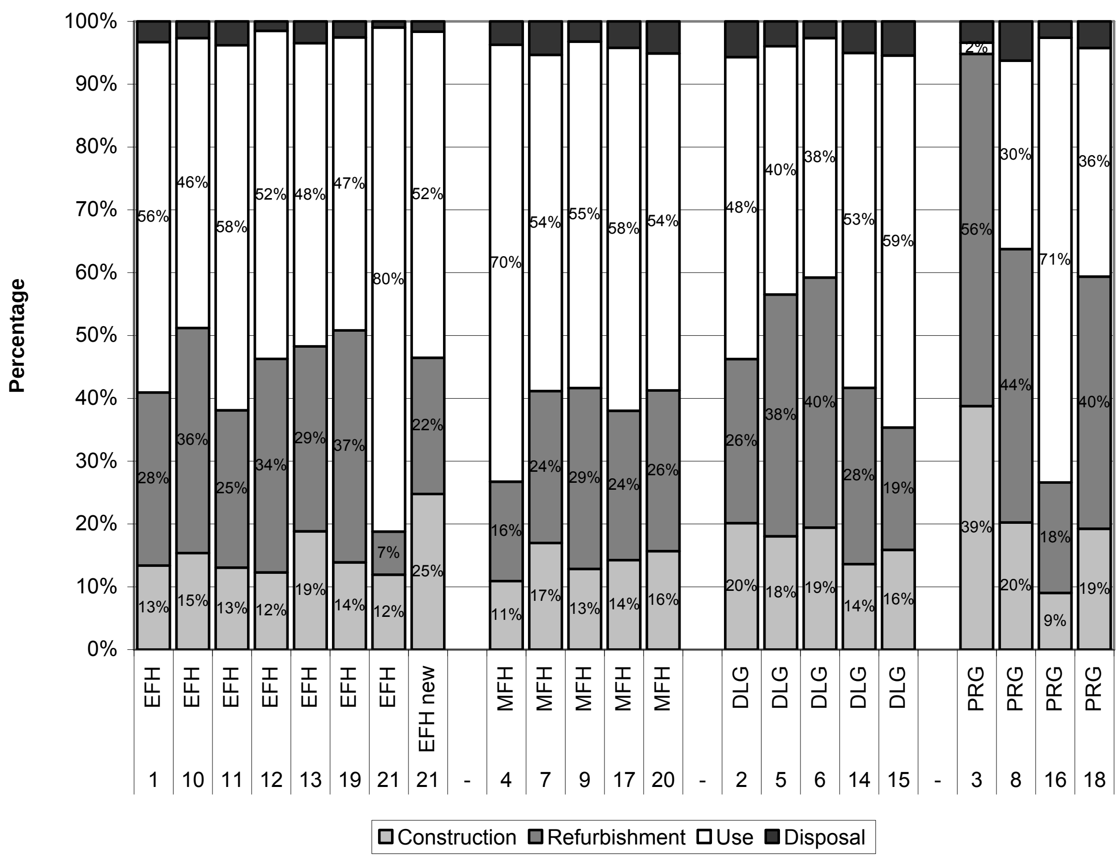


Figure 6-14: Relative importance of the different phases of the life cycle of the 20 houses with EI 99.

As it was expectable, in **CED – Non renewable** the use phase gains importance because of the energy utilized for heating and lightning. This stage is responsible generally for 70-80% of the whole impact (21EFH$_{old}$ and 5DLG make exception), followed by the refurbishment (7-31%) and by the construction (6-14%). Disposal does not play a big role on the whole (0-2%) because of the relative low energy needs for the dismantling in comparison to the rest. For the first three categories of buildings, differences of the distribution inside the group are once again slight (Figure 6-15).

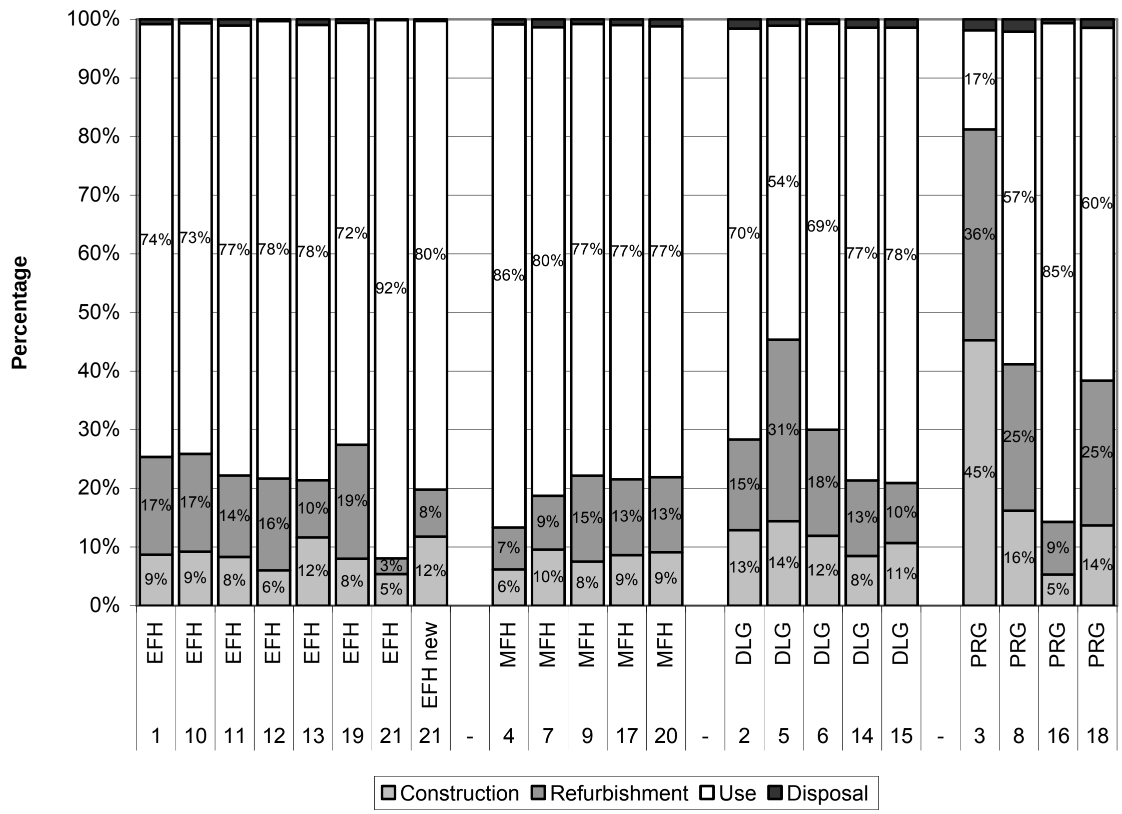


Figure 6-15: Relative importance of the different phases of the life cycle of the 20 houses with CED – non renewable.

In **UBP**, disposal acquires more importance because the space occupied by landfills is highly considered in the method. The use phase becomes responsible of only 27-59% of the whole impact, followed by the refurbishment (16-43%), the disposal and the construction (3-27% and 8-22% respectively) ones (Figure 6-16), once again PRG buildings and 21EFH$_{old}$ are not considered in the comparison because of not following the trend.

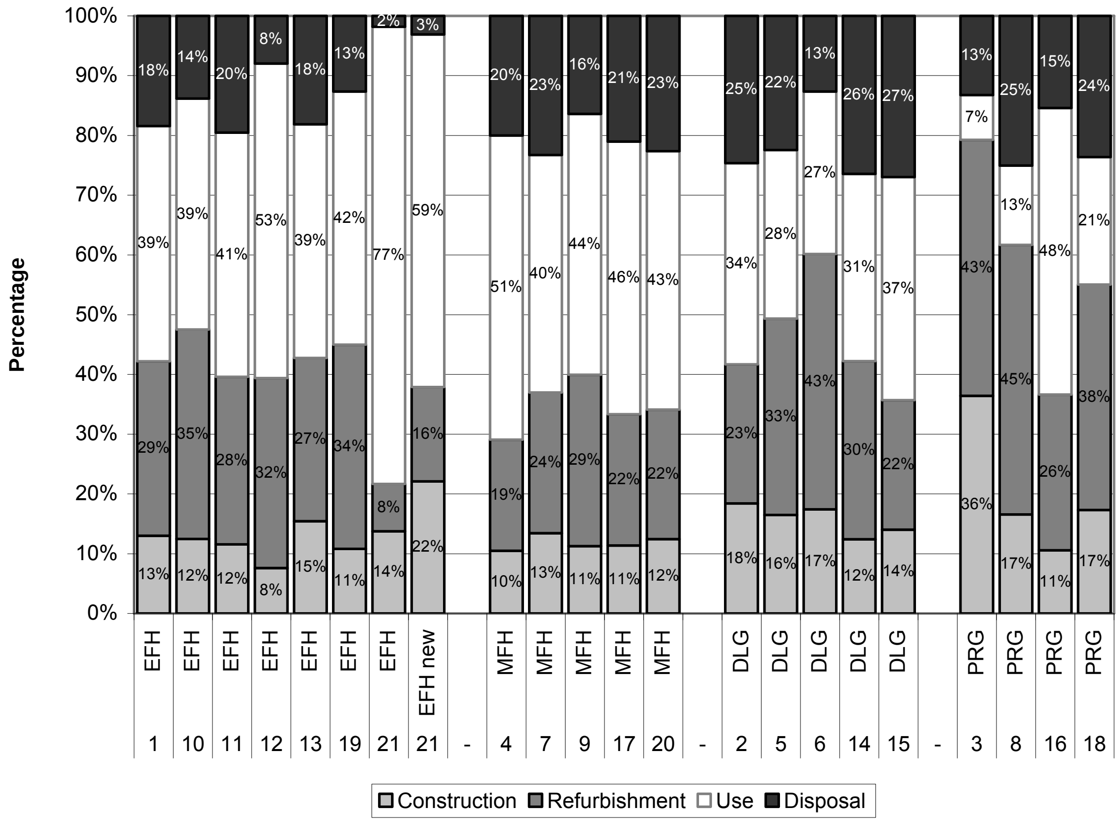


Figure 6-16: Relative importance of the different phases of the life cycle of the 20 houses with UBP 97.

In the three methods utilised the use phase dominates. It does it deeply in the Cumulative Energy Demand, considerably in the Ecoindicator 99 and slightly in Ecological scarcity 97, in where it is quite comparable to the refurbishment phase. In all the methods, the three first categories do not have a big variation intra group, the last one (PRG), on the contrary, does. 21EFH$_{old}$, the building inventoried in Part A and which age is considerably higher than the one of the other houses, generally does not follow the trend. For all the methods, EFH is between the categories with the highest impact, together with the DLG one. MFH and PRG do have on average a smaller impact. Differences between classes are not significant for all the methods employed.

In the following Chapters only the Ecoindicator 99 (H, A) method is discussed.

Decomposing the score of the different life phases between the three classes constituting EI 99 (ecosystem quality, human health and resources depletion) it appears that all the houses respond in a similar way (Figure 6-17). It emerges that, generally, the construction phase highly affects the human health because mainly of the respiratory effect brought by the production of insulating materials (Appendix C.3). It also has an effect on resources depletion, mostly because of fossil fuel consumption for the production of insulating materials, concrete and steel. In the refurbishment, the ecosystem quality gains importance, because of the impact that wood production has on land occupation. In the use phase resources depletion dominates clearly, because of the fossil fuel consumption for heating. In the disposal is once again human heath that plays the central role. Impacts are caused by carcinogenic and respiratory effects arising from the sorting of concrete.

Some odd data can be discussed. For house 12EFH, the proportion played by ecosystem quality is particularly elevated because of the high utilisation and replacement of wood and its effects on land utilisation. For 5DLG the reason is resources depletion, which becomes important because of mastic asphalt and the need of fossil fuel for its production.

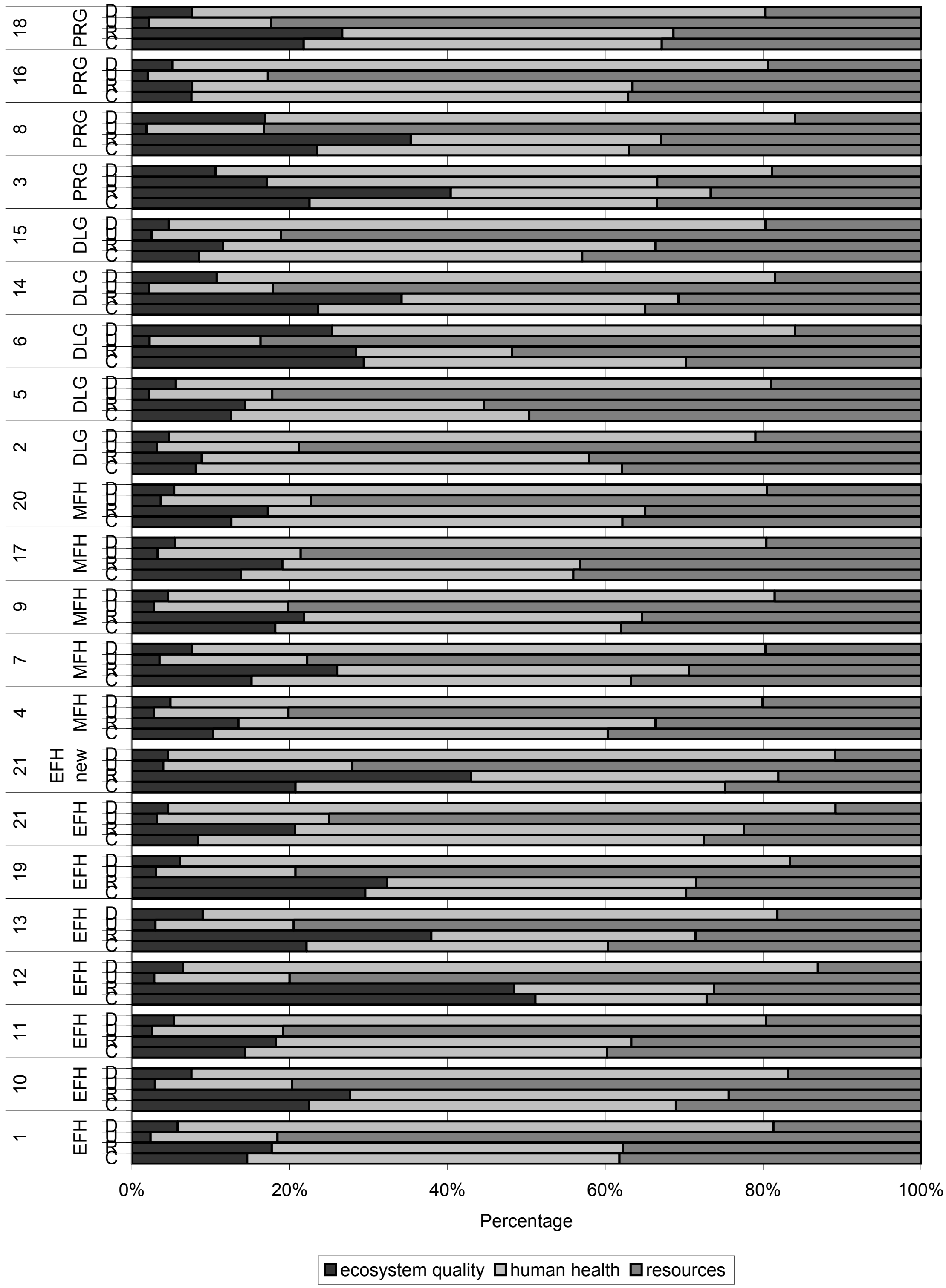


Figure 6-17: Relative importance of the three categories of impact composing EI 99. C: construction, R: refurbishment, U: use, D: disposal.

6.3 Single contribution of components and elements to the overall impact

In the following chapter, the causes of the impact were more thoughtfully investigated. The examination begins with the assessment of the relative importance of the eight components (materials for construction, transport of materials for construction, materials for refurbishment, transport of materials for refurbishment, disposal of materials in the refurbishment phase, heating, lighting and disposal) on the overall impact. Then, in Chapter 6.3.1, the causes of the impact of the most important components inside the different life phases are investigated. In the Chapter 6.3.2 that follows, the causes of differences between building classes are sought.

As it is shown in Figure 6-18, heating is responsible on average of 44% of the total impact. The second component in order of importance is material for refurbishment (28%). Follow material for construction (15%), lighting (5%), the disposal of material for construction (4%), the disposal of material for refurbishment (2%), the transport of materials for construction and the one of materials for refurbishment (both 1%). Summing it up, it appears that materials play a similar role to heating (43% against 44%). Disposal (6%), lighting (5%) and the transport (2%) have a far smaller impact.

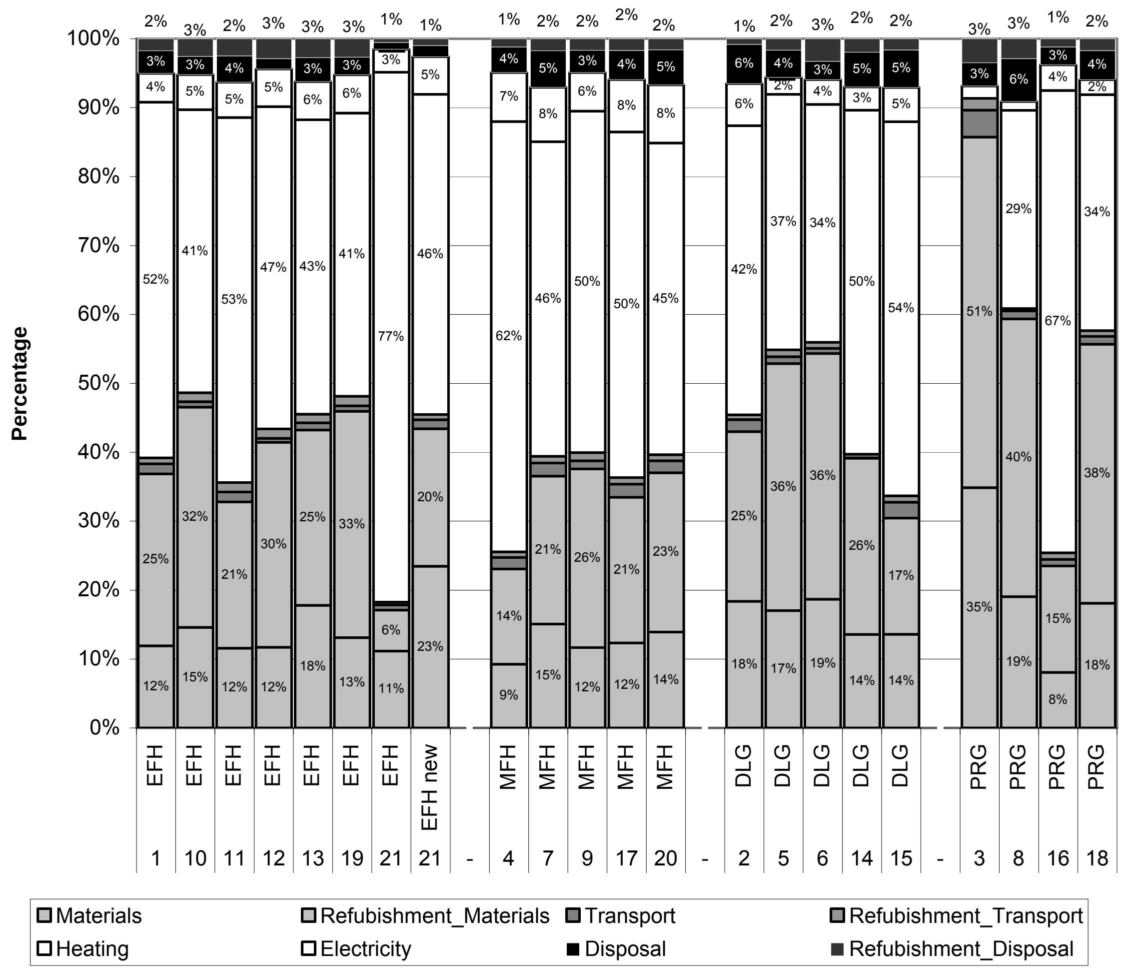


Figure 6-18: Relative importance of the different components of the life phases of the 20 houses with EI 99.

6.3.1 Impact of the principal components inside the life phases

In the following section, components that play an important role on the overall impact meaning heating, material for refurbishment and material for construction were retained. The other five ones (electricity, disposal, disposal of refurbishment material, transport and transport of material for refurbishment) are ignored because playing a minor role. The goal is to determine what exactly causes the impact and, therefore, does contribute significantly to the environmental score of the buildings.

For **heating**, different parameters, which could explain variations of energy consumption between buildings, were retained:

Continual variables:

- The year of construction;
- The weight of the house;
- The EFA;
- The volume of the EFA;
- The compactness (envelope's surface/EFA);
- The part of the envelope occupied by window;
- The part of the envelope occupied by windows exposed to the North;
- The part of the envelope occupied by windows exposed to the sun (South+ ½ West + ½ East);
- The total amount of insulation materials;
- The average internal temperature;
- The occupancy hours per day;
- The internal energy production (from houseold equipment, people, etc)
- The construction costs;

Categorical variables:

- The kind of building (EFH, MFH, DLG, PRG);
- The structure (masonry, reinforced concrete, solid building, wood skeleton and steel skeleton);
- The type of roof (flat or not);
- The type of ceiling (in contact with the soil or with a not heated surface);

House 3PRG was not considered because not heated, house $21EFH_{old}$ because too old in comparison to the other buildings and 8PRG because having only an annex room heated. Being outliers, they would have diminished the strength of the model. It appeared that, between the continual variables, four could well explain the heat flow at a significance threshold of 95% (between 37% and 60% of the variability explained). These variables are the compactness (R^2=0.593; p-value< 0.001), the EFA (R^2=0.428; p-value 0.003), the volume of the EFA (R^2=0.410; p-value 0.004) and the part of the envelope occupied by windows exposed to the sun (R^2=0.373; p-value 0.007) (Figure 6-19). The EFA and its volume are however redundant (R^2=0.98, p-value< 0.001).

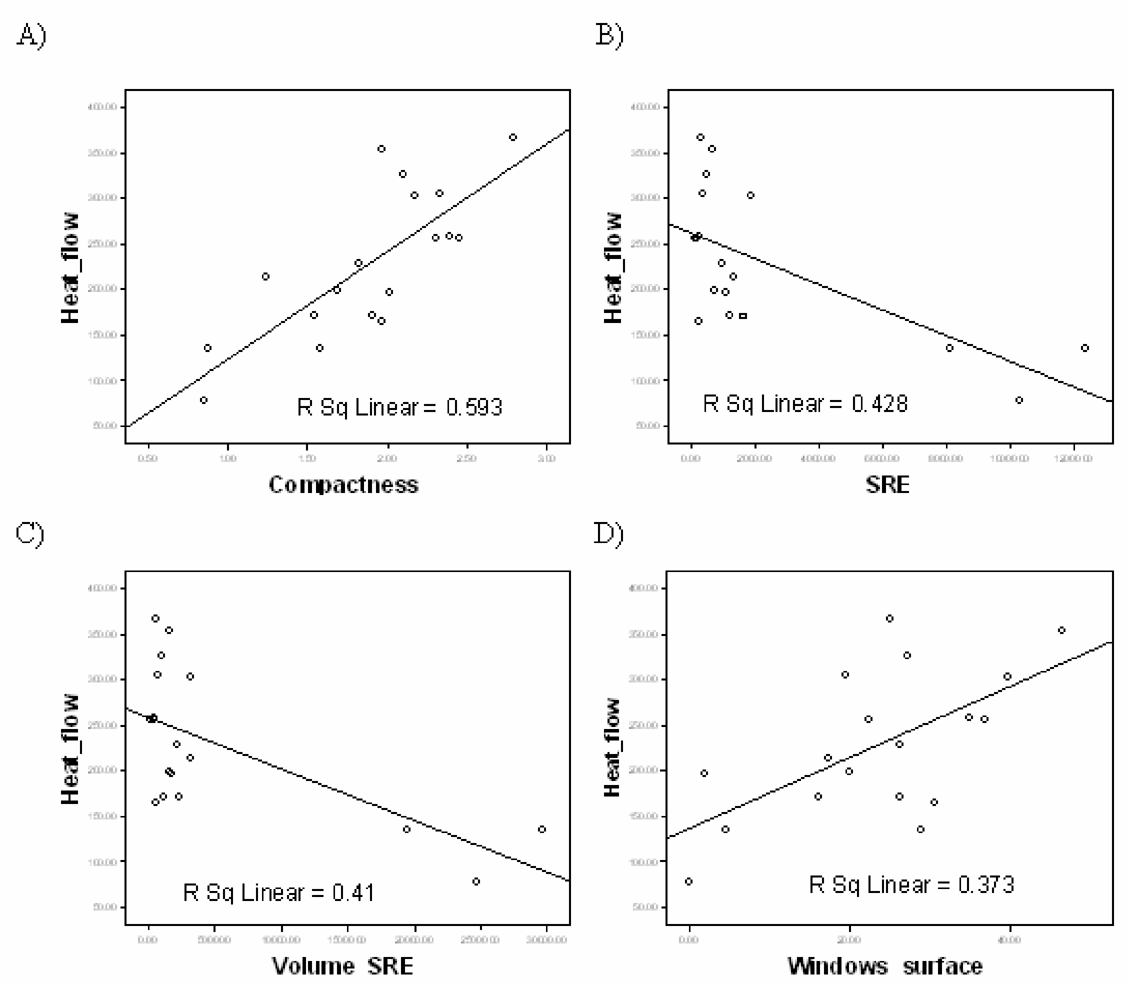


Figure 6-19: Linear regressions illustrating the relationship between the heat flow and respectively the compactness, the SRE, the volume of the SRE and the part of the envelope occupied by windows exposed to the sun.

Between the categorical variables, it appeared a small relationship between the categories and the heat flow. The only significant assumption that could be made is that the heat flow for the DLG is lower than the one of the EFH buildings (Wilcoxon z=-2.1, p-value 0.018). The following multiple linear regression was created: Hear flow= 66.59 + 71.82 (compactness) – 0.005(SRE) + 1.635(windows surface). It explains 67.0% of the variability of the heat flow significantly (p-value 0.001).

For **material for refurbishment,** the materials responsible of 95% of the impact were retained and presented in Table 6-15. For each material, the average weight per square metre of NGF is given, as also the average score and the percentage. Additionally, in order to see the recurrence of each material, its number of apparition is given. Houses

$21EFH_{old}$ and $21EFH_{new}$ are not considered because of different appellations of the materials composing their inventory.

Table 6-15: Materials causing the 95% of the EI 99 impact during the refurbishment phase.

Material	Average weight [Kg/NGF]	Average EI 99 score [Points]	Percentage	Number of appearances
Steel - not reinforcing	151	143	15%	19
Wood	234	142	15%	20
Zinc	7	117	12%	15
Mineral wool	42	113	12%	24
PS - expanded plastic slab	5	64	7%	17
Tiles from ceiling and walls	12	62	6%	36
Asphalt- mastic asphalt	11	43	4%	2
Carpet	4	40	4%	11
Copper	1	31	3%	2
Window - aluminum	2	27	3%	8
Gypsum carton board	36	21	2%	17
Wood - plywood	5	18	2%	3
Aluminum	1	17	2%	19
Window - wood glass	18	15	2%	7
PE-film	2	13	1%	18
PVC	2	11	1%	11
Linoleum	1	10	1%	5
Wood - laminated beam	8	7	1%	8
Modern insulation	3	7	1%	14
Roof - concrete tile	10	6	1%	5
Window - wood	10	6	1%	14
Lead	<1	6	1%	1
Bitumen and bitumen sheet	2	6	1%	21

*MIneralfaser and mineralwolle in German

23 materials are responsible of 95% of the impact. It appears that steel in replaced components (the one in reinforced concrete is not changed) and wood cause the biggest impact during renovation, with respectively a score of 143 and 142 EI 99 points (15%). Follow zinc and mineral wool accountable both of 12%, polystyrene (7%) and tiles (6%). The 17 following materials are responsible of no more than 1-4%. Both two first materials have an important weight on the overall (hundreds of kilos for square metre of NGF) and are frequently present. The ones following, on the other hand, are only fairly present in weight (in the order of kilos) and very heterogeneously in number of appearances (from one presence of lead to the omnipresence of wood).

The same was done for **material for construction.** As it appears in Table 6-16, 28 materials cause together more than 95% of the impact during the construction phase. Steel dominates once again, causing 24% of the impact. Its average weight per square metre of NGF is however minor than in the refurbishment phase, even if its presence is higher (between reinforcing and not reinforcing steel, it appears 39 times). Follows concrete, which, even if possessing an enormous average weight, is responsible only of 10% of the impact. Next comes wood (83Kg/NGF but only 9% of the impact). Then follow zinc (7%), mineral wool (7%), Polystyrene (4%) and tiles (also 4%). Materials that follow cause less than 3% of the whole impact. All of them are quite highly frequent between the buildings. Only mastic asphalt, copper, clinker, plywood, particle boards, light concrete, gas concrete and linoleum appear less than 6 times.

Table 6-16: Materials causing the 95% of the EI 99 impact during the construction phase.

Material	Average weight [Kg/NGF]	Average EI 99 score Points	Percentage	Number of appearances
Steel – reinforcing and not	83	126	24%	39
Concrete B5, B10, B15 and B25	907	53	10%	47
Wood	83	47	9%	20
Zinc	2	39	7%	15
Mineral wool	14	38	7%	24
PS – expanded plastic slab	2	21	4%	17
Tiles	4	21	4%	18
Asphalt- mastic asphalt	4	14	3%	2
Concrete - light and lightweight concrete block	9	14	3%	4
Brick HLZ, MZ and hollow block	62	14	3%	13
KSL and KSV	107	12	2%	15
Copper	<1	10	2%	2
Wood – plywood	3	9	2%	3
Window – aluminum	1	9	2%	8
Concrete – autoclaved aerated concrete	32	9	2%	8
Concrete – gas concrete	27	7	1%	5
Floor – cement layer	66	7	1%	16
Gypsum carton board	12	7	1%	17
Carpet	<1	6	1%	11
Aluminum	<1	6	1%	19
Window - wood glass	6	5	1%	14
Clinker	13	5	1%	2
PE-film	1	4	1%	18
PVC	1	4	1%	11
Wood - laminated beam	5	4	1%	13
Linoleum	<1	3	1%	5
Modern insulation	1	2	<1%	14
Wood - particle board	6	2	<1%	3

The impact of renovation is importantly higher than the one of construction as seen in Chapter 6.2 (the average score for square metre of NGF being 48 EI 99 points against 26). In the following paragraph, a reason for this difference is sought. In Figure 6-20 materials composing the houses (without refurbishment) of the set have been summed up and an average weight for square metre of net floor area was made. The most heavy materials (the ones forming 80% of the total weight) have been retained. Similarly, the materials with the highest ECOINVENT score (the one possessing 80% of the EI 99 points per Kg) have been kept. Totally, 20 materials are shown (for a translation see Appendix D.1).

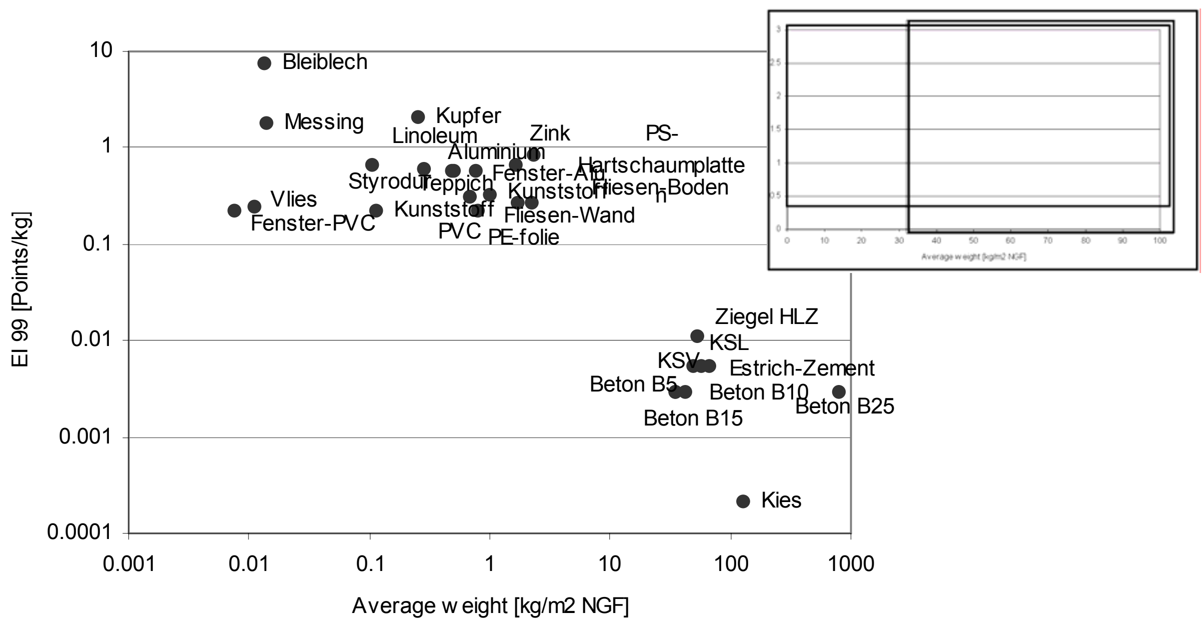


Figure 6-20: Distribution of the materials for their impact and for their weight. The scale is logarithmic.

It appears that the heaviest materials, as concrete, gravel, cement and brick have a relative low ECOINVENT score. Some materials fairly present in weight (mostly metals as lead, copper and brass) have, on the opposite, an extremely high impact. Also insulating materials, window components and tiles, not particularly weighty, have an important impact on the environment. This reflects what found by Shreuer *et al.* (2003). Together with the fact that quantities of materials augment, this explains why refurbishment causes such a bigger impact than construction. Those not weight-dominant materials are the ones that are typically replaced during the phase. So, on the whole life of the building their cumulated mass augments. In the following graphics

(Figure 6-21 - Figure 6-22) some buildings were taken as example. 6DLG is the one with the largest gap between the impact of materials during construction and during refurbishment; 10EFH is an average building.

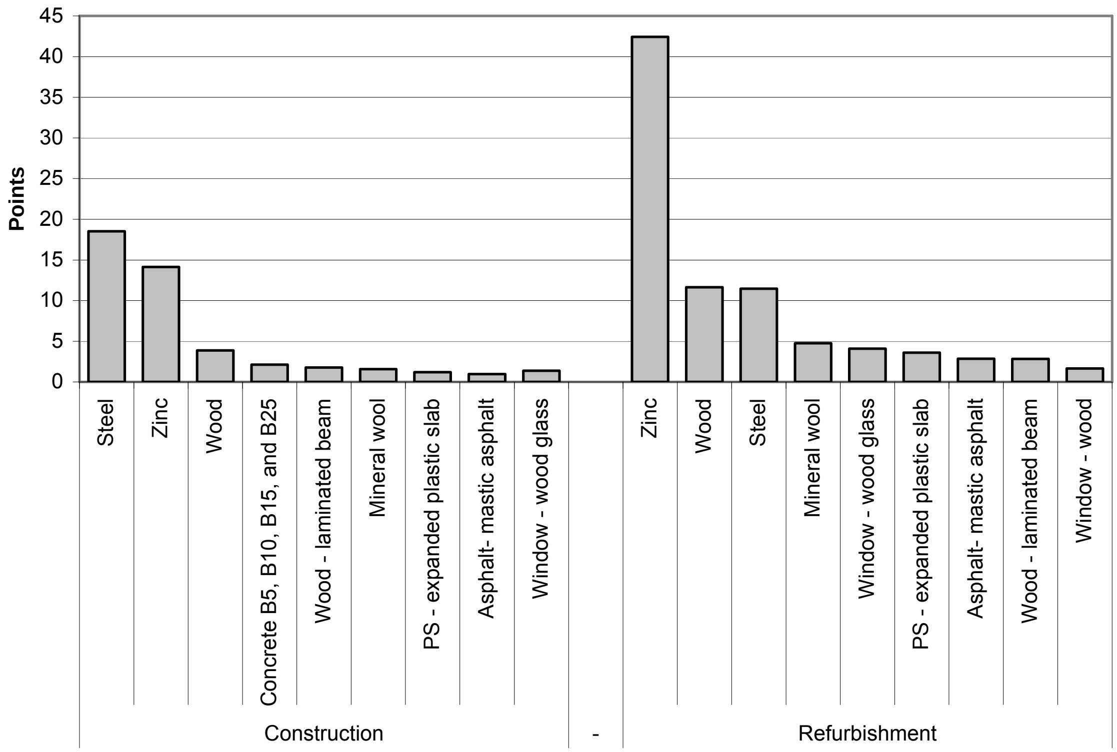


Figure 6-21: Ranking of materials responsible of 90% of the impact in respectively the construction and the refurbishment phases in house 6DLG for the EI 99 impact assessment method. House 6DLG possesses the greatest gap between the score of those two phases.

The cause of the big gap in 6DLG is zinc and its repeated replacement (on the external walls and on the roof). Follow the replacement of steel, wood and insulating materials. During the construction those critical materials were still relatively infrequent and therefore not carrying a big impact. It is because of the refurbishment of this material and the high score that is associated to it in EI 99 that house 6DLG has such a different score in the EI 99 and the CED methods. This is illustrated in Figure 6-11 and Figure 6-12.

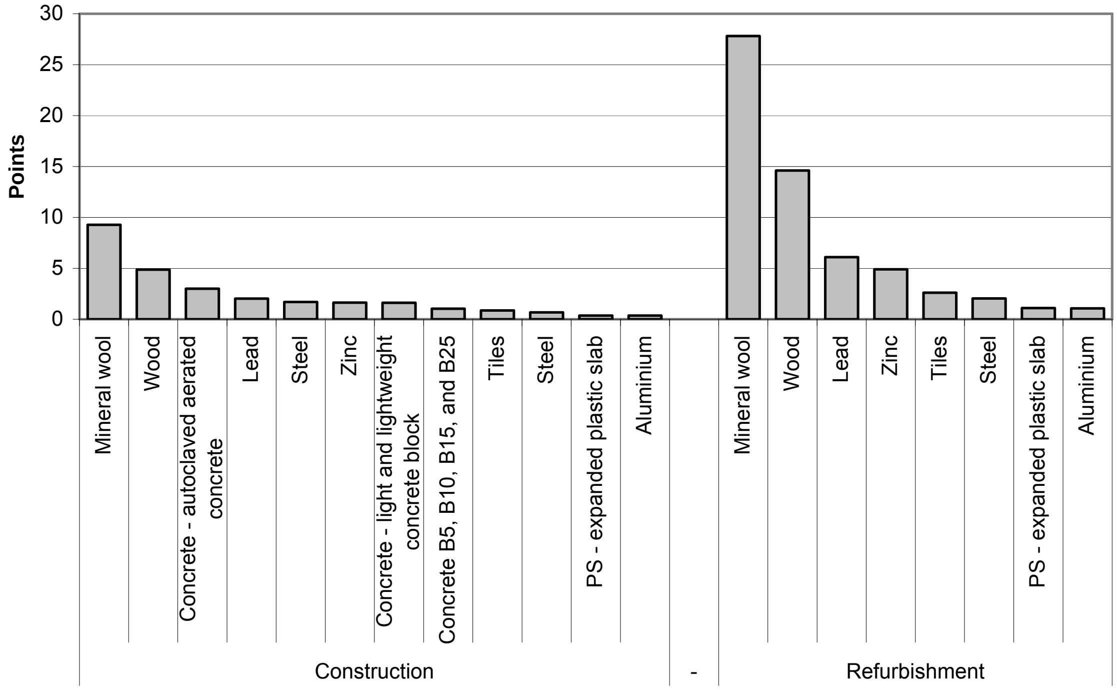


Figure 6-22: Ranking of materials responsible of 90% of the impact in respectively the construction and the refurbishment phases in house 10EFH for the EI 99 impact assessment method.

In house 10EFH, concrete and wood had an influence on the impact during construction in conjunction with mineral wool. Their influence is however little in comparison with the one of insulating materials (mineral wool), of wood, and of metals (lead and zinc) in the refurbishment phase.

This exercise was made with other buildings. It often appeared that a single material (generally an insulation one or a metal) elevates considerably the impact of refurbishment. In the construction, the first material is often steel, an insulation one or concrete.

6.3.2 General impact within the four different categories of buildings

Hereafter it was statistically analyzed if some parameters taken singularly could explain the total impact within the total group and within the different categories of buildings: EFH; MFH; DLG and PRG. And if yes; if those differed from a category of buildings to the other. Building $21EFH_{old}$ and $21EFH_{new}$ were not taken into consideration. Data concerning the elements chosen can be found in Appendix B.1. The threshold was fixed at 95%. The parameters retained are:

- The year of construction;
- The weight of the house;
- The BGF;
- The compactness (envelope's surface/EFA);
- The construction costs;
- The total score of the CED- non renewable (the cumulative demand for non renewable energy);

Categorical variables:

- The structure (masonry, reinforced concrete, solid building, wood skeleton and steel skeleton).

Considering the whole set, without distinctions of class, it appeared that three parameters could explain the total impact at a significance threshold of 95% (between 21% and 84% of the variability explained). These variables are the CED- non renewable (R^2=0.841; p-value< 0.001), the compactness (R2=0.264; p-value 0.02) and the BGF (R2=0.210; p-value 0.04) (Figure 6-19). The cost is at the limit of signification (R^2=0.182; p-value 0.06). The BGF and the compactness are redundant (R^2=0.404, p-value 0.005).

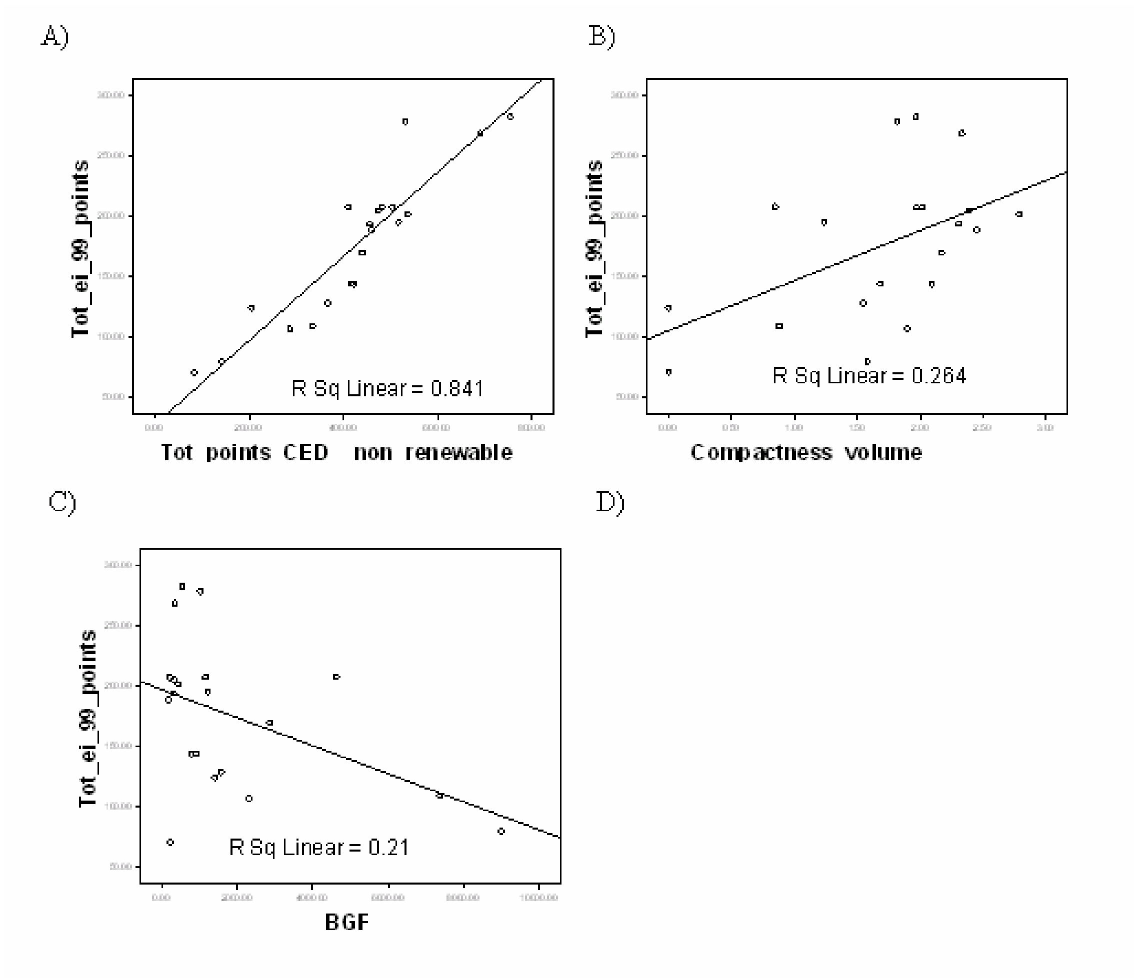


Figure 6-23: Linear regressions illustrating the relationship between the total environmental score for EI 99 and respectively the total environmental score for CED- non renewable, the compactness and the BGF.

Single occupancy houses have a very similar impact. The only parameter that could explain the difference in impact of the houses appeared to be CED- non renewable (R^2=0.912; p-value 0.003). Building 1EFH has several additional points in comparison to the other five buildings in the category. The impact is generally higher for all the four life phases but it is mainly the use one that causes the elevated score. This phase possesses one of the highest energy needs for heating of the group (together with 11EFH) and the greatest relationship between BGF and EFA (1.0 against 0.7 of 11EFH). The reasons for the high energy needs are difficult to find, as seen in Chapter 6.3.1. The compactness of the house does not differ from the others and the building is well insulated; nonetheless it possesses an important surface occupied by standard-insulating windows. Three buildings possess a wood structure (10EFH, 12EFH, 19EFH), three other a masonry one (1EFH, 11EFH, 13EFH). A difference between those two kinds of construction does not appear (ANOVA p-value= 0.235). The best insulated building (10EFH) does not have the lowest impact. 13EFH, the worst insulated one, does not have the worst one.

Also **apartment houses** don't differ considerably. Only 7MFH is considerably different. For this kind of houses too only the CED- non renewable explains the difference within the class (R^2=0.883; p-value 0.018). Also the correlation between number of apartments and impact is not significant (R^2= 0.01, p-value 0.907). 7MFH has a lower impact because of its use phase and its low energy needs for heating.

Not the same was found for **service buildings**. CED- non renewable explained the difference (R^2= 0.810, p-value 0.037) together with the BGF (R^2= 0.855, p-value 0.025). 6DLG, an administration building, has an importantly higher impact. The main reasons subside in the refurbishment and in the construction phases; there is a high presence of zinc in the roof structure and its relatively frequent substitution contributes to raise even more the impact.

The **manufacturing buildings** category is extremely inhomogeneous, with scores ranging from 71 (3PRG) and 283 (16PRG). For it as well CED- non renewable (R^2= 0.971, p-value 0.015) did not explain alone the difference. The compactness explained it as well (R^2= 0.919, p-value 0.041). 3PRG, a farm machines hall, has the lower imprint because of the small impact of its use phase (the building is not heated). 16PRG, a centre of distribution playing also the role of warehouse and incorporating offices, possesses the highest impact because of the importance of its use phase. The considerable heat losses from the roof and the windows are the principal causes.

6.4 Comparison of impact assessment methods – differences between EI 99 and CED – non renewable

Often it was said that the Cumulative Energy Demand (CED) is a good criteria to assess the impact of a house on the environment (Adalberth 1999). As it is shown in Figure 6-24, in where the ranking and the relative importance of each house are shown, the order of the buildings vary. This does, however, often only of one position and between houses that have a very similar score (for example 10EFH passes from the 3° place in

CED to the 2° in EI 99 and 4MFH from the 2° to the 3°). In the PRG category, there are not shifts of place. Houses $21EFH_{old}$ and $21EFH_{new}$ were not considered because being based on a slightly different model.

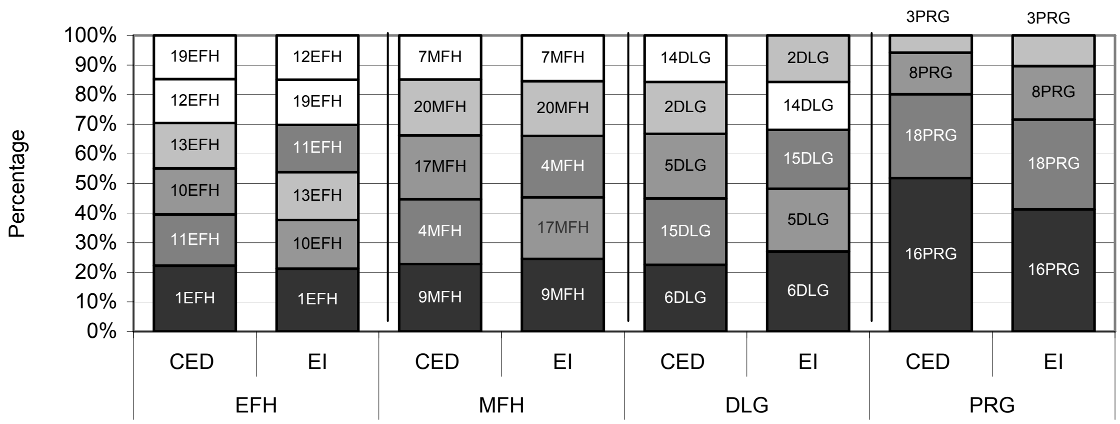


Figure 6-24: Proportion played by each house with the two different methods, CED- Non renewable and EI 99.

7 Discussion

In the following discussion, the points illustrated hereafter were treated:

- The overall impact of buildings on the environment. In particular, the following questions were analysed: "Which are the variations in impact between buildings of different shapes, materials and functions?", in Chapter 7.1. "Which phases generally dominate?" and "How is the environmental impact generally divided between the life phases?", in Chapter 7.2. Finally, in Chapters 7.3, the following question "Which elements determine the impact on the environment?" were discussed. In Chapter 7.4, it is sought if there is an element explaining the distribution of the impact within each of the four categories of buildings.
- The link between energy consumption and total impact of a building. More specifically, it was assessed if CED – Non renewable can be taken as an indicator of the general impact on the environment. This is illustrated in Chapter 7.5.
- The similarities of this study with others presented in the literature. A list is discussed in Chapter 7.6.

Results obtained can be considered complete; data could be gathered thanks also to the utilisation of models and programs. Results can be regarded as reliable and the comparison with the existing literature done in Chapter 7.6 confirms it. Uncertainty is taken into consideration and discussed in Chapter 8.1.

7.1 The overall impact of the 21 buildings

The aim of this section was to determine how the overall impact vary between the 21 buildings analysed and if there is a significant difference between classes of buildings.

Comparing the methods, it appears a similarity between results and analogies among tendencies for the three impact assessment methods utilized: CED – Non renewable, EI 99 and UBP 97. Nonetheless, because it is not the goal of this study to compare methods, the discussion will, at this point, not be taken further and only results concerning the EI 99 method will be discussed.

It appears a big variation of the overall impact of buildings. The score of less problematic building (3PRG) is rather five times smaller than the one of the more critical (the house in Wetzikon before its renovation). Housing buildings are generally fairly constant; score for industrial buildings vary enormously depending from attributions possessed. A significant distinction between the categories of buildings could be only made between EFH and DLG buildings, as shown in Chapter 6.1. It is interesting to note the big difference between $21EFH_{old}$ and the other single occupancy houses. $21EFH_{new}$, on the other hand, fits perfectly in the trend. This is related to its age ($21EFH_{old}$ dates from the '60s in contrast with the '90s of all the other buildings) and resulting differences in insulation conceptions. The building lacked rather completely of insulation materials and therefore its energy needs for heating were outstandingly higher.

It is interesting to note that single occupancy houses have a bigger impact than apartment houses. This can be explained by a major compactness of the MFH buildings and therefore a relative smaller fuel consumption.

It appears odd that buildings in the EFH category have such a similar impact even if they are of different constitution and of different architectural characteristics. The big variation in the distribution of the PRG buildings was explained in Chapter 6.1 and is originated mostly from differences concerning the heating of the buildings. In the following chapters, an explanation is sought.

7.2 Distribution of the impact between the four phases

This section wants to examine the distribution of the impact between life phases and to asses which of them generally dominate.

Usually, for all the buildings, the ranking between phases stays equal; the use phase dominates, followed by the refurbishment one, the construction and the disposal. The use phase and its fossil fuel consumption are the elements carrying the biggest burden in the life cycle of a traditional house. This was confirmed in several publications (Dinesen et Traberg-Borup 1994, Kohler 1994, Hebel 1995, Blanchard et Reppe 1998). What had seldom appeared because often not considered, is the importance of refurbishment. This phase was found to be responsible up to 44% of the whole impact (in 8PRG) and to 56% in 3PRG. For all the buildings studied, this phase outclasses the construction one. Examining the single components of the different life phases (Chapter 6.3.1), the importance of the materials for refurbishment is also shown off (28% of the total impact). This leads to new considerations that need to be made in the planning of a house. Materials do have to be taken more into account; if materials utilised during construction and during refurbishment are aggregated, their impact is equals to the one of heating.

The small score of the disposal phase confirms what found in literature, in which this phase does normally not reach more than 2% of the overall impact (Hebel 1995, Quack 1998, Kohler 1994 in Pulli 1998).

7.3 Impact of the principal components inside the life phases

Pushing further the analysis of the causes of the buildings' impact on the environment, the contribution of all the components constituting the four life phases (materials for construction, transport of materials for construction, materials for refurbishment, transport of materials for refurbishment, disposal of materials in the refurbishment phase, heating, lighting and disposal) was studied. The following emerged: the principal cause of the most important phase, use, it clearly heating, which is the biggest responsible of the impact on the overall. The component that causes principally the impact of the second phase in order of importance is materials for refurbishment in the eponymous phase. Finally, for the construction phase, materials once again carry the biggest burdens. The cause of a higher use of fossil fuel is correlated with the compactness of the buildings, with their energy related floor Area and the percentage of the whole envelope occupied by windows exposed to the sun. It is interesting to note that neither the total percentage nor the percentage of the surface occupied by windows exposed to the north appeared to be significant. The elements with the higher score in the materials for refurbishment are mostly materials belonging to the structure as steel and wood, other metals (zinc, copper, aluminium) and insulating materials. There is a number of materials that, even if slightly present in weight, do have a big impact. They are, for example, zinc, carpet, copper, aluminium in the window frame, plywood, aluminium, PE-sheets, PVC and linoleum. It is therefore important to pay attention not only to the main structure of a building when projecting a house, but also on those materials. On the other hand, materials highly present in weight as concrete do not appear between the ones responsible of the 95% of the impact. Finally, in the construction phase, they are principally the materials composing the main structure that contribute to the impact. They are, for example, steel, concrete and wood. Insulating materials and metals still play an important role but their score is considerably lower than in the refurbishment phase.

7.4 General impact within the four different categories of buildings

It appears that three parameters could explain the total impact at a significance threshold of 95%. All three are directly or indirectly linked with energy consumption. This confirms the tight relation between energy utilization (during all the life phases of the building) and the impact on the environment. The first, is the cumulative demand for non-renewable energy (CED- non renewable). The second one, the compactness, is an architectural characteristic with a significant influence on the heat flow (as seen in chapter 6.3): results show that more a house is compact (smaller is the envelope in comparison to the heated surface) and smaller is the impact on the environment. The third one, BGF, does not influence significantly the energy consumption for heating in the use phase but is correlated with the compactness. More a building is big and generally smaller is the relationship between envelope and heated surface. These results differs from the ones found by Hinz (2004) on the construction phase of the same set of buildings, in were it was suggested that no architectural characteristic could explain the environmental score of a building. This dissimilarity in the results is understandable because it is generally the use phase and not the construction one that influences the total impact and it is only considering it that a trend can appear.

7.5 Comparison of impact assessment methods – differences between EI 99 and CED – non renewable

As it was shown in Chapters 6.3.2 and 6.4, Cumulative Energy Demand reflects effectively the total impact of buildings on the environment and it will remain a good indicator to grade different buildings. This is at last true when comparing different buildings among each other and until when the use phase and the heating would continue to play such a considerable role in the whole impact of the house.

7.6 Comparison with the existing literature

Several studies were undertaken to asses the lifecycle of buildings, mainly on single occupancy houses. Hereafter some cases are presented. More details are given in Table 7-17. The goal of this comparison is to assess if the distribution of the impact between the different life phases corresponds to ours and if the impact has the same range.

This comparison has to be watched with some precautions. Because the authors of the studies have made different hypothesis, choices, uses of programs and of inventories and because the purpose of those researches was dissimilar, this data is not directly comparable.

Residential homes- single occupancy houses:

Dinesen and Traberg-Borup (1994) studied the energy flows for three houses with different consumption levels. The results were a domination of the use phase for the standard and the low-energy consumption dwellings, the construction for the experimental house.

Kohler (1994) compared 100 different simulated houses with the ECOPRO program finding a domination of the use and renovation phases for the environmental impact caused by water and energy consumption, the waste production, recycling, the critical air and water volumes, UBP, greenhouse effect, cleaning, photochemical oxidation, financial costs and external costs.

Hebel (1995, in Pulli 1998) assessed the energy utilisation during the life of a single occupancy house. He observed the predominance of the use phase. More details will be given in the following table.

Blanchard and Reppe analysed in 1998 the life cycle of a residential home in Michigan (Blanchard and Reppe 1998), and evaluated the energy consumption and the greenhouse gases emission. For their house in Michigan, they found that the primary life cycle energy consumption was 15’455 GJ.

Other cases are presented in Table 7-17.

Apartment houses, multi-dwelling buildings:

Bringolf *et al.* (1997, in Pulli 1998) compared different variants for a double-family house, finding that the use phase was predominant for the energy use, the construction for the material flow and the renovation for the total non-renewable energy and material flows, for ozone depletion, UBP, cleaning and costs.

Quack (1998, in Pulli 1998) compared five low-energy consumption houses with a reference house finding that the renovation phase's impact dominated distinctly. The criteria used were UBP, greenhouse effect and waste production.

Adalberth (1999) analysed four multi-dwelling buildings in order to establish which phase in the life cycle has the highest environmental impact; whether there are parallels between environmental impact and energy use; and whether differences in environmental impact subsist due to a choice of building construction. She also considered the difference of energy mix uses. She found that, for an occupation period of 50 years, the occupation phase is responsible approximately of 70–90% of the environmental impact during the dwelling's life cycle and the energy use during the occupation phase constitutes 85% of the total. The manufacture phase was found to having a small impact during the life cycle, nearly 10–20% of the total.

Service buildings as for example offices

Cole and Kernan (1996) made life cycle analyses for the energy use in office buildings. In particular, they studied a 4'645 m^2 three-story generic office building for alternative wood, steel and concrete structural systems. They discussed, in addition, in which way renovation has to be considered in an LCA.

Junilla (2004) quantified the potential environmental impact caused by a 24'000 m^2 office building and determined the life cycle phases contributing most to the impact. The study found that the operating electricity causes most of the environmental impact during the life cycle of those types of buildings. The other significant life cycle phases were the manufacturing of building material, the operating heat and maintenance.

Sheuer *et al.* (2003) studied a 7'300 m^2, six-story building located on the University of Michigan campus. They found that all impact categories measured (global warming potential, ozone depletion potential, acidification potential, nitrification potential and solid waste generation) correlate closely with primary energy demand.

Michiya and Tatsuo (1998) developed a method to quantify the total amount of energy consumption and CO_2 emission caused during the life cycle of office buildings. They worked on a set of 10 office buildings and found predominance in energy consumption of the operating phase. However, data varied considerably between buildings do to the difference in materials and in systems used.

Manufacturing buildings

No study was found.

Table 7-17: Comparison, for different studies, of the different phases' importance in the life cycle of a building (after Pulli 1998, completed).

	Study	Lifespan; type	Evaluation category	Construction	Refurbishment	Use	Disposal	Impact range
EFH	Dinesen et Traberg-Borup (1994)	50 years; Standard house	Energy consumption	5%	Considered in the construction phase	96%	-1%	
		50 years; Low energy house	Energy consumption	22%	Considered in the construction phase	80%	-2%	
		50 years; Experimental house	Energy consumption	76%	Considered in the construction phase	55%	-31 %	
	Kohler (1994)	80 years; Simulated houses	Water use, energy consumption, critical water volume, greenhouse effect	15-25%	10-20%	60-75%	<1%	0.07 tons CO_2eq/m²y, 443 kWh/m²y and 432300UBP/m²y
			Critical air volume, UBP, acidification, photochemical oxidation potential, external costs	30-40%	15-20%	40-50%	1%	
			Recycling, direct disposal at the dismantling site	64-66%	34-36%	0%	0%	
			Total waste	27%	56%	7%	11%	
			Financial costs	29%	52%	20%	0%	
	Hebel (1995)	50 years	Energy consumption	13%	<1%	86%	<1%	120 kWh/m²y
	Blanchard et Reppe (1998)	50 years	Energy consumption	6%	Considered in the use phase	94%	<1%	430 kWh/m²y
			Greenhouse effect					0.09 tons CO_2eq/m²y
	Scholz *et al.*(1995)	80 years	Radioactivity, abiotic resources consumption	4-10%	Considered in the construction phase	90-96%	Not calculated	
			Human toxicology, greenhouse effect, ozone layer depletion	21-27%	Considered in the construction phase	73-79%	Not calculated	
			Ecotoxicology, acidification, eutrophication	33-41%	Considered in the construction phase	59-67%	Not calculated	
			Photochemical oxidation potential	48%	Considered in the construction phase	52%	Not calculated	

	Reference house	REGENER (1997)	80 years	Waste	7%	2%	30%	60%	
				Potential ozone layer depletion	21%	2%	77%	0%	0.05 tons CO_2eq/m^{2}y
				Ecotoxicology	47%	0%	52%	1%	
				Energy consumptions, water use, resources use, radioactive waste, greenhouse effect, acidification, eutrophication, human toxicology, exhalations	0-8%	0-2%	90-100%	0-1%	490 kWh/m^{2}y
MFH		Bringolf *et al.* (1997)	50 years	UBP	10%	80%	10%	-	-
				Acidification	15%	70%	15%	-	
		Quack (1998)	80 years	UBP	17-19%	74-78%	5-9%	<1%	320000-400000 UBP/m^{2}y
		Adalberth (1999)	50 years	Global warming potential, acidification, eutrophication, photochemical ozone creation potentials, human toxicity.	10-20%		70-90%	<1%	0.03 ton CO_2 eq/m² y and 124-174 kWh /m^{2}y
DLG	Office building	Cole et Kernan (1996)		Energy consumption					
	Office building	Junnila (2004)	50 years	CO_2 emissions	9%	3%	87%	<1%	0.09 tons CO_2eq/ m^{2}y
				Acidification, eutrophication, heavy metals	13-33%	24-75%	4-38%	0-5%	
	School/offices/hotel	Sheuer *et al.* (2003)	75 years; water consumption included	Energy consumption	2%	Considered in the construction phase	98%	<1%	1333 kWh /m^{2}y
			75 years; considers also electricity for appliances	Climate change, acidification, eutrophication, heavy metals	17%	6%	74%	3%	0.03 tons CO_2 eq/m^{2}y
PRG				No studies found					

It appears that generally the use phase dominates, extremely for the energy consumption and largely for the other categories. Refurbishment is often not considered, and when it is, its impact is often not significant. Only in the house studied by Bringolf *et al.* (1997) and in Quack (1998) refurbishment becomes important and results confirm what found in this study. Disposal plays always a minor role (negative data is caused by allocation choices).

Values for the consumption of non renewable energy found in this study correspond to163 kWh/m^2y for EFH houses, 122 for MFH, 146 for DLG and 115 for PRG. Data of other studies varies fairly much. They range from 120 kWh/m^2y for the single occupancy house analysed by Hebel (1995) to 1'333 kWh/m^2y for the university building presented by Sheuer *et al.* 2003. CO_2 emissions are not comparable because in our study they are given in EI 99 points and not in CO_2 equivalents. For the Ecological Scarcity method, the comparison with our results (an average for EFH of 280'000 and of 215'000 UBP/m^2y for MFH) shows that total ecological scarcity appears considerably more elevated (320'000-400'000 UBP/m^2y in Quack (1998) and 432'300 UBP/m^2y in Kohler (1994)).

8 Uncertainty and sensitivity analysis

Sensitivity and uncertainty analysis are undertaken here for three principal reasons:
- To establish which factors, varying in the future, could modify the results of the Life Cycle Assessment;
- To test the assumptions and data used for materials in LCA. In particular, those analyses allow to test if assumptions made during the settlement of models could transform the results;
- To make the reader aware, when reading this work, that there is always vagueness in the data and the results presented.

8.1 Uncertainty discussion

In order to determine the quality of the single contributions, an uncertainty analysis was undertaken. Results obtained have to be watched with precaution; uncertainty is not negligible but particularly difficult to quantify in this case. Therefore, uncertainty is described only in a qualitative and pseudo-quantitative way and standard deviation and error bars are never shown in the results. Additionally, it has different origins. There are five principal uncertainty sources that affect the result quality: the inventory of materials (in particular in Part A) and energy sources, their matching with the ECOINVENT list, the impact damage factors, the programs used and the handling and the calculation of data.

The uncertainty brought by the **inventory** comes from the following points (in particular for Part A):

- The calculation of volumes of materials from the plans available, in particular for some materials for which thickness wasn't available and needed to be estimated;
- The calculation of the masses from the data obtained; densities of materials were estimated referring to various literature and often differed from the ones proposed by EKG;
- The completeness of the inventory: surely some materials were not noted on plans and would therefore not appear. It is the case for example of mortar, which is certainly present in the brick structure of the Wetzikon house but did not emerge on the plans. It was expressly decided not to consider it in order to allow the comparison with house 13EFH, in which this element is also missing. Also in Part B, materials as gravel and mastic asphalt were probably neglected for some houses (4EFH, 11EFH, and 13EFH for example).

The one brought by the **matching** is generated by the following aspects:

- The BKI list and the architect plans gave different names than ECOINVENT to the materials and not all the materials could find a correspondent in the list, in particular in the disposal phase. That is why the matching could not always be done successfully. Moreover, when data was not precise enough, as for example for the energy system, the average of more modules was made (nine types of boiler for gas are listed in ECOINVENT. Because their score differed very slightly, the average was used). The representativeness of the material chosen in the matching is not always granted. For Part A it was attempted to determine which matching were the more critical (big importance of the material and dubious matching) and to correct them if possible.

The uncertainty generated from the **impact damage factors**:

- In the ECOINVENT catalogue, the impact of each material was calculated more or less roughly depending from the materials or the energy source. Sometimes data is generated from a single case or a single year (the electricity mix is the average one of year 2000) that was extrapolated to the whole Switzerland and to all the years and then the repeatability and the variability are under discussion, other times data was assembled from different sources. Matrices of uncertainty are given in ECOINVENT but can difficultly be aggregated in a unique score;

- From the ECOINVENT catalogue in itself and from the transcription of the different emissions and impacts of each element. The version v 1.1 used in the first part (because the latest version was not at disposition at that moment) is known to have many mistakes. For example the emission of particulate matter during the extraction of gypsum was overestimated by a factor of more than 100 and the gross calorific value of natural gas was not adjusted to the raw gas value (before CO_2-separation), with a consequent general increase in fossil CED values of about 2% (Frischknecht 2005);
- Impact damage factors were built on many hypotheses and with more or less accurate data: for example, the global warming potential of other gases than CO_2 is known with 35% uncertainty (Scientific assessment working group of IPCC, 1994 in Peuportier 2001). Factors related to human health or ecotoxicity are uncertain because the location of the emissions is not considered. Air pollution inside buildings might have a much larger effect than diluted external emissions (Peuportier 2001).
- Data refers to the (recent) past. Are they representative for the actual and the future situation? The temporal variability is particular important for the final stage of the use and for the disposal phases.

The one brought by the **program** (EnerCAD):

- From one side, the advantages to employ a software instead of taking direct measurements are the avoiding of distortions from seasonal variations, calibrations errors of heating control equipment, irregular occupant behaviour, and abnormal weather conditions. On the other hand, however, a relevant incertitude is created from the program itself (10-20%) (CUEPE 2004) and from the low precision of the data available. This is particularly relevant in Part B, given the little precision of the plans at disposition.

Finally, there is an uncertainty brought by the **handling of data**, in all the stages of the work. When, consequently, collecting, calculating and transcribing the BKI and the plans data for the houses and when using the different sources for the evaluation of the impact of the houses on the environment.

In the following table, an essay was made to determine in a semi-quantitative way the uncertainty arising from the **inventory** and the **matching** of the materials and of the energy sources (Table 8-18) as for example the acquisition of data for house 21EFH or the matching of the list of materials at disposition.

Table 8-18: Summary of the data quality assessment according to Lindfors *et al.* (1995, modified). In data table maximum quality= 1, minimum quality= 5.

Data quality table	Acquisition method	Independence of data supplier	Representativeness	Data Age	Geographical correlation	Technological correlation
Building material from Part A	1	1	1	2	1	1
Building material from Part B	2	1	1	1	1	1
Transport	3	2	2	2	2	2
Refurbishment material	1 Part A 2 Part B	2	2	2	1	2
Transport for refurbishment	3	2	2	2	2	2
Refurbishment material disposal	2	1	2	z	1	1
Heating	2	2	2.5	2	1	1
Electricity	3	2	3	2	1	1
Final disposal	2	1	2	1	1	1

This table can be a good basis for more complex ways of analyzing uncertainties existing (Huijbregts 1998, IEA Annex 31 2001) but they were not within the scopes of this study.

8.2 Sensitivity analysis

The principal purpose of sensitivity analysis is to identify and focus on key data and assumptions that have most influence on a result. It can be used to simplify data collection and analysis without compromising the robustness of a result or to identify crucial data that must be thoroughly investigated (IEA 2001). In this section, the second point will be tested in order to ascertain which factors, varying in the future, could modify the results and to test if the various assumptions made during the settlement of the models could transform the results. The following factors, supposed to be important, were tested on a singular house ($21EFH_{old}$):

- Changes in the electricity mix used for lighting caused by an evolution of the electricity market (Chapter 8.2.1);
- Variations in energy sources for heating (Chapter 8.2.2);

- Adding of paint, as an example of the role played by secondary materials meaning materials composing the house but not being part of the main structure (Chapter 8.2.3);
- Variations in the lifespan of buildings (Chapter 8.2.4);
- Variations in the disposal paths for materials (Chapter 8.2.5).

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8.2.1 Evolution of the European electricity market

In this section will be examinated if the liberalisation of the European electricity market could modify the house's impact on the environment. The Swiss mix was substituted with the actual yearly average UCTE[14] production one (as found in the ECOINVENT software (ECOINVENT v 1.1 2004)) reported at the grid values (including therefore transformation, transport and losses in the distribution network) for, and only for, the electricity consumption during the use phase. This is the simplest simulation that could be made and does not consider the evolution of the market and a possible variation of the actual European mix composition. Forecasting of electricity mixes can be found in Dones *et al.* (1996) and in Ménard *et al.* (1998).

Additionally, two options have been tested in order to determinate how would the total impact change if $21EFH_{old}$ produced its own electricity on site or if generally electricity would come from a renewable resource. In the first, the house was equipped with average photovoltaic panels, in the second a wind power plan furnishes electricity at the house.

[14] Union for co-ordination of production and transmission of electricity.

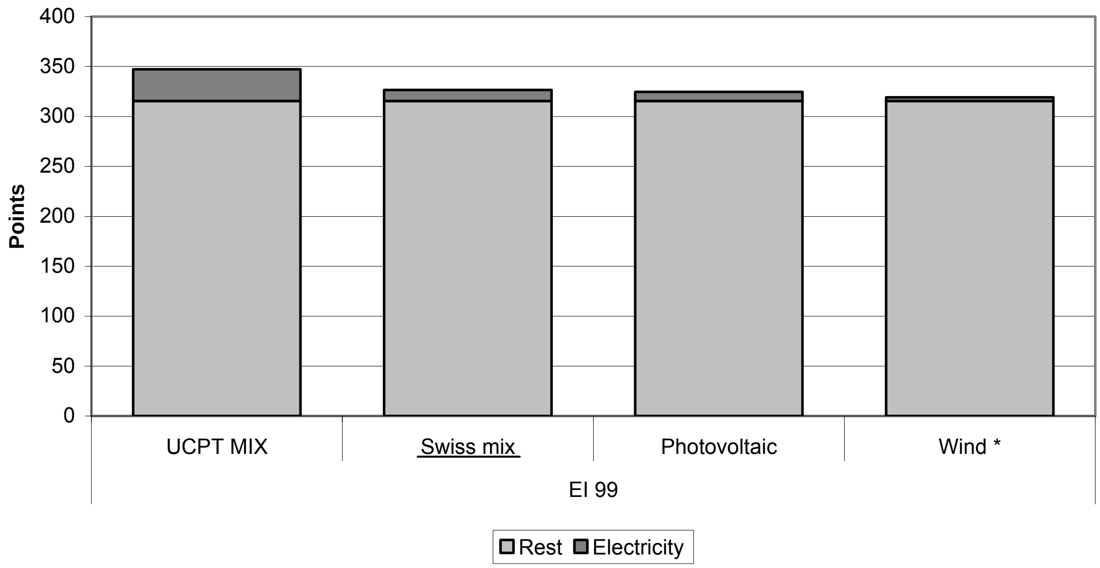

Figure 8-25: Total impact caused by modifications of electricity sources for lightning for EI 99 calculated for the actual Swiss mix, use of aeolic, photovoltaic as also the actual UCTE electricity mix for house $21EFH_{old}$. Underlined is the electricity source used. In dark gray the impact caused by the electricity, in hell gray the one caused by the other components.

As it could be seen in Figure 8-25, it appears a clear modification with the passage from the Swiss to the European mix; the electricity contribution to the total impact passes from 3 to 9% for EI 99 (results for the other methods could be found in Appendix D.1). The overall impact of the house becomes noticeably higher (+ 6.5%). For the renewable energies, on the other hand, the difference (Figure 8-25) is fairly noticeable; the use of alternative resources diminishes of 2%, respectively 0.3% the overall footprint of the house. For the other impact assessment methods, the difference is sensibly higher, as shown in Appendix D.1.

Consequently, it can be said that modifications of the provenance of electricity could difficultly diminish the overall impact caused by the building on the environment. This even if "green" sources as aeolic and photovoltaic are chosen. On the other hand, the impact could considerably raise if less clean sources were chosen, as for example mixes containing a considerable fraction of electricity produced by coal, as it is the case of the European one.

8.2.2 Variation in energy sources for heating

This test was undergone to answer the supposition that all the buildings are heated by natural gas. Different heating systems were tested on house $21EFH_{old}$: light fuel oil, solar collector system, natural gas, waste combustion, hard coal, wood energy and heat pump. The average of all the modules that could fit for the type of energy offered in ECOINVENT was done.

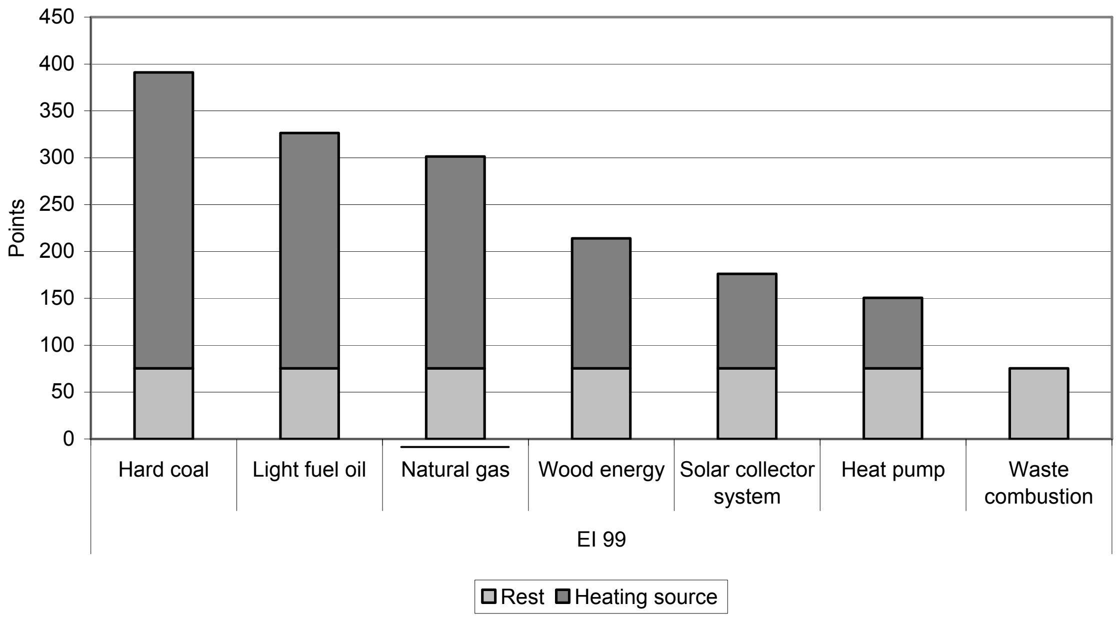

Figure 8-26: The role played by different sources of energy on the overall impact of house $21EFH_{old}$ for the EI 99 impact assessment method. Underlined is the heating source used. In dark gray the impact caused by the heating source, in hell gray the one caused by the other components.

As shown in Figure 8-26, it appears a considerable variation of the overall impact depending on the heating source. Hard coal is neatly the resource carrying the higher impact and that because of the important CO_2 emissions, follow other non renewable resources as light fuel oil, natural gas and than wood, solar systems, heat pump and finally waste combustion. This last does practically carry no impact because of the choice of allocation; all the emissions of the waste combustions were attributed to the materials incinerated (Doka 2003). Once again, it is shown how results could vary by modifying single parameters, and therefore how they have to be watched in a particular critic perspective.

8.2.3 Paint adding

Paint was not considered in the system during the compilation of the inventory, as also wood lacquer and other secondary materials. As it could play an important role on the overall impact, a sensitivity analysis for this material was done. The amount of paint was estimated from the quantity of plaster applied to the house. It was considered that paint, like plaster, is spread for 35% over the external and for 65% over the internal walls; its density was valuated to be 1.15 Kg/m^2. Refurbishment and disposal were also considered, as shown in Table 8-19. External and internal walls are repainted respectively two and seven times during the life of the building. Transport was excluded because considered not to having a big impact on the overall. An average of two types, one containing water and one solvent, of white alkyl paint was done.

Table 8-19: Data used for the evaluation of the paint's amount.

Phase	Lifespan	Amount		Paint
Construction *		0.9	m²/NGF	white alkyd paint, external (1/2 in H2O; 1/2 in solvent)
		1.7	m²/NGF	white alkyd paint, internal (1/2 in H2O; 1/2 in solvent)
Refurbishment*	35 years	1.8	m²/NGF	white alkyd paint, external (1/2 in H2O; 1/2 in solvent)
	10 years	11.9	m²/NGF	white alkyd paint, internal (1/2 in H2O; 1/2 in solvent)
Disposal		13.7	m²/NGF	disposal of paint on walls, to final disposal
		2.6	m²/NGF	disposal of paint on walls, to final disposal

* Transport has not been considered

In Figure 8-27, the impact of paint as a part of the whole is shown. Paint plays a noticeable role on the impact, in particular for the refurbishment phase (21%). The reason is the high rate of reapplication of the internal paint. If compared with plaster, which is the second element in order of importance for EI 99, it appears that they have the same importance in the refurbishment phase, both being responsible of 21% of the overall impact. For the other phases, the two materials cause respectively 3% and 7% of the impact for the construction, 0% for use and 0% and 4% for disposal phases. Totally, paint is responsible of 2% and plaster of 4% of the impact. Concrete, which is the first material, of 5%.

Table 8-20: Role played by paint in the overall impact for EI 99. Concrete and plaster are given as comparison.

EI 99	Percentage on the overall impact			
	Paint	Concrete	Plaster	Others
Construction	3%	34%	7%	57%
Refurbishment	21%	0%	21%	59%
Use	0%	0%	0%	100%
Disposal	0%	62%	4%	34%
Total	2%	5%	4%	89%

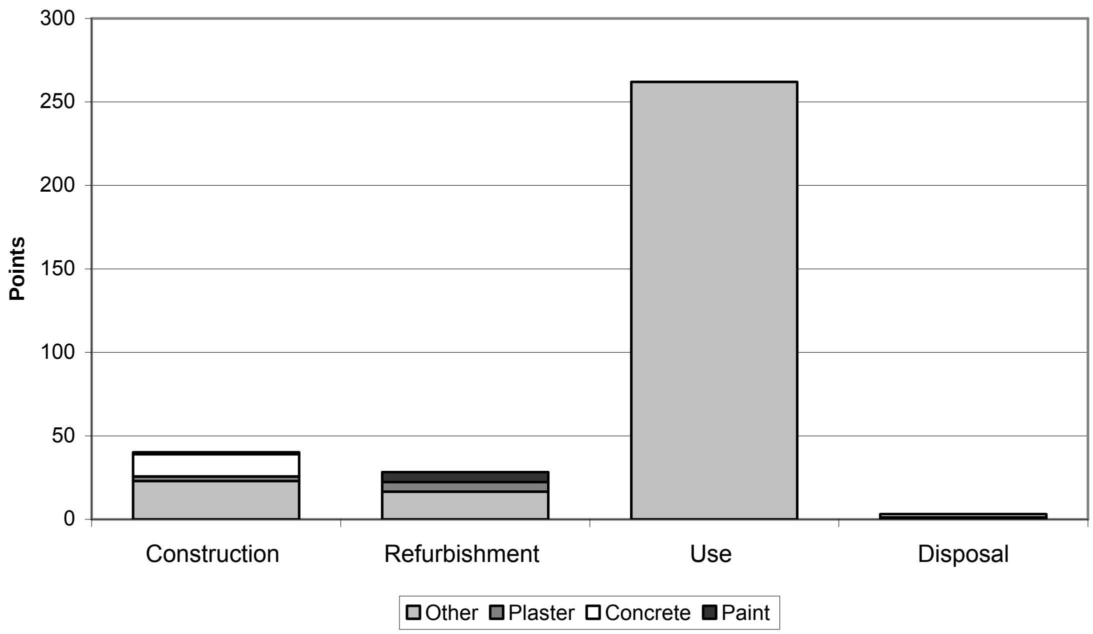

Figure 8-27: The impact of the paint as a part of the whole. Concrete and plaster, the first two elements in order of importance for EI 99 have also been given as reference.

Those results show how secondary elements, which have mostly not been considered in the inventory, could modify noticeably the results of the LCA and how the construction and the refurbishment phases could acquire importance overall.

8.2.4 Different lifespan

As mentioned before, buildings' lifetimes would never be estimated with exactitude. For this reason, and because this factor could modify significantly the impact of the house, additional life scenarios (lifespan of 50 and 100 years) for house 21EFH before and after its renovation were created.

The impact changes considerably with the variation of the lifespan of the house (Figure 8-28, Appendix D.2). As it is predictable, for the Cumulative Energy Demand impact method, it increases practically twofold with the doubling of the lifespan and therefore of the fuel consumption. For the other two methods the footprint of the house also raises considerably and this because of the importance of heating on the overall impact.

As it can be seen in Figure 8-28, the impact of the house after renovation is less time depending. This is caused by the lower relative importance of the use phase for $21EFH_{new}$.

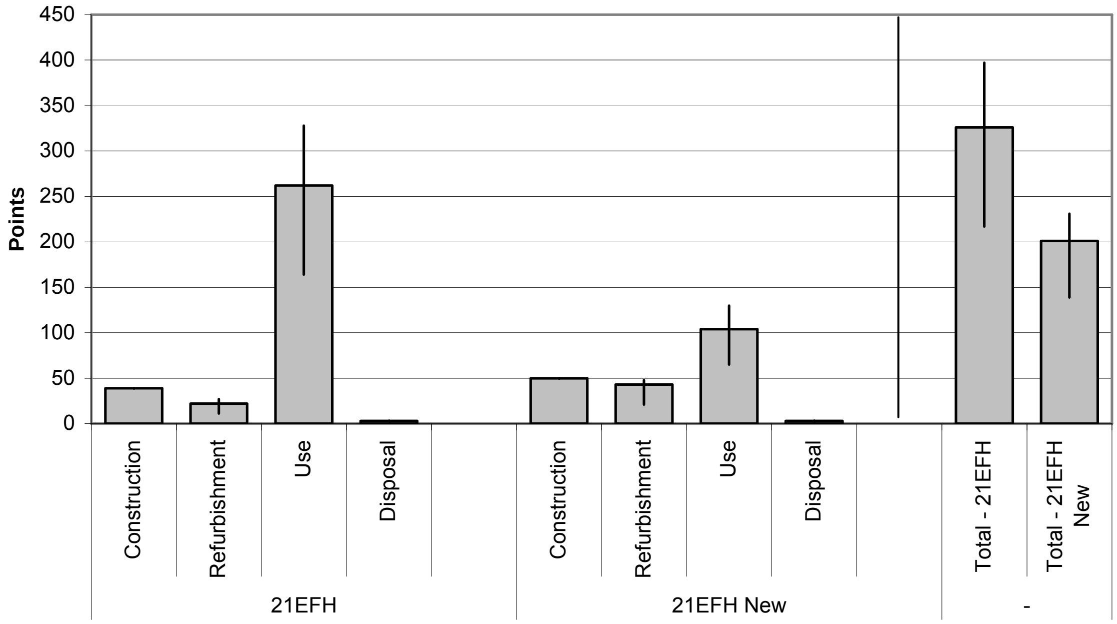

Figure 8-28: Impact of construction, refurbishment, use and disposal determined for the houses $21EFH_{old}$ and $21EFH_{new}$ for a lifespan of 80 years. Bars show the range of variation that differences in lifespan (respectively 50 and 100 years) could bring. The impact assessment method utilized is EI 99.

This sensitivity analysis serves to give a range in which the impact of the house is situated, depending from the duration of it lifespan. For $21EFH_{old}$ and with EI 99 it varies from 217 to 397 points. For $21EFH_{new}$; from 139 to 231 points.

8.2.5 The disposal phase

The disposal paths were established reflecting the actual Swiss (in Part A) and Zürich (in Part B) situations, as mentioned in Chapters 2.3.6 and 5.2.3. It is highly probable that in the future those conditions would evolve, probably towards a higher percentage of recycled materials. Therefore different possibilities are presented. In the first, shown in Figure 8-29, the best and the worst cases were tested and compared with the choice made. For best and worst cases are intended respectively a scenario which considers the recycling on place of all the materials for which this is possible and in sorting plants when not. Materials that cannot be recycled go to final disposal. In the worst case, practically all materials are incinerated or landfilled, as shown in Appendix D.3.

Results show an insignificant total difference for all the methods except for UBP 97; where the worst case swells the total impact of 21% (Figure 8-29). The final disposal of concrete is the principal cause of this higher impact, this material being highly present and its impact having 18 times a bigger weight than in the option used. The cause is the loss of space caused by landfilling. For the other assessment methods, the difference does never reach 1% because of the little role played by the disposal phase on the whole.

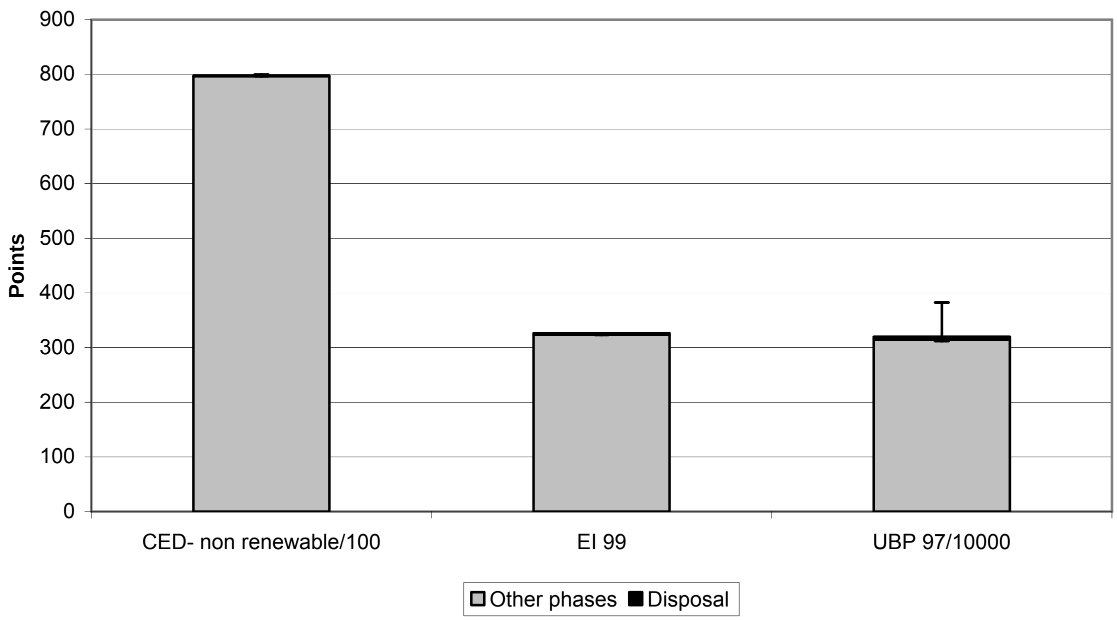

Figure 8-29: Part played by the disposal of materials of house 21EFH$_{old}$ on the total impact. Bars show the variation brought by the best and the worst cases.

The model used for allocation in the disposal phase is rather rough. A more realistic one, that became available only in a second moment, is presented in Table 8-21. In this chart, percentages reflecting the actual Zürich situation are given for the four destination paths (Althaus and Rubli, personal communication). The canton of Zürich was chosen because it is the vanguard in the Swiss scene and therefore it reflects the trend towards materials' recycling in the country.

Table 8-21: Choice of allocation for the materials' disposal reflecting the actual situation in the canton of Zürich (Althaus and Rubli, personal communication).

Materials	To direct recycling	To sorting plant	To final disposal	To municipal incineration	Material	To direct recycling	To sorting plant	To final disposal	To municipal incineration
Brick	7%	50%	43%		Mineral wool			80%	20%
Brick, not hollow	7%	50%	43%		Moisture barrier				100%
Cellular concrete	7%	60%	33%		Parquet		60%		40%
Cement layer, floor		50%	50%		Plaster	7%	50%	43%	
Ceramic tile		50%	50%		Polystyrene				100%
Clay tile, floor		50%	50%		Reinforced concrete P175	7%	60%	33%	
Concrete	7%	60%	33%		Reinforced concrete P250	7%	60%	33%	
Cork				100%	Reinforced concrete P300	7%	60%	33%	
Detritus	60%	10%	30%		Synthetic film, under roof (Isoroof)				100%
Fibre cement corrugated slab (cement asbestos)			100%		Synthetic material (Sucoflex)				100%
Fibre cement facing tile (cement asbestos)			100%		Synthetic material (Super Walton)				100%
Fibreboard (Pavatex)				100%	Tapestry	5%	35%	60%	
Fitted carpet				100%	Wood		60%		40%
Glass pane			100%		Wood, hardwood		60%		40%
Gypsum carton board			100%		Wood, softwood		60%		40%
Insulation, floor			30%	70%	Wood, window frame		30%		70%

As shown in Figure 8-30, this scenario fits in the range of worst/best cases established in precedence. Only in EI 99 the real case overtakes the worst one. The responsible are once again concrete, bricks and plaster. Their sorting in a plan (done with respectively 60, 50 and 50% in the real case in opposite to 0% in the used case) does have for EI 99 a higher impact that their final disposal. This is caused by the carcinogenic effect on human health of the emission of particulates during their sorting. Total results for EI 99 do not change in a noticeable way.

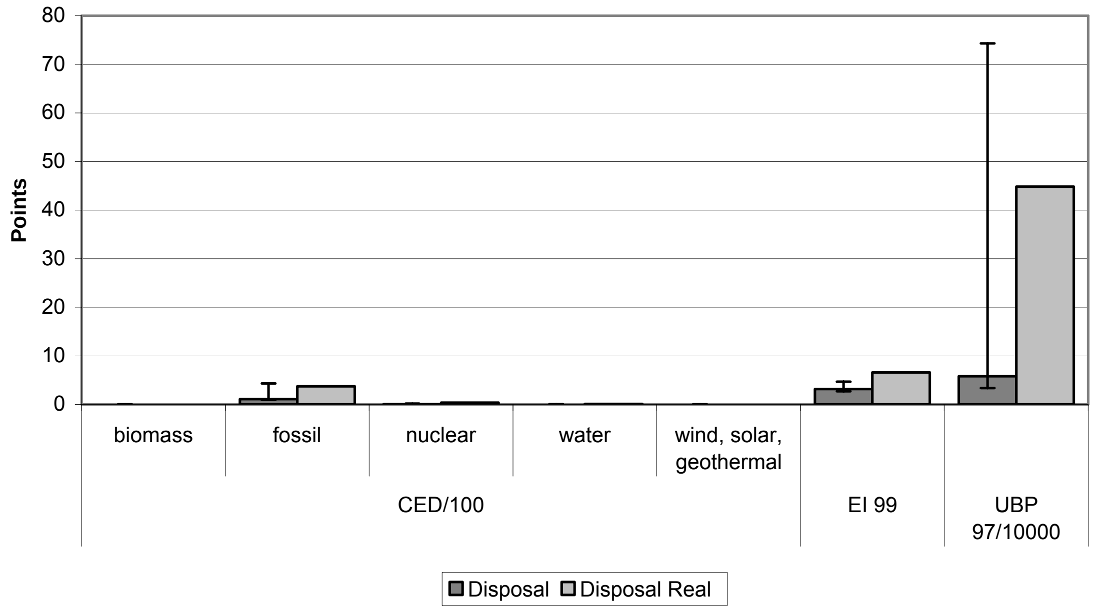

Figure 8-30: Difference between the disposal case used and the more real one reflecting the Zürich situation. Bars show the variation brought by the best and the worst cases.

8.2.6 Discussion about the sensitivity analysis

As it was illustrated, results could vary rather consistently with the changing of the parameters chosen:

- Changes in energy mixes can affect the results. If for greener energy sources the overall difference is quite unnoticeable, the switch to the European mix makes the results perceptibly worst;
- Variations in energy sources for heating affect substantially the results. The use of fossil fuels is responsible in a big amount of the total impact of buildings;
- Paint does play a rather relevant role on the overall impact, but is often forgotten in LCA. It can be supposed that the omitting of many secondary materials affects considerably the outcome;
- A big variation comes with different lifespan suppositions. Because it is difficult to predict the real duration of a building, this incertitude cannot be eliminated.
- The different cases for the disposal phase do not affect greatly the results, except in the UBP 97 method if the disposal and not the recycling of the demolition mix is chosen as an option. The biggest impact is caused by the loss of space.

9 Conclusion and outlook

Buildings are big consumers of energy and natural resources. They generate emissions and reduce landfilling capacities. In order to effectively improve their ecological performance, it is important to know where and why exactly environmental impacts occur.

The goal of this work was to analyse and compare a set of 21 buildings of different architectural and material characteristics and with different functions, to specifically assess which life phases and factors require particular attention and consideration during the effort of reducing their environmental impact. In addition, a case study allowed to assess the impact of renovation. Thanks to available data and the development of ad hoc models, both parts of the work could successfully be achieved. Results can be regarded as complete; all the information necessary to undertake the LCA was gathered successfully. They can also be considered reliable, as the comparison with a similar house and the literature show. Also uncertainty and sensitivity were considered, bringing additional value to the obtained results.

Resuming, the following was found:

- The phase causing the biggest burden appeared almost without exception to be the use one, followed by renovation, construction and disposal. For this last phase, the impact is fairly small in comparison;
- The biggest impact is without doubts caused by heating during the use phase. Many factors play a role in determining the low or high energy consumption of a building, in particular the compactness of the house, the surface heated and the surface with windows that are exposed to the sun. Also the replacement of materials, in particular of metals, wood and of insulating ones is relevant. Also materials that appear in small quantities but that do have a very high environmental score (as for example metals as zinc or lead) must be given attention. On a minor part, materials present in the original construction contribute to the overall impact. Critical materials are structural ones as steel and wood, but also the impact of insulating materials influences the results. Transport, disposal and lighting do play a truly small role in comparison. If summed up the total impact brought by materials appears to be equal to the one brought by heating;

- Results appear rather constant in between the EFH class and become increasingly variable inside the MFH, the DLG and the PRG classes. Specific causes explaining variability or constancy within classes were difficult to find;
- MFH seem to be a better solution than EFH ones, this is even more true if the inhabitant and not the surface is taken as functional unit;
- CED, for classical buildings, remains a good tool for ranking the environmental quality of buildings.

Concerning renovation:

- Renovation consents big environmental cutbacks. In the case studied, it allowed a reduction of the impact on the environment of one third. From an energetic point of view, benefits are twelve times bigger than losses;
- Renovation could have only partly been pushed further because of technical and structural limitations. However, the improvement fringe is still considerable;
- Renovation does, on a very simple comparison, result slightly better than reconstruction.

From the results obtained, it appears that actions have to be taken first and foremost for heating. As seen, insulation allows big savings and should be encouraged. Also the switch to less pollutants sources as for example a heat pump or a solar collector system brings great results, as the sensitivity analysis undertaken in Chapter 8.2.2 shows. As said in precedence, also refurbishment appears to play an important role on the impact on the environment. Its management should therefore be planned from the very beginning. In the projecting phase, a compact form and the utilisation of recycled materials should be encouraged (as for example recycled mineral wool, fibreglass and cellulose insulation, floor tiles or fibreboard). Windows, their surface and their U-value should also be taken into consideration. Instruments as the Bauteilnetz Schweiz[15] should be more exploited. Also more environmental friendly components seek to be more utilised. In particular insulation elements and metals could be substituted with less problematic ones (recycled paper, wool and straw for insulation and for example wood instead of aluminium in window frames). The replacement rate should be optimised and considered from the very beginning in the plans of the house. Also a design which minimises material use (for example one which optimises compactness) should be encouraged. The possibility to adapt the house to new future requirements acts also in this direction.

[15] http://www.bauteilnetz.ch

Single occupancy houses, by consuming more energy for heating, appear to have a worst impact than apartment houses. It could be added that they require more land for their implantation and that they possess lower compactness and density of inhabitants. In apartment houses, the number of inhabitants per m^2 is higher than the one in single occupancy houses (after SIA (2001). In an EFH a person disposes on average of 60 m^2, in MFH only of 40 m^2). Because, at the end, the number of houses reflects the number of person needing a place to live, more EFH houses are needed for the same number of people. MFH houses appear to be even more environmental friendly in comparison with EFH ones. On the other hand, if we consider the role played by inhabitants and owners, it is possible that their relative score get worst because of the smaller interest of those actors to intervent in order to reduce energy consumption (the owner does not have interests in insulating a house, seeing that principally it is not him that pays the heating bills).

Concerning the models used, the incognitos played by the evolution are considerable: "Which new materials and technologies will be created?", "How will the electricity market evolve?", "Which sources of energy and of primary resources will be still available and which one would be generally used?", "Which will be the importance of recycled materials?", "How will law evolve?", "How will the materials be disposed?", "How will esthetical and economical factors influence the lifespan of a building and the refurbishment rate of its components?" and "Which climate would Zürich have in 80 years?". Moreover, were the system borders well chosen? The impact could have dramatically changed if, for example, inhabitants' transport and furniture would have been included.

Regarding labelling; Minergie and Minergie-P are very good and effective tools but focus only on an aspect of the problem. Other life phases than the use one and other aspects than energy ought to enter in the concept. Minergie-eco (or eco-bau[16]) is a good step in this direction. Because LCA is a time consuming task, we could ask ourselves if an LCA is really always necessary in the labelling of a building. From this study, it appears that for EFH and MFH houses, "types" could be used seeing the small variability inside the group (almost similar buildings do have a comparable impact). For DLG and PRG buildings this is impossible.

At seen before, it appears that action can be directed on precise targets. Energy for heating and some particular materials could be considered as the hotspots. As both cases illustrate,

[16] http://www.eco-bau.ch

actions should already be taken at the beginning of the process; at the projecting stage. It is at this moment that architectural, materials and heating choices are made. At this instant also renovation and disposal solutions and handling have to be discussed. Goals need to be settled at the earliest stage; “What do we want to reach?”, “Which impacts would we avoid?”, “How should the house evolve in the future?”. By undertaking this work, I had the impression that knowledge and willingness to act from the scientific side exist and are ripe for allowing a more environmental friendly society. Ways to diminish energy consumption, pollution, land occupation, resources depletion are well developed and are only waiting to be applied. The wisdom exists, its application is jammed. Politic blocks, or at least slows down and does not encourage many improvements that could be undertaken. If a price, for example, would be given to environmental services; many existing “bad behaviours” would disappear because economically not rentable. For instance, the use of fossil fuel for heating or the amount of land allocated to housing. Also inhabitants have the power to diminish the environmental impact of the built environment. As said, the contribution of their behaviour to the overall impact is important. Many architects do not or are not interested in apply more innovative solutions, as also generally real estate owners do not see the reason to isolate a house during its renovation or to build innovative edifices.

As discussed here over; LCA is a great tool which allows to discover ecological hotpots in which is necessary to act in order to reduce the environmental impact of buildings. But are buildings the level in which action has to be taken? Shouldn’t it be taken on a larger level? We could ask ourselves if we still could permit ourselves to live in single families houses, disposing of so much living space per person. Could we still allow to let many buildings empty and to still build new ones? Additionally, on a more sustainable development perspective, social and economic issues should also be considered. Points like the possibility to improve the local environment’s quality, the integration and the reinforcement of social life should be integrated in the process. The population should be allowed to participate and to express itself. A building can reach environmental standards, but it has also to be accepted by the population. A Minergie standard house that does not insert in the landscape and that is not liked by the neighbourhood is not a good building. Heath of inhabitants should also be considered when choosing for example building materials. It should not only be ecological but also not mining the health of people. From an economical point of view, the building ought to be realistic; ecological should also be economically possible. For this, it could be interesting to couple the LCA with the LCC, the Life Cycle Analysis and to try to find a compromise between them. Buildings need to be projected to last on time. Quality should be sought. Flexibility should be implemented.

Actions as Agenda 21[17] are initiatives that regroup those concepts and merit to be more considered.

A final consideration could be made on the choice made during this work to consider only EI 99 (H,A) when analysing the results. Those are the principal reasons of this option:

- It would have been too long and confounding to present results for each impact assessment method;
- Only three methods have been chosen for this work, but there is a considerable further choice. If we would have made a comprehensive comparison of different approaches, we should have considered also other available methods (IMPACT 2002+, IPCC 2001, CML 2001, EDIP, EPS 2000, EI 99 (E, E), EI 99 (I, I) for instance);
- The ecological scarcity dates from 1997 and it is known to contain errors that are going to be corrected in the version that is actually being reviewed (Althaus, personal communication);
- "CED – non renewable" considers only an aspect of the whole problem (the energy consumption);
- EI 99 considers a vast range of criteria (concerning the ecosystem, the human health and resources depletion);
- EI 99 gives importance to ecotoxicology, a factor that is not taken as much into consideration in the other methods;
- EI 99 is based on Swiss and European data and on the actual situation (natural resources available, etc);
- The viewpoint chosen (H, A) is assumed to be the most pragmatically balanced perspective amongst the three proposed ((H, A), (E, E) and (I, I)) (Bajpai *et al.* 2005).

Nonetheless the following can be observed:

- EI 99 has its own weaknesses: between the three spheres used for aggregation (technosphere, ecosphere and valuesphere (Goedkoop et Spriensma 1999), the third weights the criteria not on a scientific but in a social way. It is therefore a subjective evaluation;
- Also UBP 97 is interesting because its score has being calculated basing on the goals of the Swiss environmental policy and therefore from the pollution level of that time and on the critical limits settled on that period. It is, consequently, based on a real situation. It could however be argued that data from 1997 are already old.

[17] http://www.un.org/esa/sustdev/documents/agenda21/index.htm

It would have been interesting to couple this work with the LCC made for the set of houses, in order to analyse the relationship between ecology and costs. Also a multivariate analysis in order to ascertain the reasons of difference of scores and amount of energy consumed between buildings could have been attractive.

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VDI Verein Deutscher Ingenieure, 1997. *Kumulierter Energieaufwand - Begriffe, Definitionen, Berechnungsmethoden*, VDI.

Abbreviations

BGF	Gross external floor area (Brutto Grundfläche) as defined in DIN 277 / 1987
BKI	German "centre for construction costs" (Baukosteninformationszentrum Deutscher Architektenkammern)
CED	Cumulative Energy Demand
DLG	Service buildings (Dienstleistung)
EFA	Energy-related Floor Area as defined in SIA 180/4
EFH	Single occupancy houses (Einfamilienhäuser)
EI 99	Ecoindicator 99
FF	Ancillary area for services (Funktionsfläche) as defined in DIN 277 / 1987
GF	Gross external floor area (Geschossfläche) as defined in SIA 504 416 / 2003
KSV	Sand – lime brick block (Kalksandstein, Vollblocksteine)
LCA	Life Cycle Assessment
MFH	Appartement houses (Mehrfamilienhäuser)
NF	Main function area (Nutzfläche)
NGF	Net floor area (Netto Grundfläche) as defined in CBR (2000).
PRG	Manufacturing Buildings (Produktionsgebaude)
UBP	Ecological Scarcity (Umwelt Belastung Punkte)
UCTE	Union for Co-ordination of production and Transmission of Electricity
VF	Circulation Area (Verkehrsfläche) as defined in DIN 277 / 1987

Appendixes

Appendix A - Assumptions

Appendix A.1 Thickness and density of materials

Table A-1: Thickness and density of the materials inventoried (data has been gatered from various literature).

Material	Thickness		Density		Material	Thickness		Density	
Brick			1200	Kg/m3	Mineral wool			100	kg/m3
Brick, not hollow			1600	Kg/m3	Moisture barrier	1	Mm	1500	kg/m3
Cellular concrete			800	Kg/m3	Parquet	10	Mm	720	kg/m3
Cement layer, floor			2200	Kg/m3	Plaster			2100	kg/m3
Ceramic tile	6	mm	2000	Kg/m3	Polystyrene			30	kg/m3
Clay tile, floor	20	mm	1800	Kg/m3	Reinforced concrete P175			2400	kg/m3
Concrete			2300	Kg/m3	Reinforced concrete P250			2400	kg/m3
Cork			130	Kg/m3	Reinforced concrete P300			2400	kg/m3
Detritus			1800	Kg/m3	Synthetic film, under roof (Isoroof)	3.5	Mm	1500	kg/m3
Fibre cement corrugated slab (cement asbestos)	8	mm	1200	Kg/m3	Synthetic material (Sucoflex)			1200	kg/m3
Fibre cement facing tile (cement asbestos)	5	mm	1800	Kg/m3	Synthetic material (Super Walton)	2	Mm	1200	kg/m3
Fibreboard (Pavatex)			150	Kg/m3	Tapestry	1	Mm	1100	kg/m3
Fitted carpet	1.5	mm	500	Kg/m3	Wood	40	Mm	600	kg/m3
Glass pane			1800	Kg/m2	Wood, hardwood			720	kg/m3
Gypsum carton board			950	Kg/m3	Wood, softwood			500	kg/m3
Insulation, floor			1500	Kg/m3	Wood, window frame			11.2	kg/m2

Appendix A.2 Swiss electricity mix supply for year 2000

Table A-2 : Swiss electricity mix supply for year 2000 (Frischknecht et Faist Emmenegger 2003).

Supply mix	Percentage			Supply mix	Percentage			
Oil EL		0.11	%	Waste	1.64			%
Oil M&S		0.09	%	Total CH		62.19		%
Natural gas		0.82	%	Germany	10.58			%
Propane		0.01	%	France	22.27			%
Hydro		35.86	%	Italy	0.48			%
Nuclear		23.64	%	Austria	3.01			%
Photovoltaic	0.01		%	UCTE	1.47			%
Wind	0		%	Total Import		37.81		%
Wood	0.01		%					
New renewable energies		0.02	%	Total			100	%

Appendix B - Inventory

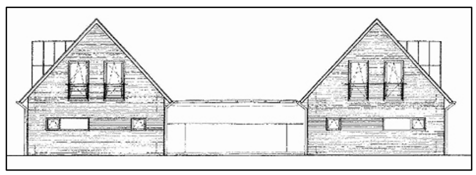
Appendix B.1 Characteristics of the set of 20 houses

Plans, pictures and description of the geometry of the houses (BKI 2003).
Material quantity and distribution between macroelements (BKI 2003).
Architectural, construction and installation attributes (BKI 2003, personal calculations).

Objekt:	**1**	**Zwei Einfamilienhäuser**
Quelle:	**BKI / 6100-255**	

Objektübersicht: Foto, Pläne, Grunddaten

Land	Niedersachsen	
Kreis	Harburg, Winsen/Luhe	
BRI	947	m^3
BGF	346	m^2
NF	257	m^2



Flächen des Grundstücks	Menge	Einheit	% an FBG
BF Bebaute Fläche	172.96	m2	16.0
UBF Unbebaute Fläche	905.04	m2	84.0
FBG Fläche des Baugrundstücks	1078.00	m2	100.0

Grundflächen des Bauwerks	Menge	Einheit	% an HNF	% an NF	% an BGF
HNF Hauptnutzfläche	227.42	m2	100.0	88.5	65.7
NNF Nebennutzfläche	29.42	m2	12.9	11.5	8.5
NF Nutzfläche	256.84	m2	112.9	100.0	74.2
FF Funktionsfläche	0.00	m2	0.0	0.0	0.0
VF Verkehrsfläche	26.45	m2	11.6	10.3	7.6
NGF Netto-Grundfläche	283.29	m2	124.6	110.3	81.9
KGF Konstruktions-Grundfläche	62.71	m2	27.6	24.4	18.1
BGF Brutto-Grundfläche	346.00	m2	152.1	134.7	100.0

Brutto-Rauminhalt des Bauwerks	Menge	Einheit	BRI/NF [m]	BRI/BGF [m]
BRI Brutto-Rauminhalt	947.00	m3	3.69	2.74

Planungskennwerte nach DIN 277

HNF	227.42	m2
NF	256.84	m2
BGF	346.00	m2

Planungkennwerte nach DIN 277	Menge	Einheit	Menge/HNF	Menge/NF	Menge/BGF
KG 320 Gründung	173.02	m2 GRF	0.76	0.67	0.50
KG 330 Aussenwände	326.76	m2 AWF	1.44	1.27	0.94
KG 340 Innenwände	358.75	m2 IWF	1.58	1.40	1.04
KG 350 Decken	173.02	m2 DEF	0.76	0.67	0.50
KG 360 Dächer	325.00	m2 DAF	1.43	1.27	0.94

Further architectural, construction and installation attributes

	MA	MB	MC	MD	MF	Gesamt
	[kg/m² GGF]	[kg/m² AWF]	[kg/m² DAF]	[kg/m² GF]	[kg/m² GF]	[kg/m² GF]
Aluminium	0.0	0.0	0.0	0.0	0.1	0.1
Beton B10	124.9	0.0	0.0	0.0	0.0	62.4
Beton B25	758.3	48.7	0.0	214.2	0.0	636.6
Beton-Gasbeton	0.0	1.8	0.0	0.0	0.3	1.9
Bitumen	0.0	0.3	0.1	0.0	1.3	1.6
Dach-Tonpfanne	0.0	0.0	21.4	0.0	0.0	20.1
Estrich-Zement	0.0	0.0	0.0	0.0	70.2	70.2
Fenster-Holz	0.0	2.2	0.1	0.0	0.0	2.0
Fenster-Holz Glas	0.0	3.9	0.1	0.0	0.0	3.5
Fliesen-Boden	0.0	0.0	0.0	0.0	2.4	2.4
Fliesen-Wand	0.0	0.0	0.0	0.0	2.3	2.3
Gipskartonplatte	0.0	0.0	0.0	0.0	7.5	7.5
Glas	0.0	0.0	0.0	0.0	0.0	0.0
Granit	0.0	0.0	0.0	0.0	0.5	0.5
Holz	0.0	0.0	35.8	0.0	1.1	34.8
Holzspanplatte	0.0	0.2	0.6	0.0	0.9	1.7
Holz-Sperrholz	0.0	0.0	0.0	0.0	1.8	1.8
Kies	387.7	0.0	0.0	0.0	0.0	193.8
Klinker	0.0	203.8	0.0	0.0	0.0	181.2
KSL	0.0	190.8	0.0	14.7	112.3	296.7
Kunststoff	0.0	1.2	0.3	0.0	0.0	1.4
Messing	0.0	0.0	0.0	0.0	0.0	0.0
Mineralfaser	0.0	5.8	28.3	0.0	3.8	35.5
Mineralwolle	0.0	0.0	3.7	0.0	0.0	3.5
Mörtel-Zementmörtel	0.0	0.9	0.0	0.0	0.0	0.8
PE-Folie	0.0	0.0	0.0	0.0	0.1	0.1
PS-Hartschaumplatten	0.0	1.3	0.0	0.0	2.0	3.2
Putz-Gipsputz	0.0	0.0	0.0	0.0	38.8	38.8
Putz-Zementputz	0.0	0.0	0.0	0.0	2.9	2.9
Stahl	18.9	0.3	0.7	10.1	1.8	22.3
Teppich	0.0	0.0	0.0	0.0	2.7	2.7
Zink	0.0	0.0	1.1	0.0	0.0	1.0
	1289.8	**461.1**	**92.1**	**239.0**	**253.0**	**1633.2**

Further characteristics	Type of building	Construction year	Construction type*[18]	Number of materials	Weight	Heating	EFAo	EFA	Height EFA	Volume EFA
	Two single occupancy houses	1998	Masonry construction	32	1633 kg/m² GF	Gas central heating	346 m²	346 m²	5 m	759 m³
Compactness (MA+MB+MC)/ EFA	**Window surface - Total**	**Window surface – North**	**Window surface - East**	**Window surface - South**	**Window surface - West**	**Window surface-Roof**	**Heat flow**	**Total insulation amount - boards****	**Total insulation amount - sheets*****	**Cost**
2.33	20%	27%	15%	27%	15%	0%	304 MJ/m² EFA	42 kg/m² GF	0.1 kg/m² GF	322 Euro/m³ BRI

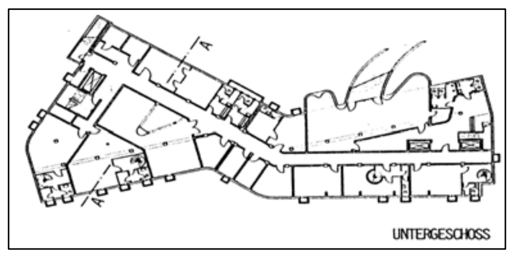
Surfaces and k-values	Floor	Composition	U- value	Roof	Composition	U-value	Roof - Window	Composition	U-value	Wall - North
	173 m²	160 mm reinforced concrete, 50 mm polystyrene insulation, 45 mm floor pavement, carpet	0.62 W/m²K	323 m²	30°; wood structure, air, wood , 140 mm mineral wool insulation, wood rafters, concrete tails	0.25 W/m² K	2 m²	Wood frame	2.04 W/m²K	44 m²
Wall - East	**Wall - South**	**Wall - West**	**Composition**	**U-value**	**Window - North**	**Window - East**	**Window - South**	**Window - West**	**Composition**	**U-value**
88 m²	44 m²	88 m²	Plaster, 17.5 0 mm brick, 80 mm polystyrene insulation, plaster	0.37 W/m² K	16 m²	16 m²	16 m²	16 m²	Insulating glass	2.04 W/m² K

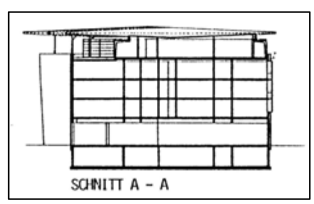
Objekt: **2** **Büro- und Geschäftsgebäude**

Quelle: **BKI / 1300-059**

Objektübersicht: Foto, Pläne, Grunddaten

Land	Nordrhein-Westfalen	
Kreis	Münster	
BRI	26'073	m^3
BGF	7'345	m^2
NF	4'434	m^2





[18] * after Hinz 2004
** Cork, mineral fiber, mineral wool, cartonboard, HP expanded polystyrene boards, cellular glass, Styrodur
*** Bitumen, bitumen sheet, glass fiber, glass fabric, modern insulating material, polyethylene sheet, PVC
**** Gas taken as reference because of the absence of detailed indications

Flächen des Grundstücks	Menge	Einheit	% an FBG
BF Bebaute Fläche	1184.60	m2	43.7
UBF Unbebaute Fläche	1525.40	m2	56.3
FBG Fläche des Baugrundstücks	2710.00	m2	100.0

Grundflächen des Bauwerks	Menge	Einheit	% an HNF	% an NF	% an BGF
HNF Hauptnutzfläche	4188.13	m2	100.0	94.4	57.0
NNF Nebennutzfläche	246.15	m2	5.9	5.6	3.4
NF Nutzfläche	4434.28	m2	105.9	100.0	60.4
FF Funktionsfläche	435.88	m2	10.4	9.8	5.9
VF Verkehrsfläche	1484.97	m2	35.5	33.5	20.2
NGF Netto-Grundfläche	6355.13	m2	151.7	143.3	86.5
KGF Konstruktions-Grundfläche	989.44	m2	23.6	22.3	13.5
BGF Brutto-Grundfläche	7344.57	m2	175.4	165.6	100.0

Brutto-Rauminhalt des Bauwerks	Menge	Einheit	BRI/NF [m]	BRI/BGF [m]
BRI Brutto-Rauminhalt	26073.23	m3	5.88	3.55

Planungskennwerte nach DIN 277

HNF	4'188.13	m2
NF	4'434.28	m2
BGF	7'344.57	m2

Planungkennwerte nach DIN 277	Menge	Einheit	Menge/HNF	Menge/NF	Menge/BGF
KG 320 Gründung	1216.09	m2 GRF	0.29	0.27	0.17
KG 330 Aussenwände	4371.54	m2 AWF	1.04	0.99	0.60
KG 340 Innenwände	6570.92	m2 IWF	1.57	1.48	0.89
KG 350 Decken	5773.77	m2 DEF	1.38	1.30	0.79
KG 360 Dächer	1590.15	m2 DAF	0.38	0.36	0.22

Further architectural, construction and installation attributes

	MA [kg/m² GGF]	MB [kg/m² AWF]	MC [kg/m² DAF]	MD [kg/m² GF]	MF [kg/m² GF]	Gesamt [kg/m² GF]
Aluminium	0.00	0.08	0.00	0.00	0.30	0.35
Beton B15	998.78	0.00	0.00	0.00	0.00	161.09
Beton B25	1930.50	225.50	51.32	605.86	1.62	1064.18
Bimsbetonvollstein	0.00	1.35	0.00	0.00	5.60	6.40
Bitumen	0.00	0.00	1.21	0.00	0.02	0.28
Estrich-Zement	0.00	0.00	0.00	0.00	73.78	73.78
Fenster-Alu	0.00	5.70	0.00	0.00	0.00	3.39
Fenster-Alu Glas	0.00	5.27	0.05	0.00	0.00	3.15
Fliesen-Boden	0.00	0.00	0.00	0.00	2.05	2.05
Fliesen-Wand	0.00	0.00	0.00	0.00	0.15	0.15
Gipskartonplatte	0.00	0.00	0.00	0.00	24.48	24.48
Glas	0.00	0.79	0.11	0.00	0.04	0.54
Holz	0.00	0.00	0.00	0.00	0.30	0.30
Holzspanplatte	0.00	0.00	0.00	0.00	1.56	1.56
Kies	0.00	0.00	128.80	0.00	0.00	27.89
KSV	0.00	18.32	0.00	101.86	29.56	142.32
Kunststoff	0.54	0.00	0.00	0.00	0.00	0.09
Linoleum	0.00	0.00	0.00	0.00	0.02	0.02
Marmor	0.00	0.00	0.00	0.00	0.13	0.13
Mineralwolle	0.00	0.40	0.00	0.00	0.00	0.24
mod. Dämmstoff	0.00	0.03	0.00	0.00	0.47	0.49
Mörtel	0.00	1.37	0.00	0.00	2.76	3.58
PE-Folie	0.00	0.00	1.04	0.00	0.09	0.31
PS-Hartschaumplatten	0.00	0.00	2.88	0.00	1.81	2.44
Putz-Zementputz	0.00	0.00	0.00	0.00	22.35	22.35
Schaumglas	0.00	0.00	0.74	0.00	0.00	0.16
Stahl	105.52	16.73	72.49	32.50	4.17	79.34
Teppich	0.00	0.00	0.00	0.00	0.06	0.06
Vlies	0.00	0.00	0.00	0.00	0.00	0.00
Ziegel MZ	0.00	59.55	0.00	0.00	0.00	35.44
	3035.34	335.08	258.63	740.22	171.34	1656.56

Further characteristics	Type of building	Construction year	Construction type*	Number of materials	Weight	Heating	EFAo	EFA	Height EFA	Volume EFA
	Officies and commercial building	1995	Reinforced concrete skeleton	30	1657 kg/m² GF	Heat exchanger, gas ****	8118 m²	346 m²	21 m	19484 m³
Compactness (MA+MB+MC)/ EFA	**Window surface - Total**	**Window surface - North**	**Window surface - East**	**Window surface - South**	**Window surface - West**	**Window surface-Roof**	**Heat flow**	**Total insulation amount - boards****	**Total insulation amount - sheets*****	**Cost**
0.88	5	14%	1%	11%	1%	0%	135 MJ/m² EFA	2.8 kg/m² GF	1.08 kg/m² GF	378 Euro/m³ BRI

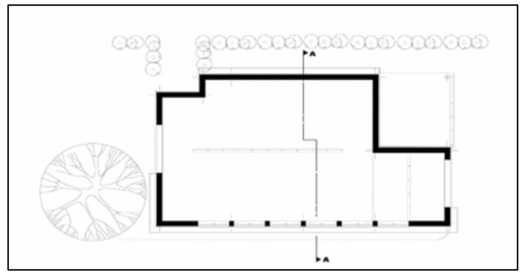
Surfaces and k-values	Floor	Composition	U- value	Roof	Composition	U- value	Roof - Window	Composition	U- value	Wall - North
	1216 m²	780 m²: reinforced concrete, formwork, concrete reinforcement, 20-40 mm polystyrene insulation, 55-65 mm floor covering; 436 m²: reinforced concrete, polystirene insulation, heating floor pavement, covering	0.83; 0.37 W/m²K	1583 m²	0°; reinforced concrete, bitumen sheet, 100 mm polystyrene insulation, PE sheet, gravel	0.33 W/m²K	7 m²	Insulating glas, aluminium frame	2.46 W/m²K	627 m²
Wall - East	**Wall - South**	**Wall - West**	**Composition**	**U- value**	**Window - North**	**Window - East**	**Window - South**	**Window - West**	**Composition**	**U- value**
1437 m²	647 m²	1437 m²	200-400 mm reinforced concrete, framework, polystyrene insulation, plaster	0.59 W/m²K	102 m²	20 m²	81 m²	20 m²	Insulating glas, aluminium frame	2.46 W/m²K

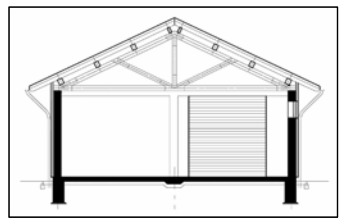
Objekt: 3 **Landmaschinenhalle**

Quelle: **BKI / 7400-003**

Objektübersicht: Foto, Pläne, Grunddaten

Land	Bayern	
Kreis	Kitzingen	
BRI	1385	m^3
BGF	218	m^2
NF	197	m^2





Flächen des Grundstücks	Menge	Einheit	% an FBG
BF Bebaute Fläche	218.37	m2	8.0
UBF Unbebaute Fläche	2523.63	m2	92.0
FBG Fläche des Baugrundstücks	2742.00	m2	100.0

Grundflächen des Bauwerks	Menge	Einheit	% an HNF	% an NF	% an BGF
HNF Hauptnutzfläche	165.66	m2	100.0	84.3	75.9
NNF Nebennutzfläche	30.96	m2	18.7	15.7	14.2
NF Nutzfläche	196.62	m2	118.7	100.0	90.0
FF Funktionsfläche	0.00	m2	0.0	0.0	0.0
VF Verkehrsfläche	0.00	m2	0.0	0.0	0.0
NGF Netto-Grundfläche	196.62	m2	118.7	100.0	90.0
KGF Konstruktions-Grundfläche	21.75	m2	13.1	11.1	10.0
BGF Brutto-Grundfläche	218.37	m2	131.8	111.1	100.0

Brutto-Rauminhalt des Bauwerks	Menge	Einheit	BRI/NF [m]	BRI/BGF [m]
BRI Brutto-Rauminhalt	1385.30	m3	7.05	6.34

Planungskennwerte nach DIN 277

HNF	165.66	m2
NF	196.62	m2
BGF	218.37	m2

Planungkennwerte nach DIN 277	Menge	Einheit	Menge/HNF	Menge/NF	Menge/BGF
KG 320 Gründung	218.37	m2 GRF	1.32	1.11	1.00
KG 330 Aussenwände	225.74	m2 AWF	1.36	1.15	1.03
KG 340 Innenwände	0.00	m2 IWF	0.00	0.00	0.00
KG 350 Decken	0.00	m2 DEF	0.00	0.00	0.00
KG 360 Dächer	313.20	m2 DAF	1.89	1.59	1.43

Further architectural, construction and installation attributes

	MA [kg/m² GGF]	MB [kg/m² AWF]	MC [kg/m² DAF]	MD [kg/m² GF]	MF [kg/m² GF]	Gesamt [kg/m² GF]
Aluminium	0.0	1.2	0.1	0.0	0.0	1.3
Beton B25	1303.3	78.9	0.0	50.5	0.0	1547.4
Beton B5	33.0	0.0	0.0	0.0	0.0	35.8
Beton-Porenbetonsteine	0.0	201.3	0.0	0.0	0.0	216.2
Bitumen	0.0	0.0	0.1	0.0	0.0	0.1
Dach-Tonziegel	0.0	0.0	31.2	0.0	0.0	18.7
Holz	0.0	24.1	62.7	0.1	7.9	71.5
Kies	235.7	0.0	0.0	0.0	0.0	255.4
Kunststoff	0.3	0.0	0.1	0.0	0.0	0.4
Kupfer	0.0	0.4	1.8	0.0	0.0	1.5
PE-Folie	0.2	0.0	1.0	0.0	0.0	0.8
Stahl	27.1	0.0	23.3	8.0	0.0	51.3
	1'599.6	**305.8**	**120.3**	**58.5**	**7.9**	**2200.3**

Further characteristics	Type of building	Construction year	Construction type*	Number of materials	Weight	Heating	EFAo	EFA	Height EFA	Volume EFA
	Farm machines hall	1996	Masonry construction	12	2200 kg/m² GF	Not heated	0 m²	0 m²	0 m	0 m³
Compactness (MA+MB+MC)/ EFA	**Window surface - Total**	**Window surface - North**	**Window surface - East**	**Window surface - South**	**Window surface - West**	**Window surface-Roof**	**Heat flow**	**Total insulation amount - boards****	**Total insulation amount - sheets*****	**Cost**
0.0	0%	0%	0%	0%	0%	0%	0 MJ/m² EFA	0.0 kg/m² GF	0.83 kg/m² GF	92 Euro/m³ BRI

Surfaces and k-values	Floor	Composition	U- value	Roof	Composition	U- value	Roof - Window	Composition	U- value	Wall - North
	0 m²	200 mm reinforced concrete, 0.2 mm PE sheet, floor covering	2.77 W/m²K	0 m²	30°; wood construction, wood rafters, PE sheet, tiles	1.46 W/m²K	0 m²			0 m²
Wall - East	**Wall - South**	**Wall - West**	**Composition**	**U- value**	**Window - North**	**Window - East**	**Window - South**	**Window - West**	**Composition**	**U- value**
0 m²	0 m²	0 m²	365 mm lighweight areated concrete, wood covering	1.11 W/m²K	0 m²	0 m²	0 m²	0 m²	Isoating glas, aluminium frame	2.46 W/m²K

Objekt: 4 **Mehrfamilienhaus mit Doppelgarage**

Quelle: **BKI / 6100-219**

Objektübersicht: Foto, Pläne, Grunddaten

Land	Hessen	
Kreis	Darmstadt-Dieburg	
BRI	2101	m^3
BGF	778	m^2
NF	579	m^2

Flächen des Grundstücks	Menge	Einheit	% an FBG
BF Bebaute Fläche	322.38	m2	44.0
UBF Unbebaute Fläche	409.72	m2	56.0
FBG Fläche des Baugrundstücks	732.10	m2	100.0

Grundflächen des Bauwerks	Menge	Einheit	% an HNF	% an NF	% an BGF
HNF Hauptnutzfläche	421.06	m2	100.0	72.7	54.1
NNF Nebennutzfläche	158.04	m2	37.5	27.3	20.3
NF Nutzfläche	579.10	m2	137.5	100.0	74.4
FF Funktionsfläche	10.05	m2	2.4	1.7	1.3
VF Verkehrsfläche	92.04	m2	21.9	15.9	11.8
NGF Netto-Grundfläche	681.19	m2	161.8	117.6	87.5
KGF Konstruktions-Grundfläche	96.95	m2	23.0	16.7	12.5
BGF Brutto-Grundfläche	778.14	m2	184.8	134.4	100.0

Brutto-Rauminhalt des Bauwerks	Menge	Einheit	BRI/NF [m]	BRI/BGF [m]
BRI Brutto-Rauminhalt	2101.32	m3	3.63	2.70

Planungskennwerte nach DIN 277

HNF	421.06	m2
NF	579.10	m2
BGF	778.14	m2

Planungkennwerte nach DIN 277	Menge	Einheit	Menge/HNF	Menge/NF	Menge/BGF
KG 320 Gründung	277.66	m2 GRF	0.66	0.48	0.36
KG 330 Aussenwände	430.71	m2 AWF	1.02	0.74	0.55
KG 340 Innenwände	612.93	m2 IWF	1.46	1.06	0.79
KG 350 Decken	383.23	m2 DEF	0.91	0.66	0.49
KG 360 Dächer	362.61	m2 DAF	0.86	0.63	0.47

Further architectural, construction and installation attributes

	MA [kg/m^2 GGF]	MB [kg/m^2 AWF]	MC [kg/m^2 DAF]	MD [kg/m^2 GF]	MF [kg/m^2 GF]	Gesamt [kg/m^2 GF]
Aluminium	0.0	0.0	0.0	0.0	0.0	0.0
Beton B25	802.9	42.3	0.0	264.1	3.7	631.2
Beton B5	104.4	0.0	0.0	0.0	0.0	43.9
Beton-Leichtbetonvollstein	0.0	10.8	0.0	0.0	0.0	6.7
Beton-Porenbetonsteine	0.0	92.9	0.0	0.0	1.2	58.5
Bitumen	0.0	0.0	0.2	0.0	0.1	0.2
Bitumenpapier	0.0	0.1	0.0	0.0	0.0	0.0
Dach-Betondachpfannen	0.0	0.0	19.3	0.0	0.0	10.6
Estrich-Zement	0.0	0.0	0.0	0.0	76.5	76.5
Fenster-Holz	0.0	0.1	0.2	0.0	0.0	0.2
Fenster-Holz Glas	0.0	0.1	0.4	0.0	0.0	0.3
Fliesen-Boden	0.0	0.0	0.0	0.0	2.0	2.0
Fliesen-Wand	0.0	0.0	0.0	0.0	2.4	2.4
Gipskartonplatte	0.0	0.0	0.0	0.0	0.0	0.0
Glas	0.0	0.2	3.1	0.0	0.0	1.8
Glasvlies	0.0	0.0	0.0	0.0	0.0	0.0
Glaswolle	0.0	0.0	0.8	0.0	0.0	0.4
Holz	0.0	0.0	11.0	0.0	0.4	6.5
Holzspanplatte	0.0	0.2	0.0	0.0	0.3	0.4
Kies	0.0	0.0	35.7	0.0	0.0	19.6
KSV	0.0	181.9	0.0	118.0	95.2	325.3
Kunststoff	0.0	0.0	0.1	0.0	0.0	0.0
Marmor	0.0	0.0	0.0	0.0	0.5	0.5
Mörtel-Zementmörtel	0.0	0.0	0.0	0.0	0.0	0.0
PE-Folie	0.0	0.0	0.1	0.0	0.0	0.0
Putz-Kalkmörtel	0.0	0.0	0.0	0.0	46.4	46.4
Putz-Kalkzementmörtel	0.0	16.6	0.0	0.0	12.7	22.9
Stahl	10.1	0.0	15.6	11.0	3.9	27.6
Teppich	0.0	0.0	0.0	0.0	0.7	0.7
Ziegel MZ	0.0	0.0	0.0	0.0	2.1	2.1
Zink	0.0	0.0	0.3	0.0	0.0	0.2
	917.4	**345.1**	**87.0**	**393.1**	**248.0**	**1287.2**

Further characteristics	Type of building	Construction year	Construction type*	Number of materials	Weight	Heating	EFAo	EFA	Height EFA	Volume EFA
	Appartament house with double garage	1994	Solid building	31	1287 kg/m^2 GF	Gas central heating	500 m^2	501 m^2	5 m	1009 m^3
Compactness (MA+MB+MC)/ EFA	**Window surface - Total**	**Window surface - North**	**Window surface - East**	**Window surface - South**	**Window surface - West**	**Window surface-Roof**	**Heat flow**	**Total insulation amount - boards****	**Total insulation amount - sheets*****	**Cost**
2.09	29%	39%	16%	31%	31%	4%	327 MJ/m^2 EFA	0.4 kg/m^2 GF	0.27 kg/m^2 GF	202 Euro/m^3 BRI

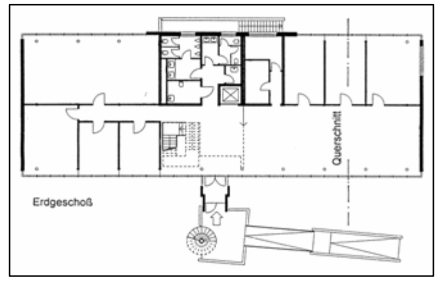
Surfaces and k-values	Floor	Composition	U- value	Roof	Composition	U-value	Roof - Window	Composition	U- value	Wall - North
	250 m^2	180 mm reinforced concrete, formwork, concrete reinforcement, cement floor covering, carpet	1.88 W/m^{2}K	348 m^2	30°; wood structure, insulation, PE sheet, tiles	0.30 W/m^{2}K	15 m^2	Wood frame	2.04 W/m^{2}K	33 m^2
Wall - East	**Wall - South**	**Wall - West**	**Composition**	**U- value**	**Window - North**	**Window - East**	**Window - South**	**Window - West**	**Composition**	**U-value**
45 m^2	37 m^2	37 m^2	137 m^2: plaster, brick, plaster; 173 m^2: plaster, lightweight areated concrete, plaster	0.86; 0.86 W/m^{2}K	21 m^2	8 m^2	17 m^2	17 m^2	Insulating glas, wood frame	2.04 W/m^{2}K

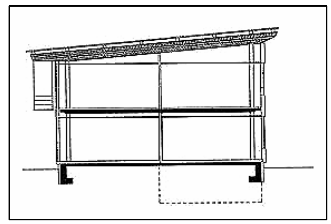
Objekt: **5** **Berufliches Fortbildungszentrum**

Quelle: **BKI / 4500-005**

Objektübersicht: Foto, Pläne, Grunddaten

Land	Bayern	
Kreis	Schweinfurt	
BRI	4'743	m^3
BGF	1'150	m^2
NF	711	m^2





Flächen des Grundstücks	Menge	Einheit	% an FBG
BF Bebaute Fläche	543.09	m2	16.7
UBF Unbebaute Fläche	2701.91	m2	83.3
FBG Fläche des Baugrundstücks	3245.00	m2	100.0

Grundflächen des Bauwerks	Menge	Einheit	% an HNF	% an NF	% an BGF
HNF Hauptnutzfläche	650.48	m2	100.0	91.5	56.5
NNF Nebennutzfläche	60.55	m2	9.3	8.5	5.3
NF Nutzfläche	711.03	m2	109.3	100.0	61.8
FF Funktionsfläche	50.97	m2	7.8	7.2	4.4
VF Verkehrsfläche	285.10	m2	43.8	40.1	24.8
NGF Netto-Grundfläche	1047.10	m2	161.0	147.3	91.0
KGF Konstruktions-Grundfläche	103.31	m2	15.9	14.5	9.0
BGF Brutto-Grundfläche	1150.41	m2	176.9	161.8	100.0

Brutto-Rauminhalt des Bauwerks	Menge	Einheit	BRI/NF [m]	BRI/BGF [m]
BRI Brutto-Rauminhalt	4742.77	m3	6.67	4.12

Planungskennwerte nach DIN 277

HNF	650.48	m2
NF	711.03	m2
BGF	1'150.41	m2

Planungkennwerte nach DIN 277	Menge	Einheit	Menge/HNF	Menge/NF	Menge/BGF
KG 320 Gründung	543.09	m2 GRF	0.83	0.76	0.47
KG 330 Aussenwände	1'068.15	m2 AWF	1.64	1.50	0.93
KG 340 Innenwände	865.81	m2 IWF	1.33	1.22	0.75
KG 350 Decken	607.31	m2 DEF	0.93	0.85	0.53
KG 360 Dächer	618.48	m2 DAF	0.95	0.87	0.54

Further architectural, construction and installation attributes

	MA [kg/m² GGF]	MB [kg/m² AWF]	MC [kg/m² DAF]	MD [kg/m² GF]	MF [kg/m² GF]	Gesamt [kg/m² GF]
Aluminium	0.0	0.3	2.7	0.0	0.2	1.9
Asphalt-Gussasphalt	0.0	0.0	0.0	0.0	63.1	63.1
Beton B10	411.3	0.0	0.0	0.0	0.0	194.2
Beton B15	464.4	0.0	0.0	0.0	0.0	219.3
Beton B25	555.3	139.0	0.0	432.0	11.0	832.4
Beton-Gasbeton	0.0	41.4	0.0	0.0	0.0	37.9
Bitumen	0.0	0.0	0.0	0.0	0.0	0.0
Estrich-Zement	0.0	0.0	0.0	0.0	8.5	8.5
Fenster-Holz	0.0	5.6	0.0	0.0	0.0	5.2
Fenster-Holz Glas	0.0	10.1	0.0	0.0	0.0	9.2
Fliesen-Boden	0.0	0.0	0.0	0.0	0.5	0.5
Fliesen-Wand	0.0	0.0	0.0	0.0	0.7	0.7
Gipskartonplatte	0.0	0.0	0.0	0.0	24.5	24.5
Glas	0.0	0.1	0.0	0.0	0.5	0.5
Holz	0.0	4.3	26.4	0.3	7.8	26.2
Holz-Brettschichtholz	0.0	0.0	19.5	0.0	0.0	10.5
Holzspanplatte	0.0	0.0	0.0	0.0	2.0	2.0
Kies	316.2	0.0	0.0	0.0	0.0	149.3
KSL	0.0	0.0	0.0	6.5	1.2	7.7
Mineralfaser	0.0	0.0	0.0	0.0	2.3	2.3
Mineralwolle	0.0	0.0	33.9	0.0	0.0	18.2
mod. Dämmstoff	0.0	0.0	0.0	0.0	0.9	0.9
Pappe	0.0	0.0	0.0	0.0	0.1	0.1
PE-Folie	0.1	0.0	0.6	0.0	0.0	0.4
PS-Hartschaumplatten	0.0	0.9	0.0	0.2	0.0	1.0
Putz	0.0	5.7	0.0	0.0	0.5	5.8
PVC	0.2	0.0	0.0	0.0	0.0	0.1
Stahl	27.2	6.0	0.9	21.6	2.3	42.7
Zink	0.0	0.0	1.4	0.0	0.0	0.7
	1'774.9	**213.4**	**85.2**	**460.5**	**126.0**	**1'665.8**

Further characteristics	Type of building	Construction year	Construction type*	Number of materials	Weight	Heating	EFAo	EFA	Height EFA	Volume EFA
	Professional training center	1995	Reinforced concrete skeleton	29	1666 kg/m^2 GF	Gas	1099 m^2	1099 m^2	4 m	1812 m^3
Compactness (MA+MB+MC)/ EFA	**Window surface - Total**	**Window surface - North**	**Window surface - East**	**Window surface - South**	**Window surface - West**	**Window surface-Roof**	**Heat flow**	**Total insulation amount - boards****	**Total insulation amount - sheets***t**	**Cost**
2.01	3%	10%	1%	3%	1%	0%	196 MJ/m^2 EFA	21.6 kg/m^2 GF	1.40 kg/m^2 GF	302 Euro/m^3 BRI

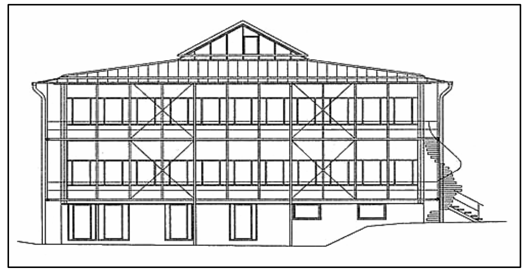
Surfaces and k-values	Floor	Composition	U- value	Roof	Composition	U- value	Roof - Window	Composition	U- value	Wall - North
	543 m^2	150-200 mm reinforced concrete, formwork, concrete reinforcement, 35 mm asphalt, 90 mm insulation, PE sheet, cement covering	0.41 W/m^2K	618 m^2	15°; wood construction, 160 mm mineral wool insulation between rafters, alu sheet, titanium zinc covering	0.27 W/m^2K	0 m^2	-	-	342 m^2
Wall - East	**Wall - South**	**Wall - West**	**Composition**	**U- value**	**Window - North**	**Window - East**	**Window - South**	**Window - West**	**Composition**	**U- value**
143 m^2	351 m^2	143 m^2	Plaster, 300 mm lightweight areated, 80 mm polystyrene insulation, concrete, plaster	0.40 W/m^2K	18 m^2	1 m^2	10 m^2	1 m^2	Insulating glas, wood frame	2.04 W/m^2K

Objekt: 6 **Verwaltunggebäude**

Quelle: BKI / 1300-049

Objektübersicht: Foto, Pläne, Grunddaten

Land	Bayern	
Kreis	Landshut	
BRI	3'508	m^3
BGF	1017	m^2
NF	708	m^2



Flächen des Grundstücks	Menge	Einheit	% an FBG
BF Bebaute Fläche	369.64	m2	17.6
UBF Unbebaute Fläche	1730.36	m2	82.4
FBG Fläche des Baugrundstücks	2100.00	m2	100.0

Grundflächen des Bauwerks	Menge	Einheit	% an HNF	% an NF	% an BGF
HNF Hauptnutzfläche	660.71	m2	100.0	93.3	65.0
NNF Nebennutzfläche	47.14	m2	7.1	6.7	4.6
NF Nutzfläche	707.85	m2	107.1	100.0	69.6
FF Funktionsfläche	22.51	m2	3.4	3.2	2.2
VF Verkehrsfläche	177.43	m2	26.9	25.1	17.5
NGF Netto-Grundfläche	907.79	m2	137.4	128.2	89.3
KGF Konstruktions-Grundfläche	108.77	m2	16.5	15.4	10.7
BGF Brutto-Grundfläche	1016.56	m2	153.9	143.6	100.0

Brutto-Rauminhalt des Bauwerks	Menge	Einheit	BRI/NF [m]	BRI/BGF [m]
BRI Brutto-Rauminhalt	3508.28	m3	4.96	3.45

Planungskennwerte nach DIN 277

HNF	660.71	m2
NF	707.85	m2
BGF	1'016.56	m2

Planungkennwerte nach DIN 277	Menge	Einheit	Menge/HNF	Menge/NF	Menge/BGF
KG 320 Gründung	369.64	m2 GRF	0.56	0.52	0.36
KG 330 Aussenwände	911.38	m2 AWF	1.38	1.29	0.90
KG 340 Innenwände	845.71	m2 IWF	1.28	1.19	0.83
KG 350 Decken	646.92	m2 DEF	0.98	0.91	0.64
KG 360 Dächer	501.31	m2 DAF	0.76	0.71	0.49

Further architectural, construction and installation attributes

	MA [kg/m^2 GGF]	MB [kg/m^2 AWF]	MC [kg/m^2 DAF]	MD [kg/m^2 GF]	MF [kg/m^2 GF]	Gesamt [kg/m^2 GF]
Aluminium	0.0	0.0	0.0	0.0	0.1	0.12
Asphalt-Gussasphalt	0.0	0.0	0.0	0.0	4.4	4.36
Beton B25	709.4	222.7	0.0	200.4	0.0	652.65
Bitumen	0.0	0.0	0.9	0.3	0.0	0.80
Fenster-Holz	0.0	9.9	0.0	0.0	0.0	8.65
Fenster-Holz Glas	0.0	17.7	0.0	0.0	0.0	15.45
Fliesen-Boden	0.0	0.0	0.0	0.0	0.1	0.13
Fliesen-Wand	0.0	0.0	0.0	0.0	1.5	1.50
Glas	0.0	0.0	3.2	0.0	1.9	3.49
Holz	0.0	10.0	42.1	15.3	15.6	60.32
Holz-Brettschichtholz	0.0	0.0	17.5	13.0	2.6	24.28
Holzspanplatte	0.0	0.0	0.0	0.0	19.4	19.39
Kunststoff	0.0	0.0	0.0	0.0	0.2	0.17
Mineralfaser	0.0	0.0	21.1	0.0	0.0	10.39
mod. Dämmstoff	0.0	0.0	0.0	0.1	0.3	0.42
Pappe	0.0	0.0	0.0	0.0	5.2	5.21
PE-Folie	2.3	0.0	0.0	0.0	0.0	0.83
PS-Hartschaumplatten	4.5	0.0	0.0	0.0	0.0	1.65
Putz-Kalkmörtel	0.0	0.0	0.0	0.0	11.3	11.26
Putz-Kalkzementmörtel	0.0	0.0	0.0	0.0	2.2	2.19
Stahl	88.6	37.3	0.6	38.0	15.1	118.21
Ziegel HLZ	0.0	0.0	0.0	0.0	36.5	36.54
Zink	0.0	0.0	29.8	0.0	0.3	14.93
	804.8	**297.5**	**115.2**	**267.1**	**116.6**	**992.9**

Further characteristics	Type of building	Construction year	Construction type*	Number of materials	Weight	Heating	EFAo	EFA	Height EFA	Volume EFA
	Administration building	1992	Wood skeleton	23	993 kg/m^2 GF	Oil (supplied by the oil-fired central heating plant)	847 m^2	968 m^2	9 m	2201 m^3
Compactness (MA+MB+MC)/ EFA	**Window surface - Total**	**Window surface - North**	**Window surface - East**	**Window surface - South**	**Window surface - West**	**Window surface-Roof**	**Heat flow**	**Total insulation amount - boards****	**Total insulation amount - sheets*****	**Cost**
1.82	26%	25%	25%	25%	25%	8%	229 MJ/m^2 EFA	17.3 kg/m^2 GF	2.05 kg/m^2 GF	437 Euro/m^3 BRI

Surfaces and k-values	Floor	Composition	U- value	Roof	Composition	U-value	Roof - Window	Composition	U-value	Wall - North
	370 m^2	185 m^2: 300 mm reinforced concrete, humidity insulation PE sheet, sound insulation, mastic asphalt, floor pavement, 22 mm parquet; 185 m^2: plaster, 240 mm concrete, formwork, concrete reinforcement, sound insulation, mastic asphalt, 22 mm parquet	0.44; 0.31 W/m^2K	462 m^2	15 °; wood construction, 60 mm air, wood planks, 120 mm insulation mineral fibre, 24 mm wood planks, bitumen sheets, titanium zinc covering	0.25 W/m^2K	39 m^2	Insulating glass, metal frame	2.31 W/m^2K	172 m^2
Wall - East	**Wall - South**	**Wall - West**	**Composition**	**U-value**	**Window - North**	**Window - East**	**Window - South**	**Window - West**	**Composition**	**U-value**
143 m^2	172 m^2	143 m^2	172 m^2: wood panels, insulating panels, titanium zinc covering, 515 m^2: plaster, inner insulation,300 mm reinforced concrete, framework, concrete reinforcement	0.30; 0.30 W/m^2K	56 m^2	56 m^2	56 m^2	56 m^2	Insulating glas, wood frame	2.04 W/m^2K

Objekt: 7 **Mehrfamilienhaus (16 WE) mit Tiefgarage**

Quelle: BKI / 6100-089

Objektübersicht: Foto, Pläne, Grunddaten

Land	Bayern	
Kreis	Ingolstadt	
BRI	6'347	m^3
BGF	2305	m^2
NF	1344	m^2

Flächen des Grundstücks	Menge	Einheit	% an FBG
BF Bebaute Fläche	472.17	m2	100.0
UBF Unbebaute Fläche	0.00	m2	0.0
FBG Fläche des Baugrundstücks	472.17	m2	100.0

Grundflächen des Bauwerks	Menge	Einheit	% an HNF	% an NF	% an BGF
HNF Hauptnutzfläche	897.79	m2	100.0	66.8	39.0
NNF Nebennutzfläche	446.29	m2	49.7	33.2	19.4
NF Nutzfläche	1344.08	m2	149.7	100.0	58.3
FF Funktionsfläche	20.49	m2	2.3	1.5	0.9
VF Verkehrsfläche	744.92	m2	83.0	55.4	32.3
NGF Netto-Grundfläche	2109.49	m2	235.0	156.9	91.5
KGF Konstruktions-Grundfläche	195.29	m2	21.8	14.5	8.5
BGF Brutto-Grundfläche	2304.78	m2	256.7	171.5	100.0

Brutto-Rauminhalt des Bauwerks	Menge	Einheit	BRI/NF [m]	BRI/BGF [m]
BRI Brutto-Rauminhalt	6346.52	m3	4.72	2.75

Planungskennwerte nach DIN 277

HNF	897.79	m2
NF	1'344.08	m2
BGF	2'304.78	m2

Planungkennwerte nach DIN 277	Menge	Einheit	Menge/HNF	Menge/NF	Menge/BGF
KG 320 Gründung	472.17	m2 GRF	0.53	0.35	0.20
KG 330 Aussenwände	1671.53	m2 AWF	1.86	1.24	0.73
KG 340 Innenwände	1856.41	m2 IWF	2.07	1.38	0.81
KG 350 Decken	1531.75	m2 DEF	1.71	1.14	0.66
KG 360 Dächer	753.82	m2 DAF	0.84	0.56	0.33

Further architectural, construction and installation attributes

	MA [kg/m² GGF]	MB [kg/m² AWF]	MC [kg/m² DAF]	MD [kg/m² GF]	MF [kg/m² GF]	Gesamt [kg/m² GF]
Aluminium	0.0	0.0	0.0	0.0	0.1	0.2
Beton B25	1023.5	103.7	320.8	284.3	0.0	740.8
Beton B5	117.2	0.0	0.0	0.0	0.0	27.6
Beton-Porenbetonsteine	0.0	2.1	0.0	0.0	0.0	1.9
Bitumen	0.0	0.0	0.7	0.0	0.0	0.3
Estrich-Zement	0.0	0.0	0.0	0.0	116.4	116.4
Faserzementplatten	0.0	2.6	0.0	0.0	0.0	2.4
Fenster-Holz	0.0	2.0	0.0	0.0	0.0	1.9
Fenster-Holz Glas	0.0	3.7	0.0	0.0	0.0	3.3
Fliesen-Boden	0.0	0.0	0.0	0.0	1.5	1.5
Fliesen-Wand	0.0	0.0	0.0	0.0	2.0	2.0
Gipskartonplatte	0.0	0.0	0.0	0.0	25.2	25.2
Glas	0.0	0.0	0.7	0.0	0.9	1.1
Holz	0.0	1.6	15.7	0.5	3.0	10.8
Holzspanplatte	0.0	0.0	0.0	0.0	2.2	2.2
Kies	571.8	0.0	0.0	0.0	0.0	134.7
Mineralwolle	0.0	0.3	0.0	0.0	0.0	0.3
mod. Dämmstoff	0.0	0.1	0.0	0.0	0.2	0.3
Putz-Kalkzementmörtel	0.0	10.3	0.0	0.0	25.9	35.3
PVC	0.0	0.0	0.1	0.0	0.0	0.0
Stahl	21.2	4.7	14.3	16.7	8.1	39.4
Styrodur	0.0	0.0	0.0	0.0	0.0	0.0
Ziegel HLZ	0.0	113.1	0.0	67.4	0.0	170.6
Ziegel MZ	0.0	0.0	0.0	66.5	0.0	66.5
Zink	0.0	0.0	3.6	0.0	0.7	2.1
	1'733.7	244.2	355.8	435.5	186.2	1'386.9

Further characteristics	Type of building	Construction year	Construction type*	Number of materials	Weight	Heating	EFAo	EFA	Height EFA	Volume EFA
	Appartament house (16) with underground garage	1993	Masonry construction	26	1387 kg/m² GF	Gas central heating	1597 m²	1608 m²	11 m	2396 m³
Compactness (MA+MB+MC)/ EFA	**Window surface - Total**	**Window surface - North**	**Window surface - East**	**Window surface - South**	**Window surface - West**	**Window surface-Roof**	**Heat flow**	**Total insulation amount - boards****	**Total insulation amount - sheets*****	**Cost**
1.90	19%	12%	23%	0%	39%	0%	171 MJ/m² EFA	0.3 kg/m² GF	0.59 kg/m² GF	224 Euro/m³ BRI

Surfaces and k-values	Floor	Composition	U- value	Roof	Composition	U-value	Roof - Window	Composition	U- value	Wall - North
	472 m²	236 m²: reinforced concrete, formwork, concrete reinforcement; 236 m²: 160 mm reinforced concrete, formwork, concrete reinforcement, insulation, cement covering	2.36; 0.37 W/m²K	786 m²	224 m²: 0°; 400 mm reinforced concrete, formwork, concrete reinforcement, 140 mm insulation; 95 m²: 160 mm reinforced concrete, formwork, concrete reinforcement, 140 mm insulation; 457 m²: 30°; wood construction, formwork, 140 mm insulation, cardboard, titan zinc covering	0.28; 0.29; 0.29 W/m²K	1 m²	Insulating glass, wood-metal frame	2.04 W/m²K	197 m²
Wall - East	**Wall - South**	**Wall - West**	**Composition**	**U-value**	**Window - North**	**Window - East**	**Window - South**	**Window - West**	**Composition**	**U-value**
191 m²	225 m²	150 m²	139 m²: plaster, 250 mm reinforced concrete, formwork, concrete reinforcement, 60-80 mm insulation, plaster; 299 m²: 365 mm insulating brick, plaster; 326 m²: plaster, 250 mm bricks, 60-80mm insulation, plaster	0.47; 0.37, 0.38 W/m²K	28 m²	56 m²	0 m²	97 m²	Insulating glass, wood-metal frame	2.04 W/m²K

Objekt: 8 **Getränkelager**

Quelle: BKI / 7700-013

Objektübersicht: Foto, Pläne, Grunddaten

Land	Bayern	
Kreis	Nürnberg	
BRI	10'172	m^3
BGF	1395	m^2
NF	1173	m^2

Flächen des Grundstücks	Menge	Einheit	% an FBG
BF Bebaute Fläche	1155.84	m2	28.2
UBF Unbebaute Fläche	2944.16	m2	71.8
FBG Fläche des Baugrundstücks	4100.00	m2	100.0

Grundflächen des Bauwerks	Menge	Einheit	% an HNF	% an NF	% an BGF
HNF Hauptnutzfläche	1173.12	m2	100.0	100.0	84.1
NNF Nebennutzfläche	0.00	m2	0.0	0.0	0.0
NF Nutzfläche	1173.12	m2	100.0	100.0	84.1
FF Funktionsfläche	0.00	m2	0.0	0.0	0.0
VF Verkehrsfläche	181.63	m2	15.5	15.5	13.0
NGF Netto-Grundfläche	1354.75	m2	115.5	115.5	97.1
KGF Konstruktions-Grundfläche	39.92	m2	3.4	3.4	2.9
BGF Brutto-Grundfläche	1394.67	m2	118.9	118.9	100.0

Brutto-Rauminhalt des Bauwerks	Menge	Einheit	BRI/NF [m]	BRI/BGF [m]
BRI Brutto-Rauminhalt	10171.67	m3	8.67	7.29

Planungskennwerte nach DIN 277

HNF	1'173.12	m2
NF	1'173.12	m2
BGF	1'394.67	m2

Planungkennwerte nach DIN 277	Menge	Einheit	Menge/HNF	Menge/NF	Menge/BGF
KG 320 Gründung	1'155.84	m2 GRF	0.99	0.99	0.83
KG 330 Aussenwände	792.48	m2 AWF	0.68	0.68	0.57
KG 340 Innenwände	126.62	m2 IWF	0.11	0.11	0.09
KG 350 Decken	59.63	m2 DEF	0.05	0.05	0.04
KG 360 Dächer	1'146.84	m2 DAF	0.98	0.98	0.82

Further architectural, construction and installation attributes

	MA [kg/m² GGF]	MB [kg/m² AWF]	MC [kg/m² DAF]	MD [kg/m² GF]	MF [kg/m² GF]	Gesamt [kg/m² GF]
Aluminium	0.0	1.1	0.0	0.2	0.2	1.0
Beton B10	1.3	0.0	0.0	0.0	0.0	1.2
Beton B25	555.1	0.0	219.7	85.6	0.0	820.7
Beton B5	261.5	0.0	0.0	0.0	1.3	250.0
Beton-Gasbeton	0.0	223.4	0.0	0.3	9.2	150.4
Bitumen	0.0	0.0	0.0	0.0	0.0	0.0
Holz	0.0	0.0	2.1	0.0	0.0	1.9
Holzspanplatte	0.0	0.0	0.0	0.0	0.9	0.9
Kies	515.3	0.0	0.0	0.0	0.0	490.0
KSV	0.0	0.0	0.0	16.4	0.0	16.4
mod. Dämmstoff	0.0	0.0	2.6	0.0	0.0	2.4
PE-Folie	1.4	0.0	0.8	0.0	0.0	2.1
PS-Hartschaumplatten	0.0	0.0	3.1	0.0	0.7	3.6
Putz-Kalkmörtel	0.0	0.0	0.0	0.0	0.4	0.4
Stahl	8.3	3.2	19.5	7.0	1.2	36.4
Ziegel HLZ	22.0	0.0	0.0	0.0	0.0	20.9
Zink	0.0	2.8	10.8	0.0	0.0	12.0
	1'364.9	230.5	258.6	109.4	13.9	1'810.6

Further characteristics	Type of building	Construction year	Construction type*	Number of materials	Weight	Heating	EFAo	EFA	Height EFA	Volume EFA
	Beverages warehouse	1990	Reinforced concrete skeleton	17	1811 kg/m² GF	Gas **** (and electrical heating), cooling system 10,4kW	190 m²	279 m²	4 m	670 m³
Compactness (MA+MB+MC)/ EFA	**Window surface - Total**	**Window surface - North**	**Window surface - East**	**Window surface - South**	**Window surface - West**	**Window surface-Roof**	**Heat flow**	**Total insulation amount - boards****	**Total insulation amount - sheets*****	**Cost**
10.99	0%	0%	0%	0%	0%	0%	463 MJ/m² EFA	3.6 kg/m² GF	4.53 kg/m² GF	63 Euro/m³ BRI

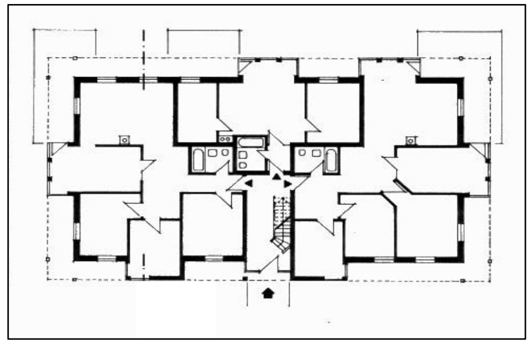
Surfaces and k-values	Floor	Composition	U- value	Roof	Composition	U-value	Roof - Window	Composition	U-value	Wall - North
	190 m²	220 mm reinforced concrete, formwork, concrete reinforcement	2.63 W/m²K	190 m²	0°; trapezoidal sheet metal, 1.2 mm humidity insulation, 100 mm insulation, covering	0.31 W/m²K	0 m²	-	-	69 m²
Wall - East	**Wall - South**	**Wall - West**	**Composition**	**U-value**	**Window - North**	**Window - East**	**Window - South**	**Window - West**	**Composition**	**U-value**
53 m²	69 m²	53 m²	100 mm areated autoclaved concrete	1.75 W/m²K	0 m²	0 m²	0 m²	0 m²	-	-

Objekt: 9 **Mehrfamilienhaus (15 WE) mit Tiefgarage**

Quelle: **BKI / 6100-077**

Objektübersicht: Foto, Pläne, Grunddaten

Land	Bayern	
Kreis	Bad Tölz	
BRI	8'018	m^3
BGF	2841	m^2
NF	1971	m^2



Flächen des Grundstücks	Menge	Einheit	% an FBG
BF Bebaute Fläche	1000.00	m2	50.0
UBF Unbebaute Fläche	1000.00	m2	50.0
FBG Fläche des Baugrundstücks	2000.00	m2	100.0

Grundflächen des Bauwerks	Menge	Einheit	% an HNF	% an NF	% an BGF
HNF Hauptnutzfläche	1258.10	m2	100.0	63.8	44.3
NNF Nebennutzfläche	712.42	m2	56.6	36.2	25.1
NF Nutzfläche	1970.52	m2	156.6	100.0	69.4
FF Funktionsfläche	15.39	m2	1.2	0.8	0.5
VF Verkehrsfläche	553.73	m2	44.0	28.1	19.5
NGF Netto-Grundfläche	2539.64	m2	201.9	128.9	89.4
KGF Konstruktions-Grundfläche	301.60	m2	24.0	15.3	10.6
BGF Brutto-Grundfläche	2841.24	m2	225.8	144.2	100.0

Brutto-Rauminhalt des Bauwerks	Menge	Einheit	BRI/NF [m]	BRI/BGF [m]
BRI Brutto-Rauminhalt	8018.70	m3	4.07	2.82

Planungskennwerte nach DIN 277

HNF	1'258.10	m2
NF	1'970.52	m2
BGF	2'841.24	m2

Planungkennwerte nach DIN 277	Menge	Einheit	Menge/HNF	Menge/NF	Menge/BGF
KG 320 Gründung	953.62	m2 GRF	0.76	0.48	0.34
KG 330 Aussenwände	1875.79	m2 AWF	1.49	0.95	0.66
KG 340 Innenwände	2236.52	m2 IWF	1.78	1.13	0.79
KG 350 Decken	1755.11	m2 DEF	1.40	0.89	0.62
KG 360 Dächer	1280.15	m2 DAF	1.02	0.65	0.45

Further architectural, construction and installation attributes

	MA [kg/m² GGF]	MB [kg/m² AWF]	MC [kg/m² DAF]	MD [kg/m² GF]	MF [kg/m² GF]	Gesamt [kg/m²
Aluminium	0.0	0.0	0.0	0.0	0.0	0.0
Beton B15	539.7	0.0	0.0	0.0	0.0	190.0
Beton B25	0.0	136.4	210.3	137.4	0.0	330.6
Beton B5	25.1	0.0	0.0	0.0	35.5	44.4
Beton-Gasbeton	0.0	0.0	0.0	35.4	0.7	36.1
Bitumen	0.0	0.0	0.1	0.0	0.0	0.0
Dach-Hohlfalzziegel	0.0	0.0	14.5	0.0	0.0	6.8
Estrich-Anhydrith	0.0	0.0	0.0	0.0	38.0	38.0
Estrich-Gussasphalt	0.0	0.0	0.0	0.0	0.7	0.7
Estrich-Zement	0.0	0.0	0.0	0.0	31.8	31.8
Fenster-Alu	0.0	0.0	0.0	0.0	0.0	0.0
Fenster-Alu Glas	0.0	0.0	0.0	0.0	0.0	0.0
Fenster-Holz	0.0	0.6	0.2	0.0	0.0	0.5
Fenster-Holz Glas	0.0	1.1	0.3	0.0	0.0	0.9
Fliesen-Boden	0.0	0.0	0.0	0.0	2.8	2.8
Fliesen-Wand	0.0	0.0	0.0	0.0	1.1	1.1
Gipskartonplatte	0.0	0.0	0.0	0.0	16.6	16.6
Glas	0.0	0.0	0.0	0.0	0.1	0.1
Holz	0.0	7.3	31.9	15.3	8.9	44.4
Holzspanplatte	0.0	0.6	0.0	0.0	0.5	1.0
Kies	596.5	0.0	0.0	0.0	0.0	210.0
Mineralwolle	0.0	0.6	1.3	0.0	0.5	1.5
mod. Dämmstoff	0.0	0.0	0.0	0.0	0.5	0.5
PE-Folie	0.0	0.0	0.9	0.0	3.1	3.5
PS-Hartschaumplatten	0.0	0.0	0.0	0.0	0.2	0.2
Putz-Kalkmörtel	0.0	0.0	0.0	0.0	18.6	18.6
Putz-Kalkzementmörtel	0.0	2.9	0.0	0.0	4.3	6.3
PVC	0.7	0.0	0.0	0.0	0.0	0.3
Sand	0.0	0.0	0.0	0.0	29.6	29.6
Stahl	7.3	4.4	46.5	7.0	1.0	35.6
Styrodur	0.0	1.2	0.0	0.0	0.0	0.8
Teppich	0.0	0.0	0.0	0.0	1.2	1.2
Ziegel HLZ	0.0	174.9	0.0	16.4	16.6	153.4
	1'169.3	330.2	305.8	211.5	212.5	1'207.4

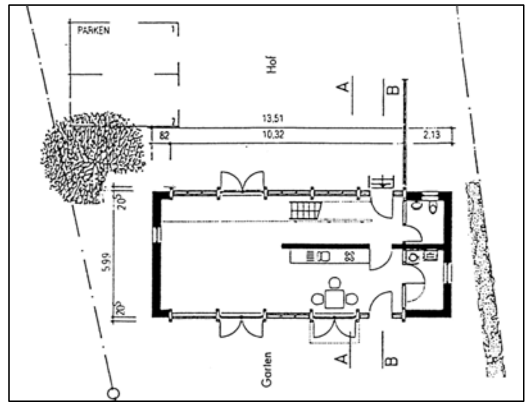
Further characteristics	Type of building	Construction year	Construction type*	Number of materials	Weight	Heating	EFAo	EFA	Height EFA	Volume EFA
	Appartament house (15) with underground garage	1989	Masonry construction	33	1207 kg/m² GF	Gas central heating	1888 m²	1888 m²	6 m	3172 m³
Compactness (MA+MB+MC)/ EFA	**Window surface - Total**	**Window surface - North**	**Window surface - East**	**Window surface - South**	**Window surface - West**	**Window surface-Roof**	**Heat flow**	**Total insulation amount - boards****	**Total insulation amount - sheets*****	**Cost**
2.17	40%	23%	23%	23%	23%	1%	303 MJ/m² EFA	2.5 kg/m² GF	4.25 kg/m² GF	201 Euro/m³ BRI

Surfaces and k-values	Floor	Composition	U- value	Roof	Composition	U- value	Roof - Window	Composition	U- value	Wall - North
	629 m²	180 mm reinforced concrete, insulation, anidrith floor pavement, carpet	0.37 W/m²K	1280 m²	30°; wood construction, 18 mm rafters, 100 mm insulation between rafters, 15 mm wood rafters, humidity insulation, air, tiles	0.41 W/m²K	19 m²	Insulating glas, wood frame	2.88 W/m²K	83 m²
Wall - East	**Wall - South**	**Wall - West**	**Composition**	**U- value**	**Window - North**	**Window - East**	**Window - South**	**Window - West**	**Composition**	**U- value**
166 m²	83 m²	166 m²	Plaster, wood boards, 50 mm mineral wool insulation between rafters, 20 mm wood covering	0.65 W/m²K	55 m²	110 m²	55 m²	110 m²	Insulating glas, wood frame	2.04 W/m²K

Objekt:	**10**	**Einfamilienhaus, Niedrigenergie**
Quelle:	**BKI / 6100-214**	

Objektübersicht: Foto, Pläne, Grunddaten

Land	Baden-Württemberg	
Kreis	Rems-Murr	
BRI	555	m^3
BGF	201	m^2
NF	150	m^2



Flächen des Grundstücks	Menge	Einheit	% an FBG
BF Bebaute Fläche	80.82	m2	16.2
UBF Unbebaute Fläche	419.08	m2	83.8
FBG Fläche des Baugrundstücks	500.00	m2	100.0

Grundflächen des Bauwerks	Menge	Einheit	% an HNF	% an NF	% an BGF
HNF Hauptnutzfläche	106.81	m2	100.0	71.3	53.0
NNF Nebennutzfläche	42.92	m2	40.2	28.7	21.3
NF Nutzfläche	149.73	m2	140.2	100.0	74.4
FF Funktionsfläche	0.00	m2	0.0	0.0	0.0
VF Verkehrsfläche	22.12	m2	20.7	14.8	11.0
NGF Netto-Grundfläche	171.85	m2	160.9	114.8	85.3
KGF Konstruktions-Grundfläche	29.50	m2	27.6	19.7	14.7
BGF Brutto-Grundfläche	201.35	m2	188.5	134.5	100.0

Brutto-Rauminhalt des Bauwerks	Menge	Einheit	BRI/NF [m]	BRI/BGF [m]
BRI Brutto-Rauminhalt	555.00	m3	3.71	2.76

Planungskennwerte nach DIN 277

HNF	106.81	m2
NF	149.73	m2
BGF	201.35	m2

Planungkennwerte nach DIN 277	Menge	Einheit	Menge/HNF	Menge/NF	Menge/BGF
KG 320 Gründung	80.92	m2 GRF	0.76	0.54	0.40
KG 330 Aussenwände	207.15	m2 AWF	1.94	1.38	1.03
KG 340 Innenwände	114.37	m2 IWF	1.07	0.76	0.57
KG 350 Decken	113.25	m2 DEF	1.06	0.76	0.56
KG 360 Dächer	186.56	m2 DAF	1.75	1.25	0.93

Further architectural, construction and installation attributes

	MA [kg/m² GGF]	MB [kg/m² AWF]	MC [kg/m² DAF]	MD [kg/m² GF]	MF [kg/m² GF]	Gesamt [kg/m² GF]
Aluminium	0.0	0.3	0.0	0.0	0.2	0.6
Beton B10	80.3	0.0	0.0	0.0	0.0	39.8
Beton B25	752.6	0.0	0.0	0.0	0.0	373.3
Beton B5	163.2	0.0	0.0	0.0	0.0	80.9
Beton-Gasbeton	0.0	162.6	0.0	33.6	0.0	233.1
Beton-leicht	0.0	4.8	0.0	3.2	14.4	23.5
Bitumen	0.0	0.1	1.0	0.0	0.5	1.7
Bleiblech	0.0	0.0	0.2	0.0	0.0	0.3
Dach-Hohlfalzziegel	0.0	0.0	13.7	0.0	0.0	16.0
Estrich-Zement	0.0	0.0	0.0	0.0	43.7	43.7
Faserzementplatten	0.0	1.0	0.0	0.0	0.0	1.2
Fenster-Holz	0.0	1.2	0.0	0.0	0.0	1.5
Fenster-Holz Glas	0.0	1.3	0.0	0.0	0.0	1.6
Fliesen-Boden	0.0	0.0	0.0	0.0	1.2	1.2
Fliesen-Wand	0.0	0.0	0.0	0.0	2.2	2.2
Gipskartonplatte	0.0	0.0	0.0	0.0	0.4	0.4
Glas	0.0	2.0	0.0	0.0	0.0	2.5
Holz	0.0	14.3	35.4	18.4	12.3	89.3
Holz-Brettschichtholz	0.0	0.0	0.0	1.2	0.0	1.2
Holzspanplatte	0.0	0.5	0.0	0.0	0.6	1.2
Kies	197.0	0.0	0.0	0.0	0.0	97.7
Kunststoff	0.0	0.0	0.6	0.0	0.0	0.8
Messing	0.0	0.0	0.0	0.0	0.2	0.2
Mineralfaser	0.0	0.0	46.3	0.0	3.0	56.8
Mineralwolle	0.0	12.1	0.0	0.0	0.0	14.9
PE-Folie	0.0	0.0	0.0	0.0	0.4	0.4
PS-Hartschaumplatten	0.0	0.0	0.0	0.0	0.6	0.6
Putz-Kalkzementmörtel	0.0	19.1	0.0	0.0	36.2	59.7
PVC	0.6	0.0	0.0	0.0	0.0	0.3
Stahl	13.7	0.3	1.2	6.8	1.9	17.3
Ziegel HLZ	0.0	0.0	0.0	16.8	0.0	16.8
Zink	0.0	0.1	1.4	0.0	0.2	2.0
	1'207.3	219.8	99.8	80.0	118.0	1'182.6

Further characteristics	Type of building	Construction year	Construction type*	Number of materials	Weight	Heating	EFAo	EFA	Height EFA	Volume EFA
	Single occupancy house, low energy	1994	Wood skeleton	31	1183 kg/m² GF	External heating supply, Gas ****, controlled ventilation	201 m²	239 m²	7 m	553 m³
Compactness (MA+MB+MC)/ EFA	**Window surface - Total**	**Window surface - North**	**Window surface - East**	**Window surface - South**	**Window surface - West**	**Window surface-Roof**	**Heat flow**	**Total insulation amount - boards****	**Total insulation amount - sheets*****	**Cost**
1.97	20%	9%	9%	41%	9%	0%	164 MJ/m² EFA	72.2 kg/m² GF	2.44 kg/m² GF	361 Euro/m³ BRI

Surfaces and k-values	Floor	Composition	U- value	Roof	Composition	U-value	Roof - Window	Composition	U- value	Wall - North
	81 m²	180 mm reinforced concrete, formwork, concrete reinforcement, insulation, floor pavement, parquet	0.27 W/m²K	187 m²	30°; wood construction, rafters, humidity insulation, 240 mm mineral wool insulation, air, tiles	0.16 W/m²K	-	-	-	64 m²
Wall - East	**Wall - South**	**Wall - West**	**Composition**	**U-value**	**Window - North**	**Window - East**	**Window - South**	**Window - West**	**Composition**	**U-value**
30 m²	42 m²	30 m²	North + south: plaster, wood boards, mineral wool insulation, wood covering; east + west: 365 mm	0.19; 0.20	6 m²	3 m²	29 m²	3 m²	Insulating glas,	1.30 W/

			lightweight concrete blocks, mineral wool insulation, plaster	W/m²K					wood frame	m²K

Objekt: 11 **Einfamilienhaus mit Doppelgarage**

Quelle: **BKI / 6100-159**

Objektübersicht: Foto, Pläne, Grunddaten

Land	Hessen	
Kreis	Darmstadt	
BRI	1234	m^3
BGF	437	m^2
NF	315	m^2

Flächen des Grundstücks	Menge	Einheit	% an FBG
BF Bebaute Fläche	187.52	m2	31.8
UBF Unbebaute Fläche	401.48	m2	68.2
FBG Fläche des Baugrundstücks	589.00	m2	100.0

Grundflächen des Bauwerks	Menge	Einheit	% an HNF	% an NF	% an BGF
HNF Hauptnutzfläche	150.53	m2	100.0	47.8	34.4
NNF Nebennutzfläche	164.46	m2	109.3	52.2	37.6
NF Nutzfläche	314.99	m2	209.3	100.0	72.0
FF Funktionsfläche	11.89	m2	7.9	3.8	2.7
VF Verkehrsfläche	44.63	m2	29.6	14.2	10.2
NGF Netto-Grundfläche	371.51	m2	246.8	117.9	85.0
KGF Konstruktions-Grundfläche	65.77	m2	43.7	20.9	15.0
BGF Brutto-Grundfläche	437.28	m2	290.5	138.8	100.0

Brutto-Rauminhalt des Bauwerks	Menge	Einheit	BRI/NF [m]	BRI/BGF [m]
BRI Brutto-Rauminhalt	1234.00	m3	3.92	2.82

Planungskennwerte nach DIN 277

HNF	150.53	m2
NF	314.99	m2
BGF	437.28	m2

Planungkennwerte nach DIN 277	Menge	Einheit	Menge/HNF	Menge/NF	Menge/BGF
KG 320 Gründung	167.06	m2 GRF	1.11	0.53	0.38
KG 330 Aussenwände	407.57	m2 AWF	2.71	1.29	0.93
KG 340 Innenwände	336.39	m2 IWF	2.23	1.07	0.77
KG 350 Decken	236.03	m2 DEF	1.57	0.75	0.54
KG 360 Dächer	253.25	m2 DAF	1.68	0.80	0.58

Further architectural, construction and installation attributes

	MA [kg/m² GGF]	MB [kg/m² AWF]	MC [kg/m² DAF]	MD [kg/m² GF]	MF [kg/m² GF]	Gesamt [kg/m² GF]
Beton B25	727.0	65.4	87.8	310.7	1.6	731.8
Beton B5	77.5	4.3	0.0	0.1	0.0	36.3
Beton-Gasbeton	0.0	145.7	0.0	41.4	0.0	181.6
Beton-Schwerbetonstein	155.4	0.0	0.0	0.0	0.0	64.4
Bitumen	0.0	0.5	1.2	0.0	0.0	1.2
Dach-Betondachpfannen	0.0	0.0	23.5	0.0	0.0	14.8
Erde	0.0	0.0	31.7	0.0	0.0	19.9
Estrich-Anhydrith	0.0	0.0	0.0	0.0	63.0	63.0
Estrich-Zement	0.0	0.0	0.0	0.0	9.6	9.6
Fenster-Holz	0.0	1.7	0.2	0.0	0.2	2.0
Fenster-Holz Glas	0.0	3.1	0.2	0.0	0.5	3.6
Fliesen-Boden	0.0	0.0	0.0	0.0	4.7	4.7
Fliesen-Wand	0.0	0.0	0.0	0.0	1.9	1.9
Gipskartonplatte	0.0	0.0	0.0	0.0	0.1	0.1
Glas	0.0	0.0	0.2	0.0	0.1	0.2
Holz	0.0	0.1	43.7	2.4	1.5	31.3
Holz-Brettschichtholz	0.0	0.0	2.3	0.8	0.0	2.3
Holzspanplatte	0.0	0.1	0.0	0.0	0.7	0.8
Kork	0.0	0.0	0.0	0.0	0.1	0.1
KSV	6.8	159.8	0.0	47.3	21.3	225.2
Kunststoff	0.0	0.0	0.0	0.0	0.0	0.0
Marmor	0.0	0.0	0.0	0.0	1.8	1.8
Messing	0.0	0.0	0.0	0.0	0.0	0.0
Mineralwolle	0.0	0.0	2.8	0.0	0.0	1.8
PE-Folie	0.0	0.0	0.0	0.0	1.9	1.9
PS-Hartschaumplatten	0.0	0.0	0.0	0.0	0.0	0.0
Putz-Gipsputz	0.0	0.0	0.0	0.0	23.8	23.8
Putz-Kalkzementmörtel	0.0	22.7	0.0	0.0	32.8	54.6
PVC	0.0	0.0	18.4	0.0	0.0	11.5
Stahl	12.7	0.8	15.1	15.5	0.3	31.2
Styrodur	0.1	0.2	0.0	0.0	0.0	0.2
Teppich	0.0	0.0	0.0	0.0	0.9	0.9
Vlies	0.0	0.0	0.0	0.0	0.0	0.0
Ziegel-Hohlblocksteine	0.0	0.5	0.0	0.0	0.0	0.4
Zink	0.0	0.0	0.7	0.0	0.0	0.4
	979.5	**404.7**	**227.7**	**418.1**	**166.6**	**1'523.4**

Further characteristics	Type of building	Construction year	Construction type*	Number of materials	Weight	Heating	EFAo	EFA	Height EFA	Volume EFA
	Single occupancy house with double garage	1993	Masonry construction	35	1523 kg/m^2 GF	Natural gas	259 m^2	290 m^2	6 m	653 m^3
Compactness (MA+MB+MC)/ EFA	**Window surface - Total**	**Window surface - North**	**Window surface - East**	**Window surface - South**	**Window surface - West**	**Window surface-Roof**	**Heat flow**	**Total insulation amount - boards****	**Total insulation amount - sheets*****	**Cost**
2.79	23%	32%	13%	42%	9%	3%	366 MJ/m^2 EFA	2.1 kg/m^2 GF	3.08 kg/m^2 GF	292 Euro/m^3 BRI

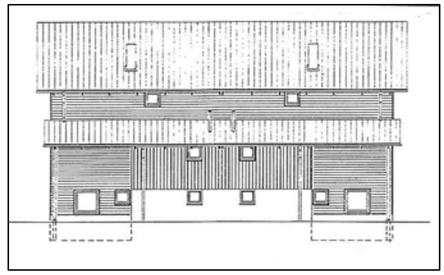
Surfaces and k-values	Floor	Composition	U- value	Roof	Composition	U- value	Roof - Window	Composition	U- value	Wall - North
	129 m^2	Plaster, 200 mm reinforced concrete, insulation, sound insulation, floor pavement, carpet	0.80 W/m^{2}K	195 m^2	30°; wood construction, rafters , 120 mm external mineral wool insulation, air, tiles	0.27 W/m^{2}K	7 m^2	Insulating glas, wood frame	2.04 W/m^{2}K	43 m^2
Wall - East	**Wall - South**	**Wall - West**	**Composition**	**U- value**	**Window - North**	**Window - East**	**Window - South**	**Window - West**	**Composition**	**U- value**
65 m^2	36 m^2	69 m^2	Plaster, 360 mm areated autoclaved concrete, styrodur insulation, plaster	0.43 W/m^{2}K	20 m^2	10 m^2	26 m^2	7 m^2	Insulating glas, wood frame	2.04 W/m^{2}K

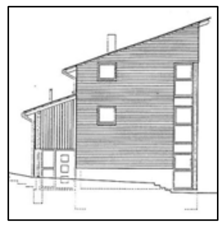
Objekt: 12 **Doppelhaushälfte, Holzrahmenbau**

Quelle: BKI / 6100-212

Objektübersicht: Foto, Pläne, Grunddaten

Land	Baden-Württemberg	
Kreis	Enz, Pforzheim	
BRI	564	m^3
BGF	183	m^2
NF	124	m^2





Flächen des Grundstücks	Menge	Einheit	% an FBG
BF Bebaute Fläche	175.18	m2	49.1
UBF Unbebaute Fläche	181.82	m2	50.9
FBG Fläche des Baugrundstücks	357.00	m2	100.0

Grundflächen des Bauwerks	Menge	Einheit	% an HNF	% an NF	% an BGF
HNF Hauptnutzfläche	107.17	m2	100.0	86.6	58.6
NNF Nebennutzfläche	16.55	m2	15.4	13.4	9.0
NF Nutzfläche	123.72	m2	115.4	100.0	67.6
FF Funktionsfläche	3.40	m2	3.2	2.7	1.9
VF Verkehrsfläche	25.96	m2	24.2	21.0	14.2
NGF Netto-Grundfläche	153.08	m2	142.8	123.7	83.7
KGF Konstruktions-Grundfläche	29.81	m2	27.8	24.1	16.3
BGF Brutto-Grundfläche	182.89	m2	170.7	147.8	100.0

Brutto-Rauminhalt des Bauwerks	Menge	Einheit	BRI/NF [m]	BRI/BGF [m]
BRI Brutto-Rauminhalt	564.15	m3	4.56	3.08

Planungskennwerte nach DIN 277

HNF	107.17	m2
NF	123.72	m2
BGF	182.89	m2

Planungkennwerte nach DIN 277	Menge	Einheit	Menge/HNF	Menge/NF	Menge/BGF
KG 320 Gründung	61.30	m2 GRF	0.57	0.50	0.34
KG 330 Aussenwände	194.04	m2 AWF	1.81	1.57	1.06
KG 340 Innenwände	174.95	m2 IWF	1.63	1.41	0.96
KG 350 Decken	113.88	m2 DEF	1.06	0.92	0.62
KG 360 Dächer	95.58	m2 DAF	0.89	0.77	0.52

Further architectural, construction and installation attributes

	MA [kg/m² GGF]	MB [kg/m² AWF]	MC [kg/m² DAF]	MD [kg/m² GF]	MF [kg/m² GF]	Gesamt [kg/m² GF]
Aluminium	0.0	0.0	0.0	0.0	0.1	0.1
Beton B25	225.6	47.9	0.0	0.0	0.0	130.2
Beton B5	52.7	0.0	0.0	0.0	0.0	18.4
Bitumen	0.0	0.1	0.0	0.0	0.0	0.1
Estrich-Zement	0.0	0.0	0.0	0.0	1.6	1.6
Faserzementplatten	0.0	0.1	10.4	0.0	0.0	5.7
Fenster-Holz	0.0	2.3	0.0	0.0	0.0	2.4
Fenster-Holz Glas	0.0	4.1	0.0	0.0	0.0	4.4
Fliesen-Boden	0.0	0.0	0.0	0.0	0.5	0.5
Fliesen-Wand	0.0	0.0	0.0	0.0	1.2	1.2
Gipskartonplatte	0.0	0.0	0.0	0.0	46.6	46.6
Holz	0.0	39.9	21.0	34.9	13.4	102.5
Holzfaserplatte	0.0	19.0	20.8	0.0	0.0	31.7
Holzleisten	0.0	0.0	0.0	0.0	0.8	0.8
Holzspanplatte	0.0	0.1	0.0	4.3	0.0	4.4
Kies	110.3	0.0	0.0	0.0	0.0	38.6
Kunststoff	0.7	0.0	0.0	0.0	0.0	0.2
mod. Dämmstoff	0.6	3.9	5.0	2.2	0.3	9.6
PE-Folie	1.2	0.0	0.0	0.0	0.0	0.4
PS-Hartschaumplatten	0.0	1.4	0.0	0.0	0.0	1.5
Putz	0.0	2.9	0.0	0.0	0.0	3.0
PVC	0.3	0.0	1.0	0.0	0.0	0.7
Stahl	2.8	2.3	1.1	1.0	3.3	8.3
Styrodur	0.0	0.1	0.0	0.0	0.0	0.1
Zink	0.0	0.4	0.4	0.0	0.0	0.6
	394.2	**124.3**	**59.7**	**42.4**	**67.9**	**413.7**

Further characteristics	Type of building	Construction year	Construction type*	Number of materials	Weight	Heating	EFAo	EFA	Height EFA	Volume EFA
	Half of a double house, wood construction	1995	Wood skeleton	25	414 kg/m² GF	Gas, controlled ventilation	138 m²	141 m²	8 m	141 m³
Compactness (MA+MB+MC)/ EFA	**Window surface - Total**	**Window surface - North**	**Window surface - East**	**Window surface - South**	**Window surface - West**	**Window surface-Roof**	**Heat flow**	**Total insulation amount - boards****	**Total insulation amount - sheets*****	**Cost**
2.45	26%	14%	25%	34%	25%	0%	257 MJ/m² EFA	1.6 kg/m² GF	10.82 kg/m² GF	306 Euro/m³ BRI

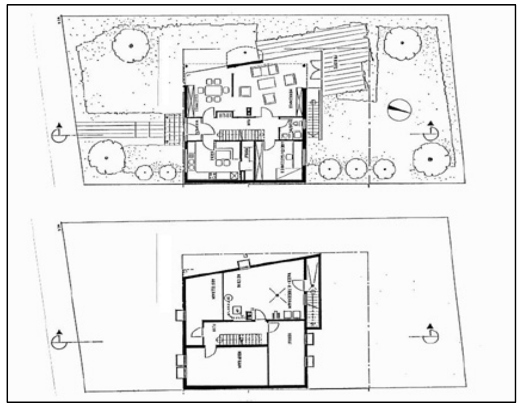
Surfaces and k-values	Floor	Composition	U- value	Roof	Composition	U- value	Roof - Window	Composition	U- value	Wall - North
	46 m²	150 mm reinforced concrete, formwork, insulation, PE sheet, wood covering	0.44 W/m²K	96 m²	30°; wood construction, rafters , PE sheet, 240 mm external Isofloc insulation, bitumen sheet, air, tiles	0.17 W/m² K	-	-	-	36 m²
Wall - East	**Wall - South**	**Wall - West**	**Composition**	**U- value**	**Window - North**	**Window - East**	**Window - South**	**Window - West**	**Composition**	**U- value**
17 m²	44 m²	17 m²	Wood construction, wood boards, 220 mm insulation, wood covering	0.21; 0.29 W/m²K	6 m²	6 m²	23 m²	6 m²	Insulating glas, aluminium-wood frame	1.76 W/m² K

Objekt: **13** **Einfamilienhaus**

Quelle: **BKI / 6100-083**

Objektübersicht: Foto, Pläne, Grunddaten

Land	Rheinland-Pfalz	
Kreis	Frankenthal	
BRI	890	m^3
BGF	332	m^2
NF	206	m^2



Flächen des Grundstücks	Menge	Einheit	% an FBG
BF Bebaute Fläche	113.00	m2	24.4
UBF Unbebaute Fläche	350.00	m2	75.6
FBG Fläche des Baugrundstücks	463.00	m2	100.0

Grundflächen des Bauwerks	Menge	Einheit	% an HNF	% an NF	% an BGF
HNF Hauptnutzfläche	180.60	m2	100.0	87.8	54.4
NNF Nebennutzfläche	25.06	m2	13.9	12.2	7.6
NF Nutzfläche	205.66	m2	113.9	100.0	62.0
FF Funktionsfläche	11.42	m2	6.3	5.6	3.4
VF Verkehrsfläche	35.02	m2	19.4	17.0	10.6
NGF Netto-Grundfläche	252.10	m2	139.6	122.6	76.0
KGF Konstruktions-Grundfläche	79.65	m2	44.1	38.7	24.0
BGF Brutto-Grundfläche	331.76	m2	183.7	161.3	100.0

Brutto-Rauminhalt des Bauwerks	Menge	Einheit	BRI/NF [m]	BRI/BGF [m]
BRI Brutto-Rauminhalt	889.68	m3	4.33	2.68

Planungskennwerte nach DIN 277

HNF	180.60	m2
NF	205.66	m2
BGF	331.76	m2

Planungkennwerte nach DIN 277	Menge	Einheit	Menge/HNF	Menge/NF	Menge/BGF
KG 320 Gründung	115.99	m2 GRF	0.64	0.56	0.35
KG 330 Aussenwände	295.88	m2 AWF	1.64	1.44	0.89
KG 340 Innenwände	225.22	m2 IWF	1.25	1.10	0.68
KG 350 Decken	234.98	m2 DEF	1.30	1.14	0.71
KG 360 Dächer	144.83	m2 DAF	0.80	0.70	0.44

Further architectural, construction and installation attributes

	MA [kg/m² GGF]	MB [kg/m² AWF]	MC [kg/m² DAF]	MD [kg/m² GF]	MF [kg/m² GF]	Gesamt [kg/m² GF]
Aluminium	0.0	0.1	0.0	0.0	0.0	0.1
Beton B15	57.7	0.0	0.0	0.0	0.0	20.1
Beton B25	634.2	263.1	0.0	142.1	0.0	590.5
Beton B5	110.0	0.0	0.0	0.0	0.0	38.4
Beton-leicht	0.0	24.3	0.0	56.4	42.7	120.1
Beton-Porenbetonsteine	0.0	66.0	0.0	0.0	0.0	56.9
Bimsbetonvollstein	0.0	0.0	0.0	0.0	14.1	14.1
Bitumen	0.0	0.0	0.3	0.1	0.1	0.3
Dach-Betondachpfannen	0.0	0.0	30.3	0.0	0.0	13.2
Estrich-Zement	0.0	0.0	0.0	0.0	60.6	60.6
Fenster-Holz	0.0	2.1	1.1	0.0	0.0	2.4
Fenster-Holz Glas	0.0	3.8	2.0	0.0	0.1	4.2
Fliesen-Boden	0.0	0.0	0.0	0.0	0.9	0.9
Fliesen-Wand	0.0	0.0	0.0	0.0	1.2	1.2
Gipskartonplatte	0.0	0.0	0.0	0.0	0.9	0.9
Holz	0.0	0.3	66.4	31.7	7.0	67.9
Kunststoff	0.0	0.0	0.0	0.0	0.2	0.2
Kupfer	0.0	0.0	3.7	0.0	1.1	2.7
Linoleum	0.0	0.0	0.0	0.0	0.2	0.2
Marmor	0.0	0.0	0.0	0.0	1.7	1.7
Messing	0.0	0.0	0.0	0.0	0.0	0.0
Mineralfaser	0.0	0.0	0.0	0.0	0.2	0.2
Mineralwolle	0.0	0.2	0.0	0.0	0.0	0.2
mod. Dämmstoff	0.0	0.1	1.8	0.1	0.5	1.4
PE-Folie	0.0	0.0	0.0	0.0	0.2	0.2
PS-Hartschaumplatten	0.0	0.0	0.0	0.0	0.1	0.1
Putz	0.0	11.4	0.0	0.0	67.8	77.7
PVC	0.0	0.0	0.0	0.0	0.0	0.0
Stahl	18.0	7.6	1.6	5.1	6.7	25.2
Teppich	0.0	0.0	0.0	0.0	0.9	0.9
Ziegel HLZ	0.0	0.0	0.0	3.7	0.0	3.7
	819.8	379.1	107.2	239.2	207.2	1'106.4

Further characteristics	Type of building	Construction year	Construction type*	Number of materials	Weight	Heating	EFAo	EFA	Height EFA	Volume EFA
	Single occupancy house	1990	Masonry construction	31	1106 kg/m² GF	Gas central heating	221 m²	229 m²	5 m	426 m³
Compactness (MA+MB+MC)/ EFA	**Window surface - Total**	**Window surface - North**	**Window surface - East**	**Window surface - South**	**Window surface - West**	**Window surface-Roof**	**Heat flow**	**Total insulation amount - boards****	**Total insulation amount - sheets*****	**Cost**
2.39	33%	23%	16%	31%	62%	5%	258 MJ/m² EFA	0.4 kg/m² GF	1.97 kg/m² GF	307 Euro/m³ BRI

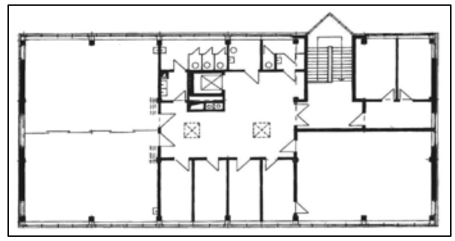
Surfaces and k-values	Floor	Composition	U- value	Roof	Composition	U-value	Roof - Window	Composition	U- value	Wall - North
	113 m²	160 mm reinforced concrete, insulation, floor pavement, mortar, carpet	0.30 W/m²K	145 m²	30°; wood construction, wood rafters, external polyuretane slab insulation, alu sheet, air, concrete, tiles	0.23 W/m²K	7 m²	Wood frame	2.04 W/m²K	36 m²
Wall - East	**Wall - South**	**Wall - West**	**Composition**	**U- value**	**Window - North**	**Window - East**	**Window - South**	**Window - West**	**Composition**	**U-value**
40 m²	33 m²	18 m²	Plaster, 300 mm lightweight areated concrete, 30 mm mineral fibre bords (east side), 20 mm plaster	0.28; 0.63 (east side) W/m²K	11 m²	7 m²	15 m²	29 m²	Insulating glas, wood frame	2.04 W/m²K

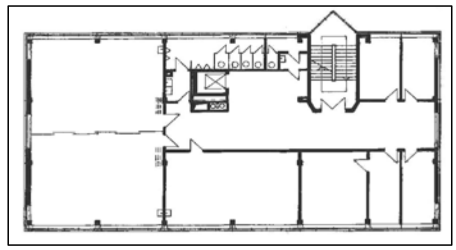
Objekt: 14 **Lehrbauhof**

Quelle: BKI / 4200-004

Objektübersicht: Foto, Pläne, Grunddaten

Land	Brandenburg	
Kreis	Frankfurt/Oder	
BRI	37'086	m^3
BGF	8974	m^2
NF	6123	m^2





Flächen des Grundstücks	Menge	Einheit	% an FBG
BF Bebaute Fläche	6876.70	m2	32.4
UBF Unbebaute Fläche	14323.30	m2	67.6
FBG Fläche des Baugrundstücks	21200.00	m2	100.0

Grundflächen des Bauwerks	Menge	Einheit	% an HNF	% an NF	% an BGF
HNF Hauptnutzfläche	5447.61	m2	100.0	89.0	60.7
NNF Nebennutzfläche	675.81	m2	12.4	11.0	7.5
NF Nutzfläche	6123.42	m2	112.4	100.0	68.2
FF Funktionsfläche	360.19	m2	6.6	5.9	4.0
VF Verkehrsfläche	1434.63	m2	26.3	23.4	16.0
NGF Netto-Grundfläche	7918.24	m2	145.4	129.3	88.2
KGF Konstruktions-Grundfläche	1055.76	m2	19.4	17.2	11.8
BGF Brutto-Grundfläche	8974.00	m2	164.7	146.6	100.0

Brutto-Rauminhalt des Bauwerks	Menge	Einheit	BRI/NF [m]	BRI/BGF [m]
BRI Brutto-Rauminhalt	37086.00	m3	6.06	4.13

Planungskennwerte nach DIN 277

HNF	5'447.61	m2
NF	6'123.42	m2
BGF	8'974.00	m2

Planungkennwerte nach DIN 277	Menge	Einheit	Menge/HNF	Menge/NF	Menge/BGF
KG 320 Gründung	6662.50	m2 GRF	1.22	1.09	0.74
KG 330 Aussenwände	3694.61	m2 AWF	0.68	0.60	0.41
KG 340 Innenwände	5583.80	m2 IWF	1.02	0.91	0.62
KG 350 Decken	1573.17	m2 DEF	0.29	0.26	0.18
KG 360 Dächer	9247.76	m2 DAF	1.70	1.51	1.03

Further architectural, construction and installation attributes

	MA [kg/m^2 GGF]	MB [kg/m^2 AWF]	MC [kg/m^2 DAF]	MD [kg/m^2 GF]	MF [kg/m^2 GF]	Gesamt [kg/m^2 GF]
Aluminium	0.0	0.0	0.0	0.0	0.2	0.2
Beton B25	933.6	62.7	255.2	103.7	0.0	1173.2
Bimsbetonvollstein	0.0	1.4	0.0	0.0	0.0	0.6
Bitumen	0.1	0.0	0.1	0.0	0.0	0.2
Estrich-Zement	0.0	0.0	0.0	0.0	77.1	77.1
Fenster-Alu	0.0	5.6	0.0	0.0	1.0	3.5
Fenster-Alu Glas	0.0	5.2	0.0	0.0	0.9	3.2
Fenster-PVC	0.0	0.1	0.0	0.0	0.0	0.0
Fenster-PVC Glas	0.0	0.1	0.0	0.0	0.0	0.0
Fliesen Boden	0.0	0.0	0.0	0.0	1.6	1.6
Fliesen Wand	0.0	0.0	0.0	0.0	2.2	2.2
Gipskartonplatte	0.0	0.0	0.0	0.0	1.4	1.4
Glas	0.0	0.0	0.0	0.0	0.0	0.0
Holz	0.0	0.0	21.4	0.0	3.0	27.0
Holzspanplatte	0.0	0.0	0.0	0.0	1.1	1.1
KSV	0.0	145.2	0.0	201.9	32.8	298.8
Linoleum	0.0	0.0	0.0	0.0	0.9	0.9
Mineralfaser	0.0	0.1	0.6	0.0	0.2	0.9
mod. Dämmstoffe	0.0	0.0	0.7	0.0	0.8	1.6
Naturstein	0.0	0.0	0.0	0.0	7.7	7.7
PE-Folie	0.1	0.0	0.0	0.0	0.0	0.1
PS-Hartschaumplatten	0.0	0.0	0.9	0.0	0.0	1.0
Putz	0.0	1.3	0.0	0.0	20.5	21.1
Stahl	0.0	2.9	3.9	17.3	1.0	24.0
Styrodur	0.0	0.8	0.0	0.0	0.0	0.4
Teppich	0.0	0.0	0.0	0.0	0.2	0.2
Zink	0.0	1.3	4.3	0.0	0.0	5.4
	933.8	**226.7**	**287.1**	**322.9**	**152.6**	**1'653.3**

Further characteristics	Type of building	Construction year	Construction type*	Number of materials	Weight	Heating	EFAo	EFA	Height EFA	Volume EFA
	Training for constructors yard	1995	Masonry construction	27	1653 kg/m^2 GF	External heating supply, Gas ****	8614 m^2	12347 m^2	4 m	29632 m^3
Compactness (MA+MB+MC)/ EFA	**Window surface - Total**	**Window surface - North**	**Window surface - East**	**Window surface - South**	**Window surface - West**	**Window surface-Roof**	**Heat flow**	**Total insulation amount - boards****	**Total insulation amount - sheets*****	**Cost**
1.58	29%	29%	29%	29%	29%	3%	136 MJ/m^2 EFA	2.3 kg/m^2 GF	1.86 kg/m^2 GF	220 Euro/m^3 BRI

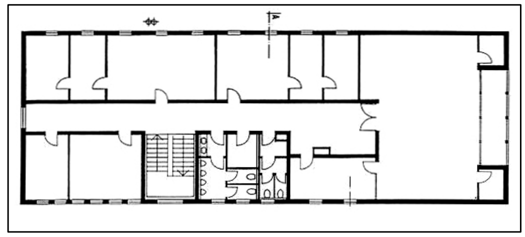
Surfaces and k-values	Floor	Composition	U- value	Roof	Composition	U- value	Roof - Window	Composition	U- value	Wall - North
	6663 m^2	Reinforced concrete, bitumen sheets, PE sheets, 45-50 mm cement covering	2.78 W/m^{2}K	8979 m^2	0°; 265 mm reinforced concrete, bitumen, humidity insulation sheet, PE panels, insulation, sealing, 265 mm roof covering panels	0.28 W/m^{2}K	269 m^2	Insulating glas, aluminium frame	2.46 W/m^{2}K	661 m^2
Wall - East	**Wall - South**	**Wall - West**	**Composition**	**U- value**	**Window - North**	**Window - East**	**Window - South**	**Window - West**	**Composition**	**U- value**
661 m^2	661 m^2	661 m^2	240-365 mm bricks, insulation, bricks, plaster	0.47 W/m^{2}K	269 m^2	269 m^2	269 m^2	269 m^2	Insulating glas, aluminium frame	2.46 W/m^{2}K

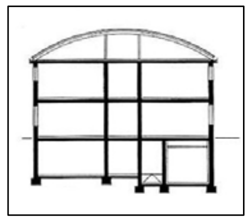
Objekt: 15 **Autobahnpolizei, Personalgebäude**

Quelle: **BKI / 1300-033**

Objektübersicht: Foto, Pläne, Grunddaten

Land	Baden-Württemberg	
Kreis	Lörrach	
BRI	4'165	m^3
BGF	1223	m^2
NF	716	m^2





Flächen des Grundstücks	Menge	Einheit	% an FBG
BF Bebaute Fläche	726.08	m2	14.8
UBF Unbebaute Fläche	4164.92	m2	85.2
FBG Fläche des Baugrundstücks	4891.00	m2	100.0

Grundflächen des Bauwerks	Menge	Einheit	% an HNF	% an NF	% an BGF
HNF Hauptnutzfläche	602.48	m2	100.0	84.1	49.3
NNF Nebennutzfläche	113.64	m2	18.9	15.9	9.3
NF Nutzfläche	716.12	m2	118.9	100.0	58.5
FF Funktionsfläche	64.75	m2	10.7	9.0	5.3
VF Verkehrsfläche	239.56	m2	39.8	33.5	19.6
NGF Netto-Grundfläche	1020.43	m2	169.4	142.5	83.4
KGF Konstruktions-Grundfläche	202.78	m2	33.7	28.3	16.6
BGF Brutto-Grundfläche	1223.21	m2	203.0	170.8	100.0

Brutto-Rauminhalt des Bauwerks	Menge	Einheit	BRI/NF [m]	BRI/BGF [m]
BRI Brutto-Rauminhalt	4164.65	m3	5.82	3.40

Planungskennwerte nach DIN 277

HNF	602.48	m2
NF	716.12	m2
BGF	1'223.21	m2

Planungkennwerte nach DIN 277	Menge	Einheit	Menge/HNF	Menge/NF	Menge/BGF
KG 320 Gründung	403.17	m2 GRF	0.67	0.56	0.33
KG 330 Aussenwände	831.33	m2 AWF	1.38	1.16	0.68
KG 340 Innenwände	1217.14	m2 IWF	2.02	1.70	1.00
KG 350 Decken	1106.44	m2 DEF	1.84	1.55	0.90
KG 360 Dächer	447.46	m2 DAF	0.74	0.62	0.37

Further architectural, construction and installation attributes

	MA [kg/m^2 GGF]	MB [kg/m^2 AWF]	MC [kg/m^2 DAF]	MD [kg/m^2 GF]	MF [kg/m^2 GF]	Gesamt [kg/m^2 GF]
Aluminium	0.0	0.0	3.4	0.0	0.5	1.8
Beton B10	1.6	174.6	0.0	0.0	0.0	117.3
Beton B25	720.2	268.8	0.0	594.8	15.9	1027.9
Beton-leicht	0.0	0.3	0.0	0.1	0.0	0.2
Bimsbetonvollstein	0.0	0.0	0.0	0.0	0.4	0.4
Bitumen	0.0	0.1	0.0	0.0	0.0	0.1
Estrich-Zement	0.0	0.0	0.0	0.0	76.9	76.9
Faserzementplatten	0.0	7.0	0.0	0.5	2.7	7.8
Fenster-Alu	0.0	0.0	0.0	0.0	0.0	0.0
Fenster-Alu Glas	0.0	0.0	0.0	0.0	0.0	0.0
Fenster-Holz	0.0	1.6	0.0	0.0	0.0	1.1
Fenster-Holz Glas	0.0	2.9	0.0	0.0	0.0	2.0
Fliesen-Boden	0.0	0.0	0.0	0.0	3.0	3.0
Fliesen-Wand	0.0	0.0	0.0	0.0	2.7	2.7
Gipskartonplatte	0.0	0.0	0.0	0.0	2.8	2.8
Holz	0.0	0.2	3.3	0.0	0.2	1.6
Holz-Brettschichtholz	0.0	0.0	2.6	0.0	0.0	1.0
Holzspanplatte	0.0	0.2	0.0	0.0	1.1	1.2
Kies	199.1	0.0	0.0	0.0	0.5	66.2
KSL	0.0	0.0	0.0	0.0	1.5	1.5
KSV	0.0	0.0	0.0	0.0	0.3	0.3
Kunststoff	0.0	0.4	0.0	0.0	0.3	0.6
Linoleum	0.0	0.0	0.0	0.0	1.2	1.2
Mineralfaser	0.0	0.0	34.9	0.0	0.0	12.8
Mineralwolle	0.0	0.1	0.0	0.0	0.0	0.1
mod. Dämmstoff	0.0	0.2	0.0	0.0	0.0	0.2
Mörtel	0.0	0.3	0.0	0.0	1.8	2.0
PS-Hartschaumplatten	0.0	0.0	0.0	0.0	0.4	0.4
Putz	0.0	20.5	0.0	0.2	81.4	95.4
Putz-Kalkzementmörtel	0.0	0.0	0.0	0.0	0.1	0.1
PVC	2.2	0.0	0.0	0.0	0.0	0.7
Stahl	14.1	5.4	6.1	12.5	7.3	30.3
Styrodur	0.0	0.0	0.0	0.0	0.0	0.0
Teppich	0.0	0.0	0.0	0.0	0.0	0.0
Ziegel HLZ	0.0	0.0	0.0	88.0	434.5	522.5
Ziegel-Hohlblocksteine	0.0	90.6	0.0	0.0	0.0	60.6
	937.3	**573.4**	**50.4**	**696.1**	**635.8**	**2'042.9**

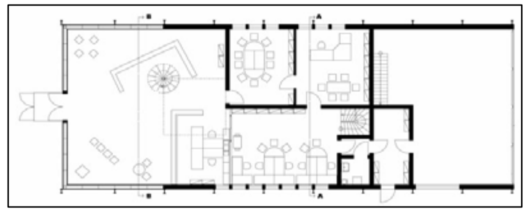
Further characteristics	Type of building	Construction year	Construction type*	Number of materials	Weight	Heating	EFAo	EFA	Height EFA	Volume EFA
	Motorway police, personnel building	1994	Masonry construction	36	2043 kg/m^2 GF	Gas central heating	1159 m^2	1351 m^2	10 m	3229 m^3
Compactness (MA+MB+MC)/ EFA	**Window surface - Total**	**Window surface - North**	**Window surface - East**	**Window surface - South**	**Window surface - West**	**Window surface-Roof**	**Heat flow**	**Total insulation amount - boards****	**Total insulation amount - sheets*****	**Cost**
1.24	17%	18%	10%	18%	10%	0%	214 MJ/m^2 EFA	13.3 kg/m^2 GF	0.96 kg/m^2 GF	328 Euro/m^3 BRI

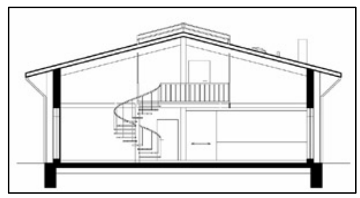
Surface and k-values	Floor	Composition	U- value	Roof	Composition	U-value	Roof - Window	Composition	U- value	Wall - North
	405 m^2	338 m^2: 150 mm reinforced concrete, 40-50 mm insulation, PE sheet, 45-50 mm floor pavement; 65 m^2: 200 mm reinforced concrete, insulation, floor pavement, plaster	0.61; 0.37 W/m^2K	447 m^2	curved, laminated wood construction, 0.75 mm trapezoidal sheet metal, 120mm insulation, 1 mm alu panels	0.34 W/m^2K	-	-	-	225 m^2
Wall - East	**Wall - South**	**Wall - West**	**Composition**	**U-value**	**Window - North**	**Window - East**	**Window - South**	**Window - West**	**Composition**	**U-value**
84 m^2	225 m^2	84 m^2	Plaster, 300 mm lightweight areated concrete, styrofoam insulation, plaster	0.67 W/m^2K	55 m^2	10 m^2	55 m^2	10 m^2	Insulating glas, wood frame	2.04 W/m^2K

Objekt: 16 **Vertriebszentrum, Lager, Büros**
Quelle: BKI / 7700-028

Objektübersicht: Foto, Pläne, Grunddaten

Land	Bayern	
Kreis	Kitzingen	
BRI	2276	m^3
BGF	540	m^2
NF	453	m^2





Flächen des Grundstücks	Menge	Einheit	% an FBG
BF Bebaute Fläche	391.00	m2	16.5
UBF Unbebaute Fläche	1982.00	m2	83.5
FBG Fläche des Baugrundstücks	2373.00	m2	100.0

Grundflächen des Bauwerks	Menge	Einheit	% an HNF	% an NF	% an BGF
HNF Hauptnutzfläche	438.00	m2	100.0	96.7	81.1
NNF Nebennutzfläche	15.00	m2	3.4	3.3	2.8
NF Nutzfläche	453.00	m2	103.4	100.0	83.9
FF Funktionsfläche	4.00	m2	0.9	0.9	0.7
VF Verkehrsfläche	29.00	m2	6.6	6.4	5.4
NGF Netto-Grundfläche	486.00	m2	111.0	107.3	90.0
KGF Konstruktions-Grundfläche	54.00	m2	12.3	11.9	10.0
BGF Brutto-Grundfläche	540.00	m2	123.3	119.2	100.0

Brutto-Rauminhalt des Bauwerks	Menge	Einheit	BRI/NF [m]	BRI/BGF [m]
BRI Brutto-Rauminhalt	2276.00	m3	5.02	4.21

Planungskennwerte nach DIN 277

HNF	438.00	m2
NF	453.00	m2
BGF	540.00	m2

Planungkennwerte nach DIN 277	Menge	Einheit	Menge/HNF	Menge/NF	Menge/BGF
KG 320 Gründung	391.43	m2 GRF	0.89	0.86	0.72
KG 330 Aussenwände	467.90	m2 AWF	1.07	1.03	0.87
KG 340 Innenwände	304.65	m2 IWF	0.70	0.67	0.56
KG 350 Decken	133.06	m2 DEF	0.30	0.29	0.25
KG 360 Dächer	523.18	m2 DAF	1.19	1.15	0.97

Further architectural, construction and installation attributes

	MA [kg/m² GGF]	MB [kg/m² AWF]	MC [kg/m² DAF]	MD [kg/m² GF]	MF [kg/m² GF]	Gesamt [kg/m²
Aluminium	0.0	0.2	0.7	0.0	0.0	0.9
Beton B10	201.8	0.0	0.0	0.0	0.0	150.6
Beton B25	764.4	7.9	0.0	124.5	12.3	714.1
Beton-Porenbetonsteine	0.0	109.3	0.0	64.3	19.0	177.9
Bitumen	0.0	0.3	0.0	0.0	0.0	0.3
Estrich-Anhydrith	0.0	0.0	0.0	0.0	132.6	132.6
Estrich-Zement	0.0	0.0	0.0	0.0	0.8	0.8
Fenster-Alu	0.0	0.3	0.0	0.0	0.4	0.6
Fenster-Alu Glas	0.0	0.3	0.0	0.0	0.4	0.6
Fenster-PVC	0.0	0.0	0.1	0.0	0.0	0.1
Fenster-PVC Glas	0.0	0.0	0.1	0.0	0.0	0.1
Fliesen-Boden	0.0	0.0	0.0	0.0	10.5	10.5
Fliesen-Wand	0.0	0.0	0.0	0.0	2.3	2.3
Gipskartonplatte	0.0	0.0	0.0	0.0	2.7	2.7
Glasfaser	0.0	0.0	0.0	0.0	0.0	0.0
Hartfaser	0.0	0.0	0.0	0.0	0.7	0.7
Holz	0.0	0.0	0.0	0.6	0.9	1.4
Holzspanplatte	0.0	0.0	0.0	0.0	0.2	0.2
Kies	410.6	0.0	0.0	0.0	0.0	306.4
KSL	0.0	0.0	0.0	3.9	0.0	3.9
KSV	0.0	0.0	0.0	0.0	0.0	0.0
mod. Dämmstoff	0.0	0.0	0.0	0.0	0.0	0.0
Pappe	0.0	0.0	0.0	0.0	0.1	0.1
PE-Folie	0.0	0.0	0.0	0.0	0.1	0.1
PS-Hartschaumplatten	4.6	0.2	0.0	0.0	0.0	3.6
Putz-Kalkmörtel	0.0	0.0	0.0	0.0	41.6	41.6
Putz-Kalkzementmörtel	0.0	17.8	0.0	0.0	0.0	15.4
Putz-Zementputz	0.0	0.0	0.0	0.0	1.0	1.0
Stahl	10.5	4.3	13.0	16.5	0.3	41.2
Teppich	0.0	0.0	0.0	0.0	1.3	1.3
Zink	0.0	0.0	0.3	0.0	0.0	0.3
	1'391.9	**140.4**	**14.2**	**209.8**	**227.2**	**1'611.3**

Further characteristics	Type of building	Construction year	Construction type*	Number of materials	Weight	Heating	EFAo	EFA	Height EFA	Volume EFA
	Centre of distribution, warehouse, offices	1995	Steel skeleton	31	1611 kg/m² GF	Gas central heating	540 m²	697 m²	6 m	1565 m³
Compactness (MA+MB+MC)/ EFA	**Window surface - Total**	**Window surface - North**	**Window surface - East**	**Window surface - South**	**Window surface - West**	**Window surface-Roof**	**Heat flow**	**Total insulation amount - boards****	**Total insulation amount - sheets*****	**Cost**
1.96	36%	13%	33%	98%	26%	12%	354 MJ/m² EFA	3.6 kg/m² GF	0.40 kg/m² GF	105 Euro/m³ BRI

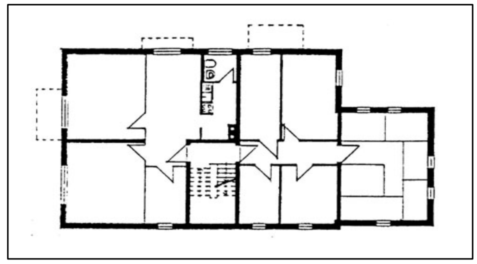
Surfaces and k-values	Floor	Composition	U- value	Roof	Composition	U-value	Roof - Window	Composition	U- value	Wall - North
	391 m²	Polystyrene insulation, 150-200 mm reinforced concrete, formwork, concrete reinforcement, 140 mm floor pavement	0.32 W/m²K	460 m²	0°; steel beams, metal construction, 60 mm insulation	0.63 W/m²K	63 m²	Insulating glas, PVC frame	2.26 W/m²K	51 m²
Wall - East	**Wall - South**	**Wall - West**	**Composition**	**U-value**	**Window - North**	**Window - East**	**Window - South**	**Window - West**	**Composition**	**U-value**
118 m²	1 m²	129 m²	300 mm lightweight areated concrete, 60 mm polystyrene boards insulation, plaster	0.41 W/m²K	8 m²	57 m²	57 m²	46 m²	Insulating glas, aluminium frame	2.46 W/m²K

Objekt: 17 **Mehrfamilienhaus (6 WE)**

Quelle: BKI / 6100-213

Objektübersicht: Foto, Pläne, Grunddaten

Land	Bayern	
Kreis	Nürnberg	
BRI	2'685	m^3
BGF	904	m^2
NF	671	m^2



Flächen des Grundstücks	Menge	Einheit	% an FBG
BF Bebaute Fläche	229.86	m2	29.2
UBF Unbebaute Fläche	556.14	m2	70.8
FBG Fläche des Baugrundstücks	786.00	m2	100.0

Grundflächen des Bauwerks	Menge	Einheit	% an HNF	% an NF	% an BGF
HNF Hauptnutzfläche	567.62	m2	100.0	84.6	62.8
NNF Nebennutzfläche	103.10	m2	18.2	15.4	11.4
NF Nutzfläche	670.72	m2	118.2	100.0	74.2
FF Funktionsfläche	18.95	m2	3.3	2.8	2.1
VF Verkehrsfläche	65.09	m2	11.5	9.7	7.2
NGF Netto-Grundfläche	754.76	m2	133.0	112.5	83.5
KGF Konstruktions-Grundfläche	148.94	m2	26.2	22.2	16.5
BGF Brutto-Grundfläche	903.70	m2	159.2	134.7	100.0

Brutto-Rauminhalt des Bauwerks	Menge	Einheit	BRI/NF [m]	BRI/BGF [m]
BRI Brutto-Rauminhalt	2685.27	m3	4.00	2.97

Planungskennwerte nach DIN 277

HNF	567.62	m2
NF	670.72	m2
BGF	903.70	m2

Planungkennwerte nach DIN 277	Menge	Einheit	Menge/HNF	Menge/NF	Menge/BGF
KG 320 Gründung	218.47	m2 GRF	0.38	0.33	0.24
KG 330 Aussenwände	670.14	m2 AWF	1.18	1.00	0.74
KG 340 Innenwände	789.99	m2 IWF	1.39	1.18	0.87
KG 350 Decken	737.46	m2 DEF	1.30	1.10	0.82
KG 360 Dächer	356.29	m2 DAF	0.63	0.53	0.39

Further architectural, construction and installation attributes

	MA [kg/m² GGF]	MB [kg/m² AWF]	MC [kg/m² DAF]	MD [kg/m² GF]	MF [kg/m² GF]	Gesamt [kg/m² GF]
Aluminium	0.0	0.0	0.1	0.0	0.0	0.1
Beton B15	32.4	0.0	0.0	0.0	0.0	7.8
Beton B25	619.5	0.0	1.8	322.9	0.0	473.5
Beton B5	110.5	0.0	0.0	0.0	0.0	26.7
Beton-Gasbeton	0.0	0.0	0.0	0.0	0.4	0.4
Bitumen	0.0	0.5	1.0	0.0	0.1	0.9
Dach-Frankfurter Pfanne	0.0	0.0	21.1	0.0	0.0	8.3
Estrich-Zement	0.0	0.0	0.0	0.0	86.5	86.5
Fenster-Alu	0.0	0.1	0.0	0.0	0.0	0.1
Fenster-Alu Glas	0.0	0.1	0.0	0.0	0.0	0.1
Fenster-Holz	0.0	2.0	0.2	0.0	0.0	1.5
Fenster-Holz Glas	0.0	3.5	0.3	0.0	0.0	2.7
Fenster-PVC	0.0	0.0	0.0	0.0	0.0	0.0
Fenster-PVC Glas	0.0	0.0	0.0	0.0	0.0	0.0
Fliesen-Boden	0.0	0.0	0.0	0.0	0.3	0.3
Fliesen-Wand	0.0	0.0	0.0	0.0	1.5	1.5
Gipskartonplatte	0.0	0.0	0.0	0.0	23.1	23.1
Holz	0.0	0.0	43.7	0.2	1.0	18.5
Holzspanplatte	0.0	0.0	0.0	0.7	1.0	1.7
Kies	358.2	0.0	0.0	0.0	0.0	86.6
KSL	0.0	316.5	0.0	123.3	8.1	362.2
KSV	0.0	1.2	0.0	3.2	0.1	4.1
Marmor	0.0	0.0	0.0	0.0	0.7	0.7
Messing	0.0	0.0	0.0	0.0	0.0	0.0
Mineralfaser	0.0	0.0	0.0	0.0	3.7	3.7
mod. Dämmstoff	0.0	0.2	0.0	0.0	0.0	0.2
Naturstein	0.0	0.0	0.0	0.0	1.4	1.4
PE-Folie	0.0	0.0	0.0	0.0	1.4	1.4
PS-Hartschaumplatten	0.0	4.2	1.0	0.0	1.0	4.4
Putz	0.0	0.0	0.0	0.0	4.5	4.5
Putz-Gipsputz	0.0	0.0	0.0	0.0	17.9	17.9
Putz-Zementputz	0.0	0.0	0.0	0.0	8.2	8.2
Stahl	26.5	0.0	4.6	12.3	2.1	22.6
Vlies	0.0	0.0	0.0	0.0	0.0	0.0
Zink	0.0	0.0	1.3	0.0	0.0	0.5
	1'147.1	**328.4**	**75.2**	**462.7**	**163.0**	**1'172.2**

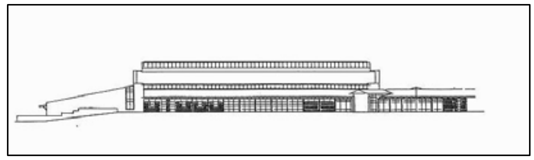
Further characteristics	Type of building	Construction year	Construction type*	Number of materials	Weight	Heating	EFAo	EFA	Height EFA	Volume EFA
	Appartament house (6)	1995	Masonry construction	34	1172 kg/m² GF	Gas central heating	722 m²	734 m²	12 m	1646 m³
Compactness (MA+MB+MC)/ EFA	**Window surface - Total**	**Window surface - North**	**Window surface - East**	**Window surface - South**	**Window surface - West**	**Window surface-Roof**	**Heat flow**	**Total insulation amount - boards****	**Total insulation amount - sheets*****	**Cost**
1.68	17%	9%	25%	19%	19%	0%	199 MJ/m² EFA	8.2 kg/m² GF	2.51 kg/m² GF	186 Euro/m³ BRI

Surfaces and k-values	Floor	Composition	U- value	Roof	Composition	U- value	Roof - Window	Composition	U- value	Wall - North
	218 m²	Reinforced concrete, formwork, 60mm polystyrene insulation, cement covering	0.50 W/m²K	287 m²	109 m²: 0°; plaster, 180 mm reinforced concrete, formwork, concrete reinforcement 60 mm polystyrene insulation, 178 m²: 30°; wood construction, wood rafters, 140 mm polystyrene insulation, wood rafters, concrete tiles	0.50; 0.25 W/m²K	-	-	-	202 m²
Wall - East	**Wall - South**	**Wall - West**	**Composition**	**U- value**	**Window - North**	**Window - East**	**Window - South**	**Window - West**	**Composition**	**U- value**
83 m²	181 m²	91 m²	365 mm brick, 80 mm polystyrol insulation, plaster	0.32 W/m²K	21 m²	28 m²	42 m²	21 m²	Double glass, wood frame	2.04 W/m²K

Objekt: 18 **Sporthalle (Typ 27/45)**
Quelle: BKI / 5100-015

Objektübersicht: Foto, Pläne, Grunddaten

Land	Bayern	
Kreis	München	
BRI	26991	m^3
BGF	4613	m^2
NF	2965	m^2



Flächen des Grundstücks	Menge	Einheit	% an FBG
BF Bebaute Fläche	3315.11	m2	82.9
UBF Unbebaute Fläche	684.89	m2	17.1
FBG Fläche des Baugrundstücks	4000.00	m2	100.0

Grundflächen des Bauwerks	Menge	Einheit	% an HNF	% an NF	% an BGF
HNF Hauptnutzfläche	2480.33	m2	100.0	83.6	53.8
NNF Nebennutzfläche	484.94	m2	19.6	16.4	10.5
NF Nutzfläche	2965.27	m2	119.6	100.0	64.3
FF Funktionsfläche	329.75	m2	13.3	11.1	7.1
VF Verkehrsfläche	928.82	m2	37.4	31.3	20.1
NGF Netto-Grundfläche	4223.84	m2	170.3	142.4	91.6
KGF Konstruktions-Grundfläche	389.13	m2	15.7	13.1	8.4
BGF Brutto-Grundfläche	4612.97	m2	186.0	155.6	100.0

Brutto-Rauminhalt des Bauwerks	Menge	Einheit	BRI/NF [m]	BRI/BGF [m]
BRI Brutto-Rauminhalt	26990.88	m3	9.10	5.85

Planungskennwerte nach DIN 277

HNF	2'480.33	m2
NF	2'965.27	m2
BGF	4'612.97	m2

Planungkennwerte nach DIN 277	Menge	Einheit	Menge/HNF	Menge/NF	Menge/BGF
KG 320 Gründung	3315.11	m2 GRF	1.34	1.12	0.72
KG 330 Aussenwände	1922.94	m2 AWF	0.78	0.65	0.42
KG 340 Innenwände	3229.68	m2 IWF	1.30	1.09	0.70
KG 350 Decken	1057.11	m2 DEF	0.43	0.36	0.23
KG 360 Dächer	3527.06	m2 DAF	1.42	1.19	0.76

Further architectural, construction and installation attributes

	MA [kg/m² GGF]	MB [kg/m² AWF]	MC [kg/m² DAF]	MD [kg/m² GF]	MF [kg/m² GF]	Gesamt [kg/m² GF]
Aluminium	0.0	0.0	0.1	0.0	0.0	0.0
Beton B10	32.8	0.0	0.0	0.0	0.0	24.9
Beton B15	192.1	0.0	0.0	0.0	0.0	145.7
Beton B25	355.8	438.8	81.7	317.4	2.3	844.1
Beton B5	110.5	0.0	0.0	0.0	0.0	83.8
Bitumen	0.0	0.0	0.7	0.0	0.1	0.6
Estrich-Zement	0.0	0.0	23.2	0.0	412.2	430.9
Eternit	0.0	0.2	0.0	0.0	0.0	0.1
Fenster-Alu	0.0	6.8	4.3	0.0	0.2	6.6
Fliesen-Boden	0.0	0.0	0.0	0.0	3.1	3.1
Fliesen-Wand	0.0	0.0	0.0	0.0	1.9	1.9
Gipskartonplatte	0.0	0.0	0.0	0.0	6.9	6.9
Glas	0.0	7.6	3.8	0.0	0.4	6.7
Glas-Spiegelglas	0.0	0.0	0.0	0.0	0.4	0.4
Holz	0.0	0.6	42.8	0.0	7.2	42.1
Holz-Brettschichtholz	0.0	0.0	9.7	0.0	0.0	7.8
Holzspanplatte	0.0	0.0	0.1	0.0	0.4	0.4
Holz-Sperrholz	0.0	0.0	0.0	0.0	12.1	12.1
Kies	207.1	0.0	21.3	0.0	0.0	174.2
Klinker	0.0	35.5	0.0	0.0	27.9	43.2
Linoleum	0.0	0.0	0.0	0.0	2.7	2.7
Mineralfaser	0.0	5.6	16.6	0.0	3.5	19.4
Mineralwolle	0.0	0.0	0.0	0.0	4.5	4.5
mod. Dämmstoff	0.0	0.0	0.0	0.0	0.0	0.0
PE-Folie	0.0	0.0	0.2	0.0	0.0	0.2
PS-Hartschaumplatten	0.0	0.0	0.6	0.0	0.1	0.6
Putz-Kalkzementmörtel	0.0	0.0	0.0	0.0	17.9	17.9
PVC	0.1	0.0	0.0	0.0	0.0	0.1
Stahl	9.8	15.0	31.7	16.3	1.6	57.4
Styrodur	0.0	0.7	0.2	0.0	0.0	0.5
Teppich	0.0	0.0	0.0	0.0	0.3	0.3
Vlies	0.2	0.0	0.0	0.0	0.0	0.2
Ziegel HLZ	0.0	0.0	0.0	0.0	22.8	22.8
Zink	0.0	0.0	3.8	0.0	0.0	3.0
	908.4	**510.8**	**240.7**	**333.7**	**528.8**	**1'965.2**

Further characteristics	Type of building	Construction year	Construction type*	Number of materials	Weight	Heating	EFAo	EFA	Height EFA	Volume EFA
	Sport hall	1990	Steel skeleton	34	1965 kg/m² GF	Gas central heating	4283 m²	10308 m²	8 m	24740 m³
Compactness (MA+MB+MC)/ EFA	**Window surface - Total**	**Window surface - North**	**Window surface - East**	**Window surface - South**	**Window surface - West**	**Window surface-Roof**	**Heat flow**	**Total insulation amount - boards****	**Total insulation amount - sheets*****	**Cost**
0.85	32%	99%	0%	0%	0%	21%	78 MJ/m² EFA	25.0 kg/m² GF	0.94 kg/m² GF	241 Euro/m³ BRI

Surfaces and k-values	Floor	Composition	U- value	Roof	Composition	U- value	Roof - Window	Composition	U- value	Wall - North
	3315 m²	105 mm reinforced concrete, bitumen, floor pavement, linoleum	0.45 W/m²K	2718 m²	600 m²: 0°; 200 mm reinforced concrete, 80-100 mm insulation, concrete reinforcement; 100 mm gravel; 2118 m²: 30°; steel, 20 mm rafters, 0.4mm PE sheet, wood beams, 120mm insulation between beams, 24 mm rafters, cartonboard, 0.7 mm titanium zinc covering	0.40, 0.34 W/m²K	722 m²	Insulating glas, steeel-alu frame	2.31 W/m²K	10 m²
Wall - East	**Wall - South**	**Wall - West**	**Composition**	**U- value**	**Window - North**	**Window - East**	**Window - South**	**Window - West**	**Composition**	**U- value**
481 m²	48	481 m²	200-300 mm reinforced	0.4	697 m²	0 m²	0 m²	0 m²	Insulatin	2.3

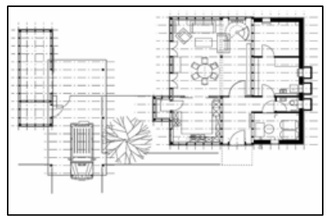
1 m^2	concrete, humidity insulation, 80 mm mineral fiber insulation	2 W/ m^2 K	g glas, metal frame	1 W/ m^2 K

Objekt: 19 **Einfamilienhaus; Holzrahmenbau**

Quelle: BKI / 6100-327

Objektübersicht: Foto, Pläne, Grunddaten

Land	Bayern	
Kreis	Günzburg	
BRI	756	m^3
BGF	310	m^2
NF	228	m^2



Flächen des Grundstücks	Menge	Einheit	% an FBG
BF Bebaute Fläche	104.90	m2	15.0
UBF Unbebaute Fläche	595.10	m2	85.0
FBG Fläche des Baugrundstücks	700.00	m2	100.0

Grundflächen des Bauwerks	Menge	Einheit	% an HNF	% an NF	% an BGF
HNF Hauptnutzfläche	104.10	m2	100.0	45.6	33.6
NNF Nebennutzfläche	123.97	m2	119.1	54.4	40.0
NF Nutzfläche	228.07	m2	219.1	100.0	73.5
FF Funktionsfläche	7.14	m2	6.9	3.1	2.3
VF Verkehrsfläche	30.26	m2	29.1	13.3	9.8
NGF Netto-Grundfläche	268.97	m2	258.4	117.9	86.7
KGF Konstruktions-Grundfläche	41.14	m2	39.5	18.0	13.3
BGF Brutto-Grundfläche	310.11	m2	297.9	136.0	100.0

Brutto-Rauminhalt des Bauwerks	Menge	Einheit	BRI/NF [m]	BRI/BGF [m]
BRI Brutto-Rauminhalt	755.99	m3	3.31	2.44

Planungskennwerte nach DIN 277

HNF	104.10	m2
NF	228.07	m2
BGF	310.11	m2

Planungkennwerte nach DIN 277	Menge	Einheit	Menge/HNF	Menge/NF	Menge/BGF
KG 320 Gründung	104.90	m2 GRF	1.01	0.46	0.34
KG 330 Aussenwände	297.54	m2 AWF	2.86	1.30	0.96
KG 340 Innenwände	199.27	m2 IWF	1.91	0.87	0.64
KG 350 Decken	211.33	m2 DEF	2.03	0.93	0.68
KG 360 Dächer	102.06	m2 DAF	0.98	0.45	0.33

Further architectural, construction and installation attributes

	MA [kg/m² GGF]	MB [kg/m² AWF]	MC [kg/m² DAF]	MD [kg/m² GF]	MF [kg/m² GF]	Gesamt [kg/m² GF]
Aluminium	0.0	0.0	0.0	0.0	0.0	0.0
Beton B10	107.2	0.0	0.0	0.0	0.0	34.5
Beton B25	1044.7	119.7	0.0	0.0	0.0	444.9
Bitumen	0.0	0.0	0.4	0.0	0.0	0.2
Dach-Betondachpfannen	0.0	0.0	37.1	0.0	0.0	12.2
Fenster-Holz	0.0	1.4	0.0	0.0	0.2	1.5
Fenster-Holz Glas	0.0	2.6	0.0	0.0	0.3	2.7
Fliesen-Boden	0.0	0.0	0.0	0.0	1.3	1.3
Fliesen-Wand	0.0	0.0	0.0	0.0	0.7	0.7
Gipskartonplatte	0.0	0.0	0.0	0.0	21.7	21.7
Glasfaser	0.0	0.0	0.0	0.0	0.0	0.0
Holz	0.0	32.9	37.8	40.1	10.9	93.3
Holz-Brettschichtholz	0.0	0.0	0.0	1.0	0.0	1.0
Holzspanplatte	0.0	0.1	0.0	0.0	13.2	13.3
Kies	374.9	0.0	0.0	0.0	0.0	120.7
Mineralfaser	0.0	0.0	0.0	0.0	20.3	20.3
Mineralwolle	0.0	0.0	0.0	0.0	27.8	27.8
PE-Folie	0.0	0.0	0.0	0.0	0.1	0.1
PS-Hartschaumplatten	0.0	0.6	0.0	0.0	1.6	2.2
Putz	0.0	0.0	0.0	0.0	0.3	0.3
PVC	1.3	0.0	0.2	0.0	0.0	0.5
Stahl	24.6	6.6	0.1	4.5	0.1	18.5
Teppich	0.0	0.0	0.0	0.0	0.6	0.6
Vlies	0.0	0.0	0.1	0.0	0.0	0.0
Zink	0.0	0.0	2.1	0.0	0.1	0.8
	1'552.7	**164.0**	**77.8**	**45.6**	**99.1**	**819.0**

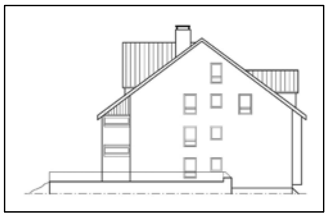
Further characteristics	Type of building	Construction year	Construction type*	Number of materials	Weight	Heating	EFAo	EFA	Height EFA	Volume EFA
	Single occupancy house, wood construction	1999	Wood skeleton	25	819 kg/m² GF	Oil	210 m²	210 m²	6 m	483 m³
Compactness (MA+MB+MC)/ EFA	**Window surface - Total**	**Window surface - North**	**Window surface - East**	**Window surface - South**	**Window surface - West**	**Window surface-Roof**	**Heat flow**	**Total insulation amount - boards****	**Total insulation amount - sheets*****	**Cost**
2.30	18%	16%	12%	33%	12%	0%	257 MJ/m² EFA	50.2 kg/m² GF	0.77 kg/m² GF	286 Euro/m³ BRI

Surfaces and k-values	Floor	Composition	U- value	Roof	Composition	U-value	Roof - Window	Composition	U- value	Wall - North
	105 m²	300 mm reinforced concerete, PE sheet, 80 mm polystyrene insulation, concrete reinforcement, 15 mm wood panels	0.39 W/m²K	105 m²	0°; ceiling: wood construction, 30 mm formwork, 180 mm insulation, 0.1 mm PE sheet, 50 mm wood rafters, 12.5 mm wood rafters	0.17 W/m²K	-	-	-	62 m²
Wall - East	**Wall - South**	**Wall – West**	**Composition**	**U-value**	**Window - North**	**Window - East**	**Window - South**	**Window - West**	**Composition**	**U-value**
66 m²	50 m²	66 m²	(+45°) wood construction, wood boards, 120 mm insulation, wood covering	0.35 W/m²K	12 m²	9 m²	25 m²	9 m²	Insulating glas, wood frame	1.10 W/m²K

Objekt: 20 **Mehrfamilienhaus (9 WE) mit Tiefgarage**
Quelle: BKI / 6100-221

Objektübersicht: Foto, Pläne, Grunddaten

Land	Hessen	
Kreis	Hochtaunus	
BRI	4379	m^3
BGF	1564	m^2
NF	1256	m^2



Flächen des Grundstücks	Menge	Einheit	% an FBG
BF Bebaute Fläche	807.98	m2	82.2
UBF Unbebaute Fläche	175.02	m2	17.8
FBG Fläche des Baugrundstücks	983.00	m2	100.0

Grundflächen des Bauwerks	Menge	Einheit	% an HNF	% an NF	% an BGF
HNF Hauptnutzfläche	775.70	m2	100.0	61.8	49.6
NNF Nebennutzfläche	479.99	m2	61.9	38.2	30.7
NF Nutzfläche	1255.69	m2	161.9	100.0	80.3
FF Funktionsfläche	11.48	m2	1.5	0.9	0.7
VF Verkehrsfläche	89.01	m2	11.5	7.1	5.7
NGF Netto-Grundfläche	1356.18	m2	174.8	108.0	86.7
KGF Konstruktions-Grundfläche	208.13	m2	26.8	16.6	13.3
BGF Brutto-Grundfläche	1564.31	m2	201.7	124.6	100.0

Brutto-Rauminhalt des Bauwerks	Menge	Einheit	BRI/NF [m]	BRI/BGF [m]
BRI Brutto-Rauminhalt	4379.06	m3	3.49	2.80

Planungskennwerte nach DIN 277

HNF	775.70	m2
NF	1'255.69	m2
BGF	1'564.31	m2

Planungkennwerte nach DIN 277	Menge	Einheit	Menge/HNF	Menge/NF	Menge/BGF
KG 320 Gründung	431.35	m2 GRF	0.56	0.34	0.28
KG 330 Aussenwände	950.78	m2 AWF	1.23	0.76	0.61
KG 340 Innenwände	934.12	m2 IWF	1.20	0.74	0.60
KG 350 Decken	1167.50	m2 DEF	1.51	0.93	0.75
KG 360 Dächer	524.54	m2 DAF	0.68	0.42	0.34

Further architectural, construction and installation attributes

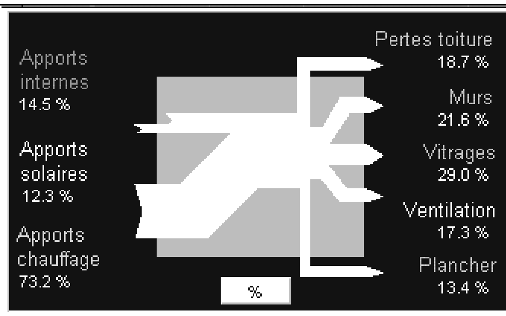
	MA [kg/m^2 GGF]	MB [kg/m^2 AWF]	MC [kg/m^2 DAF]	MD [kg/m^2 GF]	MF [kg/m^2 GF]	Gesamt [kg/m^2 GF]
Aluminium	0.0	0.0	0.0	0.0	0.1	0.1
Beton B10	0.1	0.0	0.0	0.0	6.8	6.8
Beton B15	86.5	0.0	0.0	0.0	0.0	23.8
Beton B25	955.0	113.9	101.8	441.1	0.0	806.9
Beton-Gasbeton	0.0	0.0	0.0	2.6	0.0	2.6
Bitumen	0.0	0.0	0.4	0.0	0.2	0.3
Dach-Betondachpfannen	0.0	0.0	21.6	0.0	0.0	7.2
Estrich-Zement	0.0	0.0	0.0	0.0	55.8	55.8
Fenster-Alu	0.0	0.0	0.0	0.0	0.1	0.1
Fenster-Alu Glas	0.0	0.0	0.0	0.0	0.1	0.1
Fenster-Holz	0.0	1.0	0.5	0.0	0.0	0.7
Fenster-Holz Glas	0.0	1.7	0.8	0.0	0.0	1.3
Fliesen-Boden	0.0	0.0	0.0	0.0	1.5	1.5
Fliesen-Wand	0.0	0.0	0.0	0.0	2.5	2.5
Gipskartonplatte	0.0	0.0	0.0	0.0	7.3	7.3
Glas	0.0	0.0	0.0	0.0	0.1	0.1
Glaswolle	0.0	0.0	0.0	0.0	0.0	0.0
Granit	0.0	0.0	0.0	0.0	2.0	2.0
Gusseisen	0.0	0.0	0.0	0.0	0.0	0.0
Holz	0.0	1.0	28.5	0.6	4.1	14.8
Holzspanplatte	0.0	1.2	0.0	0.0	3.4	4.1
Kies	157.6	0.0	0.0	0.0	0.0	43.4
KSL	0.0	225.4	0.0	0.0	13.3	148.4
KSV	0.0	0.0	0.0	77.6	2.8	80.3
Mineralfaser	0.0	0.0	6.4	0.0	12.5	14.7
Mineralwolle	0.0	0.0	0.0	0.0	3.7	3.7
mod. Dämmstoff	0.0	0.0	0.1	0.0	0.0	0.1
PE-Folie	0.0	0.0	0.1	0.0	0.0	0.1
PS-Hartschaumplatten	0.7	2.5	0.0	0.0	1.0	2.7
Putz-Gipsputz	0.0	0.0	0.0	0.0	14.4	14.4
Putz-Kalkmörtel	0.0	3.1	0.0	0.0	0.0	1.9
Putz-Zementputz	0.0	0.0	0.0	0.0	7.1	7.1
PVC	0.6	0.0	0.0	0.0	0.0	0.2
Stahl	16.4	5.2	4.7	14.6	1.7	25.6
Styrodur	0.0	0.0	0.0	0.0	0.0	0.0
Vlies	0.0	0.0	0.0	0.0	0.0	0.0
Zink	0.0	0.4	0.8	0.0	0.0	0.5
	1'216.7	**355.4**	**165.8**	**536.5**	**140.5**	**1'281.2**

Further characteristics	Type of building	Construction year	Construction type*	Number of materials	Weight	Heating	EFAo	EFA	Height EFA	Volume EFA
	Appartament house (9) with underground garage	1995	Masonry construction	37	1281 kg/m^2 GF	Gas****	1187 m^2	1225 m^2	8 m	1225 m^3
Compactness (MA+MB+MC)/ EFA	**Window surface - Total**	**Window surface - North**	**Window surface - East**	**Window surface - South**	**Window surface - West**	**Window surface-Roof**	**Heat flow**	**Total insulation amount - boards****	**Total insulation amount - sheets*****	**Cost**
1.55	24%	29%	9%	38%	9%	4%	172 MJ/m^2 EFA	21.1 kg/m^2 GF	0.71 kg/m^2 GF	219 $Euro/m^3$ BRI

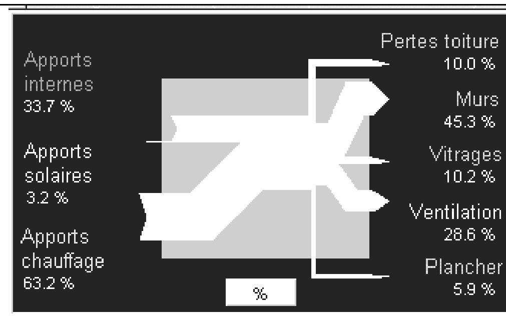
Surfaces and k-values	Floor	Composition	U- value	Roof	Composition	U- value	Roof - Window	Composition	U- value	Wall - North
	431 m^2	200 mm reinforced concerete, formwork, concrete reinforcement, 15 mm parquet	0.36 W/m^2K	502 m^2	30°; wood construction, beams, sealing, 200 mm mineral wool insulation, 16 mm wood rafters, concrete tails	0.44 W/m^2K	22 m^2	Insulating glas, wood frame	2.04 W/m^2K	160 m^2
Wall - East	**Wall - South**	**Wall – West**	**Composition**	**U- value**	**Window - North**	**Window - East**	**Window - South**	**Window - West**	**Composition**	**U- value**
136 m^2	140 m^2	136 m^2	240 mm bricks, 60 mm insulation, plaster	0.29 W/m^2K	65 m^2	14 m^2	85 m^2	14 m^2	Insulating glas, wood frame	2.04 W/m^2K

Appendix B.2 Energy flows

1EFH



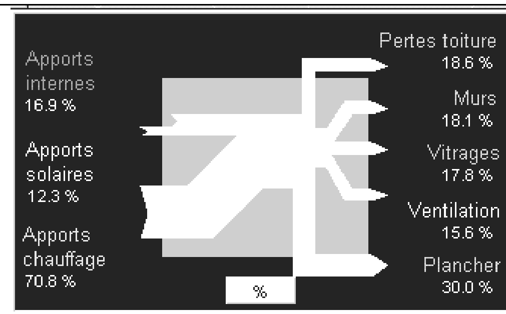
2DLG



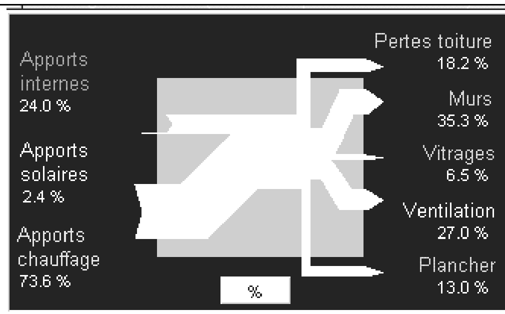
3PRG

This building is not heated

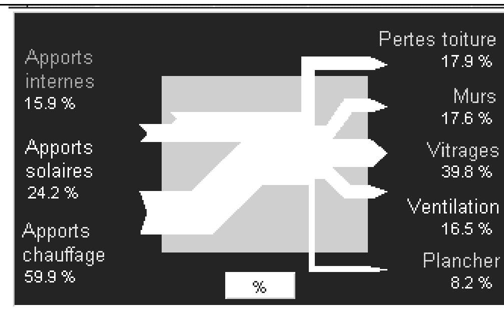
4MFH



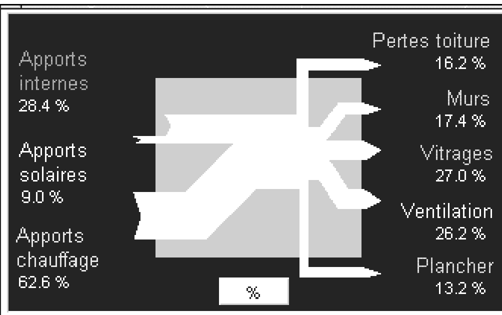
5DLG



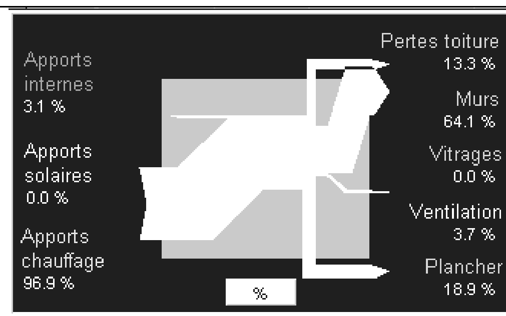
6DLG



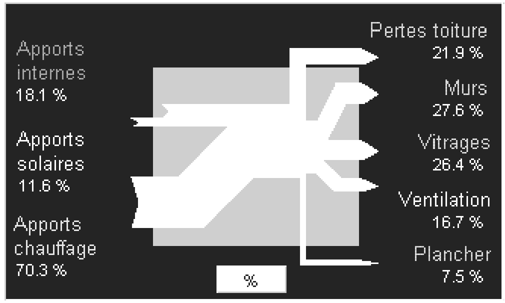
7MFH



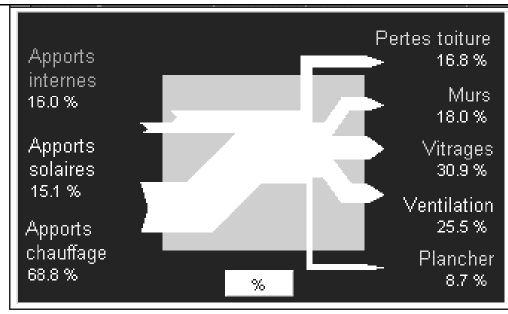
8PRG



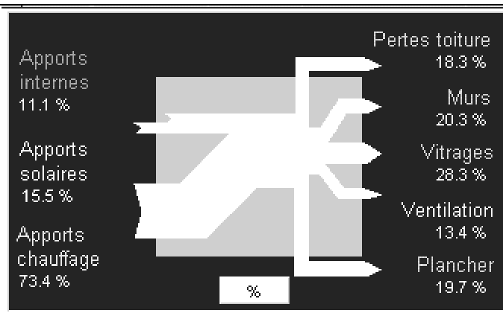
9MFH



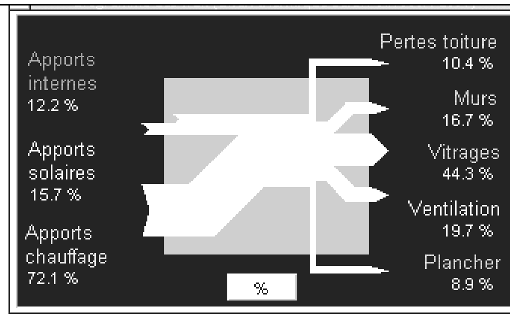
10EFH



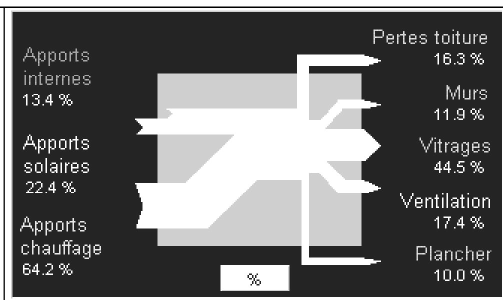
11EFH



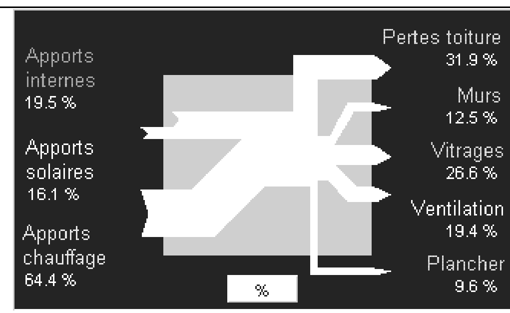
12EFH



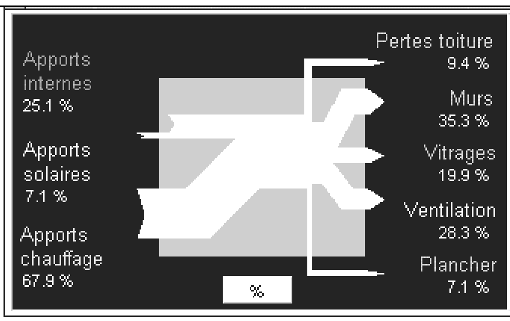
13EFH



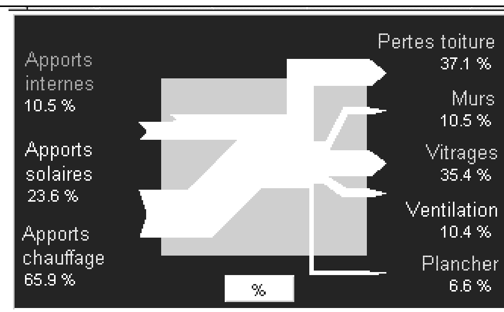
14DLG



15DLG



16PRG



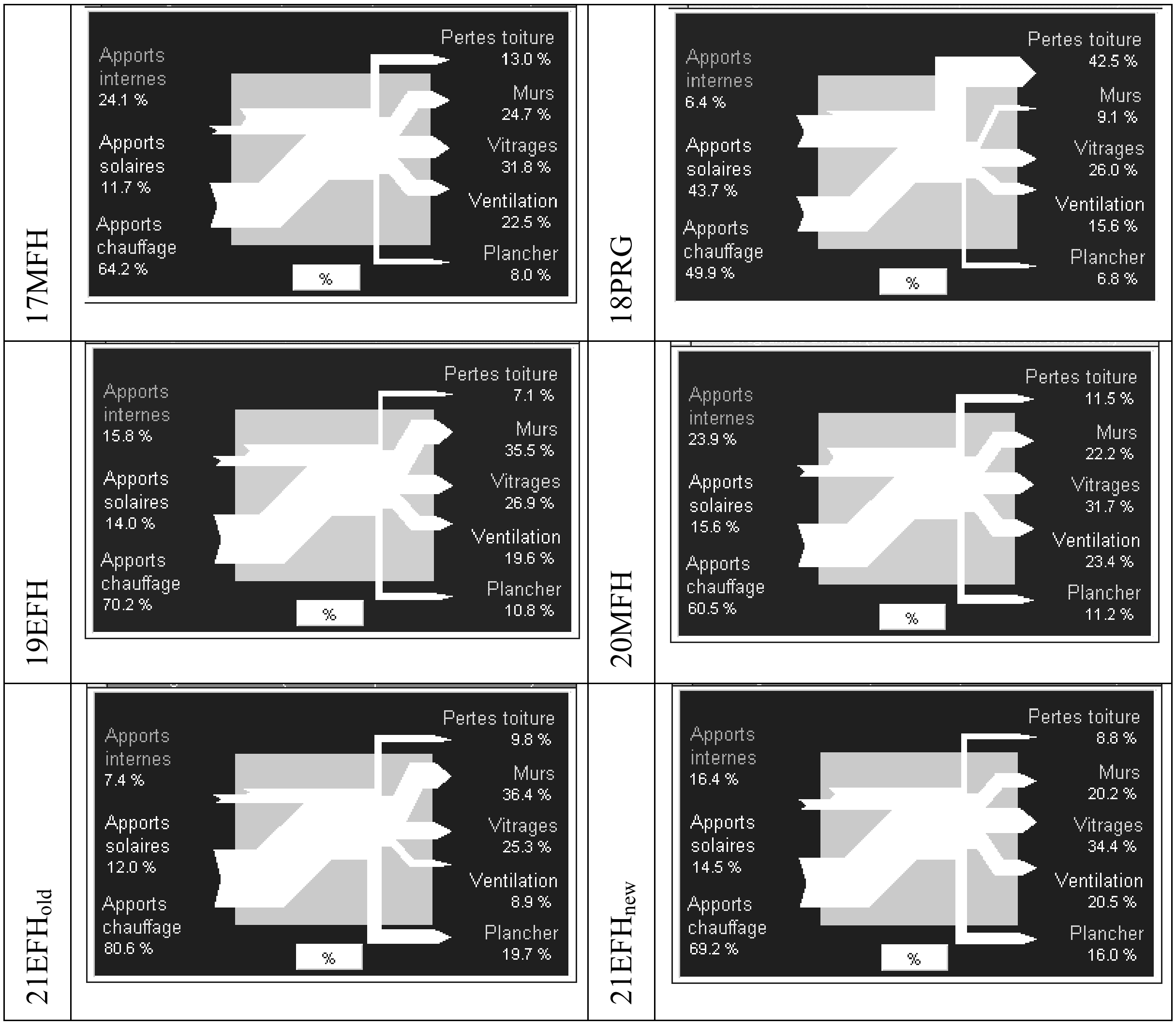


Figure A-1: Results obtained with EnerCAD for the energy flow of the set of houses.

Appendix C - Results

Appendix C.1 Non – energy related effects of renovation

Table A-3: Score of the different lifephases and of the total building before and after undergoing renovation presented for different impact assessment methods.

		CED biomass MJ-Eq	CED fossil MJ-Eq	CED Nuclear MJ-Eq	CED water MJ-Eq	CED wind, solar, etc MJ-Eq	EI 99 total points	UBP 97 total UBP
Construction	21 EFH	1091	3791	501	117	9	39	440629
	21 EFH New	2587	4402	617	140	12	50	477976
	Difference	1496	611	116	23	2	11	37347
Refurbishment	21 EFH	2040	1787	340	81	6	22	252492
	21 EFH New	5032	2874	562	126	11	43	341360
	Difference	2992	1087	222	45	4	21	88868
Use	21 EFH	77	62552	10649	3330	76	262	2448514
	21 EFH New	63	24588	9521	3050	60	104	1276722
	Difference	-15	-37965	-1128	-280	-17	-158	-1171791
Disposal	21 EFH	0	108	4	1	0	3	57986
	21 EFH New	0	112	4	1	0	3	67030
	Difference	0	4	0	0	0	0	9044
Total	21 EFH	3208	68239	11494	3528	92	326	3199621
	21 EFH New	7682	31976	10704	3316	82	201	2163089
	Difference	4474	-36262	-790	-212	-10	-126	-1036532

Appendix C.2 Non – energy related effects of renovation

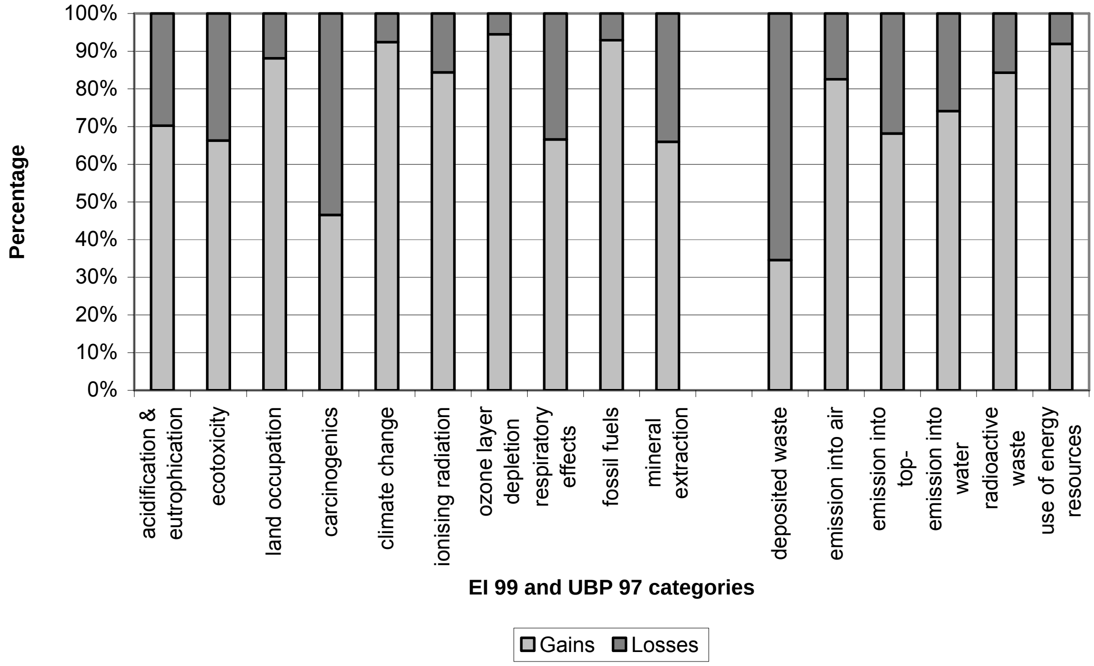


Figure A-2: Part of gains and losses brought by renovation for the different EI 99 and UBP 97 categories of impact.

Table A-4: Environmental score of gains and losses brought by renovation.

	EI 99 acidification & eutrophication	EI 99 Ecotoxicity	EI 99 Land occupation	EI 99 carcinogenics	EI 99 climate change	EI 99 ionising radiation	EI 99 ozone layer depletion	EI 99 respiratory effects
	Points	Points	Points	Points	Points	Points	Points	Points
Gains	1.5	1.0	1.7	1.8	14.3	0.1	0.0	16.1
Losses	0.6	0.5	0.2	2.0	1.2	0.0	0.0	8.1

	EI 99 fossil fuels	EI 99 mineral extraction	UBP 97 deposited waste	UBP 97 emission into air	UBP 97 emission into top-soil/groundwater	UBP 97 emission into water	UBP 97 radioactive waste	UBP 97 use of energy resources
	Points	Points	UBP	UBP	UBP	UBP	UBP	UBP
Gains	120.9	0.5	11841	1001385	11383	49130	58682	39365
Losses	9.2	0.3	22394	211842	5311	17169	10940	3447

Appendix C.3 Impact related to three different maintenance models

Table A-5: Impact caused by SI, SII and SIII maintenance models for different impact assessment methods.

		CED Biomass MJ Eq	CED Fossil MJ Eq	CED nuclear MJ Eq	CED water MJ Eq	CED wind, solar, etc MJ Eq	EI 99 Total Points	UBP 97 Total UBP
Construction	S I	3678	8194	1119	256	21	89	918606
	SII	1091	3791	501	117	9	39	440629
	SIII	1091	3791	501	117	9	39	440629
Refurbishment	S I	3524	2272	443	102	8	32	284382
	SII	3524	2272	443	102	8	32	284382
	SIII	2851	2174	418	96	8	27	297233
Use	S I	87	54463	12606	3987	85	229	2328272
	SII	1648	55140	12733	4012	87	240	2372821
	SIII	97	78190	13311	4162	96	328	3060642
Disposal	S I	0	220	7	1	0	6	125016
	SII	0	112	4	1	0	3	67030
	SIII	0	108	4	1	0	3	57986
Total	S I	7290	65148	14175	4347	114	356	3656276
	SII	6263	61315	13681	4232	105	314	3164862
	SIII	4038	84263	14234	4375	113	397	3856491

Appendix C.4 Comparison between components of EI 99 classes inside life phases

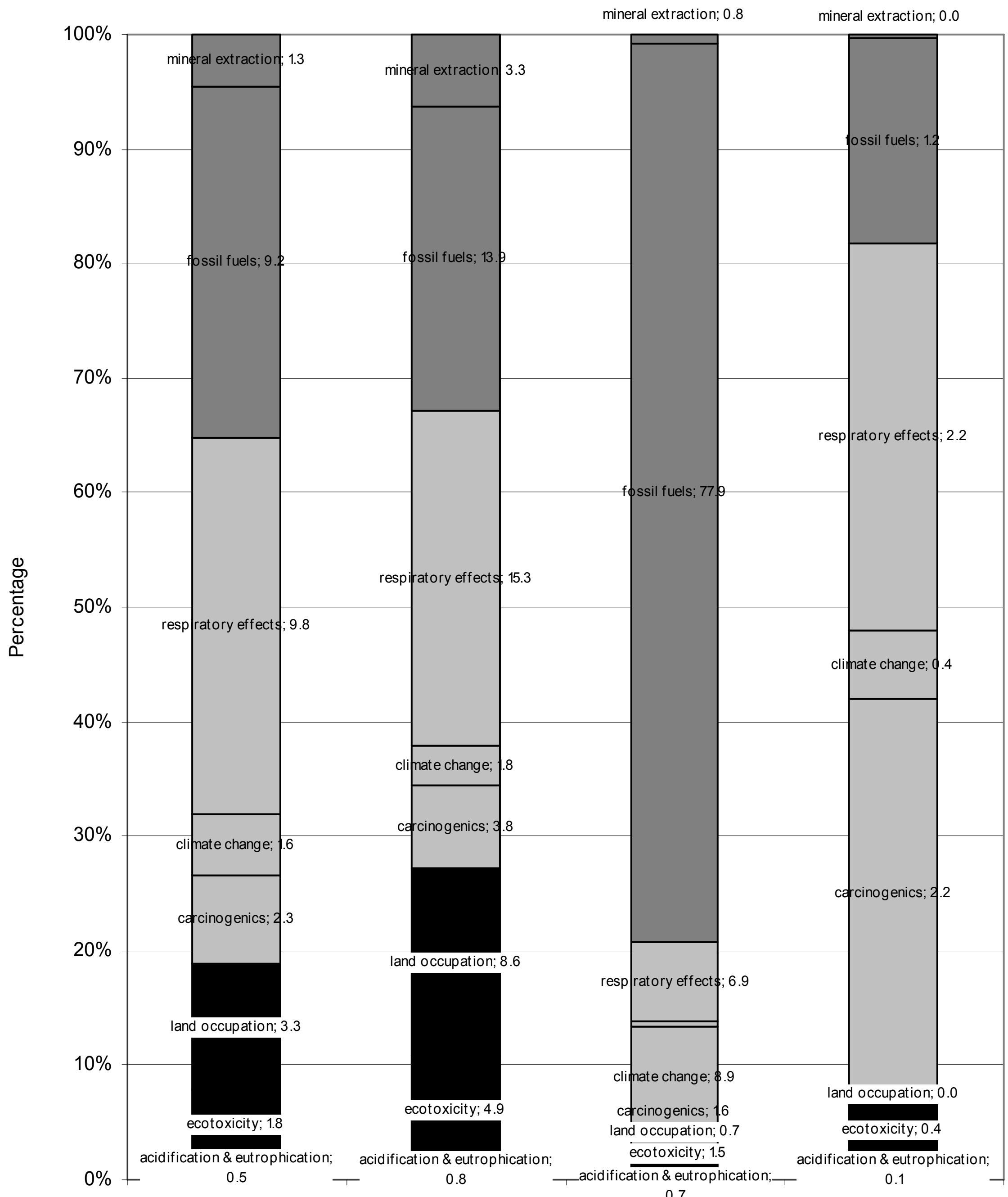


Figure A-3: Contribution of each component of the three EI 99 classes inside the lifephases. In black components of the Ecosystem quality class, in hell gray of the Human health and in dark gray of the Resources ones.

Table A-6: Score for the different life phases and for the different EI 99 classes.

		acidification & eutrophication	ecotoxicity	land occupation	carcinogenics	climate change	ionising radiation	ozone layer depletion	respiratory effects	fossil fuels	mineral extraction
		Points	Points	Points	Points	Points	Points	Points	Points	Points	Points
1 EFH	Construction	0.8	1.3	3.2	2.0	2.9	0.0	0.0	12.0	12.8	0.9
	Refurbishment	1.4	3.1	8.6	3.4	4.2	0.1	0.0	25.4	26.0	2.0
	Use	0.9	1.9	0.8	1.9	13.3	0.6	0.0	8.3	121.4	1.0
	Disposal	0.1	0.3	0.1	3.2	0.6	0.0	0.0	2.9	1.6	0.0
10EFH	Construction	0.6	1.5	5.1	3.1	1.4	0.0	0.0	10.3	8.7	1.2
	Refurbishment	1.2	4.5	14.9	8.8	2.4	0.1	0.0	24.4	14.9	3.3
	Use	0.6	1.6	0.6	1.7	8.5	0.5	0.0	5.9	75.5	0.9
	Disposal	0.1	0.3	0.0	1.9	0.6	0.0	0.0	1.6	0.9	0.0
11EFH	Construction	0.5	0.9	2.3	2.0	1.8	0.0	0.0	8.2	9.6	0.9
	Refurbishment	0.8	2.1	6.3	4.1	2.4	0.0	0.0	16.2	16.7	1.8
	Use	0.7	1.7	0.6	1.7	10.4	0.5	0.0	6.8	93.8	0.9
	Disposal	0.1	0.2	0.1	2.8	0.5	0.0	0.0	2.5	1.5	0.0
12EFH	Construction	0.3	0.8	10.7	1.0	-0.4	0.0	0.0	4.4	5.9	0.4
	Refurbishment	0.9	2.4	27.8	3.5	0.9	0.1	0.0	11.8	15.6	1.2
	Use	0.6	1.6	0.6	1.6	8.8	0.5	0.0	6.0	77.9	0.9
	Disposal	0.0	0.1	0.0	0.8	0.8	0.0	0.0	0.7	0.4	0.0
13EFH	Construction	0.7	2.5	5.3	2.9	2.1	0.0	0.0	9.6	12.7	2.6
	Refurbishment	0.8	6.8	15.3	6.4	0.8	0.0	0.0	13.0	10.2	7.1
	Use	0.6	1.6	0.5	1.6	7.6	0.5	0.0	5.4	66.6	0.8
	Disposal	0.1	0.5	0.0	2.6	0.5	0.0	0.0	2.1	1.3	0.0
19EFH	Construction	0.5	0.8	6.2	1.3	0.5	0.0	0.0	8.5	6.9	0.6
	Refurbishment	1.2	2.2	18.4	2.7	1.9	0.1	0.0	21.7	17.7	1.5
	Use	1.0	1.9	1.1	2.0	9.1	0.5	0.0	10.3	69.8	1.0
	Disposal	0.1	0.2	0.0	1.5	0.7	0.0	0.0	1.4	0.8	0.0
$21EFH_{old}$	Construction	0.6	0.6	2.1	2.4	1.3	0.0	0.0	21.3	10.5	0.2
	Refurbishment	0.3	0.4	3.9	1.1	0.6	0.0	0.0	10.9	4.8	0.2
	Use	2.5	2.9	2.9	4.2	23.8	0.6	0.0	28.6	195.0	1.5
	Disposal	0.1	0.0	0.0	0.1	0.2	0.0	0.0	2.4	0.3	0.0
$21EFH_{new}$	Construction	0.7	0.7	8.9	2.5	0.9	0.0	0.0	23.6	12.0	0.3
	Refurbishment	0.6	0.6	17.5	1.5	-0.2	0.0	0.0	15.6	7.6	0.3
	Use	1.1	1.9	1.2	2.4	9.5	0.5	0.0	12.5	74.1	0.9
	Disposal	0.1	0.0	0.0	0.1	0.3	0.0	0.0	2.4	0.4	0.0
4MFH	Construction	0.3	0.7	0.6	1.5	1.4	0.0	0.0	5.0	5.5	0.7
	Refurbishment	0.4	1.3	1.4	2.7	1.3	0.0	0.0	8.0	6.0	1.7
	Use	0.6	1.6	0.6	1.6	8.9	0.5	0.0	6.0	79.3	0.9
	Disposal	0.1	0.2	0.0	2.1	0.1	0.0	0.0	1.8	1.1	0.0
7MFH	Construction	0.4	1.5	0.9	1.7	1.3	0.0	0.0	5.6	5.6	1.1
	Refurbishment	0.3	4.1	2.3	2.6	0.8	0.0	0.0	8.1	5.0	2.6
	Use	0.4	1.3	0.4	1.2	5.1	0.4	0.0	3.9	43.8	0.7
	Disposal	0.1	0.3	0.0	2.1	0.2	0.0	0.0	1.9	1.1	0.0
9MFH	Construction	0.4	0.9	2.7	1.7	1.1	0.0	0.0	6.7	7.1	1.2
	Refurbishment	0.7	2.1	7.9	4.0	1.8	0.0	0.0	15.1	14.2	3.2
	Use	0.6	1.5	0.5	1.5	8.3	0.5	0.0	5.6	74.4	0.8
	Disposal	0.1	0.1	0.0	2.0	0.3	0.0	0.0	1.8	1.0	0.0
17MFH	Construction	0.4	0.9	1.5	1.5	1.3	0.0	0.0	5.8	8.5	0.6
	Refurbishment	0.5	1.9	4.1	2.0	1.8	0.0	0.0	9.1	13.7	1.1

		acidification & eutrophication	ecotoxicity	land occupation	carcinogenics	climate change	ionising radiation	ozone layer depletion	respiratory effects	fossil fuels	mineral extraction
		Points	Points	Points	Points	Points	Points	Points	Points	Points	Points
	Use	0.6	1.7	0.5	1.6	7.4	0.6	0.0	5.4	64.6	0.9
	Disposal	0.1	0.2	0.0	2.2	0.3	0.0	0.0	2.0	1.2	0.0
20MFH	Construction	0.4	0.8	1.3	1.6	1.4	0.0	0.0	6.9	7.0	0.6
	Refurbishment	0.5	1.7	3.5	2.1	1.7	0.0	0.0	11.9	10.2	1.2
	Use	0.5	1.6	0.5	1.6	6.2	0.6	0.0	4.8	52.4	0.8
	Disposal	0.1	0.2	0.0	2.4	0.3	0.0	0.0	2.2	1.3	0.0
2DLG	Construction	0.6	1.5	0.4	3.7	2.5	0.0	0.0	10.5	9.8	1.9
	Refurbishment	0.6	2.3	0.7	4.0	2.3	0.1	0.0	13.4	12.6	4.3
	Use	0.5	1.4	0.4	1.4	6.6	0.5	0.0	4.7	57.5	0.7
	Disposal	0.1	0.2	0.1	3.2	0.3	0.0	0.0	3.0	1.8	0.0
5DLG	Construction	0.7	1.2	2.8	2.2	2.0	0.0	0.0	9.9	17.6	1.0
	Refurbishment	1.1	2.7	7.7	3.0	2.7	0.1	0.0	18.4	42.2	2.0
	Use	0.5	0.9	0.4	0.9	7.2	0.3	0.0	4.4	67.0	0.5
	Disposal	0.1	0.3	0.1	3.1	0.4	0.0	0.0	2.7	1.5	0.0
6DLG	Construction	0.8	8.5	5.8	4.9	1.4	0.1	0.0	14.6	11.2	4.1
	Refurbishment	1.5	27.4	15.6	5.6	2.0	0.1	0.0	23.2	19.5	10.4
	Use	0.6	1.5	0.6	1.5	9.0	0.5	0.0	5.9	80.4	0.8
	Disposal	0.1	1.6	0.0	1.7	0.7	0.0	0.0	1.7	1.1	0.0
14DLG	Construction	0.4	2.8	1.9	1.6	1.4	0.0	0.0	6.0	5.9	1.7
	Refurbishment	0.6	9.3	5.3	3.2	1.4	0.0	0.0	10.9	9.2	4.4
	Use	0.5	0.9	0.4	1.0	7.5	0.3	0.0	4.5	69.0	0.5
	Disposal	0.1	0.7	0.0	2.9	0.3	0.0	0.0	2.5	1.4	0.0
15DLG	Construction	0.7	0.9	1.1	2.4	2.8	0.0	0.0	9.8	12.2	1.1
	Refurbishment	0.6	1.4	2.4	4.3	2.2	0.0	0.0	14.2	10.4	2.4
	Use	0.7	1.6	0.6	1.6	10.2	0.5	0.0	6.6	92.9	0.9
	Disposal	0.2	0.3	0.1	4.1	0.3	0.0	0.0	3.5	2.1	0.0
3PRG	Construction	0.5	1.6	4.1	2.7	1.8	0.0	0.0	7.6	7.2	2.0
	Refurbishment	0.5	3.9	11.7	3.9	0.2	0.0	0.0	8.9	5.5	5.1
	Use	0.0	0.2	0.0	0.2	0.1	0.1	0.0	0.3	0.3	0.1
	Disposal	0.0	0.2	0.0	0.8	0.1	0.0	0.0	0.8	0.4	0.0
8PRG	Construction	0.4	5.1	0.3	1.7	1.6	0.0	0.0	6.5	6.7	2.6
	Refurbishment	0.7	17.6	0.8	3.2	1.9	0.0	0.0	12.0	10.4	7.4
	Use	0.2	0.3	0.2	0.3	3.3	0.1	0.0	1.9	30.8	0.2
	Disposal	0.1	1.2	0.1	2.7	0.2	0.0	0.0	2.3	1.2	0.0
16PRG	Construction	0.5	1.0	0.4	2.5	2.0	0.0	0.0	9.5	8.4	1.1
	Refurbishment	0.7	2.2	0.9	5.1	2.7	0.0	0.0	19.9	15.6	2.6
	Use	1.1	1.9	1.0	2.0	17.6	0.6	0.0	10.3	164.6	1.1
	Disposal	0.1	0.2	0.0	2.8	0.2	0.0	0.0	2.5	1.4	0.0
18PRG	Construction	0.7	2.6	5.3	3.2	2.4	0.1	0.0	12.5	10.4	2.7
	Refurbishment	1.2	7.6	13.4	6.4	3.1	0.1	0.0	25.5	18.9	7.3
	Use	0.4	0.8	0.4	0.8	6.7	0.2	0.0	4.0	61.9	0.4
	Disposal	0.1	0.5	0.0	2.9	0.5	0.0	0.0	2.9	1.7	0.0

Appendix D – Sensitivity analysis

Appendix D.1 Impact related to changes in electricity supply

Table A-7: For each electricity source, the total impact and the relative contribution of electricity are given.

		CED biomass MJ Eq	CED fossil MJ Eq	CED nuclear MJ Eq	CED water MJ Eq	CED wind, solar, etc MJ Eq	UBP 97 total UBP
Swiss mix	Total	3208	68239	11494	3528	92	3199621
	Electricity	2%	3%	77%	82%	54%	18%
Wind *	Total	3157	66347	2717	666	19322	2655819
	Electricity	0%	0%	3%	3%	100%	2%
Photovoltaic	Total	3180	67556	3001	849	31365	2784501
	Electricity	1%	2%	12%	24%	100%	6%
UCTE MIX	Total	3263	74128	9850	1865	210	3455288
	Electricity	3%	11%	73%	65%	80%	24%

* at power plant

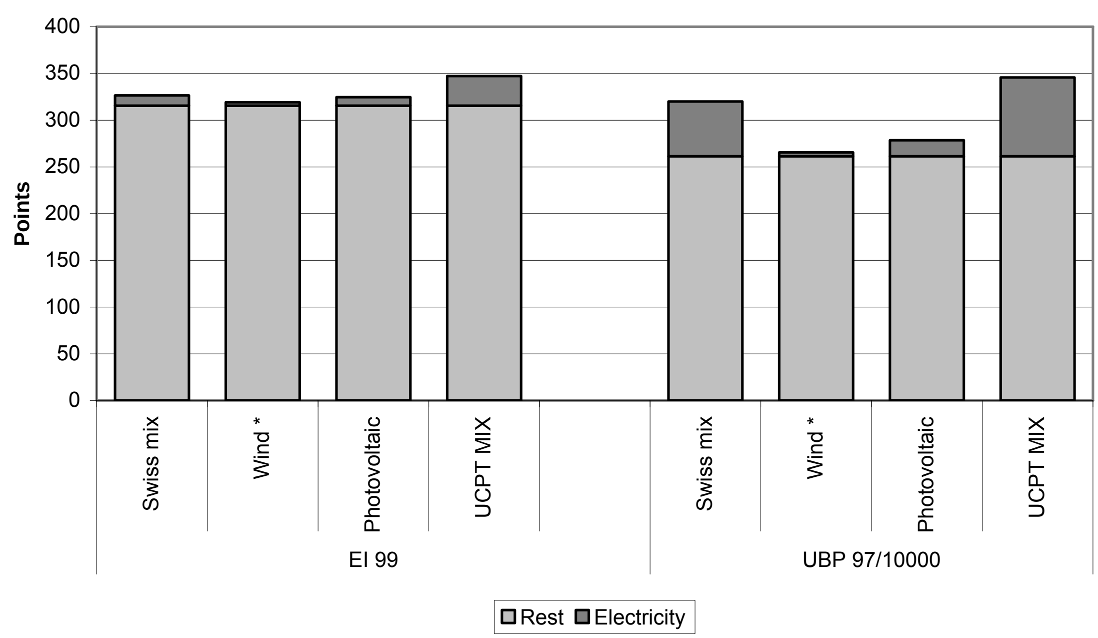


Figure A-4: Differences on the total impact caused by switches to aeolic, photovoltaic and UCTE electricity for, respectively, EI 99 and UBP 97.

Appendix D.2 Impact related to differences in lifespan

Table A-8: Impact variation for house 21EFH before ($21EFH_{old}$) and after renovation ($21EFH_{new}$). Results are given in EI 99 points and in percentage for three different lifespan scenarios: 50, 80 and 100 years.

EI 99 $21EFH_{old}$	Lifespan	Points	Percentage	$21EFH_{new}$	Lifespan	Points	Percentage
Construction	50	39	18%	Construction	50	50	36%
	80	39	12%		80	50	25%
	100	39	10%		100	50	21%
Refurbishment	50	11	5%	Refurbishment	50	21	15%
	80	22	7%		80	43	22%
	100	27	7%		100	48	21%
Use	50	164	76%	Use	50	65	47%
	80	262	80%		80	104	52%
	100	328	83%		100	130	56%
Disposal	50	3	1%	Disposal	50	3	2%
	80	3	1%		80	3	2%
	100	3	1%		100	3	1%
Total	50	217	100%	Total	50	139	100%
	80	326	100%		80	201	100%
	100	397	100%		100	231	100%

Table A-9: Environmental impact for house 21EFH before ($21EFH_{old}$) and after renovation ($21EFH_{new}$). Results are given in points and in percentage for three different lifespan scenarios: 50, 80 and 100 years.

		CED biomass		CED Fossil		CED nuclear		CED Water		CED wind, solar, etc		UBP 97 total	
		MJ Eq	%	MJ Eq	%	MJ Eq	%	MJ Eq	%	MJ Eq	%	UBP	%
$21EFH_{old}$													
Construction	50	1091	51%	3791	9%	501	7%	117	5%	9	15%	440629	21%
	80	1091	34%	3791	6%	501	4%	117	3%	9	10%	440629	14%
	100	1091	27%	3791	4%	501	4%	117	3%	9	8%	440629	11%
Refurbishment	50	1014	47%	876	2%	167	2%	40	2%	3	5%	120444	6%
	80	2040	64%	1787	3%	340	3%	81	2%	6	7%	252492	8%
	100	2851	71%	2174	3%	418	3%	96	2%	8	7%	297233	8%
Use	50	48	2%	39095	89%	6656	91%	2081	93%	48	79%	1530321	71%
	80	77	2%	62552	92%	10649	93%	3330	94%	76	83%	2448514	77%
	100	97	2%	78190	93%	13311	94%	4162	95%	96	84%	3060642	79%
Disposal	50	0	0%	108	0%	4	0%	1	0%	0	0%	57986	3%
	80	0	0%	108	0%	4	0%	1	0%	0	0%	57986	2%
	100	0	0%	108	0%	4	0%	1	0%	0	0%	57986	2%
Total	50	2153	100%	43870	100%	7327	100%	2238	100%	60	100%	2149380	100%
	80	3208	100%	68239	100%	11494	100%	3528	100%	92	100%	3199621	100%
	100	4038	100%	84263	100%	14234	100%	4375	100%	113	100%	3856491	100%
$21EFH_{new}$													
Construction	50	2587	50%	4402	21%	617	9%	140	7%	12	21%	477976	32%
	80	2587	34%	4402	14%	617	6%	140	4%	12	14%	477976	22%
	100	2587	30%	4402	11%	617	5%	140	3%	12	12%	477976	19%
Refurbishment	50	2510	49%	1396	7%	276	4%	62	3%	5	10%	163938	11%
	80	5032	66%	2874	9%	562	5%	126	4%	11	13%	341360	16%
	100	5863	69%	3218	8%	639	5%	140	3%	12	13%	385311	15%
Use	50	39	1%	15367	72%	5951	87%	1906	90%	37	69%	797951	53%
	80	63	1%	24588	77%	9521	89%	3050	92%	60	73%	1276722	59%
	100	78	1%	30735	80%	11901	90%	3812	93%	74	76%	1595903	63%
Disposal	50	0	0%	112	1%	4	0%	1	0%	0	0%	67030	4%
	80	0	0%	112	0%	4	0%	1	0%	0	0%	67030	3%
	100	0	0%	112	0%	4	0%	1	0%	0	0%	67030	3%
Total	50	5136	100%	21277	100%	6848	100%	2108	100%	54	100%	1506896	100%
	80	7682	100%	31976	100%	10704	100%	3316	100%	82	100%	2163089	100%
	100	8528	100%	38468	100%	13161	100%	4093	100%	98	100%	2526220	100%

Appendix D.3 Impact related to changes in disposal paths

Table A-10: Best case/Worst case analysis for the allocation of the disposal of materials. B: Best case, X: Case used, W: Worst case.

Material	To direct recycling	To sorting plant	To final disposal	To municipal incineration	Material	To direct recycling	To sorting plant	To final disposal	To municipal incineration
Brick	BX		W		Mineral wool	B		X	W
Brick, not hollow	BX		W		Moisture barrier				BXW
Cellular concrete	BX		W		Parquet	B	X		W
Cement layer, floor	BX		W		Plaster	BX		W	
Ceramic tile	B		XW		Polystyrene	B			XW
Clay tile, floor	B		XW		Reinforced concrete P175	B	X	W	
Concrete	BX		W		Reinforced concrete P250	B	X	W	
Cork	B	X		W	Reinforced concrete P300	B	X	W	
Detritus	BX		W		Synthetic film, under roof (Isoroof)				BXW
Fibre cement corrugated slab asbestos)	B		XW		Synthetic material (Sucoflex)				BXW
Fibre cement facing tile	B		XW		Synthetic material (Super Walton)				BXW
Fibreboard (Pavatex)	B		XW		Tapestry	BX			W
Fitted carpet				BXW	Wood	B	X		W
Glass pane	B		XW		Wood, hardwood	B	X		W
Gypsum carton board	B		XW		Wood, softwood	B	X		W
Insulation, floor	B		X	W	Wood, window frame	B		X	W

Table A-11: Score for the different cases used for the disposal phase (Disposal: used case; Disposal B: best case; Disposal W: worst case, Disposal Z: actual Zürich situation) and for the total of the used case (Total). – and + indicate the percentage of variation with Disposal. Total + and - the one with Total.

	CED - biomass	CED - fossil	CED - nuclear	CED - water	CED - wind, solar, etc	EI 99	UBP 97
Disposal	<1	108	4	<1	<1	3	57986
Total	3208	68239	11494	3528	92	326	3199621
Disposal B	<1	92	2	<1	<1	3	33927
-	43%	15%	35%	41%	31%	15%	41%
Total -	<1%	<1%	<1%	<1%	<1%	<1%	<1%

	CED - biomass	CED - fossil	CED - nuclear	CED - water	CED - wind, solar, etc	EI 99	UBP 97
Disposal W	<1	434	17	4	<1	5	743266
+	498%	304%	395%	562%	242%	50%	1182%
Total +	<1%	<1%	<1%	<1%	<1%	<1%	21%
Disposal Z	<1	373	37	11	<1	7	448406
+	679%	247%	951%	1597%	352%	110%	673%
Total +	<1%	<1%	<1%	<1%	<1%	1%	12%

Appendix E - Complements

Appendix E.1 German – English translation for building materials

English	German
Aluminium	Aluminium
Asbestos	Asbest (Eternit)
Asphalt- mastic asphalt	Asphalt-Gussasphalt
Bitumen	Bitumen
Bitumen sheet	Bitumenpapier
Brass	Messing
Brick – hollow block	Ziegel-Hohlblocksteine
Brick HLZ	Ziegel Hochlochziegel
Brick MZ	Ziegel Mauerziegel
Carpet	Teppich
Cartonboard	Pappe
Cast iron	Gusseisen
Cellular glass	Schaumglas
Clinker	Klinker
Concrete - autoclaved aerated concrete	Beton-Gasbeton
Concrete – gas concrete	Beton-Porenbetonsteine
Concrete – light	Beton-leicht
Concrete - lightweight concrete block	Beton-Leichtbetonvollstein
Concrete - pumice concrete block	Bimsbetonvollstein
Concrete B10	Beton B10
Concrete B15	Beton B15
Concrete B25	Beton B25
Concrete B5	Beton B5
Concrete-concrete block	Beton-Schwerbetonstein
Copper	Kupfer
Cork	Kork
Fibre cement corrugated slab	Faserzementplatten
Fibre cement facing tile	Faserzementplatten
Fiberglas	Glasgewebe
Fleece	Vlies
Floor – anhydrite	Estrich-Anhydrith
Floor – cement layer	Estrich-Zement
Floor – mastic asphalt	Estrich-Gussasphalt
Glass	Glas
Glass – polished sheet glass	Glas-Spiegelglas
Glass fibre	Glasfaser

English	German
Glass fleece	Glasvlies
Granit	Granit
Gypsum carton board	Gipskartonplatte
Hartfaser	Hartfaser
Hollow sand – lime brick	KSL
Gravel	Kies
Lead	Bleiblech
Linoleum	Linoleum
Marble	Marmor
Mineral wool	Mineralfaser
Mineral wool	Mineral wool
Modern insulation	mod. Dämmstoff
Mortar	Mörtel
Mortar – cement mortar	Mörtel-Zementmörtel
Natural stone	Naturstein
PE-film	PE-folie
Plaster	Putz
Plaster – cement plaster	Putz-Zementputz
Plaster – gypsum plaster	Putz-Gipsputz
Plaster – lime cement plaster	Putz-Kalkzementmörtel
Plaster – lime plaster	Putz-Kalkmörtel
Plastics	Kunststoff
PS – expanded plastic slab	PS- Hartschaumplatten
PVC	PVC
Roof – tile	Dach-Hohlfalzziegel
Roof – "Frankfurter" tile	Dach-Frankfurter Pfanne
Roof – clay brick	Dach-Tonziegel
Roof – clay tile	Dach-Tonpfanne
Roof - concrete tile	Dach-Betondachpfannen
Sand	Sand
Sand – lime brick block	KSV
Soil	Erde
Steel	Stahl
Steel*	Stahl
Styrodur	Styrodur
Tile – floor	Fliesen-Boden
Tile – wall	Fliesen-Wand
Window – aluminium	Fenster-Alu
Window – PVC	Fenster-PVC
Window - PVC glass	Fenster-PVC Glas
Window – wood	Fenster-Holz
Window - wood glass	Fenster-Holz Glas
Window -aluminium glass	Fenster-Alu Glas
Wood	Holz
Wood - laminated beam	Holz-Brettschicht
Wood - particle board	Holz-Spanplatte
Wood - plywood	Holz-Sperrholz
Zinc	Zink