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The neglected Potential

Energy conservation and CO_2 reduction in rented buildings

Potentials of technical approaches and behaviour change

A study of German cases

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Prelude

My mother explained to me once how well good language could describe problems. The sentence

"A device is useless."

shows quite efficiently the problems of technology, it is always dependent of the way it is used. Without the right way of use and the demand for the use of this device, it is useless. This is something engineers and designer should always have in mind.

Abstract

The household sector is responsible for around one third of German power consumption. This leads to significant environmental impacts, of which CO_2 emissions are in a special focus. Modernization of existing houses, especially of rented Multi Flat Dwellings, which have a large share of the German housing stock, is a possibility to reduce these emissions.

A purely technical approach limits the chances of emission reduction. Behavioural changes of residents and the integration of tenants in the planning and implementation of conservation measures gives a higher potential than a technical approach alone. The areas where the highest conservation potentials can be achieved are influenced by the usage and purchase behaviour of the tenants.

To create a higher demand for modernization, the financial figures of rent should be improved and the information of key actors enhanced. To prove this point, five cases have been studied and the achieved conservations of energy and CO_2 emissions has been analysed.

Based on this analysis, a set of recommendations based on modernisation concepts have been provided for the different actors in the industry.

Keywords: Energy Conservation, Tenant Integration, Behavioural change, Ecological Rent Mirror, Renovation, Multi Flat Dwelling,

Executive Summary

The purpose of this thesis was to find out the potential of energy conservation and GHG (Greenhouse gasses) emission reduction in the housing sector and how this potential can be achieved. The focus-group were landlords and housing companies, with a strong view on aspects of the tenants. However, these actors cannot be seen as independent of other actors.

The sector of household holds a large share of the German emissions of GHG that should be reduced, according to the Kyoto Protocol, by 21% by 2010. Therefore, the conservation of greenhouse gasses originating from the households is a major field of environmental interest. Further, the energy uses that are responsible for these greenhouse gas emissions also create significant costs for households and society.

The energy used in households is mainly happening due to the demand for space heat, hot water and electricity to run various devices. To reduce this energy consumption, it is recommended to reduce the heat losses of houses by insulation and efficient boiler technology. This is since some years a focus of the architectural design of new houses. New housing developments make a relatively small contribution to the German housing market, and the focus is shifting to the renovation of existing buildings, which often show large consumption figures, mainly of heat energy. Today, houses are built and renovated that, after the renovation works, need less than 1/10 of the heat energy that uninsulated houses consume.

However, electricity and, partly, hot water demand is not often the focus of the conservation efforts. These aspects, and partly the aspects of heat losses, are strongly influenced by the responsibility of the consumption behaviour of tenants. Therefore, the influence for the people planning and erecting buildings is limited in these fields. The total consumption of electricity is growing, especially compared to the declining heat losses in modern buildings. The production of electricity creates larger GHG emissions than the same amount of heat energy and, besides that, is a significant cost factor for the residents and the community. Therefore, the reduction of these losses has to be a goal as well to achieve sustainable energy use.

So, the hypothesis was stated that energy conservation measures are more efficient when the tenants and their behaviour are together with technical aspects, a focus of the implementation. To prove this hypothesis and to answer the stated research questions, how the housing companies can improve energy efficiency, a number of cases were analysed. The core of this analysis was the case of a renovation project in Bielefeld Sennestadt. The conservation levels due to technical solutions and the attitudes and information levels of the tenants were surveyed. To locate the conservation concept in a national context, the modernization and building projects of

- Wiesbaden Lummerlund;
- Münster Am Breul;
- Hannover Kronsberg; and
- Freiburg Vauban;

were surveyed. The outcome of these surveys together with two further brief cases were analysed in terms of GHG emissions.

Based on this analysis, it could be stated that the efforts in the field of heat losses can be covered mainly by technical aspects and partly by improved ventilation behaviour of the tenants. In the field of hot water, there are opportunities of energy conservation on both sides – a more efficient production of the heat and a lower consumption of the hot water.

From the aspect of tenant integration, the best results are achievable in the sectors of electricity consumption and energy fuels. The electricity consumption is a field where housing companies have a very limited influence, as the tenants have contracts with the power supplier directly and purchase the electrical devices themselves.

The purchase and use of power is therefore a clear field of the tenants' responsibility, where measures relating to tenant information and integration show promising results of conservation. A similar situation can be found in the case of the purchase of fuels for heat supply. The decision to purchase fuels with lower environmental impact can create also significant emission reductions. The integration of the tenants in this decision can lead to solutions that are only conditionally possible without the tenants.

In total is it possible to reduce the energy consumption of buildings to a sustainable level. The surveyed options of technical improvements as well as approaches of tenant integration and to influence tenants behaviour show both good results of energy efficiency improvements, but a sustainable GHG emission level is only possible when tenants integration and technical improvements are both aspects of the conservation concepts.

This could be clearly shown by the analysis of the different cases, where the cases with an integration concept or information and motivation offers to the tenants, showed significantly lower emission values than the comparable cases where integration was not a focus of conservation efforts.

However, energy conservation aspects are often perceived as costly and not necessary. So is today the maximum technically possible reduction and the normal building and renovation standard very different. To create a higher motivation of tenants and housing companies to implement conservation measures, with the integration of tenants it is recommended that public support programs should also integrate tenants' aspects in their demanded conservation efforts. A further opportunity to create larger conservation efforts is the implementation of the ecological rent mirror or integrated rent mirror. Therefore, the further development and implementation of this tool is strongly recommended.

The implementation of these tools, the integration of tenants and residents in energy conservation measures and the information and motivation of tenants and landlords to modernize dwellings and conserve energy shows great promise in:

- Reducing the GHG emissions of the household sector to a sustainable level,
- Significantly reducing costs for tenants and society,
- Creating business opportunities for housing companies, construction companies and architects through lower costs and competitive advantage; and
- Creating a considerable number of jobs.

A visionary model is promising that these improvements on a national level could be done in a time scale of 30 to 50 years from now, when the various actors are willing to do their part.

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1 Introduction

This study is structured as follows: After an introduction to the topic and the project (Chapter 1), follows an outline of the study, hypothesis, research questions, methodology and scope (Chapter 2). The next chapter (Chapter 3) includes a description of the technical and physical aspects of energy conservation. The aspects of human behaviour and how this behaviour can be guided in energy conserving direction (Chapter 4) are then elaborated. This theoretical framework goes over to the cases described in this study. First, a framework of legal and financial aspects is described (Chapter 5). After that, the case of the Sennestadt settlement (Chapter 6) and the comparison cases are described (Chapter 7). The cases are compared and the outcome analysed in chapter 8. In the last section, recommendations are provided and the study ends with conclusions in chapter 9.

This introductory section shall help the reader to understand the focus of the author on the problem.

1.1 Background

In 1997 and 1998, during my first studies of Civil Engineering, I was working for the e&u energiebüro, reviewing the construction plans of Niedrig Energie Häuser (Low Energy Buildings, NEH). I was criticising the heat losses of these buildings in detail, for example that the window was not built in the insulation layer of the wall. However, I did not calculation the influence such a detail had on the Greenhouse Effect as global problem. Therefore, I tried to scope the problem larger and larger and, after seeing the whole picture, I came to the point where I could perhaps understand the global problem but then had to scope it down again to a level where I could actually solve a part of this problem. Therefore, I am back on the construction side with a readjusted focus.

1.2 The link between the global Greenhouse…

The Greenhouse Effect is a phenomenon that makes life on earth possible. It is the atmospheric reflection of heat waves with a long wavelength, by so-called Greenhouse Gasses (GHG) like Carbon Dioxide (CO_2) and Methane (CH_4). These gasses work like a greenhouse, letting solar rays pass to the earth, and reflect around 85% of the heat waves from the earth back to the surface.

However, due to the large anthropogenic emissions of Greenhouse Gasses, the level of these gasses in the atmosphere has risen by 2.2% per year since 1850 [Heinrich & Hergt, 1990, p.165]. This is creating the problem that more heat waves are reflected back to the surface of the earth and the surface temperature is raising. The increase of the amount of CO_2 in the atmosphere from 355 ppm (1992 levels) would cause an increase of 2-5°C of the earth surface temperature in the next 100 years, with adverse climatic effects. The emissions are mainly caused by the burning of fossil fuels to utilise the embedded energy. The humans are utilising annually 402 EJ (in 1998) of energy and are by this creating 23 Bio. Tons of CO_2 [Loske & Bleischwitz, 1996]. Of this energy-use, 80% is happening in the industrialised countries of the northern hemisphere.

To reduce these emissions, the German government agreed, in the Kyoto Protocol, to reduce national annual GHG emissions, until 2012, from 1222.8 Mio. Tons CO_2 Eq (1990 levels) by 21% [Gugele, Ritter, Mareèková, & Jol, 2002][1]. To reduce the GHG emissions, a reduction of

[1] The differing reflection potential and lifespan in the atmosphere of Greenhouse Gasses is calculated to CO_2 Equivalent, as CO_2 contributes to 82% of the global GHG emissions.

the energy consumption[2] of 45% is technically feasible, and a 30% reduction is currently economically feasible [using a market price perspective]. A use of this economic potential would lead to a reduction of energy costs of 36 Bio. €/a, not accounting for positive ecologic aspects[3] [Wolters, 1998]. Loske & Bleischwitz even state that a human should not produce more than 2.3 tons CO_2 annually, which is 20% of the 12 tons that an average German is currently producing. Other scientists even demand a Factor 10 [Friedrich Schmidt-Bleek & Tischner, n.D.] improvement down to 1.2 tons. Nevertheless, technical solutions do very often not really solve the problem. A more comprehensive solution may involve a fundamental technological change or changes in the way people use technology, in their expectation of it and, therefore, in consumption patterns. Indeed, it may also require wider changes in economic and social patterns [F. Schmidt-Bleek, 1993].

1.3 … and the German building sector.

The contribution of German households to the national emissions of CO_2 is difficult to express with a simple number. Farah, Veit et al. and Steimer state that in Germany around one third of the CO_2 emissions are caused by heating, cooling and lightning of buildings [Farah, 2002; Steimer, 1999; Veit et al., 2001]. The Final report of the Enquête commission of the German Bundestag ranks the share of the sector "Space Heat" of the "Used energy" to 47%, but with no allocation of the process losses to a certain sector [Wuppertal Institut für Klima Umwelt Energie & Planungs-Büro Schmitz, 1996, p.16]. Flade et al., on the other hand, allocate only a quarter of the Total Energy Consumption to households [Flade, Hallmann, Lohmann, & Mack, 2003, quoting Wortmann 1994, p.1] and similar shares to traffic and industry. The Statisches Bundesamt states that in 2000, households consumed 44% of the End-energy but created only 25% of the direct CO_2 emissions due to their consumption. These figures already include traffic that is necessary for the consumption. In this source, 33.9% of the emissions were allocated to energy supply, but the location of this consumption was not identified [Statistisches Bundesamt (Hrsg.) et al., 2002 pp.368, pp.380]. However, to summarize these confusing figures, the share of the households in energy consumption and CO_2 emissions is significant, and has to be reduced to reach the goals of sustainable development. When the figures of Schmitt-Bleek and Loske and Bleichschwitz are taken as a level of sustainable emissions of CO_2, and keeping the contribution of households constant, this leads to a maximum allowable annual household-based CO_2 emission of 0.4-0.8 tons per capita.

A modern Single Flat Dwelling (SFD) sets around 370 tons of CO_2 free in its life. Of that, ca. 100 tons is released during the production [and deconstruction] phase and 270 tons is released during a use phase of 80 years [Öko Institut, 2001][4]. *(DQ 3)*[5], a similar typical house of the 1950s with an oil boiler even sets free 1300 tons of CO_2 and more *(DQ 5)*. To reduce this source of emissions, the German government is regulating the heat energy consumption of new and renovated houses. The Energie Einspar Verordnung ["Verordnung über energiesparenden Wärmeschutz und energiesparende Anlagentechnik bei Gebäuden (Energiesparverordnung - ENEV) *(Ordinance of energyconserving heat insulation and energy conserving heating system technology in buildings (Energy Saving Ordinance))*," 2001] has the goal of reducing the

[2] From the physical perspective it is not possible to consume energy, the energy is just shifting type to a less usable form. The term "energy consumption" is used in this study for this process, as it is a frequently used phrase.

[3] Wolters speaks of 70 Bio. DM. One Euro [€] is 1,93 DM.

[4] A single flat dwelling of 140 m^2, a heating-energy loss of 98 kWh/m^2*a, supplied by a gas condensing heating system. Values of the usage phase interpolated from 50 to 80 years.

[5] For a description of the ranking of the data quality see section 2.6.

energy consumption of new buildings and, besides that, also regulates the energy improvements of old buildings if renovations are done. The goal of this ordinance is to save 4 Mio tons/a of CO_2. Further subsidies for efficient technologies and information like labels should save an additional 12 Mio tons/a of CO_2 [Farah, 2002].

Today, the reduction potential of modern buildings is shifting more and more from the usage phase to the construction and deconstruction phases. However, the older the building, the higher the heat losses are and by that, the larger reduction potential can be found in the usage phase.

Table 1, Primary-energy consumption of the life-phases of buildings, [Based on Wolpensinger, 2001; Wuppertal Institut für Klima Umwelt Energie & Planungs-Büro Schmitz, 1996; Öko Institut, 2001 (DQ3-4r)]

Standard	Heat energy- losses	Building	Usage-phase (80 years)	Deconstructio n
Un-renovated building	365 kWh/m²*a[6]	-5%	90+%	-5%
WSVO 1995	120 kWh/m²*a	-10%	80-90%	-10%
Modern single flat dwelling	98 kWh/m²*a	15%	70-75%	10-15%
Low energy building (ENEV 2002)	70 kWh/m²*a	20%	60-70%	10-20%
Passive house	15 kWh/m²*a[7]	30-35%	30-35%	30-35%

Therefore, the focus of energy efficiency measure should be the reduction of the energy consumption during the usage phase and, as annually only 1-2% of the German housing stock is newly built, the main focus should be on the renovation, modernization and retrofitting of existing houses. Due to energy efficiency improvements, it is possible to improve the energy efficiency of houses significantly. The energy reduction-potential of existing buildings in Germany is assumed at 70-90% *(DQ3)* [Knissel, Loga, Born, & Grossklos, 1997; Wuppertal Institut für Klima Umwelt Energie & Planungs-Büro Schmitz, 1996]. This retrofitting is very often less resource consuming than building new houses [Hein & Saulich, 2001], less costly [Knissel et al., 1997] and, in some cases when the houses are inhabited, also better from social and legal perspectives. As around 50% of the German housing stock is rented and most of these flats are found in Multi Flat Dwellings (MFD), a large conservation potential lies in the modernization of these houses. This can be in the interest of the large housing companies that very often are more progressive in energy conservation aspects than landlords and house owners [L. Schneider et al., 2003]. Therefore, it is an interesting focus of conservation efforts to focus on the potential of the large housing companies and the tenants.

[6] The value of kWh/m²*a is used in Germany to display the energy consumption of flats, 1 kWh/m²*a is equivalent to 3.6 W/m², in more internationally used units.

[7] Wolpensinger speaks here of 30 kWh/m²*a, but the correct definition is 15 kWh/m²*a [Flade et al., 2003].

2 Outline

This section gives a theoretic outline of the study. The general research problem, that form the basis of the research questions and hypothesis is explained in Section 2.1. The hypothesis (see Section2.2) and the research questions are defined in Section 2.3. Following this, the methodology structure and scope of the study are explained in the Sections 2.4&2.5. The quality of data used in the study is described in Section 2.6 and, in Section 2.7, the focus group of this study is defined. Finally, the parallel of energy conservation and GHG reduction is elaborated in Section 2.8.

2.1 Research Problem

The problem is the too high energy consumption of the housing sector and its adverse environmental and economic aspects. Of this problem definition, the research problem emerges:

How can the efforts of energy conservation in the housing sector become more successful?

2.2 Hypothesis

Based on the defined problem and after a survey of literature sources, the following hypothesis became the focus of this study:

The purely technical approach to conserve energy in the housing sector is not optimal. A larger conservation potential can be reached with a conservation concept in that housing companies or landlords also focus on the integration of tenants aspects.

2.3 Research Questions

To test the validity of the hypothesis, two research questions, that should be answered in this study, were developed

- By which actions in the technical field or by changes of tenants behaviour can housing companies or landlords realise energy conservation in their houses?
- Which results can be achieved by an integration of the tenants in the planning and conduction of an energy conservation concept?

2.4 Methodology

This study is based on a framework created on a survey of recent literature sources. The aspects of the literature were divided to technical approaches and behavioural changes. To define the case in the settlement, an interview was performed on 38 tenants in the Sennestadt settlement to find out the baseline of the behaviour of the tenants. The technical part of the case is based on literature and interviews with experts of the housing company.

Parallel to the study of the Sennestadt case, further cases were surveyed to make a comparison possible. These cases are taken from literature, and individual interviews were performed to support the literature sources.

To place the findings into context and to answer emerging questions, interviews with experts of the fields energy conservation, tenant behaviour, law and finances were performed. After a comparison of the cases, recommendations were created.

As sources of literature about behavioural aspects date back several years, no age limit was defined for these sources. The technical literature should not date back further than 1995, as in this year, with the release of the "Heat Conservation Ordinance" (Wärmeschutzverordnung, WSVO 95), studies on energy conservation in the housing sector had new guidance. The literature about law and finances included the latest version of the laws and support programs as far as known.

The study has following structure:

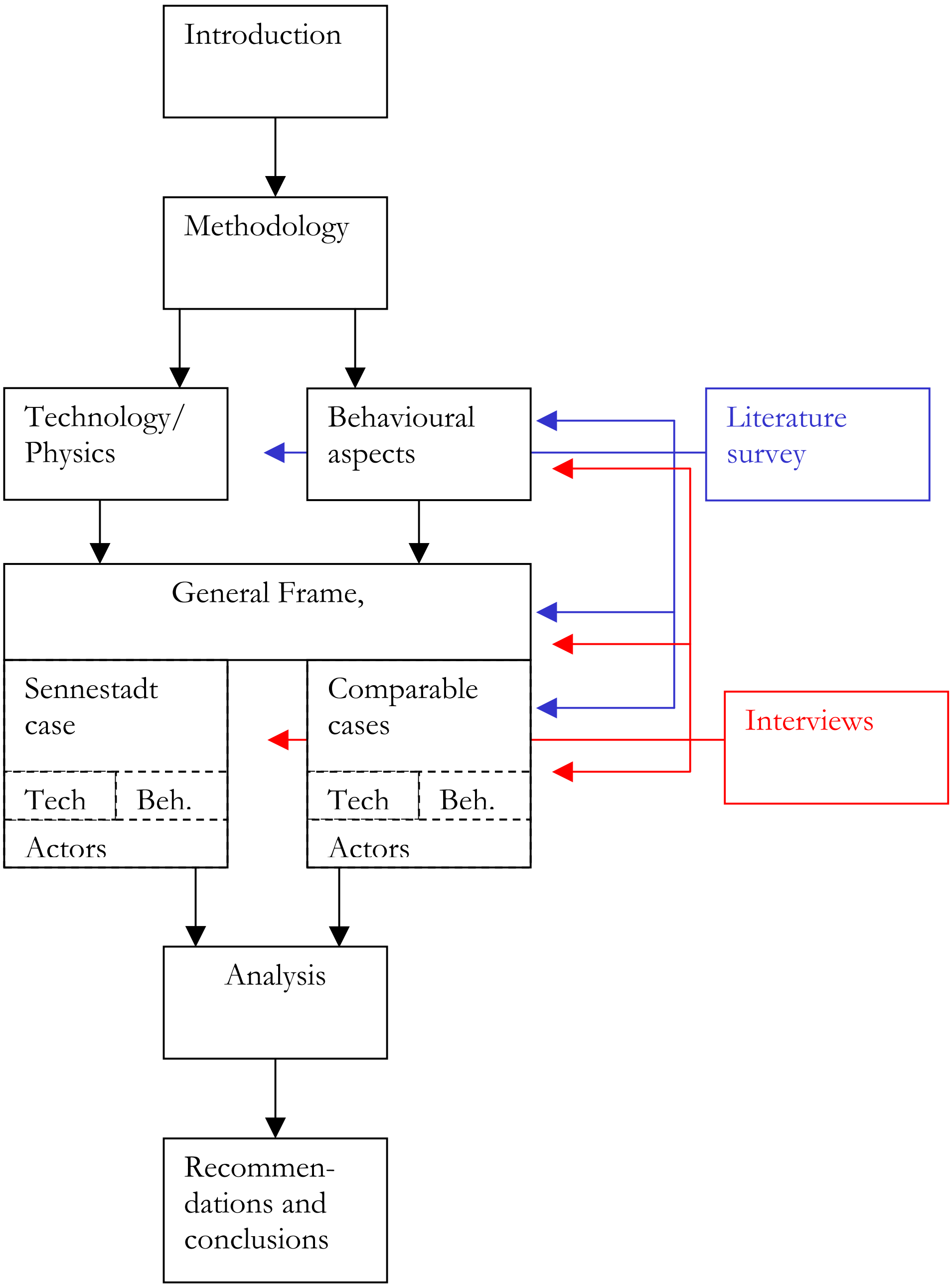

Figure 1, Structure of the study

2.5 Scope

The core of the survey was the first construction section of the settlement in Sennestadt. How far the figures can be transferred to other studies is unclear as the social structure is specific. Further a variety of laws, regulations and public support programs from the national, federal and state level have an impact on the exact way in which the particular programmes are implemented. Nevertheless, the data should give a hint on what can be improved in general.

In Germany, far more energy is consumed to heat housing dwellings than to cool them. Therefore, in the survey of heat energy consumption only the case where indoor temperatures are lower than the outdoor temperatures is used. Good insulation layers also protect against high outside temperatures but these cases are not of greater interest in the housing sector in Germany, yet.

The energy consumption in this study refers only to the usage time. The life-cycle energy consumption is not surveyed.

The findings should only conditionally be used in the sector of Office Buildings, due to their very different design and usage conditions.

Maintenance was outside of the scope of this study, even though it is acknowledged that good maintenance can lead to significant reduction results.

2.6 Data quality

The data used in this study are mostly taken from literature and partly from interviews with tenants and experts of the field. When experts are quoted, their position is mentioned in the reference list (see Bibliography). Figures displayed in the study are taken directly from literature sources or are calculated by the author. Assumptions of figures are seldom made. Measurements of the energy consumption of the cases were not possible. Therefore, a ranking of the data quality was elaborated that orientates itself with the German school mark system.

1 Own measurements,

2 Literature sources (measured),

3 Literature (calculated or unknown) or interview sources,

4 Own calculations based on literature sources,

5 Own assumptions.

The data quality is displayed in the text in italic letters in brackets *(DQ 1)*.

Sometimes, the exact situation of the case is not known, like the exact boiler system, but calculations based on the known figures are sufficient to define the success of conservation efforts. In these cases, the figures are rounded to the nearest 5% or 50 kg CO_2 and the data are signed by an 'r' *(DQ 4r)*.

2.7 Focus group of the study

This study in general should help to improve the energy conservation efforts in the housing sector. It focuses, therefore, mainly on the housing companies that own and run the houses, and that plan and arrange the modernization efforts. The tenants who are living in the houses and consume the energy are a further main actor, but as the traditional way of arranging conservation programs is by the owner for the tenants (i.e. a Top Down approach), the housing companies should be the main focus group. These companies have to shift their view to see problems from the tenants' perspective and reach the goal of satisfied customers. Therefore, the focus on the housing company always has to include the focus on the tenants.

These two main focus groups do have the most influence on the outcome of the conservation concept, but they cannot be seen independent from the other actors like policy makers and planners. These actors also have influence on the outcome of the energy conservation and, therefore recommendations are also developed for policy makers and planners.

2.8 GHG reduction by energy conservation and generation

The purpose of the energy reduction efforts in the housing sector is, besides a cost reduction, the reduction of environmental impacts. A main environmental impact due to energy use is the creation of Green House Gasses, so-called $CO_{2\ Eq.}$ emissions. Therefore, energy conservation is mostly driven by the concern for climate and a reduction of GHG emissions. An energy system consists of energy generation, supply and consumption. The environmental impact of energy use can be reduced by reduction of energy consumption and by improvements in the generation of energy. These different aspects often not easy to divide, as improvements in the generation of energy are often done in conjunction with improvements in the energy efficiency of the house. When the insulation of a house is improved, the house consumes less heat. Therefore, the heating system is often dimensioned too large and it becomes cost efficient to use a new, smaller and mostly more efficient boiler. In this study, the first focus is the reduction of energy consumption at the usage point and, later, the improvement in energy creation, as the improvements of energy efficiency are often cheaper and lead to better reduction results. Apart from this is the influence of tenants and landlords on production of power limited. As the aspects of use and generation are closely linked, it makes sense to display both of them at the same location. To bring a higher stringency of figures, the sections are separated into energy consumption, energy generation and supply. The energy consumption and the GHG emissions of the energy usage are then calculated at the end (see sections 8.1&8.2). Therefore, in the first sections, the energetic qualities of the buildings are given in energy figures (kWh) and are calculated later in the form of environmental impact categories of $CO_{2\ Eq.}$ Emissions for the whole energy system.

3 Technical possibilities

In this section, the technical aspects of energy conservation are explained. After a short introductory explanation, where and how energy is used in houses, the constraints of the physical aspects of energy consumption are explained in Section 3.1. Following this, the technical possibilities of improvement are explained in Section 3.2.

In a house, energy is used mostly in the forms of heat and electricity. Both forms of these "End Energy" come from a broad variety of primary energies that also have a variety of environmental impacts. To simplify these initial sources of confusion, in this study only the most popular sources of the End Energies Heat and Electrical Power are used. Heat is supplied in German Households mostly by natural gas and oil. Sometimes power is used, especially for the heating of hot water. Furthermore, solar collectors are becoming more popular and wood pellets or chips are used occasionally. The latter are counted as "renewable sources". Coal and Lignite can also be found, especially in the eastern part of Germany but the use of this source for space heat and hot water is outdated and unpopular. Coal and lignite are only used in modern houses in Central Heating Grids.

Power is used in the houses to run various appliances, but also to heat up food, water and, seldom, the living space. As power is usually created from the burning of fuels with significant process losses, it has a higher energy quality than heating fuels like gas or oil. Power can be created from a variety of sources and the environmental impacts of this creation are numerous. In addition, the ranking of the different environmental impacts is difficult. For example, nuclear power plants emit no CO_2 during operation, but the nuclear waste can create significant problems. Because of these different environmental aspects, a number of Swedish people perceive nuclear power as clean while the Germans rate nuclear power as almost as problematic as the CO_2 impacts related to the use of fossil fuels. A history of these discussions would be sufficient to write several of these studies. Therefore, in this study, the "German power mix" will be used when the emissions of the power consumption are calculated. This is not the exact share of the Sennestadt case, as the power in Bielefeld is, up to 68%, supplied by the nuclear power plant Grohnde [Weiser, 2003], but it makes the German cases comparable.

The field is limited where heat, supplied from non-electric fuels, is used. It is mainly the heating of the space; often hot water and sometimes cooking. Very seldom, gas is also used to heat air in tumblers. The usage of electricity compared to this is broad: for lighting, electronic devices, motors, heating and cooling. The share of these two energy forms is changing from an old building to a modern house. So, in a house built at the dawn of the last century heat losses of 400 kWh/m^2*a *(DQ 3)* were normal while a modern Passive House has heat losses of 15 kWh/m^2*a *(DQ2-3)* and lower. Besides the shear amount of heat loss it is interesting how the heat is created to calculate the environmental impacts. A modern condensation boiler fired with gas creates only about one third of the GHG emissions of coal heating *(DQ 3)* [Öko Institut, 2001]. When power is used to supply the heat, this ratio is even worse.

The electricity consumption is almost the same in modern houses ~~or~~ as in old ones. It stays quite constant at a level of approximately 1000-1500 kWh/capita*a. Most often, this consumption is only shifted by the size of the dwelling, the wealth and lifestyle of the residents or the possibility to cook and heat water with gas. In Passive Houses, the consumption of electricity is very often higher than the heat energy use, while in the old buildings it is only a relatively marginal share. On average, the electricity consumption is one quarter of the heat energy [ifeu Institut & ebök, 1998]. When a level of low energy buildings is reached by improved insulation, better windows and heating the primary energy consumption of the electricity use can be equal to the primary energy consumption of heating and hot water [Feist, 1996].

In the case of renovating existing buildings, the focus should therefore be on both the heating (primarily) and the electricity consumption. These two fields can be influenced by technical improvements, like insulation and energy saving devices, or by attempts to make the behaviour of the tenants more sustainable.

3.1 Physical basis of energy consumption in houses

3.1.1 Energy quality

Energy can be found in different qualities that are depended on the usability for humans.

Primary Energy is the embedded energy in raw energy resources (e.g. Coal in a coalmine, oil in a well). The energy is found in this form in nature. Therefore, it is occasionally used to display the impacts on the nature of an energy use.

Secondary Energy is the embedded energy in a refined form like coke.

Final Energy is the energy that is used by the humans to run or propel a process like car-petrol or electric power.

Useful Energy is the energy set free by the use of final energy that the humans use. Examples are space heat, light and kinetic energy to propel a car.

Energy Service is the service of the energy use that humans originally demand. The need for the energy service is the reason why the energy is used. Transportation of persons or need for warmth are the energy services that result in the use of energy. [Based on Johansson & Goldemberg, 2002].

The quality of the energy form is therefore dependent on its usefulness. For example, electricity has a broader field of use than natural gas and, therefore, has a higher quality.

3.1.2 Energy consumption

The three fields of energy consumption in a household, as already mentioned, are space heat, electricity for utilities and hot water. Hot water should be considered separately as although it can be heated up by both the other sources, its use as hot water alone is different and the saving potentials are significant. A supposed household used for calculations performed here has the following figures.

Table 2, Figures of the supposed household (DQ5)

Size / Cold Rent	66 m^2[8]	4.17€/m^2
Space heating (Gas)	250 kWh/m^2*a	4,2 Cent/kWh
Hot water	21 kWh/m^2*a	
Power	3000 kWh/a	15,5 Cent/kWh

Further, it is inhabited by two tenants.

Heat

Humans feel most comfortable in a surrounding temperature of 19.5-23°C [Arpert, 1992]. Based on the second law of thermodynamics heat is always trying to reach an equal level of heat in a medium [Miller, 1999, pp. 400]. Therefore, the heat energy that creates a comfortable temperature around the human flows to the surrounding air of lower temperature. In the winter, this causes a constant heat flow from heated environments (indoor rooms) to the colder air outside. To keep the air surrounding the humans at a temperature level of 20°C the air must be heated. To reduce this required heating, it is possible to reduce the heat flows to the surrounding air. The heating of the ambient air consumes energy. Therefore, it is important to reduce these heat losses. These reductions can be achieved by an insulation layer that hinders the heat flow.

The heat transfer can be calculated using the transmission value of the material used, the strength of the material and the combination of the layers of material in the construction.

Equation 1, Equation of the transmission of heat-energy

$$q=U*(\theta_{L\ inside} - \theta_{L\ outside})$$

Equation 2, Equation of the heat transfer value of a construction

$$U_{Constr.}[W/m^2*K] = 1/(1/\dot{\alpha}_{inside} + 1/\dot{\alpha}_{outside} + \Sigma\ s/\ \lambda_R)$$

[Knublauch & Czielsielski, 1996]

q: Mass of energy that is transmitted

U: Heat transfer value

θ_L: Temperature of the environment

$\dot{\alpha}$: Transfer-constant

λ_R: Energy transmission value of a material

s: Strength[cm] of a material layer

As the temperature of the environment of the building cannot be changed by the inhabitants and the indoor temperature should not be lower than 16 °C, one can say that the lower the heat transfer value of a construction the lower the energy losses by transmission over the construction. Therefore, the value can be improved by the strength of the insulation layer or the insulation quality of the material. However, as the value is decreasing on a logarithmic scale after a certain level, a thicker insulation only makes sense conditionally. The temperature level of the air is also important, as the larger the difference between indoor and outside temperature the faster the heat-flow. Therefore, a low temperature in the house saves energy, but it can create problems with humidity on the walls if it is too low and under 16 °C, potentially leading to health problems [Richter & Hartmann, 2003].

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[8] Compared to the German average this is slightly smaller, the German average is a household inhabited with 2.2 residents and a flat size of 87 m^2.The size was chosen as it represents the average rented flat better, that is, smaller.

Humans perceive heat not directly from the temperature of their surrounding air. The perception of the so-called "Comfort Temperature" is dependent of the temperature of the air and the temperature of the surrounding areas, like walls and windows that are radiating the heat to the room. The Comfort Temperature can be calculated as follows:

Equation 3, Equation of the Comfort Temperature [Arpert, 1992]

$$t_e = (t_l + t_u)/2$$

t_e: *felt temperature [C°]*

t_l: *air temperature [C°]*

t_u: *Temperature of the surrounding areas [C°]*

This shows that if the surface temperature of the surrounding walls is low the air has to have a higher temperature. In case of a high temperature of the surrounding areas, the air temperature can be reduced. A reduction of the air temperature of 1 C° reduces the heat energy consumption by 5% [Hiller, 2003]. Therefore, surface temperatures of 20-24 C° achieved by well-insulated walls and windows and large radiators or surface heating will help to reduce the energy consumption of the flat with an even higher level of comfort.

The comfort of radiation heat is higher than the comfort of the temperature of the air. The surface temperature of the walls and ceilings is dependent of the temperatures on both sides of the construction and the insulation value of the construction (U-Value). The improvement of the insulation value raises the surface temperature on the heated inside of the wall. This leads to a lower required temperature of the inside air to reach the Comfort Temperature. Therefore, it makes sense to have a high surface temperature of the constructions. Nevertheless, if a construction of wall- or floor heating systems is not possible in inhabited buildings, the insulation value of the walls has to be improved.

Hot water and electricity

The consumption of hot water and electricity is based more on lifestyle than on physical constraints. Therefore, this issue is described further in chapter 4. Only the quality of the devices and boiler and the water flow of the fittings can deal with these aspects from the physical side. Therefore, it should always be the goal to use the most efficient devices in the right way.

3.1.3 Energy supply

The source of energy is also very important for the final production of GHG for a certain lifestyle. The use of renewable fuels for the energy supply is one option, the other being to utilize as much energy from the fuel as possible at the right place. This means that the insulation of hot water tubes, power from renewable sources like Wind or Photovoltaic cells or an efficient boiler technology like a cogeneration plant are all options to reduce the environmental impact of living and lifestyle. These aspects are mainly technical aspects so they are dealt with in the next subsections.

3.2 Technological improvements

In most literature about renovation of buildings, technical solutions have, by far, the larger share, and tenant behaviour is often not mentioned at all. Further, as already mentioned the focus is usually on the reduction of heat losses. A limit of technical improvement is not defined. Thus, today, new houses are built that produce more energy than they consume during their usage phase. Besides, if this absolute maximum of energy conservation makes ecological and economical sense, it can be said that, today, the maximum proven level of renovation is a Low Energy House (see section 3.2.3). This level is defined when a Multi Flat Dwelling consumes less heat than 55 kWh/m²*a [Eicke-Hennig, 1998]. First renovations to a Passive House level (≤15 kWh/m²*a) are also already done, but their performance should be proven before this level should be the goal for large-scale renovations. To reach even lower levels may be possible in some years with new insulation materials, but today very often, the sketch of the ground plan does not allow stronger insulation levels and the insulation values of the windows have to be in the same region as the insulation value of the walls, to not create droughts. Also, the main windows of the house should look to the south while, to the north, only a small number of windows should be built. In addition, a controlled ventilation device with heat recovery has to be built in, that demands extreme air-tightness.

3.2.1 Energy consumption

The reduction of energy consumption is the main focus of a building design that aims to reduce the environmental impacts of the building. In the last years, the focus was mainly on the reduction of heat losses over the surface areas of the building. These surfaces that protect the residents from the adverse climatic conditions can be summarized as a climate shield. Further technical aspects of reduction of energy losses focus on the air exchange and more energy efficient supply of services like light and cooked food.

3.2.2 Climate shield

One of the most important functions of a house is that it is a shield against adverse climatic conditions. Without houses or similar shelters, humans would not be able to live in most climatic zones. The surface of the house that is in direct contact with the ambient air is an area of constant heat flow from and to the ambient air (of different temperature). In Germany, the main problem is the heat loss but it also can be a too high heat gain. To improve the insulation of the surfaces of the house is a way to reduce the energy consumption due to heat losses. Therefore, materials with a good insulation potential are applied on the surface areas of the house where the most reduction can usually be achieved. However, to do this, quite a lot of construction work is necessary. In addition, this step is only conditionally possible, as in Multi Flat Dwellings (MFD), the wall of the whole house has to be covered and not only of one flat. Further problems can appear when the building is heritage-listed and the facade cannot be changed. In addition, the residents of the houses need a constant supply of fresh oxygen-rich ambient air and a constant output of pollutants and unhealthy gasses like CO_2, cigarette smoke and humidity. Therefore, the layout of the building also has to secure a certain level of air exchange.

3.2.2.1 Insulation of walls, roofs and ceilings

The improvement of the insulation of the surfaces is crucial. Without this, it is difficult to achieve real improvements in energy efficiency.

The insulation of walls can be achieved by applying layers of insulation tiles of polystyrene, glass fibre or other light material on the walls. This can achieve a reduction of 30% of the energy demand for heating *(DQ3)* [ifeu Institut & ebök, 1998]. The quality of insulation materials has recently by progressed by a factor of ten through the use of evacuated tiles.

However, as already mentioned, the insulation value of a wall increases logarithmically, so the improvement due to these tiles are also reaching their limit. As it is possible to achieve the same insulation value of the wall more cheaply with traditional materials, these evacuated tiles have their niche in insulation layers that cannot be as thick as wanted. This can be under the basement ceiling, beside doors or on surfaces that are heritage-listed and cannot be significantly altered.

Figure 2a&b, Corner of the house without and with insulation layer

For the insulation of roofs and especially walls, a large expenditure is necessary, as usually a scaffold is needed to bring the tiles on the walls and new plaster and paint have to be put on the insulation. A maximum strength of insulation is not defined by technical means but usually by other factors. The economic limit of the strength is therefore defined by the price of energy. This is today around 14 to 16 cm. A static problem can occur if the strength is over twenty centimetres and the floor plan, which also defines the limits when the insulation strengths collide with doors and corridors, reduce the size of windows or make it necessary to increase the size of the roof. Thus, an improvement of the insulation of the walls is especially cost efficient when a renovation of paint and plaster is already necessary. In that case, the higher investments would be only ca. one third of the anyway needed investments for the renovation of the surface. [Grossklos, Hinz, & Enseling, 2001].

Step roofs are insulated by adding the insulation material between the beams of the roof. The maximum strength of the insulation is given here by the strength of the beams. In some houses where the room under the roof is not used for anything other than storage, the ceiling of the level below can also be improved by an insulation layer. This is usually cheaper and easier to do, but the room above can only be used conditionally.

The insulation of the ceiling of the basement is fairly cheap and easy. In this case, the strength of the insulation can be a problem, as the basements are often not very high. Also, the reduction potential is not so large as, in the winter, the basement contacts the fairly warm soil and not the cold air. In addition, under the basement ceiling, the basement walls always work as “heat bridges”.

3.2.2.2 Windows

Historically, windows were a very weak point in the thermal protection layer. With U-Values of 5 W/m^2*a or more, they were associated with heat losses around four times larger than the surrounding walls [Wuppertal Institut für Klima Umwelt Energie & Planungs-Büro Schmitz, 1996]. This was the reason why, in the winter, the water condensed and froze on the windows, creating the beautiful crystal flowers. Then, after the first oil crisis, the parts that were first improved were the windows, because to change the glazing was quite easy and cheap and the possibilities for improvement were significant. The new double glazing had a better U- Value than the surrounding uninsulated walls and, in the winter, the water again condensed on the walls, creating mould. Therefore, a crucial point in the planning of insulations is the way walls and windows are insulated together. If done well, the heat losses can be halved. Today, double-glazing windows with argon or xenon in between or even triple-glazing windows are normal. These triple glazing “Passive House Windows” have U Values of down to 0.4 W/m^2*a, but they are also almost double the price of normal double-glazing windows with U-Values of around 1.0 W/m^2*a.

3.2.2.3 Ventilation and Airtightness

The interior surface temperature of insulated walls and windows should be so high that no water wills condense on the surface, even in a winter with –10°C.

At points where the air can leak out of the house, the surface temperature decreases rapidly. This is a problem because large amounts of heat energy are lost and water can condense on these surfaces. Mould can grow on surfaces that have a humidity on the surface of 80% [Heinz, 2002]. Therefore it is also important to reach, in a highly insulated building, a certain level of airtightness [Peper, 2002]. During the erection of old buildings, nobody cared for this relatively new demand for building-quality. Since this warm air very often leaks out through leaky windows, walls or infrastructure lines, to close as many of these holes as possible is one of the most complicated and important issues in the renovation of old buildings.

This level of airtightness is contrary to the demand of fresh air for the inhabitants. In an average household of three persons, 5.6 litres of water are produced daily as humidity that has to be transported out of the flat [Heinz, 2002]. Humans feel most comfortable with a relative humidity of 35-75% at 18-22 °C [Arpert, 1992]. To achieve a comfortable and healthy condition in the rooms and to remove the humidity, an air-exchange rate of 0.15 - 0.7 times the air volume per hour is necessary [Richter & Hartmann, 2003]. A reduction of the air humidity over the ventilation is a critical factor influencing the success of the energy conservation efforts as a lot of heat energy is lost by constant ventilation over tilted windows. If the indoor air temperature is 20°C and the humidity is 50%, the walls should have a surface temperature of at least 12.8°C to ensure that the humidity over the surface does not exceed 80%. Under German climatic conditions, uninsulated walls very often have surface temperatures of down to 5°C in the corners. These temperatures would allow the tenants only a maximum humidity of 30% at 20°C, which is perceived as uncomfortable. If the tenants react to the low surface temperature by increasing air temperature, the relative humidity even has to decrease to create no humidity on the walls.

A technical solution to secure this air-exchange rate is the use of a ventilation system. This can supply the rooms with a constant controlled airflow. Manual ventilation is no longer necessary. A ventilation system needs a very airtight building. Besides the measures to secure air-tightness already described, ventilation systems require installation works that are difficult in an inhabited flat, as holes have to be cut into the walls. The ventilation system is a basic requirement for a Passive House, as this needs such high levels of air-tightness that manual ventilation is almost impossible. Energy recovery devices for ventilations systems are energy efficient but sometimes quite expensive and complicated to install. These devices should be considered carefully before use.

However, as ventilation systems secure a constant air exchange in the night, with the option of in-built poll filters, they will become increasingly demanded as the number of allergic reactions of people increase further. A sufficient amount of ventilation will also become gradually more necessary as more walls will be insulated with polystyrene tiles that reduce the possibility of walls to transfer sufficient humidity to the ambient air. Nevertheless, this shall not be misinterpreted like a common fairy tale from the construction sector: Walls cannot breath. The air exchange through massive walls is almost zero.

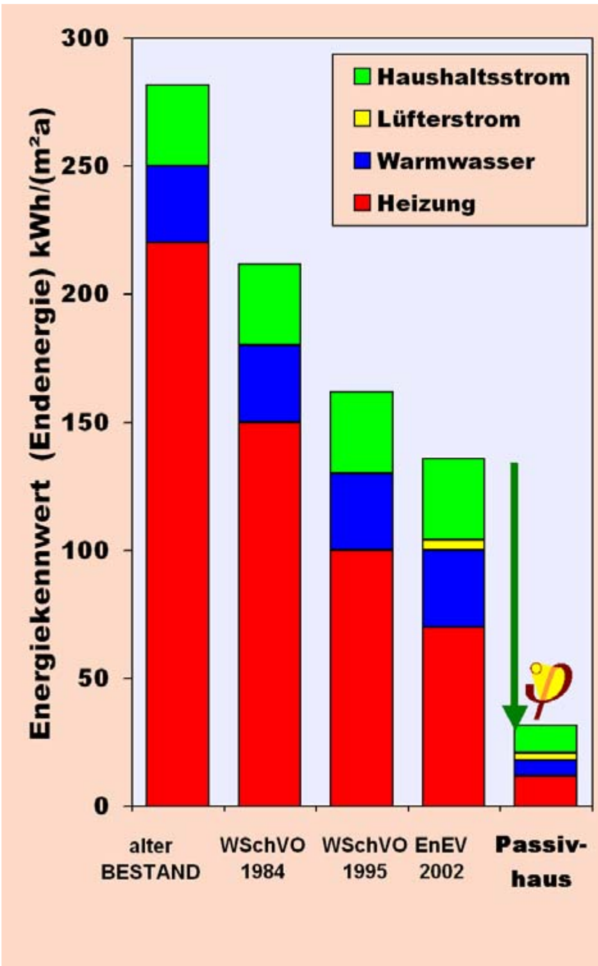

Figure 3, Consumption of End Energy by different house types (DQ 3) [Passivhaus Institut, 2003b]

3.2.3 Passive- and Low Energy Houses

A house is called a Low Energy House (Niedrig Energie Haus, NEH) when the heat energy consumption is not higher than 70 kWh/m^2*a for a single flat dwelling or 55 kWh/m^2*a if it is a multi flat dwelling. If the insulation is even so strong that the heat losses are lower than 15 kWh/m^2*a, the house is called Passive House, as a heating system is not required any more. The house is simply heated passively by the sun, the residents and their devices. The heat of the expelled air is recovered to heat up the impelled air. This consumes electrical power. When a house produces more energy by its solar systems than it consumes it is called a “Plushouse”. These houses are very uncommon and are therefore, not discussed further. The design of these houses demand windows to the south, strong insulation, special windows and a ventilation with a certain level of airtighness of the surface. Therefore, they require a planning of the insulation to be included in the early stages of house design. Also, they require a higher quality of construction work, therefore architects and craftsmen should have experience in this field. The labels “Low Energy House” and “Passive House“ are not owned, so they can be misused. Besides the low consumption of heat energy, the energy consumptions of Hot Water and Electrical Power are not regulated. But the residents of Passive Houses usually value energy conservation efforts higher than normal tenants, as shown by consumption figures of Passive Houses in Wiesbaden [Flade et al., 2003].

Therefore, Figure 3 shows only conditionally the correct figures for Hot Water and Electrical Power (Blue and green segment in the right column).

3.2.4 Hot Water

The energy consumption of water heating is very often not seriously addressed in the planning of buildings. Sometimes especially in MFD, the heating of hot water is separate to the space heating of the rooms, and is therefore addressed separately to space heating. Sometimes, the hot water is heated up with power and the costs of the heat appear on the power bill. However, the separation makes sense as the technical solutions for hot water use are different to the technical issues associated with the use of space heat and the tenants have different possibilities to reduce consumption.

Around 35-40% of the fresh water demand of an average German (130 litres/capita) is used in the shower/bath and 20% is used for laundry, dishwashing and food. Most of this water is heated up to temperatures of 35-100 °C. This is a significant share of the energy consumption of the house. In Passive Houses the energy consumption of hot water is even higher than the consumption for Space Heat. However, the possibilities to reduce this consumption are good even with low cost solutions. The first actions that can be implemented by the tenants themselves are the insulation of uninsulated hot water tubes. This measure is easy and the cost of insulation is paid back quickly. Further, the use of water-saving showerheads and faucets can reduce the water consumption by 8-12% [Farah, 2002, quoting Lorek et al. 2001] *(DQ 3)*. A further No Cost solution is the reduction of the temperature of hot water to a lower level and a reduction of the amount of hot water held in "stand by" by the boiler. The lifestyle of the residents determines very much the optimal temperature of the hot water, and this aspect is discussed further in the behaviour section (see section 4.5.2).

3.2.5 Electrical and electronic devices

The consumption of electricity is a field where the tenants have a significant influence and the housing companies and outside actors have very limited influence. The consumption of electrical energy in Germany is rising. The amount of electrical power increased by 8% in 1990-2000 [Statistisches Bundesamt (Hrsg.) et al., 2002] while the consumption of other Primary Energy stayed the same. In addition, as the households consume a larger share of energy combined with the decreasing heat losses of the houses the use of electricity will increasingly become the focus of energy conservation.

Traditionally, the largest fields of electrical consumption are connected to the need for warmth. The pump of the heating system is very often using one quarter of the power consumption of the house. These devices are very often running all year, and by that, have a reduction potential of 80% [ifeu Institut & ebök, 1998]. Moreover, the heating of warm water for drinks, bathing or washing, the stove and oven are large consumers of electricity. The switching of the electrical stove to a gas stove is possible when natural gas is used for space heating or when butane or propane is used in bottles. Modern washing machines and dishwashers can be plugged into the hot water line, or an electronic valve can be plugged into the hose and use hot water from the central heating system. This reduces CO_2 emissions, as the heating of water with natural gas is, by a factor three, less CO_2 intensive than heating by power.

The field of lighting is traditionally perceived by the most people as an important field of consumption. This is understandable as it is most visible, but actually, the consumption of lighting contributes only 13% to electricity consumption [Lebot, Difligio, & Harrington, 2003]. Even so, is it possible to save power, money and emissions with a change to CFL Lights that are more efficient. These bulbs pay their higher purchase cost back in a short time. This pay back of energy costs can also be perceived when other energy efficient devices are used. For example, the use of class A devices of the EU classification label is criticised today as this energy efficiency class is today already reached by a large number of devices and therefore the class is not displaying the best available techniques any more. Therefore the EU commission, in 2004, will introduce A+ and A++ as new levels to display energy efficiency of modern refrigerators [N.N., 2003a].

3.2.6 Energy supply

The use and purchase of energy carrying fuels is an aspect that can be linked to all fields of energy consumption. Based on the type of fuel used, the use of an energy-consuming device has varying impacts on the environment.

3.2.7 Space Heat

One way to reduce the CO_2 emissions from the heating of a house is to improve the boiler of the heating system. The reduction potential of a change of the boiler to a modern one can be 10-30% *(DQ3)* [ifeu Institut & ebök, 1998]. Further, a large reduction potential is possible depending on the choice of the fuel. The design and efficiency of the boiler and the choice of the fuel are usually a linked decision and cannot be considered separately.

The choice of fuel for heating is mainly governed by the supply and by the design of the boiler. Therefore, this is mainly chosen by the owner of the houses. How this will change when, in the next few years, as the gas market is liberalized is unclear. It will probably not be possible to buy biogenic gasses in the public natural gas grid. For an oil boiler, it is already possible to purchase bio-fuels created from rape or other oil fruits. The use of these fuels often requires changes of the boiler design that have to be paid for by the owner, so the decision to use these fuels is made by the owner of the boiler. With modern contracting solutions, the owner of the boiler is sometimes not the owner of the house.

Coal heating systems have almost three times higher CO_2 emissions than natural gas while the use of wood pellets is almost CO_2 neutral. The same is true for solar collectors used to heat water. Solar collectors are usually designed for the amount of hot water demanded in the summer because the gas boiler can then be totally switched off. In the winter, the solar collector is supporting the boiler. In this way, around 60% of the energy needed to heat up the hot water is saved *(DQ5)*. However, a solar collector can only be run efficiently when the roof is located at least partly to the south.

Cogeneration plants use the energy in the fuel more efficiently as they are creating power and the waste heat of this generation process can be used to heat air and water. Fuel cells work in a similar way but are still in early stages of development and are not yet financially viable. Cogeneration plants only pay of when the power is used or sold, the fuel cells yet do not pay of at all [Mühleisen & Boeckh, 2003]. This creation of power involves the power supply companies and is regulated by laws like the Erneuerbare Energien Gesetz (EEG, "(Renewable Energy Sources Act)," 2000). To ease the understanding of the CO_2-Emissions caused by different types of heating-systems, some examples of the Emissions of some typical boilers are provided here:

Table 3, Emissions of different types of boiler (DQ4) [Based on Öko Institut, 2001]

Type	Emissions [kg CO_2 Eq./kWh]
Electrical Warm Water Heating	0.72
Lignite Central Heating	0.70
Gas Cogeneration plant	0.33 for 1kWh heat + 0.5 kWh Power
Oil	0.32
Atmospheric gas boiler	0.23
Heat pump (Air-air, public grid),	0.21
Gas Condensing Boiler	0.20
District Heating (Coal)	0.22
Wood pellet	0.08
Vacuum Pipe Solar Collector	0.03

These figures are very general and are dependent on size of the boiler and the exact conditions under which the boiler is operated.

Apart from the fuels, a gas condensing heating system (GCH) is today one of the most efficient technologies for buildings of this size [Knissel & Menje, 2002]. Combined heat and power plants (CHP) are also possible but usually require higher investments. As CHP are also producing power, the relative CO_2 emissions of heat and power are low. However, the problem in this case is that the power has to be used. This creates the problem that on a liberal power market, the tenants can select their power supply and, therefore, the consumption of the created power is not secured. The power from CHP plants is usually cheaper, but when the tenants do not use the power, it has to be delivered to the power supply grid. This makes it necessary for the local power supplier to purchase the power. The power supplier is obliged to purchase the power but the price conditions under the Erneuerbare Energien Gesetz, (EEG) ["(Renewable Energy Sources Act)," 2000] are not sufficient to run the plant without the guarantee of the tenants to buy the power. The power in Germany today has a price for the end consumer of 13-15€ cent/kWh *(DQ5)*. The price for power from the CHP plant delivered to the grid is only 5.11€-Cent/kWh [Energieagentur NRW, 2003a]. The price of one kWh atomic power from an existing plant is around 2-3€ cent/kWh. Therefore, even when it is technically feasible to run CHP plants in almost every size of house [N.N., 2003b], they are only financially viable when tenants consume their own power. The power suppliers are also usually not very interested to foster the installation of new plants by independent owners.

The price and purchase of the power is secured in Germany by the Erneuerbare Energien Gesetz, (EEG) ["(Renewable Energy Sources Act)," 2000] or the Kraft Wärme Kopplungs Gesetz (KWKG) [Energieagentur NRW, 2003b]. Merkschien and Brieden-Segler calculated the CO_2 emissions and energy costs per square meter of the houses in the Sennestadt case:

Table 4, CO_2 Emissions and energy costs of GCH and CHP [Based on Merkschien & Brieden-Segler, n.D.]

House Type	CO_2 Emissions [kg/m²a]	Energy-costs [€/m²*a]
I (GCH)	48.24	7,65
I (CHP)	27.74	6,69
II (GCH)	45.46	7,72
II (CHP)	34.76	

Table 4 shows that the CO_2-emissions and Costs of the CHP are lower than the GCH when the power consumption of the tenants is secured. To change the boiler is associated with relatively small expenditure and only a small amount of work, as the old infrastructure can be used further, while solar collectors require work on the roof, and some new supply lines for the hot water in the walls.

The heating system is also important for the right supply of space heat, not only due to the optimal boiler technology that secures most efficient utilization of the energy in the fuel. Large radiators create more radiation heat and less convection heat. This is preferred as the radiation heat is perceived by the tenants as more comfortable and the room temperature can be reduced keeping the same level of comfort. Further, modern radiators are not as heavy as old ones. This is important as the lighter the radiator is; the faster is heats up or cools down. The level of comfort is reached faster with less energy consumption and the risk of overheating of the rooms in sunny winter days is lower. An exchange of the radiators makes sense for most cases of renovation and the amount of required work is comparably small.

Figure 4a&b, Old boiler and new GCH boiler

3.2.8 Hot water supply

In an average flat 21 kWh/m2*a *(DQ3)* can be calculated for hot-water use. Therefore, an average tenant is using about 630 kWh/a *(DQ4)* to heat up the water for showering and food preparation. To produce this heat as efficiently as possible and to consume as little hot water as possible are the two ways to reduce emissions and costs. When the water is heated up with an electrical boiler, an average tenant has a much higher consumption of primary energy than one that uses gas or oil to heat up the water. This is even the case when the efficiency of the boiler itself is very often higher than a comparable gas boiler. This leads to 18.3 kg CO_2/m^2*a for 21 kWh/m^2*a *(DQ4)* from hot water with an electrical hot-water boiler and 6.8 kg CO_2/m^2*a *(DQ4)* if using a gas fired hot-water boiler. If a solar thermal system is connected to the hot water supply this can decrease to 2.6 kg CO_2/m^2*a *(DQ4)*, almost a factor seven improvement in efficiency [Loga & Hinz, 1999, quoting Feist et al. 1997, GEMIS 1997]. Further, the use of an electrical hot water boiler causes higher annual running costs of 74 € per tenant compared to a gas boiler. Therefore, as many heat using devices should be connected to a hot-water grid that is run by the central heating system fuelled by an efficient fuel. A washing machine and dishwasher can be connected with little work such as the installation of a hot-water pipe in washing rooms, or a small electronic valve that regulates the hot-water supply for older machines. An installation of a hot water supply in the washing rooms should be integrated with the renovation program as the installation of a new boiler is necessary in any case. Electronic valves can be sold to the tenants together with operating information and installation support.

The use of gas-fired stoves is also a possibility to utilize a more efficient source of energy. However, for these devices, a gas pipe is needed in the kitchen and the tenants have to accept the new stoves. The tenants usually already own the stoves that they use so the reluctance to buy new gas fired stove can be high. Furthermore, when the flats connect to a centralized hot water supply the installation works for the new gas lines could be expensive and disturbing compared to the relatively small benefits achieved.

3.2.9 Power supply

Figure 5, German power mix [Based on Öko Institut, 2001]

The purchase of power is a decision of the tenants. In Germany a liberal power market exists where tenants choose their own power supplier. Some of these power suppliers offer cheaper power than others, while some are offering power created by more or less renewable sources. The purchase of power from these suppliers can reduce the environmental impacts of the power consumed in a household significantly. The German power mix is made up of 28%

Black coal, 26% Lignite, 9,5% Gas, 28% Nuclear, 3.5% Hydro, 1.1% Wind 2.75%Waste and by these sources creates 0.66 kg $C0_2$ EQ./kWh *(DQ 4)* [Öko Institut, 2001].

This high emission level can be easily influenced by the tenants. They can purchase power on the liberal German power market of power suppliers that sell power mainly from renewable sources that creates only 0.1 kg $C0_2$ EQ./kWh *(DQ 4)* [Öko Institut, 2001] and less. Very often these suppliers are even cheaper than the large power suppliers. Therefore, the right choice by the tenant can be cost-efficient and reduce GHG emissions significantly.

4 Behaviour aspects

This chapter displays the aspects that are necessary to achieve a change of behaviour to a less energy consuming lifestyle. It starts with assumptions of possible conservation measures (See section 4.1). In section 4.2, the models of behavioural change that are used in this study are explained, followed by a section that gives an overview over other models that are used in the literature (See section 4.3). Based on these models, the aspects that have to be focussed upon to achieve sufficient levels of energy conservation are displayed in section 4.4. Methods of using these aspects to reach conservation results in the different fields of energy consumption are explained in section 4.5 and conclusions are made with regard to general aspects on how to implement concepts of behavioural change (See section 4.6).

Besides technical solutions, changes of consumer behaviour can be an aspect of conservation efforts. This behaviour includes the usage of devices with or without a change of the perceived comfort as well as the purchase of energy consuming devices and energy carrying fuels. Assumptions are that one-quart of the unused energy losses is created by user behaviour. That is equal the energy demand of a town of one million inhabitants [Schwarzhoff, 2000].

To understand the potential changes in the behaviour of tenants it is necessary to understand why humans behave in a way they do, possibilities to change this behaviour and cases where technical approaches are more suitable.

4.1 Potential savings

The technical approach very much represents the classical method, and the way in which architects and engineers deal with the problem of high energy consumption. The behaviour of the users and tenants, that in the end have to live with the technical solutions, is very often neglected. Studies show that technical solutions are more effective in reaching the reduction targets than behavioural changes, but very often create higher costs. Bell et al. point out that some researchers believe that the greatest savings in energy use by individuals come from changes in technology and regulations [Bell, Greene, Fisher, & Baum, 1996]. They further refer to studies showing technologies having two times the savings of behavioural changes. However, this would mean that one third of potential savings can be allocated to behaviour changes. This leads to the assumption that with the traditional focus on technical solution a large potential is neglected.

Changing the behavioural patterns of consumption can be one way to reduce the environmental impacts of the energy consumption. Bell et al. [1996, quoting Socolow, 1978] write of a possible reduction of 50% in energy consumption, by making simple physical and behavioural changes. What simple means in this case is not mentioned, but a significant reduction is possible if behavioural change is sufficient. A similar figure is given by Hiller [2003]. Siero et al at least acknowledge that research on energy conservation in family households has shown that as a result of behavioural modifications, savings of up to 30 per cent can be realized [Siero, Bakker, Dekker, & van den Burg, 1996 quoting Seligman & Darley, 1977; Geller et al. 1982]. Eicke-Hennig even reports energy consumption figures in similar houses that range from 655 kWh/m^2*a to 70 kWh/m^2*a *(DQ 2)*, a ratio of 9:1 [Eicke-Hennig, 1998]. Interestingly, the average of these last figures is in the region of the calculated losses, so a far lower consumption than the calculated values is possible by reaching the right people as well as the wrong usage leads technical solutions ad absurd. He further points out that tenants have influence on the following aspects:

- Indoor air temperature,
- Ventilation behaviour, and
- Attitude towards and operation of the technology.

These aspects are touching heat losses, which although the largest contributor to energy consumption, should be considered together with the following three aspects that also deal with the other identified aspects of energy use:

- Purchase behaviour and ownership of electrical devices and fuels,
- Usage of electrical devices, and
- Consumption of hot water for bathing, cleaning and food.

Hübner criticises the level of the values of Eicke-Hennig as being caused by other factors besides the pure user behaviour alone but he also agrees that the behaviour of tenants is a significant aspect influencing energy consumption [Hübner, 2003].

4.2 Models of behavioural change used in this study

A change of behaviour in people is dependent of various psychological aspects. In the beginning of the environmental movement in the 1970s, researchers had the opinion that education would lead to an environmental consciousness that would cause a change in behaviour [Homburg & Matthies, 1998]. This assumption had a real background, in the 1970s there was really a deficit in Germany in reliable publicly accessible knowledge about environmental degradation [Weller, 1998]. However, as these approaches were not very successful, the more recent sources see behaviour affected more by a variety of aspects, of which knowledge is only one.

Gardner and Stern [1996, based on Stern and Ostkamp, 1987] mention seven levels of causality that affect resource consumption behaviour. Of these seven levels the Levels 1-5 are internal aspects of personal behaviour and levels 6&7 are external aspects. Actual environmental behaviour is further dependent on the environmental aspects. People that are very concerned about energy saving do not necessarily care for water conservation or waste separation [Schahn & Giesinger, 1993].

Table 5, A causal model of resource-consumption behaviour with examples from Residential Energy Conservation [Based on Gardner & Stern, 1996].

Level of Causality	Type of variable	Example
7	Household background	Age, sex, income, education, number of household members, employment rate
6	External incentives and constraints	Energy prices, size of dwelling, owner/renter status, available technology, difficulty and cost of energy conservation action
5	Values and worldviews	New Environmental Paradigm, Biospheric-altruistic values, Postmaterialism, livestyle
4	Attitudes and beliefs	Concern about the national energy situation, belief household can influence it, belief neighbours expect you not to waste
3	Knowledge	Knowing that the water heater is a major energy user, knowing how to upgrade attic insulation
2	Attention, behavioural commitment	Remembering to install weather stripping before heating season
1	Resource-using or resource-saving behaviour	Decreased use of air conditioner, purchase of high-efficiency furnace, lowering winter thermostat setting

The aspects that various authors are use for their Influence-scheme are similar [Fietkau & Kessel 1981; Flade et al., 2003; Homburg & Matthies, 1998; Weller, 1998].

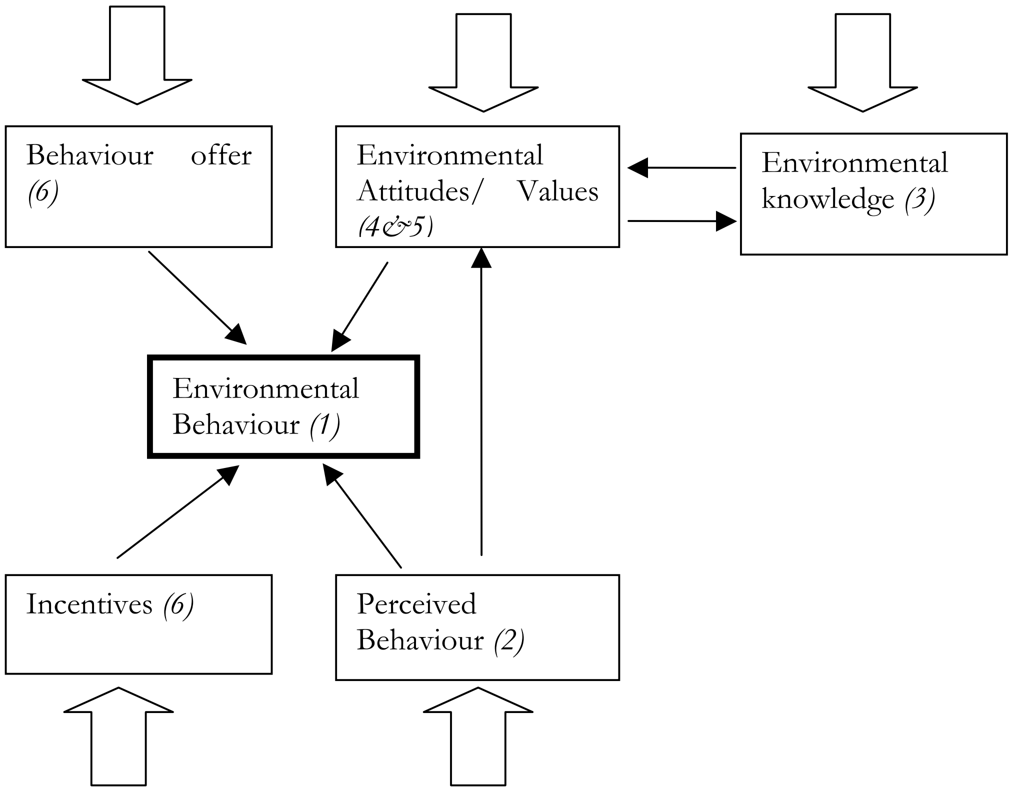

Figure 6, Influence-scheme for environmental conscious behaviour [based on Fietkau & Kessel 1981; Homburg & Matthies, 1998; Weller, 1998,Flade, Hallmann, Lohmann, & Mack, 2003], Numbers of the causal model of resource-consumption in brackets

Before behaviour is changed, it helps to know who already conserves and when, so that we know where to aim energy conservation programs [Stern, 1997]. To find these people and the methods of conservation that they already use should be one of the focuses of this survey. Later, as Champions they can serve as keystones of the conservation concept (see Section 4.6.2). To structure the findings so that they can be used later in any proposals they are based on the following aspects.

The aspects of both models that lead in the end to a wanted environmental behaviour (Level of causality, LC 1) are quite similar. Garner & Stern call the second level attention and behavioural commitments, an aspect that also can be found under the aspect of perceived behaviour. This is because the residents remember their behaviour that they otherwise do not usually perceive. To then use the attention in the right way, knowledge (LC 3) is necessary how to behave in the right way. This knowledge and the perceived behaviour influence the attitudes and values of the residents (LC 4&5) and, by this, very much the motivation to behave environmentally conscientiously. In this context, social aspects like social control also have influence on the attitudes of the residents. This social control can also be placed in the aspect of perceived behaviour, as social control only has influence when the residents, in advance of an action, know the attitude of others that can also make him/her responsible for the action. Therefore, social control is very much dependent of the attention of a resident and how this control is perceived. The aspects of incentives and offers are, in the model of Garner & Stern summarised in one point (LC 6). This is not very useful for behavioural change concepts in the surveyed cases as landlords can have influence on behaviour offers but the incentives are very much dependent on the political actors. Therefore, with a focus on the different involved actors a distribution of theses aspects make sense. The household background as seventh level of the causal model gives information as to why residents behave in a certain way, but it is not possible to change this aspect from outside. Thus, it is left out in the influence scheme and in the later recommendations but surveyed together with the other aspects.

4.3 Other models of behaviour

These models were chosen after an extensive survey of behavioural literature. The results of this survey were that the model of Fietkau & Kessel [1981] was not only used in the sources of Flade et al., 2003; Homburg & Matthies, 1998; Weller, 1998 but also referred to and in general the aspects of this model were used in other models, [Gardner & Stern, 1996; Lindström, 2003, p.22].

The aspects of the eclectic model of theoretical perspectives of Bell et al. [1996] focus on the perception of the environment that is influenced by various factors like individual differences, cultural factors and physical condition. If the perception is different than the normal range stress leads to coping. If this coping is successful, the behaviour is adjusted [Bell et al., 1996, p.146]. This looks different but the perception of the environment in the Influence-scheme for environmentally conscious behaviour is influenced by attitude, values and perceived behaviour. The successful coping is also mainly influenced by behavioural offers and incentives.

Hormuth [1993] uses a model that looks different than the model of Fietkau & Kessel but it contains mainly the same aspects but compiles them under the various actors. The behaviour and the perception of these actors are based on the internal individual aspects of motivation, values, knowledge and the external individual aspects such as financial situation. This is combined with external aspects like information, incentives and offers [Hormuth, 1993].

Besides the Fietkau & Kessel model used in this study, [Flade et al. [2003] refer to a group of other models. For this study, the theory of planned behaviour of Ajzen [1993] is also interesting. It tries to explain the inconsistency of attitude and behaviour. The reason for this inconsistency is that an attitude is built from knowledge and perception. This attitude is only building an intention of behaviour that is not always realized. Perceived social control, known consequences and possibilities to behave as intended are important for the realization of the behaviour [Flade et al., 2003]. These aspects are in addition to the social control also found in the model of Fietkau & Kessel.

Moreover, social control can be categorised under the values, attitudes and perceived behaviour. The opinion of other people is a value that can be high or low for the individual. In addition, how much certain behaviour changes this opinion is perceived by the individual. It is, therefore, possible that a tenant is sure that his neighbours would be disappointed by him wasting energy, especially when no individual bills are paid, but when the tenant is sure that nobody can make him responsible, like when individual meters are missing, he would not conserve energy.

Therefore, the choice of the Influence scheme is justified. The causal model of resource-consumption of Gartner & Stern is the optimal complement to this model.

4.4 Aspects of behaviour

The aspects in this and the following section orientate themselves on the aspects of the above-used models. To ease orientation the numbers are given in brackets. The structure should represent a usable conservation concept. Therefore, it starts with the transfer of knowledge (LC 3).

4.4.1 Knowledge (LC 3)

As already pointed out, the initial focus of most behavioural change models is the knowledge about environmental issues. Today, people are assumed to live in a situation where they receive more information than they can process, which makes them unconsciously select which information to receive. How much of the environmental information come through this filter is not very clear. After twenty years of environmental information, it can be assumed that the tenants have at least basic environmental knowledge. Wortmann et al. [1993] stress that this is not the case (in 1993), although it may have changed in the last ten years. The knowledge about the term Sustainability has risen from 13% in 2000 to 28% in 2002 [Bauer, Grunenberg, Kuckartz, & Rädiker, 2002], but a value of 28% can still be considered as low. Kaiser et al. [1999] show that around fifty percent of people know that the climate will change because of CO_2 emissions and that the sources of these emissions are fossil fuels. Stern [1997, quoting Constanzo et al, 1986] points out that the claimed knowledge about particular energy-saving programmes was much higher than the actual knowledge of them. All the same, it is not crucial whether knowledge about the environment is delivered. Several studies found either no relationship between factual environmental knowledge and ecological behaviour or, at best, a moderate relationship. When this relationship appears to be stronger, it is knowledge about an ecological behaviour i.e. knowledge about what and how something can be done, rather than factual knowledge about the environment that is related to ecological behaviour [Kaiser, Wölfing, & Fuhrer, 1999]. Therefore, are clear informations how to behave energy efficient in standard processes in the household most promising, especially when these behaviour understandably increases a concrete value for the tenants, like saving energy costs.

4.4.2 Attitudes, values and worldviews (LC 4&5)

Stern writes that four attitudes are strongly related to energy use and predict half of the variance in energy usage:

- Whether or not you think energy use is important for comfort and health;
- Whether or not your energy savings are worth the effort of conserving;
- Whether or not your efforts as an individual can make any difference and
- Whether or not the energy crisis is real [Stern, 1997].

How far the attitudes of the people change lifestyle is very much dependent on other values, besides environmental values, that people have. In older generations, people can be found that do not care very much about the environment, but save energy because saving is something they have learnt while growing up during the second world war and the times of poverty after that. Lifestyle is also important for energy conservation behaviour. This can include the so-called "voluntary simplicity", but also income and employment. To integrate the lifestyle under causality level 6 is not easy, as the lifestyle is very much influenced by income. Therefore, the voluntary aspects of lifestyle are discussed in this section and the income aspects of lifestyle are discussed in section 4.4.8, Household background.

In general, German society seams to be very sensible towards environmental issues. More than 50% think that the environmental situation will lead towards a catastrophe if nothing is done, that the limits of growth will soon be reached, and that not enough is done to prevent this [Bauer et al., 2002]. Based on Bauer et al. [2002] the, in the media very much criticised, hedonistic fun-society attitude cannot be found very often. This attitude can be found mostly in men with low or middle education. How far the attitude and lifestyle of families with a non-german heritage is different in this area cannot be concluded, as the sources do not explicitly identify this subcategory. However, it is not widely believed that the lifestyles of the second and third generation of this people are very different to the lifestyles of native Germans of the same social background and education.

Interestingly, Dörner [1993] points out that moral values in situations of crisis very often lose their function as regulator for behaviour. If the economic situation of some of the tenants is perceived as a crisis this could weaken the moral aspects of their behaviour.

4.4.3 Inconsistencies between behaviour and attitude

Even when a person has a certain attitude, he may not always act with respect to this attitude. These inconsistencies are caused by other aspects than attitude. Therefore, a person can dislike car driving because of the environmental problems caused by it. But on a Saturday evening, when no bus is going, it rains and one has to hurry to come in time to the cinema, taking the car is an acceptable alternative, even for this person. The person subconsciously perceives these inconsistencies, but creates excuses for his behaviour. The inconsistency is very often only consciously perceived if identified from outside [Schahn, 1993]. Interestingly, an outsider in this case very often seeks the responsibility for the inconsistency in the attitude of the actor, while the actor sees the responsibility in the situation. This could be a problem for these types of behavioural studies. Brandon and Lewis [1999] refer to the disagreement of researchers about the link of attitude and behaviour that is rated from very weak to fifty percent. They were able to show that people are more likely to change their consumption when they show positive environmental attitudes [Brandon & Lewis, 1999].

4.4.4 Perceived behaviour (LC 2)

People in general try to avoid self-reflection of their actions and very often, they fail to control the impacts of their action. One reason is that humans have the tendency to keep the feeling to be in control of a situation and this feeling is reduced when the human perceives a failure. The cause-effect relationship is only perceived when the time between action and effect is very short. Further they try to simplify complex situations with, very often, the result of over-simplification and generalization. The reasons for this behaviour can be found in the limited possibility of the humans to think rationally, they very much tend to only care for things that are happening now and, especially, that are hurting now. They tend to forget what already has happened and they try to ignore what will happen [Dörner, 1993]. Feedback on actions has to be given very shortly after the action takes place.

Siero et al. [1996] propose comparative feedback as a way to create a competitive situation between employees. This causes a much larger impact on energy-wasting behaviour than the basic behavioural change programme [Siero et al., 1996]. This is a statement that is opposite to the statement of Brandon and Lewis [1999] who were only able to find a marginal correlation between feedback and behaviour. However, to transfer this to tenants is problematic. The tenants could block the attempts to reach them and the competitive situation could become counter-productive.

A basic condition is that the desired behaviour is accurately specified and measured in such a way that [people] perceive feedback as reliable and contingent on their own behaviour [Siero et al., 1996]. When people receive feedback about the effects of their behaviour, the positive behaviour will become stabilized [Schahn, 1993]. Nevertheless, negative feedback should always be given together with tips for improvements that are not demotivating. If a goal of energy saving is stated, this should be a goal that people agree on, is ambitious but achievable. Energy savings of 5-15%, especially with ambitious goals, are possible if combined with frequent feedback in the way described above. Feedback should be given as information in a "language" that the audience understands.

4.4.5 Incentives (LC 6)

A reason for environmentally destructive behaviour is that it creates, in the short run, benefits to the individual, while it harms the society in the end. Therefore, it is understandable that people only adopt behaviour that also creates, in the short run, more benefits than costs for the individual [Schahn, 1993]. Dörner writes of a "troubleshooting system" that we humans have inherited from our ancestors that, some 50.000 years ago, had to solve their problems ad hoc. As their actions had no side- and distance effects, they had no need to think about them [Dörner, 1993]. So, only for some environmental conscientious people, is it enough to perceive that they are doing well. For most people this is not enough. Incentives should address the values of the people. These incentives do not necessarily have to be financial, but monetary values are very common values for most people.

An "economic incentive" leads people to channel their efforts […] related to economic consumption in certain directions [Field, 1997]. Financial incentives may be good from the view of an economist, but psychologists criticise that individuals are not purely rational and this market approach does not seem to be very effective in reducing overall consumption. As individual consumers are more complex than institutions, they are reacting not only to economic changes but also to idiosyncratic personal factors [Bell et al., 1996, quoting Dennis et al., 1990]. The ways in which people react on financial incentives is also very dependent on their financial situation. Therefore it makes sense, to use incentives that create direct benefits in a "currency" that is scarce for the individuals.

The [British] Institute of Fiscal Studies has estimated that the poorest 20% of households is 10 times more sensitive to energy prices than the richest 20% [Milne & Boardman, 2000 quoting Crawford et al., 1993] because of the higher scarcity of money for these people.

The creation of energy conservation incentives is difficult for housing companies. Here, the only way is to subsidise small devices to trigger energy conserving behaviour. Faucets and light bulbs are of interest. They can be offered through games or quizzes to improve motivation. Positive financial incentives are difficult to create on this level as the energy is already a high cost item and the tenants have the possibility to change the power supplier.

High energy prices can already be called punishments. The definition of "high" in this case depends on the perception of the consumer. Punishments are only effective when perceived as punishments. Punishments have a similar effect like incentives. They raise the individual costs of an action to counteract the benefits and the action becomes less interesting for the actor. The advantages of disincentives, like green taxes, are that the society receives money and does not have to pay. However, the acceptance by the actors is generally lower, so the motivation for the action could be reduced. Wortmann et al. [1993] states the opposite – that people are much more sensitive to losses than to gains and that a program that demonstrates that money can be saved is more successful than a program that shows that money can be gained [Wortmann et al., 1993]. The motivation of the participants is, in general, a problem of incentives and disincentives. The behaviour will only make sense for the actor as long as his personal cost benefit ratio is changed artificially. This ratio can also change when the incentive becomes less scarce for the actor. People on a low income could decide not to drive by car because the petrol is too expensive, but if they receive a pay rise, this attitude could change.

4.4.6 Behaviour offers (LC 6)

One of the most commonly used excuses for a non-environmental friendly behaviour is that possibilities to behave better do not exist. Most people know that using buses is better than driving cars, but the bus is not used because it is not going the way it should at the time it should, the price is too high and one does not find a seat. These excuses are sometimes true, but very often only an excuse (see Section 4.4.3). However, the issue is that people do not behave in the desired way. In the case of houses, this is very often found in the heating and ventilation field. The tenants know how to ventilate in the right way, but the casements are tilted open in the winter the whole night. This can be solved, for example, by only using windows that can only be opened fully. On the other hand, a ventilation system could also be installed that, even during the night, exchanges the right amount of air, so the tenants do not have to ventilate at all. Further, building in thermostatic valves in the heating systems that can be programmed by the tenants, can help to keep the correct temperature. These are all, at least partially, technical solutions.

4.4.7 Mistaken offers and incentives

The problem with a programme of offers and incentives is that it should be very clear who is the focus group of intended behavioural change. The method of delivery, has to be defined very clearly, as the offers can also change the behaviour of groups where a change is not, or only conditionally, desired. This could cause unwanted side effects, especially if a rewarded behaviour can be easily achieved or if the offer is very high. Some people would behave in a certain way just to receive the incentive. A cheap energy saving light-bulb may be a better incentive than a free bulb, as this encourages people to buy only as many lightbulbs as needed and not more than are needed. Alternatively, an energy reduction incentive should not be based on a desired percentage reduction, as the tenants could boost their consumption one month and reduce it the next, just to receive the incentive. As the environmental aspects of the energy consumption can be best guessed over the consumption itself and the energy prices already include disincentives, it would be very difficult to create a new incentive system that could work and is legal. This should at least also include the other aspects of change so that people do not only take part in the programme to receive the reward [Schahn, 1993].

4.4.8 Household background, income and employment (LC 7)

Low-income households generally have lower average indoor temperatures than wealthier households. They are responsible for a smaller proportion of total carbon dioxide emissions, with the 30% of households with the lowest incomes emitting only 24% of UK carbon dioxide (CO_2) [Milne & Boardman, 2000]. This is consistent with the findings of Brandon and Lewis [1999], who find the lowest energy consumption in the "rented from public authority" sector and the highest in the "owner-occupier" sector. Stern points out that, as households both of the high and low income sectors already save much energy, the main focus group should be higher to mid level income groups, who have not yet changed their behaviour [Stern, 1997]. This conclusion can be challenged, as the energy conservation of lower income groups is only based on the relatively high expenses for energy and improvement in the insulation of homes can also include health benefits. Kühn [2003] mentions that some surveyed flats had rooms with temperatures of 11°C *(DQ2)* and, sometimes, ice on the walls. The lowest temperature for a healthy environment is 16 °C [Milne & Boardman, 2000, quoting Boardman, 1991], so a rise of the temperature could, in some cases, have an improvement for the health situation of the tenants. Also, it is possible to attack the problem of mould in the rooms, which can also be counted as a health improvement. The average temperature of the flats in the heating period is estimated at 18.5-19.5°C [Kühn, 2003]. Based on Milne & Boardman [2000] this would predict efficiency improvements due to heating and insulation of 80-85%.

Figure 7, Information Brochures

The employment rate is also interesting. People that are at home during the day consume more energy in their flat [Kühn, 2003; Stern, 1997].

The household size and structure also gives hints related to consumption. It cannot be said that the age of the residents has a high influence on environmental behaviour, only that people with small children and the elderly consume more heat during the night [Stern, 1997]. The average temperature increases by 0.7C when children under 16 are living in the household [Milne & Boardman, 2000]. This shows clearly that attitude does not always govern behaviour, because the highest concern for the environment is, in general, shown by parents with young and elder children. These groups have a significantly higher concern for the environment than the young and the old single [Bauer et al., 2002]. Single households consume relatively more energy per capita than households with more inhabitants [Farah, 2002], even with lower temperatures.

The sex of the consumers is significantly important for their environmental attitude - women have, in general, a higher concern for the environment and this concern rises with educational level. They are far more willing to start actions like energy saving without support, while especially lowly educated men more usually demand the state to the actions [Bauer et al., 2002].

As the buildings surveyed in this study are only populated by renters, are all Multi Flat Dwellings and are all owned by the BGW, the aspect that homeowners, especially in Single Flat Dwellings, have a higher perception of energy consumption and take more actions to improve the energy efficiency than renters is not of interest here [Haas, Auer, & Biermayr, 1998; Stern, 1997].

4.5 Possibilities to conserve energy by behaviour changes

Similarly to the technical aspects in section 3.2, this section lists the ways related to human behaviour, in which conservation measures in the different fields of household energy consumption could look.

These aspects are very much dependent on the individual attitudes of the tenants. While some tenants could rank the environment very highly, the others could hold money as the highest value. Information level, motivations to conserve, abilities and acceptance to work with technical devices also differ. Therefore, to ensure success, a tenant survey is first required followed by an individually designed conservation measure based on the results of this survey.

4.5.1 Space heat and ventilation

Space heat can be conserved by the tenants by a reduction of the temperature level in the flats. This is problematic as, as already mentioned, a certain level of temperature is necessary to secure mould-free outside walls. In addition, temperatures of less than 16°C can create health problems. However, the reduction of air temperature in flats by 1°C reduces the space heat consumption by 5%. Therefore, the tenants in a well-insulated building should reduce the indoor temperature to a normal level of around 20°C. Indoor temperatures that reach 24°C or more are not necessary, and a reduction in temperature by opening the windows should be avoided. Also, heating systems should be turned of in times of absence or during the night. In a well-insulated building with surrounding inhabited flats, the heat losses will not be so high that tenants risk a freezing of tubes.

The best results of energy conservation in this field can be achieved by changing the ventilation behaviour. The correct ventilation behaviour is crucial for energy conservation results. This field is traditionally a focus of information and behavioural changes as the correct ventilation can save significant amounts of energy and money. In old houses the heat-losses of ventilation are already around 20-35%. After modernization with improved insulation this share will rise to approximately 50% *(DQ 3)* [Borsch-Laaks, 2001].

To secure healthy conditions in a flat, air exchange rates of 0.15-0.70 $^1/_h$ have to be reached. This exchange rate can be reached by controlled ventilation through the windows. Three times a day the windows on opposite sides of the house have to be fully opened for five to ten minutes [Siepe, Mobers, & Krause, 1999]. When the windows are open the whole day, only the heat losses are high. Hiller is critical that shortly opening the windows only creates an air exchange of 0.1-0.2 $^1/_h$, but excludes from the calculation the constant air exchange through leaks that can reach levels of 1-3 $^1/_h$ and often even more.

In general, the rule of thumb of "three times a day five minutes ventilation through windows on the opposite side of the house" is the right ventilation behaviour, but the results are very much dependent of the airspeed, the humidity of the ambient air [Borsch-Laaks, 2001] and the layout of the flat[Schulze Darup, 1996].

Besides information regarding energy consumption, the tenants should learn that an open window in the winter does not increase the humidity of the indoor air. This is widely believed, as the humidity of the cold outside air is very high. Therefore, when the tenants have the feeling that the air in the rooms is dry and an uncomfortable feeling occurs, the windows are left open to increase the humidity. This behaviour can cause, beside energy losses, irritation of skin and breathing organs.

4.5.1.1 Knowledge (LC 3)

The first way to transfer the relevant information to the tenants is to send heat or gas bills to them and not to simply draw the money from their accounts by automatic transfers.

There should be an understanding that higher temperatures lead to higher costs, and this information should be brought to the tenants by information. A temperature control device for heating would also make sense here. The correct usage of these devices should be taught in an energy conservation information session. The tenants should be invited by leaflets and receive pamphlets with the information that they were taught. This also includes also the correct ventilation behaviour. When ventilation is not automatic, the tenants should be taught how to ventilate in the right way.

To reach the health values of tenants, it should be taught that that constant ventilation in the winter reduces the humidity of the indoor air instead of raising it (which is often supposed) and that this low humidity can cause skin irritation. Therefore, the right ventilation behaviour can guard against health problems. It should also be communicated that tenants should ventilate sufficiently to reduce the humidity to a normal level, to keep the risk of mould low.

4.5.1.2 Attitudes and Values (LC 4&5)

The values that should be triggered here are the costs of energy consumption together with health aspects. A translation of the energy reduction into economic value for the tenants is crucial. This corresponds with the four aspects of attitudes of Stern (See Section 4.4.2). The importance of energy use for comfort and health should be perceived together with the comfort of the conserved energy. The conservation concepts should be very easy to implement so that the predicted savings are always more valuable than the cost of the action that has to be performed. The difference that the individual tenant can make is not important as he makes a difference in his own pocket and it is there that he feels whether the energy crisis is real or not.

4.5.1.3 Perceived behaviour (LC 2)

A good way to perceive ones own behaviour is through reliable feedback. Feedback can be given by electronic meters that show tenants the current temperature or a hygrometer that reminds the tenants when ventilation is necessary. These devices should be located at a visible and frequently passed place. Locating the devices beside the entrance door would be a good way to remind the tenants of turning off the heating and closing the windows when they leave the flat. The hygrometer could use a sound that is activated when a certain humidity is surpassed.

These measures can be supported by prompts that the tenants can place on the windows. These prompts should not only be visible, but should also have an aesthetic value. They should remind the tenants to close the windows with, not more than one, easy and short sentence.

4.5.1.4 Incentives (LC 6)

A small incentive as a "foot in the door" motivator to influence the tenants ventilation behaviour could be the supply of hygrometers. These devices can be a cheap way to motivate and teach tenants how to ventilate correctly.

The actual energy costs should be sufficient incentive to reduce consumption. Energy costs are negative incentives, so called punishments. Other incentives are difficult to create and the necessity is limited. Anyhow, the incentives, say the prospected savings, should be large enough to create a motivation for the tenants. Therefore, it is crucial before a conservation concept is created to know the values of the tenants.

4.5.1.5 Behaviour offers (LC 6)

Hygrometers that give tenants feedback can also be a behaviour offer. Further, windows that cannot be tilted and have no windowsills, so as to force tenants to open them in the right way are an option. In addition, window shades that protect the windows against high sun with strong radiation and heating systems with radiators that heat up quickly could also be considered.

In the wintertime, the shock of coming out of the bed into a cold bathroom makes tenants to sometimes leave the heating running the whole night in the bathroom. When the radiator in the bathroom is light and has a large area, and the walls are sufficiently insulated, this behaviour will no longer be necessary.

4.5.1.6 Commitments (LC 2)

Commitments of the tenants can best be reached when the success can be metered. Therefore, a commitment of the tenants can be to run the heating system at no higher than 20°C. Therefore, a thermometer or an automatic heating control is necessary. In addition, it could be a commitment that tenants will no longer tilt the windows. This commitment should be given in public so that a social pressure is created when neighbours could see the tilted windows. The successful keeping of a commitment should always be rewarded.

4.5.2 Hot Water

Hot water consumption is usually connected with aspects of comfort. Comfort means not only the comfort of a hot bath or shower but also the comfort of more often washed cloth, warm drinks and food and also the more easily reachable dish cleaning results with hot washing water.

A reduction in the demand for hot water can only be reached when a loss of comfort of using hot water is not perceived or is compensated by something that gives more comfort. Around two thirds of hot water is consumed in showers and bathtubs. The temperature of the hot water coming directly from the boiler is in most cases too high for humans to touch. Therefore, the consumer has to mix this water with cold water to achieve temperatures of comfort for shower, bathing and washing. Heating up and than mixing down the water is inefficient as the heat losses of boiler and supply line rise with higher temperatures. Also are large, unnecessary energy consumptions created by a large amount of water in a "stand by" tank, which keeps the water the whole day at a constant high temperature. Therefore, temperature and hot water reserve should be reduced as far as possible.

For hygiene, the tenants should learn how much more water a full bathtub consumes than a shower and how the costs that this bathtub creates. It should also be communicated that switching off the water during soaping or brushing of teeth conserves water, energy and money.

For the heating of water for food, the electrical stove or water kettle is mostly used. Here it is necessary to teach the tenants that the stove consumes far more energy for small amounts of water than the kettle, as the mass of the plate has to be first heated. Correct cooking behaviour, with the use of the right plate, for the right time, turning off the plate or the oven before the food is ready to serve and the use of appropriately sized pots and lids can save significant amounts of energy. A lower consumption of frozen food and the use of the microwave at the right times can also contribute.

Today, most Germans use washing machines to clean their clothes. In this field, behaviour is limited to supply of clothing amounts and the selection of the program. The tenant should learn how much washing powder is necessary and which temperature is demanded. In addition, should they use the highest gear to tumble the clothes. The use of clothes dryers should be avoided. If sufficient space is not available for the drying of clothes in ambient air ventilation boxes should be used.

4.5.2.1 Knowledge (LC 3)

The information supplied should include the already mentioned behaviour together with justifications for these behaviours. The information should be delivered to the tenants in a form relevant to their perception of their lives. Information about hot water would create less reaction than information about cooking, hygiene or washing.

As the tenants will not have to learn new technical devices to behave appropriately, the information does not have to include these aspects.

4.5.2.2 Attitudes and values (LC 4&5)

As in the case of space heating discussed above, the main value is again the cost of the behaviour. The tenants are required to pay for their individual consumption. Therefore, the costs of a full bathtub, running clothes dryer or the savings of a closed lid should be given to the tenants. A more theoretical explanation of the potentials of financial values can be found in section 4.5.1.2.

4.5.2.3 Perceived behaviour (LC 2)

Feedback could be supplied by power- and water-meters that can be installed at a prominent location in the flat. In addition, tenants could borrow power meters that they can plug into the power plug when a device is running.

Additionally, prompts could be used for the washing machines. These prompts should be a reminder to fully load the machine. In addition, prompts beside the stove to use lids or to turn off the stove 5 minutes before the food is done could be an option.

4.5.2.4 Incentives (LC 6)

In the field of cooking, an incentive could be to run cooking courses where the tenants can learn how to conserve energy in the kitchen. However, the best incentives are again the costs of the consumption of energy.

4.5.2.5 Behaviour offers (LC 6)

Behaviour offers also include cooking courses. Water-saving showerheads and faucets that consume less water by mixing the water-spray with air can be also offered. This reduces the through-flow water by around 25% *(DQ 1)* with the same cleaning results and can, therefore, reduce the energy bills of an average household by 12 €, if gas is used to heat up the water and up to 43€ if power is used *(DQ 5)*. The cheapest water saving showerhead in the local Praktiker shop has a price of 15,99€ *(DQ 1)*. Therefore, a pay back time of these devices can be potentially reached in four months or a maximum one and a half years *(DQ 5)*. These devices can be supplied as standard as part of renovations, when the tenants are in any case to receive a new boiler. They also can be offered as small compensation for the troubles due to the renovation or as prizes when tenants answer an energy quiz right after an information session.

4.5.2.6 Commitments (LC 2)

When water saving showerheads or faucets are presented, the tenants could be asked for a commitment to save water and energy. This can be done with a reduction of the full baths a tenant takes or the use of only full washing machines. To control the commitments is difficult.

4.5.3 Electrical Power

The field of electrical power is a very heterogeneous field for energy consumption. The broad variety of devices is used differently, for different purposes and at different times. However, the possibilities to give feedback are good. In the sector of electrical power, the tenants have a broad influence, while the housing company has lowest influence. The reason for this situation is that power supply is liberalized in Germany.

As their influence and potential for income generation or savings is very low in this segment, the housing companies have low motivation to influence tenants to conserve power [Schwarzhoff, 2000]. However, the motivation of the tenants should be higher as the power bill is directly perceived. In addition, as housing companies are using the energy conservation efforts not only to save running costs but also to create a service for the tenants, this should be a sufficient motivation to implement a conservation measure.

As the tenants have the influence on the efficiency of the devices, this efficiency should also be a focus of the information campaigns. The efficiency of the devices that lay within the range of influence of the housing companies is the topic of Section 3.2.

Besides the efficiency of the devices and their usage patterns, the environmental impacts of power consumption are also dependent on the sources of the power. Therefore, the tenants should be motivated to think of using another power supplier that perhaps supplies power from renewable sources. This was for a time difficult to justify as, especially the cheap power suppliers, were criticised for offering power from problematic sources. However, today the offer of power from renewable sources can also compete on price [Janzing, 2003] while the historically cheap power suppliers have raised their prices to a normal level, similar to levels before the market was liberalized [Mikosch, 2003]. To encourage a change in power supplier, only information can be offered. Moreover, sometimes even this is problematic, as a large number of German housing companies are owned by the municipalities that also own local power suppliers.

4.5.3.1 Knowledge (LC 3)

The information level on the costs of the power consumption can be assumed to be relatively high. This is because tenants receive a separate power bill from their power supplier. The housing companies have no influence on these bills, as the tenants can choose their power supplier themselves. In the survey for this study, the magnitude of the power bill was mostly known, but the costs per kWh were not. Therefore, it would be difficult to convince tenants of the merits of a new power supplier or energy conserving behaviour with a cost expressed per kWh. The costs should be given in terms that are reasonable. For example, during interviews in this study, tenants were asked about their knowledge of power consumption relating to stand-by mode of TVs. In two cases, the tenants did not know the consumption and asked how high the consumption would be. After being told that the TV that is in stand-by mode can consume up to 50€ annually the tenants immediately turned it off. It can be assumed that an explanation in hours or days will not have the same result. Therefore, the costs should always be given in terms of whole Euro.

A more theoretical explanation of the potentials of financial values can be found in section 4.5.1.2.

4.5.3.2 Attitudes and values (LC4&5)

The main aspect here is again the financial values of the tenants. Besides, it can also be supported by the critical position that a large group of Germans has regarding nuclear power. This should be used carefully not to start extensive discussions, but it should be possible to show tenants figures related to nuclear power. The saying that "when all Germans turn off their devices in stand-by mode two nuclear power plants could be turned off" is quite well known. This should show tenants that their behaviour can have influence, and is consistent with the goal of addressing the values of the tenants (See section 4.4.2).

4.5.3.3 Perceived behaviour (LC 2)

To give feedback in the field of power consumption is perhaps easiest. A large number of tenants knew the level of their power bills. This knowledge could be supported by lending a power meter to tenants or could be shown in information lessons. The power meter can be plugged into the power line of the device and shows power consumption. This motivates tenants to try out the different modes of operation, like a toy. The meter should not only show the abstract power consumption in kWh, but also show the financial values of this consumption. Alternatively, the tenants should receive a supporting brochure where the annual costs can be displayed. These power meters could even be built-in like the previously mentioned water-, heat-, thermo- and hygrometers at a prominent place so that the current consumption can always be seen by the tenants.

Figure 8, Powermeter [Oksatec, n.D.]

Walker [1979] points out that an average reduction of the power-consumption by circa 5% could be reached even without sufficient information, simply by feedback on behaviour. These savings can increase up to 35% [Walker, 1979, quoting Midwest Research Institute, 1975], although he warns against making generalisations from these figures. These figures can be between 5 % and 15% for the use of Continuous-Display Electricity-Use Monitors (CDEUM), small meters that are showing the consumption of power [Sexton, Brown-Johnson, & Konakayama, 1987]. These devices can be programmed with a power-price and show the tenant information about the consumption in a quantity he/she understands and that has a value for him/her.

Further, ways of feedback are prompts that could in this case be placed besides the main consuming devices. These devices are typically the stove, washing machine and TV and will probably not be moved very often, and prompts will stay visible. They should remind of using the device in the right way and to turn off the stand-by. They should also be placed besides light switches and doors as a reminder to turn off lights and devices when leaving the room.

4.5.3.4 Incentives (LC 6)

The best incentive here again is the price of the power. It is difficult to justify that the housing company should give large incentives in this case.

4.5.3.5 Behaviour offers (LC 6)

Real offers of behaviour are difficult to give for the housing companies. It would be possible to offer small devices like CFL light bulbs. These bulbs have lower power consumption and can be purchased today for 1.50€. They can be offered as “foot in the door” offers, or as prizes in a quiz, as the perception of the devices is good as the light is visible. In case of larger devices only the information regarding the offered devices should be given to the tenants. A subsidy of energy efficient devices would be critically viewed as only stoves, washing machines, TVs and fridges are found in almost every German household [Statistisches Bundesamt (Hrsg.) et al., 2002]. Other devices will probably not be replaced but the tenants would just use the opportunity to purchase more devices. This would lead to higher rather than lower consumption.

4.5.3.6 Commitments (LC 2)

A commitment that could be taken from the tenants in this segment would be to always turn off the stand-by mode. Further, it would be possible to give the commitment to reduce the power consumption by a certain amount. This amount should be high, but not too high. Values around 20% have proven successful. They are taken seriously but the tenants do not have the feeling that they are unattainable.

4.6 Concepts to change tenants behaviour

All the different fields of energy conservation above have, in common, a number of aspects that should be transferred to the tenants. Therefore, a concept of implementation of the behaviour has to be developed. This concept has to focus on a long-term change and not only on the short-term transfer of information.

4.6.1 Implementation

The implementation of energy conservation concepts could use the Four drive theory [Lawrence & Nohria, 2002] to trigger the aspects of behavioural change from the Fietkau & Kessel Model. This theory is trying to explain our natural behaviour on four drives that are the basic of all our behaviour. It is used mainly to motivate workers in companies. The four drives are:

- The drive to Acquire,
- The drive to Bond,
- The drive to Learn,
- The drive to Defend.

These four innate drives are said to be subconsciously governing our behaviour by emotions that cannot be understood by rationality. They are grounded in human evolution.

The drive to acquire is shown through a human trying to acquire goods and abstract things that show a value to him, like reputation. The possibility to save energy costs and by this, acquiring wealth should trigger this drive. The promise to reduce emissions is worthless for this drive, as emissions are not perceived as valuable. Also, it is possible to trigger the drive to acquire to give "Champions" (See section 4.6.2) a higher reputation.

The drive to bond exists because every human has the need to establish and keep relationships to other humans, especially when they have a high reputation. The drive can be triggered through a local "Champion" that can convince the other tenants to shift their behaviour. Therefore, this "Champion" should have a high reputation in the settlement and needs support from the official site. It could be possible, in this case, to motivate some proactive people in the settlement to organize a Dwelling Festival (see Section 4.6.5) or to establish a dwelling organization (see Section4.6.6). This drive also explains that these ways of bonding can never be forced, and must be voluntary.

The drive to learn is our innate drive to satisfy curiosity. The problem in the Sennestadt settlement is that the people have limited initial information about energy issues, and a low motivation to change this by themselves. An initial offer of information transfer has to be given to trigger this drive. The information has to be given in the right way, as described below in Section 4.6.4.

The fourth drive is the drive to defend, against threat and harm. This can be triggered if health aspects are also used as a value to transfer information about energy conservation (See Section 4.5.1.2). In addition, the saving of money is part of this drive, as higher costs are seen as a threat to ones lifestyle. However, this drive can also create problems for the integration of the tenants. If tenants feel victimised as over-consumers, they consume too much energy, they could try to defend their valuable reputation, and by this block further attempts to motivate them for energy conservation. In addition, during the interviews, the relationships between the tenants were perceived as suspicious. The risk is here that tenants have the feeling in the beginning that they have to defend their position against other tenants.

4.6.2 Champions

A key of a successful implementation strategy is to find people that have roots in the dwelling that can link the tenants to the organizer of a conservation measure. These so-called "Champions" should be people that have a high reputation in the dwelling and are motivated to conserve energy. Therefore, it is good to find out which tenants already conserve energy and how. This can be done through information events. People that are outspoken on these events that receive positive feedback from other tenants and that show good ideas and motivation should be a focus of the search for Champions. Additionally, caretakers can also potentially fill this position.

4.6.3 Caretaker

An indirect effect could be reached if the caretaker would be informed and they would be supported to transfer their information to the tenants. The caretakers have a key position in energy saving programs in schools and companies, as they know the technical devices and the consumption behaviour of tenants. Therefore, they could take the champion position in cases of implementing environmental procedures in companies. A problem here is that the job of the caretaker is very often off-site as communication technology today allows to control the heating centrally and other work is out-sourced to service companies. Therefore, if at all, only one tenant has a small responsibility for the house. However, as a caretaker very often gives the tenants a feeling of security, housing companies have started to reemploy the caretakers for their houses.

4.6.4 Information

The right amount of information given in the right way is crucial for the success of the whole concept. These are the key aspects, even when the modern environmental psychology points out that information is not the only aspect. The information level of most of the tenants was not sufficient. In addition, the curiosity of them has to be reached. Perhaps it would make sense to put an advertising or public relations company in charge of such a concept.

4.6.4.1 Content

The information given to the tenants should be built up like a website, first a summary of the most important things, short and precise. If further information is demanded, the tenants should be able to get them easily. However, this information should not be included from the beginning, as too much information would only demotivate the tenants that are not that deeply interested. Pictures should be used and the language should not be too technical. One brochure, letter or seminar should be available for each distinct topic. These should have a consistent layout, size and font. If seminars are offered the tenants should be motivated to experience the use of technical devices in the seminar, possibly bring their own devices and learn how to use them correctly, and later obtain information-pamphlets that they can bring home where the information can be read again later. Prompts that they can put on switches or devices should be offered to remind the tenants of the correct behaviour.

4.6.4.2 Information Media

In Germany, regional TV is not consumed very much and advertisements via nationwide TV are too expensive by far, even when the tenants use it most frequently. TV can only be used to create larger publicity for projects like this over the borders of the settlement, but not really to reach the tenants. The second most used medium was newspaper, which also has a too broad scope. Nevertheless, as the focus group is located so close together an initial method of information transfer to the tenants is to start with pamphlets and newspaper advertisements for a meeting where the tenants could be taught more energy conserving behaviour. The letters regarding the interviews for this survey were spread in half hour and some tenants read them so well, that they could tell the author that the date on the letter was wrong. The pamphlets should be short and precise. In general, information pamphlets should not be longer than one A4 page [Theven, 2003]. The problem with letters is that even when they are read they are forgotten very fast, so the letter can only be an introduction or an invitation to a more personal communication. In the Wuppertal Institut, good results were achieved with a calendar that, every month, offered an aspect on how to conserve energy, water or waste. The design should be professional and the information given there must be short and precise.

Brochures can be offered for further usage at the information event in the information centre. However, it has to be taken into consideration that many people of low education are very often not motivated to read. Therefore, a video could be useful, especially as most tenants choose the TV as their media of choice. A video is also perceived as something special, so the chance that people will see the video is higher than reading a pamphlet. Informations over the Internet are problematic yet, as most old people and people with low education have no Internet access yet, but this will change in some years. Than the Internet will be the Information medium of choice as it already is today for young and high educated people.

4.6.4.3 Information Centres

An information centre in the settlement or at frequently passed point is likely to be useful. There, it would be possible to run information events at regular time intervals. Most energy suppliers already have information centres in the city centres. There, everybody can obtain free information about power, gas and water, how to conserve them and how to utilize them in the best way. Usually, this is used by the energy supplier for marketing to offer the consumer a service portfolio, as they cannot compete on the price [Weiser, 2003]. In Bielefeld, around 6,000 people use this offer annually. This is around 5% of the inhabitants of Bielefeld.

The information events should commence by acknowledging the ways in which some tenants have already saved energy, but also make them realize that these old ways were not always completely right. Most of the pensioners had the opinion that they were already using energy correctly, so to teach them how to do it "right" could create barriers of acceptance. These information events should be done at variable times. The time when employed men are coming from the work is usually the evening. Nevertheless, at this time, some pensioners do not like to go out onto the streets and in traditional families; the women bring the children to bed. So, an event should always be offered at least once in the morning when the children are in school and once in the evening. In addition, events only for women are effective, as they do not have to be afraid to ask "stupid" technical questions in front of the men that claim to know everything. Further, the holidays of the major cultures in the settlement should be respected. It would be ideal to offer the events in English, Russian and Turkish, the main languages of the immigrants in the settlements.

Further, the information centre can be used to teach caretakers, students or planners and to run publicity campaigns for the involved actors.

4.6.4.4 Schools

The children of the settlements can be reached very easily and cost effectively by energy conservation lessons in school. It is possible to reach a large number of children at once in the schools and these children can transfer the methods of energy conservation to the households. Children usually like to teach their parents and the parents will either start to think about information they already had or find ways to cope with the behaviour of their children. A good way to start this is to run so-called "school projects" where the school is surveyed by specialists that teach and motivate the caretaker and the children how to conserve energy. These types pf projects originally had the purpose to reduce the energy consumption in the schools. The cost-effectiveness of these measures is proven. The savings of behavioural aspects only that can be reached in these types of project are around 10-15% of power- and gas bills [Meves, 2003]. This needs, especially in the beginning, intensive support and personal contact. Later on, the concept has to be taken further by the teachers, as the schools need a time of seven or eight years to properly internalise the concept in the school processes and schedule [Gramckow, 2003].

The integration of the parents can be done at a festival where the school is used as an integration point and the tenants are motivated to improve their energy efficiency at home, while the children are doing this in the school. Here the actors can come into an interesting situation as the schools are run by the municipality and the caretakers are employed by the city, but the teachers are employed by the federal state or the county. The teachers should also be involved in the process. A combination of the school festival and the dwelling festival described in Section 4.6.5 is possible.

4.6.5 Dwelling Festivals

Festivals organized in the dwelling can, on one side, create communication between the tenants, as the festivals have to be first organized. It is also a good chance to integrate the various nationalities and cultures. Moreover, a festival can give the tenants a feeling that they have organized it, so they perceive a success after an action. Therefore, festivals are a good way of implementing a "Champion". The "Champion" that leads the organisation of the festival can build a reputation by this and come in touch with the people. The tenants should organise the festival themselves in the way that they like it, but it could be a good chance for a housing company to support the festival financially and ideologically to say "sorry for the inconvenience" after the renovation. In addition, a festival is a good way to earn money for a tenant association that also could present itself at this festival.

4.6.6 Dwelling or tenants association

To build a local nucleus of tenants it is possible to support the tenants to establish an organization for the dwelling. This foundation has to be established by the tenants and the foundation, and later the organization, can only be supported, but not be influenced, by the housing company. The housing company would lose direct influence and the power of the tenants will probably be strengthened, especially against the housing company. Therefore, on the first look it is unlikely by the housing company to support such a foundation. Nevertheless, two reasons can be given in support of this measure.

Energetical modernisations are done by the housing companies to raise the value of the flats. However, the perceived value for the tenants, that in the end justifies the rent level, is mainly dependent from the value of the settlement and by that very much dependent from the level of comfort that the tenants perceive by living in the settlement. This level of comfort can be raised when tenants can reach a higher level of identification with the settlement especially, when they have the feeling that they can decide important things. Tenants that have the opinion “we cannot change anything anyway” will perhaps not show high resistance to the rising of rents. However, these tenants will also not care when old people feel uncomfortable about going out in the evening, when vandalism occurs or when smaller repairs are needed. As the financial aspects such as rent level are in any case restricted by laws (See sections 5.1&5.2), a law complying housing company should not have significant problems with the tenants in this field. Therefore, this argument should not hinder modern housing companies to have a close relationship with the tenants association instead.

The second argument in favour of dwelling organizations is the expectation of lower administration costs of the dwellings. As the tenants organize more small works themselves and address minor complaints and conflicts internally, the amount of necessary administration works can decrease. Administration currently provides a significant cost burden for housing companies and examples as the cases in Münster and Freiburg have proven the predictions of lower administration costs (See section 7.2).

For a dwelling organization to be successful, the tenants have to want this success themselves. If the initiative in the dwelling is low, it can be supported with, for example, financial support for festivals, but it cannot be forced. Probably, in many cases, the organization will fail. However, it may be worth a try.

The organizations also need a certain budget that they can use for repairs and modernizations. Further, they need influence on decisions about the settlement, perhaps even on decisions regarding incoming tenants.

To support these dwelling organizations in the single dwellings, it is possible for the relevant actors in a dwelling project to create a coordination agency where the communication between the actors happens directly. In the meetings of this coordination agency, goals that a dwelling project should reach like rent level; consumption of power, water and gas; the happiness of the people with the dwelling; cleaning and renovations can be discussed. These goals can then be referred to the dwelling organization. If done right, the tenants have a more direct influence on their dwelling situation, with a possible outcome that the happiness of the tenants rises, the complaints decrease and costs for administration, cleaning and small works decrease [Bischoff et al., 1999]. For the establishment of dwelling organizations, the housing company should first test the outcomes of such an organization in some dwellings, as usually, experiences are lacking in such a company. This would need, in the beginning, relatively high support and some scientific advice and evaluation. However, later, experience will show how far this concept can be used for other settlements.

5 Political aspects of German Cases

This chapter explains the situation of all the German cases that are described in the chapters 6&7. It includes the financial (See section 5.1) and legal (See section 5.2) situation that is similar for all German cases. How far this situation can be transferred to other countries is not known.

This study should review the planned steps of the renovation and show improvement possibilities by an integration of the tenants in the planning and execution of the renovation. To be able to do these proposals a survey of the tenant energy consumption, attitude and behaviour was done. The findings were compared with results from other settlements in Germany.

The cases that should be compared here are cases of Multi Flat Dwellings with different energy efficiency concepts. Some were renovation cases but also cases of newly built energy efficient houses were surveyed. All of the cases showed besides the technical improvements of at least low energy building level more or less intensive integration or information aspects of the residents. These cases were selected after and extensive survey of literature about energy efficiency in the German housing sector.

In Germany a stock of 15 Mio. flats in Multi Flat Dwellings (MFD) is existing. Fifty percent of the building space in Germany is rented. Of that rented flats the most are found in MFD. This is a huge potential of energy conservation with a group of users that has only limited influence on renovations that are done on theirs houses. These people do not decide by their environmental consciousness to build an energy conserving Passive House or cannot afford it. How they can be integrated in a program of energy conservation shall be shown in this study (see section 2.3). It should be shown how these people can be reached to reduce their energy consumption, what could make them consume less and how this can be integrated in a renovation project. Renters are especially interesting not only as they build a large group of tenants but also as they from experience identify themselves less with their houses than owners do and the motivation […] to change their behaviour is lower [Hübner & Hermelink, 2001].

Here the general outline of cases in Germany is displayed to show the common ground of the cases. This is not always possible as Germany due to its federal structure has different legislations and support programs dependent from the federal state. However, in general, legislation and financial figures are the same.

5.1 Legal aspects

Germany as a federal state has various different levels of law. The highest level that influences economic situations in general and especially competitive law is the EU legislation. The next level is the national law, then the law of the federal state and the legislation of the commune. While the federal state and the national state have direct influence on the next highest level the commune has no influence on the legislation on the federal law. The legal aspects in this case are mainly financial aspects. Standard and regulations for the technical aspects of the renovation are also given on various levels. Most standards are today moved from the national level to the EU or even to international standard (ISO) level. Nevertheless, of these standards only the following are of interest in this case.

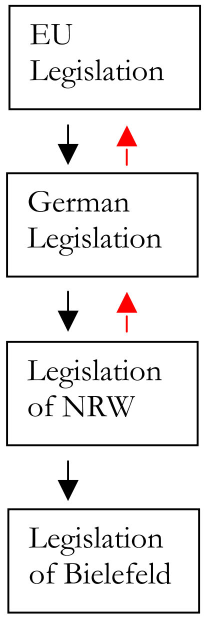

Figure 9, Hierarchy of legislation in Germany

5.1.1 ENEV

The predecessor of the current ordinance, the WSVO 95 mainly governed the maximum heat losses of house surface areas. However, since 2002, the Energy Saving Ordinance (Energie Einspar Verordnung, ENEV) also included a calculation of the heating system and fuels, to make it possible to internalise the Primary Energy Consumption of the heating of the house. This is calculated by:

Equation 4, Equation of the primary energy consumption of heat and hot water supply [Ries, n.D.]

$$Qp = (Qh + Qw)*ep$$

- Qp: Annual Primary energy demand
- Qh: Annual demand of heat energy
- Qw: Addition value for Hot Water
- ep: Constant value for the heating system based on DIN V 4701-10

The limits demanded of the Primary energy consumption can only be reached by the use of insulation and efficient boiler techniques. In general, the insulation and boilers demanded by the ENEV have to be quite efficient. The only criticism stated is that an efficient boiler can compensate for insulation that is relatively weak, when compared with the goal of implementing the NEH standard for all new buildings. However, even with these drawbacks, the ENEV demands a good insulation level, also including old buildings that were previously excluded. Therefore, until 2005, old boilers from prior to 1978 have to be exchanged. In addition, the ENEV requires certain standards of insulation when major changes in the façade are performed.

The ENEV is a national ordinance.

5.1.2 Mietrecht (Rental law)

Rental law in Germany is based at the national level. It is mainly governed by the "Bürgerliches Gesetzbuch *(Civil law book)*," 1996; §§ 535- 580 and the "*Gesetz zur Regelung der Miethöhe (Law of the regulation of the level of rents)*," 1995; §§ 1-17. These limit the level and increase of rent. Rent is split up into a so-called "Cold Rent" that includes the costs of the flat, maintenance, profit of the housing company, etc., and "Secondary Costs" that include waste, insurance, water and heat. While waste, insurance and water are usually calculated for the whole house and then split equally by the number of flats, tenants have the right to receive their own bills for their respective heat or gas consumption. This is usually calculated once per year and tenants that were paying a certain sum every month receive money back or have to pay more, dependent on their consumption. The heat or gas costs are usually automatically transferred in one sum together with the rent and the other secondary costs from the tenant's bank account. The tenants receive only one annual bill over the previous year's payments. Due to this payment structure, most tenants cannot determine what proportion of this payment is for rent and what is for gas, water or waste. The housing companies are only allowed to make profit from "Cold Rents" and have to pass on changes in the other costs to the tenants. The level of "Cold Rent" is governed by the "Mietspiegel *(rent mirror)*", a communal document that shows the average rents for flats of a certain age and quality, and defines the maximum level of "cold rent" for houses. The "Cold Rent" for the houses in Sennestadt may be in a range of 4.02€/m² to 6.02€/m² [Stadt Bielefeld, 2003]. The quality of the flats before renovation and their local area place them in the lower section of this range. The "Mietspiegel" provides a limit for the upper level of rent in a city (§2). Further, it limits the permissible increase if rent is lower than the upper level of the "Mietspiegel". An increase of rent after modernization works is possible. This increase may be annually 11% of the modernization costs, so that a modernization pays off after nine years (without interest) (§3). This is only possible for investments that increase the value of the flat. Therefore, in the Sennestadt case, the new balcony of the flats is an investment that justifies an increase, whilst the renovation of plaster and paint will not justify an increase of the rent.

Modernization that reduces the secondary costs of the flat justify an increase of rent up to double the amount of the value of the conserved energy.

This legal construct should be enough to motivate landlords to modernize their properties, as the cost of the modernization can be returned to them. However, this is always capped by the "Mietspiegel". So the BGW may only raise the "Cold Rent" to a level of 4.17€/m². Based on this level of rent, the BGW pays more for the renovation works than they will earn directly. The tenants, on the other hand, will receive a saving of approximately 30% of their heating bills *(DQ 3)* [Kühn, 2003].

5.1.3 Bundessozialhilfegesetz (Welfare law)

As a number of tenants in the settlements receive welfare payments, the structure and legal conditions of welfare payments are of interest here as well.

Welfare law is national law that regulates the amount of welfare payments poorer people receive. The lowest level of existence (Existenzminimum) governs the amount of the base payment. This also includes lump sums for power, water and cooking energy. Rent and heat are paid separately. The Welfare Department provides figures as to how high the rent may be, dependent on family size, and the tenant may then decide to take a flat that costs that amount or pay a surplus, if hiring a larger flat. Payment for heat is similar: the welfare office receives figures of average heat consumption in flats from the Stadtwerke. These figures provide the level of heat consumption that a tenant may not exceed. If the tenant consumes extra, the welfare office can cut his payment by 20%. The landlord assumes the risk of tenants running up debts. The welfare office has to determine rents using the "rent mirror". Therefore, the welfare office cannot allot higher rent payments to a tenant living in a house with good insulation and low heating costs. The welfare office is a contract-partner only of the tenant, not of the landlord. The welfare office also provides tenants with technical appliances when needed. These appliances are supplied by a dealer that has competitively outbid other dealers. Price of the appliances is the key factor, so higher costs for devices with low power consumption can not be paid [Wittler, 2003].

5.2 Financial Aspects of energy consumption and conservation

Reduction in energy consumption is the result of a highly complex system. Reductions can be achieved by technical improvements and behaviour changes. Possibilities of technical solutions and aspects of behavioural change already have been outlined in Chapters 3 & 4. As these aspects have to somehow be realized, financing of the various aspects has to be secured. Very often, this is influenced by legal constraints and supporting programs of various political actors. The different elements of the system have to be kept in mind by planning a program that focuses on the successful reduction of emissions

5.2.1 Social costs

The correct calculation of social or external costs is a difficult task and requires a broad range of assumptions to be made. Due to this uncertainty, these calculations usually result in a broad range of costs. As a result, the figures used here should only display the different calculations by internalising the social costs. Herz mentions that the thermal insulation of houses has external benefits of job creation and a net impact on GDP of 1,75 €cent/kWh, whilst heating based on power creates costs of 1,60-1,74 €cent/kWh mainly due to climate change and pollution [Herz, 1994]. This would make insulation of buildings like this 3.35 €cent/kWh more interesting to municipalities or other political entities than to market-based actors. Due to the age of these figures and the different situations of every case, they should not be used in an absolute sense, however they clearly show that the community, and not just market actors, should have a higher interest in energy conservation. Hohmeyer gives a range of external costs of different fossil fuels. Mineral oil is stated as 4.5-33€cent/kWh and hard coal as 2.7-22 €cent/kWh, but in all cases the use of renewable fuels reduces external costs by a factor of 2 as compared to gas, the fossil fuel with the lowest external costs. Further, he points out that the use of power from renewable sources can reduce external costs by 10.65-11.45 €cent/kWh [Hohmeyer, 2002]. Therefore, it can be stated that political actors should have higher interest in energy conservation than market based actors so long as the external costs of the energy consumption are not internalised (particularly as the correct level of external costs is so difficult to define).

5.2.2 Financial structure of a modernization

The financial structure of the concept of conservation can be detailed as the following:

Costs for the works have to be separated into modernisation costs and maintenance costs.

The maintenance costs have to be paid by the housing company or landlord, as they have to be done anyway to maintain the house's value. This includes paint, plaster and the renovation of worn out parts.

A certain proportion of modernisation costs can be added to the tenant's rent (See section 5.1.2). This includes improvements to the insulation or a boiler with a higher efficiency. Nevertheless, the level to which the rent can be increased is limited.

In the case of the renovation project in the Sennestadt settlement the housing company will have higher costs to carry than it will receive back. This is regarded as a long time investment intended to keep the rentability high [Kühn, 2003]. However, the company has to keep track of expenses and profits. These profits are tenancy rents and their level must be maintained within a certain range governed in rental law, as described above (See Section5.1.2). As the costs will only be partially paid back, the company is trying to reduce these.

5.2.3 Public support

One opportunity for this reduction is to use public support programs. These programs require a certain standard of the renovation works. A total overview of all the support programs that can be used is not possible here due to the sheer number, and the data would have little value as the programs change frequently and are different in most federal states. The structure of Germany as a federal state in the European Union (EU) creates this large number of support programs. The following description of the national support program should reveal the underlying context and its necessity due to its importance to the renovation sector.

The main program used by the BGW in the Sennestadt case (see section 6) is the "KfW-CO_2-Gebäudesanierungsprogramm" [KfW, 2003]. This program is provided for the construction of energy efficient buildings and the renovation of old buildings by the KfW (Kreditanstalt für Wiederaufbau), a national state bank. The program stipulates that the houses should not produce more than 40 kg CO_2/m^2*a for power, hot water and space heating. Further, it stipulates a maximum transmission heat loss of 0.4 W/m^2*K, a solar covering value of not less than 0.25 and the usage of at least one active solar system (photovoltaic or solar heating) [Merkschien & Brieden-Segler, n.D.]. The program supports renovations with low interest loans, for certain improvements performed. The maximum support of 250€/m^2 is granted when a house's emissions will not exceed a level of 40 kg CO_2/m^2*a after renovation [Energieagentur NRW, 2003c; KfW, 2003]. This entails insulation with heat losses of around 100 kWh/m^2, and generation of heat and power by at least a GCH, solar collectors and PV or other efficient means.

In addition, other programs support certain technical devices such as ventilation systems, biomass boilers and solar heating. Moreover, a small number of programs support the consultancy work of engineers contracted by landlords to create energy conservation systems. To what extent the programs can be joint-funded and which one is most effective has to be determined individually.

The public support programs do not include special demands and offers for changes in behaviour. Due to the payment structure, with caps for rent and rent increases, there is no strong interest to affect tenant behaviour in the field of energy consumption [Schwarzhoff, 2000].

5.2.4 Ecological rent mirror

Higher costs and lower revenues limit the motivation of landlords and housing companies to improve the energy efficiency of the houses beyond a certain level. An integration of the house energy use into the rent is therefore demanded by researchers and associated parties [Hinz & Knissel, n.D.; Knissel et al., 2001; Knissel et al., 2002; Kühn, 2003]. The ecological rent mirror was developed with this integration in mind, by researchers of the Institut

Wohnen und Umwelt (IWU), It reduces the general cold rent (green area column 1&2) for all buildings. Landlords now have the chance to improve their house with better insulation that, after being registered, allows them to claim higher total rents (green and blue area column 2). The tenants profit from lower heating costs (red area), landlords from the higher "cold rent", so that the profit, that presently only the tenant receives, is shared. Therefore, the costs of conservation are regained more easily by landlords. But this calculation is criticized by other actors, who claim that landlord knowledge of this field of energy conservation and cost savings is limited, that they resent making unprofitable changes to house energy usage, or that these financial aspects are not understood by landlords [L. Schneider et al., 2003]. Due to these reasons, existing public support programs are widely under-utilised [Vesper, 2003]. Therefore, the ecological rent mirror is criticized for pulling the wrong trigger by assuming motivation can be increased purely by financial aspects. This criticism may be correct when this financial tool is used without regard to other aspects of motivation (see sections 4.2&4.4). Anyhow, a combination of the ecological rent mirror together with marketing aspects could be a good way to motivate landlords, especially as large housing companies are not particularly against renovation so long as it is financially viable [L. Schneider et al., 2003], and the average landlord could be motivated to follow this lead. This should be combined with an information campaign, but lobby groups and journals for landlords exist that could perform this efficiently.

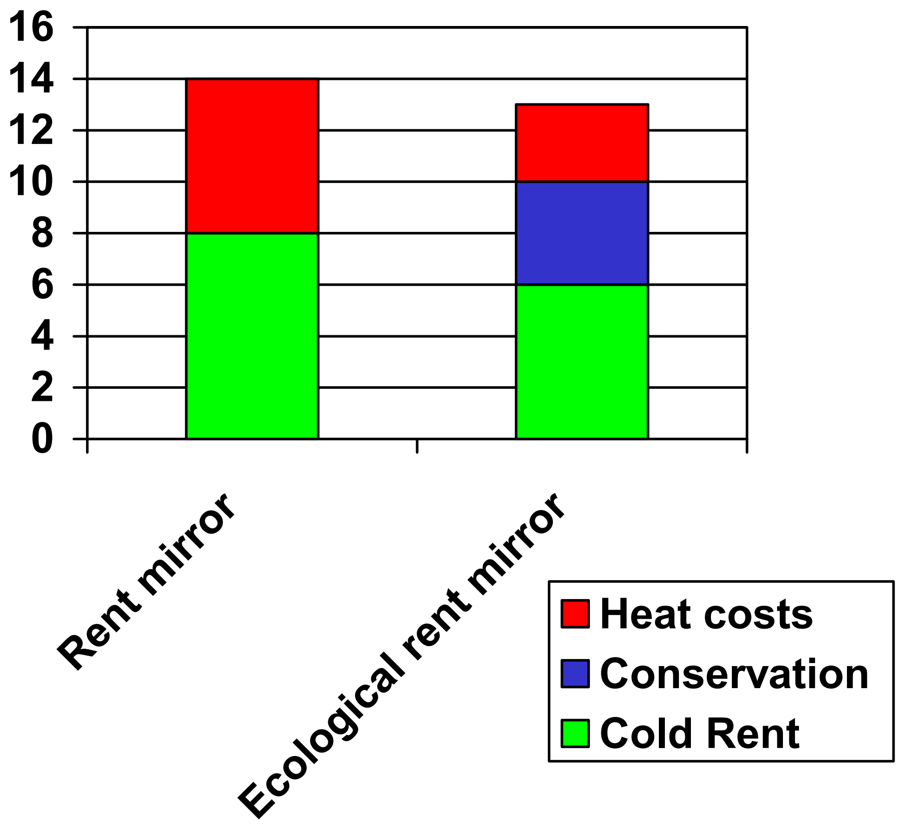

Figure 10, Cost structure ecological rent mirror [Based on Knissel et al., 2002], (Figures not real)

Whilst housing companies have higher costs due to this renovation work, the tenants profit from a reduction in their heat bills. As already stated, the payment structure of power bills is different to the bill for heat consumption. In Germany the power market is a liberal market, where every consumer can choose the power supplier they wish to have. As this power supplier was, some years ago, the municipal Stadtwerke, most tenants remain customers of their local Stadtwerke. The Stadtwerke usually also run the local grid. As tenants are normal customers of these power suppliers, they receive normal bills from the power supplier or grant similar access to their bank account. For the housing companies, there are no aspects of the power bill of particular interest. Accordingly, the replacement of electrical devices such as an old power heated water boiler with new gas fired central heating system is purely a cost aspect for the company.

An additional way for larger housing companies to reduce works' costs is to standardize the works and to create frame contracts with construction companies, as they usually have a large housing stock. This gives good prices and a certain level of security as both sides are familiar with each other and build mutual experience. However, these standardized contracts can limit the efficiency of improvements where the contract partners doggedly stick to an old contract.

6 The Sennestadt Case

The basis of this study is a case of renovation of a dwelling area in Bielefeld, Germany. In this chapter, the circumstances of the settlement are described (See section 6.1) as are the renovation works that are performed in the surveyed dwelling (See section 6.2). Further, the aspects of tenant integration performed by the housing company are described, and the attitudes and knowledge of the tenants are elaborated upon in section 6.3, based on an interview process (section 6.4). The full interview can be found in the Appendix. To finalize the description of this case, the actors involved are described in section 6.5.

6.1 The Sennestadt settlement

The settlement in Bielefeld Sennestadt was build as an entirely new settlement by Bernhard Reichow. The settlement was planned with consideration to the most modern aspects of housing in these times. It has a total size of around 24 square kilometres in the southeast part of Bielefeld, lies close to two Highways and around 10 km from the city centre.

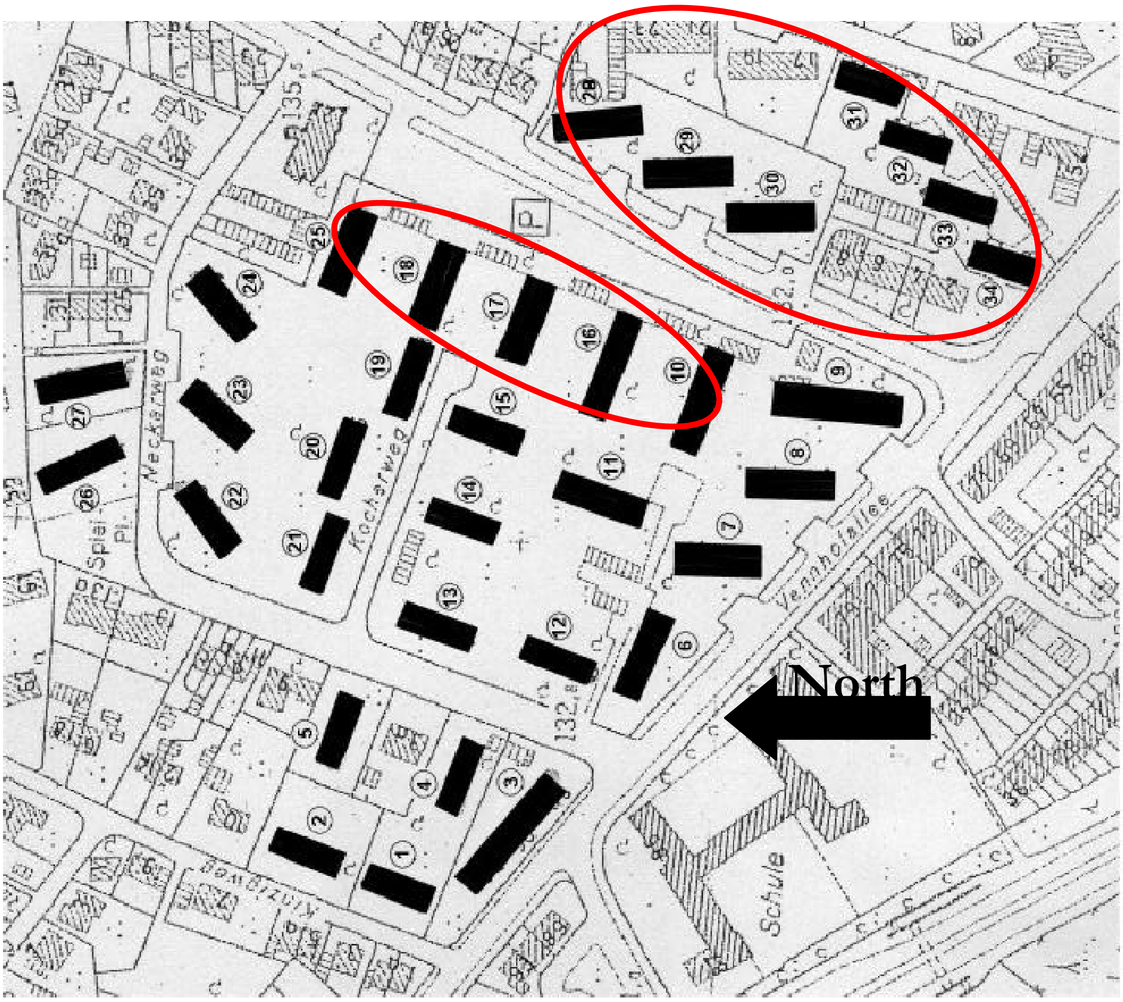

Figure 11, Surface-plan of the Sennestadt settlement

The communal housing company BGW (Bielefelder Gemeinnützige Wohnungsbau-gesellschaft) owns 11.000 flats in Bielefeld and is the largest housing company in the region. In Sennestadt the company owns, amongst others, a dwelling area of 34 Multi flat Dwellings (MFD) with together 375 flats. These houses were built between the years 1952 and 1968.

The surveyed settlement has houses very typical of those built in the 1950s and 60s. The tenants have, on average, a low income; the ratio of unemployed and immigrants is relatively high. The settlement is not very attractive for new tenants due to the considerable distance to the city centre and the proximity of two highways and a larger street. The first generation of tenants that moved in after the settlement was built are now growing old, and new tenants are mainly immigrants and people on welfare. To reduce the risk of creating a social-problem area and as the houses were in need of a renovation, the company decided to undertake an energetic renovation to raise the value of the flats and to make the settlement more attractive. To sell the aspect of cost reduction to the tenants can have a positive effect on the value of the flats.

6.2 The energy conservation concept

As the houses were in incidental need of renovation, the high consumption of energy became a focus of the planners, and the question arose as to how to reduce this environmental problem and cost factor. One goal of energy efficiency was to reach the margins of the financial support program "KfW-CO_2-Gebäudesanierungsprogramm". To reach this level of energy efficiency an energy concept was developed by the e&u energiebüro. The authors of the concept calculated the costs of the use of various heating systems and the expected CO_2 emissions of these heating systems. Based on this concept, the BGW designed the renovations and started the work with 12 houses (red circles). This group of houses is termed the 'first construction section'.

The renovation works includes

- Façade insulation of 12 cm Polystyrene (035),
- Roof insulation of 16 cm Glass-fibre (035),
- Insulation of the cellar ceiling of 8 cm Polystyrene (035),
- New window panes with an U-Value of 1.1,
- A natural gas cogeneration plant for houses No.31-34 (see Figure 11),
- Heating systems with natural gas condensing boiler in the other houses,
- Photovoltaic roofs on houses 10 and 16 (7.5 kWp each),
- Solar thermal roofs on houses 17 and 18 (32 m^2 each),
- Also outside of the first construction phase PV and solar thermal heating on houses 4-6,
- Improved insulation in house No. 26, with the ventilation system reaching a level of less than 40 kWh/m^2*a *(DQ 3)*,
- A natural gas fired fuel cell heating in house 24,
- Also new balconies, entrance doors etc. that have no effect on energy use.

The houses have calculated heat losses of around 100 kWh/m²*a *(DQ 3)*. Instead of a gas-condensing boiler, a wood pellet boiler was calculated to reduce the CO_2 emissions from heating. These emissions are lower than those of the cogeneration plant. The costs are 10 percent higher than the costs of a gas condensation boiler, but the emissions are only half those of a gas condensation boiler *(DQ 3)* [Merkschien & Brieden-Segler, n.D.]. Nonetheless, the BGW decided to run with the cheapest boiler, given the assumed tenant attitude.

Further solar heating and/or photovoltaic systems are proposed on houses 3, 19-21, however the decision has not been undertaken. A photovoltaic system on house No. 3 could be a good marketing proposal for BGW as this house has a large roof direct facing a crossroad.

Houses no. 10 & 16, already renovated in 2001, did not receive a hot water supply over the central heating. The electrical boiler was not replaced. Electrical heating of water consumes large amounts of primary energy and creates high costs for renters. Therefore, tenants are to receive water saving faucets and showerheads.

The use of the fuel cell is a test drive of a fuel cell company that will end in one year. After that, the house will also be equipped with gas condensing boiler. Due to the huge costs of fuel cells, they are of no present interest, especially as, when powered with natural gas, they are not much more efficient than CHP plants.

6.3 Aspects of the tenants

6.3.1 Information campaign

The BGW informed the tenants in advance of the renovation works. Pamphlets were sent to the tenants. Information sessions were held wherein the tenants could obtain the information they needed and ask questions. During the renovation works, a weekly question hour was held and the tenants provided with the possibility to speak directly with the building supervisors that are daily on the construction site. For these information sessions and weekly question hour, the BGW and the Stadtwerke ran a small pavilion in the settlement, also used for marketing.

Figure 12, Information pavilion in the Sennestadt settlement

6.3.2 Inhabited flats during the renovation

One main goal of the works was that the tenants would be disturbed as little as possible by the renovation. Therefore, it was decided to perform renovation works only where the tenants could stay in their flats. The resultant house insulation value was the maximum possible that could be achieved with tenants in residence. Better insulation of the surfaces is possible, but then the exchange of whole windows would become necessary. This would create extensive work in the flats of the tenants, making it necessary for them to move out for a while. In a settlement like Sennestadt, moving the tenants out could be problematic as the old tenants are not partial to temporary dislocation and the younger tenants could find more attractive, central places in Bielefeld. Therefore, it is risky that many tenants would potentially not return. This could even speed the effect of "social dis-mixture" that the renovation is supposed to mitigate [Hertrampf, 2003].

The tenants were not asked if they would accept a slightly higher heat price to reduce emissions by running a wood pellet boiler. Here arguments such as the closed supply of the pellets from the nearby woods could have been good as well.

6.4 Tenant interview

To find out the knowledge and attitudes of the tenants, interviews were performed with 38 tenants. The results can be found in the appendix. The following summary of the tenants' answers of the tenants is divided into aspects of the Model of behaviour change.

6.4.1 Household background (LC 7)

The households have a lower income, a higher unemployment rate, a higher proportion of immigrants, a lower education level of household heads and are populated with more residents than the average German household. Therefore, the average flat size per tenant is lower than the German average. In addition, a high rate of pensioners lives in the settlement. This shows a heterogeneous structure of inhabitants, pensioners that are living in the flats since the houses were built and low-income groups of unemployed and immigrants that moved into the dwellings in latter years. A significant potential of conflicts between the different groups could be discovered during the interviews, even when this was not the topic or a specific question of the interviews.

6.4.2 Knowledge (LC 3)

It can be said that the knowledge level of the tenants in the field of energy conservation is low, even when tenants are interested in more information pertaining to this issue. The tenants do not appear capable of acquiring this information themselves, so they must be directed to it by an external source. The information has to be offered in a way that reaches the tenants efficiently. All tenants received information pamphlets when they moved in, but almost none knew about them or how to obtain further information on this topic. Therefore, effective information transfer should be considered. This is the first and crucial point that should be focussed upon by a tenant integration program.

6.4.3 Attitudes and Values (LC 4&5)

The values of the groups seem be very different. In general, the tenants rank the value of the environment lower than the average German, but the costs of the energy consumption are a significant cost factor for the tenant households. The general perception of energy conservation is that it is a cost reduction. In the surveyed migrant families, the environment does not have such a high value; here the financial value of energy conservation rates most highly. Pensioners do often save energy because they have learned this in their youth. As money is also one of the main values of tenant families, this should be the predominant value to focus upon, along with health and environment to support the arguments.

Only for some tenants is the environment important. This can be found especially amongst families with children. Here health has even a higher value. This could be derived from the tenants' living conditions, as half of the interviewees reported mould in the flats before the renovation. The chances of mould reduction, better internal climate and less emissions could be used here to reach tenant parents.

The health aspect could further be combined with the aspect of comfort. This possible improvement in the level of comfort is important, as even the tenants of the high conservation Passive Houses in the Lummerlund case (see section 7.1) were not willing to trade off their comfort for energy conservation [Flade et al., 2003]. Comfort should never be less than before and a higher level of comfort should be used as a marketable value as well.

The use of financial value has the additional advantage that it is not necessary to explain the processes that are happening in the environment. The problem of global climate change is mainly accepted and understood in high education groups, while lower education groups understand this more loosely [Bauer et al., 2002].

6.4.4 Incentives (LC 6)

Almost the same can be said for incentives as has been said for values: that is, the costs of energy consumption are already a negative incentive strong enough to motivate tenants to conserve energy. Other incentives will probably not be necessary; besides, small offers such as "foot in the door" offers are used to motivate disinterested tenants.

6.4.5 Perceived behaviour through feedback (LC 2)

Feedback should be given by a frequent publishing of gas, water and electricity consumption, of room temperature and humidity. The tenants demanded open and clear publishing of this information. This should be calculated if the heating control devices already planned can not be equipped with hygrometers and meters for power and heat consumption. If this is not possible, every household should receive a heating bill showing the consumption of the last month as separate from the 'cold rent' bill.

6.4.6 External offers (LC 6)

The external offers related to heating provided to the tenants should be enough combined with insulation and the new boiler. Ventilation is the field in which the tenants should receive more information and prompts, e.g. hygrometers that show tenants the humidity in the flats. To conserve hot water saving faucets and showerheads were given to the tenants in houses 10&16. This offer could also be extended to other tenants.

As power consumption is not related to the housing company it is difficult to justify external offers to the tenants. However, energy conserving light bulbs could be used as presents or quiz-prizes to excuse the disturbance during the renovation works, as well as to motivate tenants to come to information sessions and to read information pamphlets thoroughly. This also can be done by the second main actor, the Stadtwerke (See section 6.5 below).

6.5 Actors involved

A number of different parties are involved, more or less in depth, within the renovation project and settlement. The main actor beside the heterogeneous group of tenants is BGW, owner of the houses and initiator of the renovations. BGW is a daughter company of the municipality of Bielefeld (share of 75%), run under business conditions.

A second actor is the municipal energy and water supplier, the Stadtwerke. The Stadtwerke is similar in that the municipality of Bielefeld is a 50% shareholder. This makes the municipality the third interesting actor; due to these connections, the political situation can be interesting for the first two parties named and can have an impact on the implementation of concepts of energy conservation. Particularly, the municipality is presently almost bankrupt, and so is not able to inject money into projects like this.

In the Bielefeld town council, the conservative party, together with liberal and a local party, hold the majority. This majority rejected the application of the social-democratic party within the town council to develop a support program for the energy-use-related renovation of existing buildings [Rat der Stadt Bielefeld, 2002].

Beside this communal organ of the municipality, a less important party includes the superior legislative organs that mainly govern support programs, laws and ordinances. Additional support comes from the state Northrhine-Westfalia [Merkschien & Brieden-Segler, n.D.]. The KfW also runs support programs for refurbishment and now is in the midst of an attempt to obtain funding from the EU commission. Additionally, these actors are involved in legislation as shown in section 5.1.

Figure 13, Flags of the BGW and the Stadtwerke

Other involved parties include the Mieterbund (Renters association) that supports tenants in legal and financial questions, and offers brochures and information about energy conserving behaviour. The Mieterbund can be useful for the integration of the heterogeneous variety of tenants' interests into the conservation concept. The Verbraucherzentrale (Consumers central) is a similar organisation with a broader focus on all consumers, but also able to provide tenancy information, and especially information about the purchase of energy saving devices.

Further parties that should be considered involved are consultants and construction companies performing the insulation works. These two actors are difficult to define as they have only a loose organization level. Instead, associations of these actors like the BDA (Bund deutscher Architekten) or the labour union and local Handwerkskammer (Association of craftsmen) could be involved.

7 Related German cases

This chapter outlines four different cases of German settlements that should be used to understand possibilities and constraints of conservation concepts and tenant integration possibilities. The cases include the Passive House settlement Lummerlund in Wiesbaden (see section 7.1) the renovation project Münster Am Breul (see section 7.2), the EXPO project Hannover Am Kronsberg (see section 7.3) and the reuse of an abandoned barrack area in Freiburg Vauban (see section 7.4).

A general problem of case comparison appeared during this study. The optimal case of energetic refurbishment projects of settlements of a scale similar to Sennestadt did exist, but no data about the integration of these projects was accessible. Some social scientific studies were undertaken on low energy projects but the data were not yet available. The choice was therefore made to select imperfect cases that were described in detail and/or similar cases where data were more limited.

As very good data were available concerning projects of newly built houses, how to compare such houses with renovation projects had to be determined. Before beginning this study, I would have said the comparison is not technically possible, as in newly built houses technical devices and insulation necessary to a Passive House can be included. Because of heat bridges and limited possibilities, wrong orientation and size of windows, and so forth, my thoughts were that the Passive House standard couldn't be obtained in old buildings. That is wrong. Various architects have already proven that the Passive House standard can also be reached when an old house is refurbished [Otte, 2002; von Oesen, 2002], possible even when the house is declared as of heritage value [Viridén, 2002].

However, social aspects of a renovation case are far more different. Integration of tenants in the planning phases of renovation requires dealing with already existent group dynamics. These can be negative such as the existence of resentment against neighbours, as well as the positives of cooperation and friendships. Usually the inhabitants in a settlement of newly built houses are more easily integrated into the planning, especially where they will own them later. However, they have to be reached more individually. This can hinder decisions, such as a central heating grid, as then all tenants have to use heat from this central heating grid.

Nevertheless, the largest problem of building renovation is that tenants must leave their flats for a time when a certain level of renovation is exceeded. This is the case when a ventilation system, or new window frames have to be built in. These changes are basically the prerequisites for a level above the Sennestadt-case.

With knowledge of these limitations, the decision was made to carefully employ the cases of newly built settlements, as benchmarking would have had very limited value due to the low number of benchmarking cases. The cases where a social scientific survey were performed are further described below in detail. The other cases where data were more limited are then described in brief.

7.1 Wiesbaden Lummerlund

The settlement of Lummerlund in Wiesbaden is a newly built dwelling area with 24 low energy buildings (NEH) and 22 Passive Houses (PH) all build as row-houses. The settlement was built in 1997 on a former barracks and almost all houses were sold to inhabitants. The Institut Wohnen und Umwelt (IWU) has extensively surveyed energy consumption patterns and tenant behaviour and attitudes towards these houses, and energy conservation in general.

In 1997, the Passive House Concept was rather new; therefore, the settlement in Lummerlund is the first dwelling area of Passive Houses built in Germany. However, the concept was tested before, and the energy conservation effects were already proven. Passive Houses consume 95% less heat energy compared to the average German housing stock. The Passive Houses in Lummerlund have an average heat energy consumption of 12.2 kWh/m²*a *(DQ 2)*, and a NEH around 48 kWh/m²*a *(DQ 2)*. This heat and the heat for hot water are provided by a local central heating grid. The fuel of this heat supply was not given by the sources. Heat is supplied by radiators in both PH and NEH. Both PH and NEH have ventilation systems, the PH also with heat recovery. To use the ventilation systems appropriately the houses are extremely airtight. They have an air exchange rate of 0.45-0.54 $^1/_h$ *(DQ 2)*, a rather high value for Passive Houses, caused by a lack of real-life experience when the houses were planned.

Figure 14, Wiesbaden Lummerlund [Passivhaus Institut, 2003a]

Because of serial preconstruction both types of houses have 30-40 cm insulation layers. The PH have three paned windows with an U-Value of 0.7 W/m²K whereas the NEH have rather normal double paned heat conservation windows with an U- Value of 1.1 W/m²K.

The houses were planned to give inexpensive dwelling space to tenants combined with very low energy consumption. This financial aspect was also the driver behind the residents' decision to buy the houses. This aspect and others such as comfort and information level were surveyed by another group of the IWU. The results were that the average tenant of the dwelling had a relative high education, a high employment ratio and were living in a young family with children.

The residents were happy that the Passive House Concept actually worked and that they received relatively low energy bills. Criticisms included that some of the houses had defects and that they heat up too much in summer. The modern technology was initially perceived with concern; particularly the ventilation was regarded negatively as tenants had the feeling "of not being allowed to open the windows". This changed over the time to a perception of greater comfort, that windows do not have to be opened any more. Eventually only the noise level of the ventilation was criticised. The tenants did claim in general that their initial concerns about the houses were not proven.

Tenants complained that the information they received was too little. The explanation of the technology was not sufficient. Information sessions provided by the IWU were well frequented and power conservation actions performed and surveyed were perceived positively.

Social aspects of energy conservation were surveyed in Lummerlund as well. The importance of social influence is a factor that definitely should be more focussed upon. As the residents only had the chance to buy finished houses from an investor, a prior-established social network did not exist during the planning phase. Therefore, information sessions were perceived as more valuable in the creation of social networks.

Differences in the power consumption of similar houses are partly caused by the general attitude of the occupants. People who value energy conservation less are less willing to rethink their actions, be receptive to information and change their behaviour. Often after intervention the differences between the behaviour of motivated and unmotivated residents becomes larger.

Compared with life in other houses, the life in Passive- and Low Energy Houses is perceived as normal. Also most occupants of both types said they would move again into a house of this type. They did not accept a loss of comfort in exchange for energy conservation. The occupants of Passive Houses noticed a general shift in their energy conservation behaviour, whereas the residents of the Low Energy Houses did not perceive such a shift.

All figures of the project Wiesbaden Lummerlund are taken from Ebel, Grossklos, Knissel, Loga, & Müller, 2003; Ebel, Grossklos, & Loga, 2002; Flade et al., 2003.

7.2 Münster Am Breul

The district Am Breul 32-36/38 in Münster is a housing complex built at the end of the 19th century as housing for workers. It is located close to the centre of Münster. The dwelling contained 22 flats prior to the renovation, and was reduced to 20 larger flats during the renovation. However, even now with an average size of 30m²/tenant the flats are relatively small. The houses were owned by a private landlord who wished to sell these at the end of the 1980s to an investor intending to demolish the houses and erect a modern housing complex. Most inhabitants moved out; however new tenants together with those remaining formed an association aimed at fighting for their homes. In 1996, the newly elected municipal government bought the dwelling to renovate it together with the tenants in order to secure cheap flats close to the town centre for low-income inhabitants.

Figure 14, Münster Am Breul [Model City Muenster, n.D.]

An architect working closely with the tenants planned the renovation, and the tenants performed support construction work to keep the renovation costs low. The free support work saved the municipality a total of 264,000 DM (137,000€), that is, 4,700€ per inhabitant. At 878€/m² *(DQ 3)* the costs of the whole renovation were significantly higher than the costs of the Sennestadt renovation; however, the houses in Münster were in a far worse condition. The flats had partial bathrooms and coal fired ovens, single paned windows, a humid basement, no noise insulation and toilets in the staircase. The old owner had not performed maintenance work in the twenty years before the sale of the houses. Now maintenance and smaller refitting works are performed or decided by the tenant association that took on the administration from the municipal housing company. This association is also responsible for the collection of the rent; only the risk of unpaid rent has been taken on by the municipality. Previous to the renovation the rents of the tenants were very widespread, ranging from 1.26€/m² to 5€/m². This rent was brought to the one level of 4.50€/m² *(DQ 3)*, and hence by this solution, the administrative costs of the municipal housing company are reduced. The tenant association also organizes and decides upon the new tenants that move in. In general, the quota of tenants moving out is very small.

During the renovation works, the tenants had to move out of their flats for fifteen months, to live in an old school under very bad conditions. Nevertheless, of the original 42 tenants, 40 moved back into the houses after the works finished. This quota is very high compared to other renovation projects.

The improved insulation reduced heat losses by approximately 70%, from 246 to 73 kWh/m^2*a *(DQ 3)*. The tenants own a small gas-fired cogeneration plant ($12kW_{therm}$, $5\ kW_{el.}$) for the supply of heat and power. Power from this plant is cheaper than power from the municipal Stadtwerke, which also supplies other houses in the area with central heat. Therefore, it is understandable that the Stadtwerke were not very supportive of the project. However, they accepted that power consumed above that which the CHP produces was to be delivered to the single customer of "tenant association". Therefore, only one meter has to be read, significantly reducing the costs to tenants, as usually around one quarter of the power bill went to surveying the meter. The tenants now pay a share of the power bill as determined by the respective size of their flat. This complements the intention that tenants should know their consumption as accurately as possible in order to motivate them to conserve (See section 4.4.4). Furthermore, the houses have storm water collection that reduces the use of fresh water for toilet flushing by 900l daily *(DQ 3)*.

The key to the tenant integration was the close inhabitant relationships that already existed prior to the renovation, and that was strengthened by the outside threat of the sale and demolition of the houses. There was also a supportive political situation after the 1996 election, and the moderation of the process by external architects and scientists. The financial constraints of this process, though, reveal problems as the annual profit margin of only 3% for the housing company *(DQ 3)*. In addition, the moderation and evaluation were taken over by the ExWoSt program. The costs for the moderation are assumed as being 20,000-50,000€.

A certain know-how was given beforehand, but the importance of this was rated not so highly. Most of the tenants were not practitioner in construction works and particularly women that had to care for their kids but these people could be involved in the modernization as well. Therefore, it can be assumed that the working situation can be handled by almost all tenants when the organization is done sufficiently.

All figures of the project Münster Am Breul are based upon Bischoff, Hauff, Ingenmeyer, Russ, & Wilke, 1998; Bischoff et al., 1999; Dzulko, 2003.

7.3 Hannover Kronsberg

The settlement Hannover Am Kronsberg is a large, newly developed dwelling area that was planned in connection with the world exhibition EXPO 2000 in Hannover. The whole settlement is intended to incorporate 6,000 dwellings for 15,000 inhabitants, together with infrastructure such as schools, kindergartens and a hospital. In 2002, around half of the dwellings were completed.

In the planning of the settlement, the motto of the EXPO - "Human, Nature, Technology" - was used to create a settlement that incorporated the needs for sustainable development by use of innovative technologies. In addition to concepts for waste, water and resource conservation an energetic concept and a plan for environmental communication were developed.

The goal of the energetic concept was to reduce CO_2-emissions by 60% as compared to the normal standard of newly built houses. To reach this goal Low Energy Buildings were built that are heated by a central heating system powered by two gas-fired CHP plants, and supported by 1,350 m^2 solar heating collectors. Two wind turbines and photovoltaic cells were included for power supply.

Figure 15, Hannover Kronsberg [BauBeCon, n.D.]

Parallel to the planning of the settlement, the communication agency KUKA (*Kronsberg Umwelt Kommunikations Agentur)* was founded in 1997 to inform and integrate the various actors. The focus of this agency is the dwelling's tenants and specialists from the construction sectors such as architects and craftsmen. The KUKA is financed by the municipality of Hannover and the Bundesstiftung Umwelt *(DBU, Federal Environmental Foundation).*

The program of KUKA included, firstly, education sessions for the architects, engineers and craftsmen that were involved in the construction of the Kronsberg settlement. Knowledge of energy conservation in the building sector was limited, so the "students" perceived the lessons as valuable. After the first tenants moved in, they were also given the possibility to go to information sessions, where they were taught how to use technology, such as the ventilation, in the correct manner. Additionally pamphlets were published, a folder created for each house and a settlement journal with updated information. Also, so-called "visiting consultations" were performed in which tenants had the chance to directly show experts where in their flats they had experienced problems with the technology and in turn, the experts could inform the tenants as how to behave in the right way.

In 2001, after four years of work, the results of the work of KUKA were evaluated. The results of this evaluation showed that a clear separation of the success reasons technology or communication could not be given. The combination was very successful and KUKA was evaluated as successful. Tenants knowledge of correct environmental behaviour had increased, and they appeared to have an environmental friendly attitude. The motivation of the elder tenants could be termed as high while the motivation of the younger tenants and especially immigrants rated lower. Due to tenant turnover, fewer tenants knew of KUKA than previously. Continuous inundation of information was rated as the primary problematic point. The municipality of Hannover withdrew its support for KUKA and closed it this year due to the town's problematic financial situation.

The figures of the Kronsberg settlement are taken from Rumming, n.D., and those of KUKA are taken from Michelsen & Danner, 2001.

7.4 Freiburg Vauban

Until 1992, the settlement Vauban in Freiburg was a barrack area of the French army[9], after which it was bought by the municipality of Freiburg to develop it anew. After an urban planning competition and development of a land-use plan, the ground was decontaminated and in 1998, the first buildings were erected. Ultimately in 2006, it should be home to 5000 families.

Figure 16, Settlement Plan, Freiburg Vauban [Forum Vauban, 2003]

For the planning of the settlement the municipality of Freiburg used a concept with extended integration of citizens. This integration was organized by the association "Forum Vauban". The concept was to create a sustainable settlement with high quality housing opportunities for families inside the town of Freiburg, in order to reduce the movement of citizens to the surrounding counties. Therefore, the municipality planned and developed infrastructure for the tenants in the settlement, which included schools and kindergartens, a market place, public

[9] Troops of the Second World War Allies kept garrisons in Germany until it became one sovereign state in 1990. After this, most troops were withdrawn.

transport and a settlement centre. Apart from that, the municipality provided only a loose framework for the newly built houses. This included a minimum energy conservation level of 55 $kWh/m^{2}*a$[10]. Additionally in the settlement 150 Passive- and Plus-Energy-Houses were built. The required heat energy is supplied by solar collectors and a CHP plant fuelled with wood chips (80%) and natural gas (20%). Together with PV-cells, this plant delivers 65% of power consumed in the settlement. In addition, storm water is collected and unused storm water can seepage on the areas of the settlement. Most of the old existing trees of the area could be conserved and extensive green areas could be created in the settlement. Besides the public transport offered, the settlement is supplied with a carpooling system and residents' cars are parked in garages on the district's boundary.

Apart from the framework for basic ecological and architectural aspects, the tenants were given an unusual freedom to create their own housing projects and plan their houses. 40 housing projects emerged as a result of this freedom, offering housing space for 1200 tenants.

Most of the administration of the settlement is done by the "Forum Vauban" that, for this purpose, employs four employees. In addition to this, the municipality of Freiburg employed seven people in the planning phase, solely for the project. This number has been reduced to three today. The project required investment of 85 Mio € by the municipality to develop the area. This investment was recouped by house owner purchase of the construction sites. The administration of the "Forum Vauban" created project costs of 2 Mio € for the period 1995 until 2002. Today the annual budget of the association is 150,000 €, and it principally organizes and supports "grass-root-initiatives" of the tenants.

To a large extent, the residents are young families that are well educated, ecologically interested and relatively wealthy. Accordingly, 20% of the residents are children with an age under 10 years. This has created a higher demand for schools and kindergarten places than supplied. Besides, this previously mentioned "education bourgeoisie", only a number of the 209 flats intended for welfare recipients could be erected. This low share is in proportion with the reduction of support for these flats. Furthermore, the proportion of pensioners in the settlement is relatively low.

Data of the settlement Freiburg Vauban are taken from Sperling, 2002; Sperling et al., 1999.

[10] For the calculation of heat losses, the Swiss SIA standard was used that required higher insulations than the German WSVO95 and DIN 4108.

8 Analysis of the cases

The following chapter pools the conservation measures undertaken in the various cases in the different fields of energy consumption (see section 8.1), compares their respective GHG emissions in a table (see section 8.2) and explains on a general case the potential savings under cost perspective, motivation aspects and technical feasibility (see section8.3). These findings are discussed in section 8.4 and a prospective outcome is displayed in section 8.5.

8.1 Analysis of the energy conservation

The combined different aspects of energy conservation lead ultimately to a reduction in GHG emissions. The energy conservation that results from individual technical aspects can be calculated by formally accepted equations, and is often even demanded by different standards. These calculations presently do not include aspects of behavioural change. Calculations of technical aspects already show differences to measured figures that are often inexplicable. Similarly, the standards for calculations of heat losses (ENEV, WSVO 95, DIN 4108) display no variances between calculated and measured figures. Figures of measured heat losses are seldom published, as the most buildings are calculated, build, sold and after that, the architect does not interact with the building. In addition, residents usually do not know how to measure heat losses and are not equipped with the required devices to perform this. Therefore, it is difficult to find figures that are not solely calculated. However, when measurements are done, they often show an average in the region of the calculated figures. Thus, the Passive Houses of the Lummerlund case had (in 1998/1999) an average heat loss of 13,4 kWh/m^2*a, whilst 15 kWh/m^2*a was the figure calculated. The exact heat losses of the individual houses range from 5.5 to 25 kWh/m^2*a *(DQ 2)* [Ebel et al., 2003]. Therefore, the calculated figures can be used to display what is possible in the technical field.

8.1.1 Heat

The average German flat has heat losses of around 200 kWh/m^2*a, even 400 kWh/m^2*a for flats of certain ages [Wuppertal Institut für Klima Umwelt Energie & Planungs-Büro Schmitz, 1996]. In modern Passive Houses, these heat losses are 15 kWh/m^2*a or lower *(DQ 3)*. Technical aspects make more than 90% conservation of heat energy theoretically possible. Feasible modernizations of old buildings with heat energy conservation of between 70 and 80% are widely proven *(DQ 3)*.

The measured consumption of individual residents can be reduced to 5.5 kWh/m^2*a *(DQ 2)* [Ebel et al., 2003]. Improvement of the dwelling's technical design and triggering of appropriate tenant behaviour can be successful ways of reducing heat losses of households. However, a sole focus on heat losses does not reduce the energy consumption of the house as a system to a sustainable level (see Table 11).

8.1.2 Hot water

The calculated figures for hot water in the ENEV are 21 kWh/m^2*a *(DQ 3)* [Merkschien & Brieden-Segler, n.D.]. This can be assumed as the average usage of a German resident. Technical possibilities to reduce this consumption of energy are limited; only improvements of boiler technology are promising for reduction of the energy consumption of hot water and space heat. Modern GCH have a calculated efficiency of 103% while old boilers often only utilize 70% of the fuel's energy *(DQ 3)*. This leads to energy conservation of 30% *(DQ 4r)* by simply using a new boiler [Wuppertal Institut für Klima Umwelt Energie & Planungs-Büro Schmitz, 1996].

Apart from purely technical solutions, behavioural changes can reduce the consumption of hot water. In this field, individual measures of identical buildings show a broad variety of energy consumption figures. The average consumption of the Wiesbaden case is, with around 10 kWh/m²*a *(DQ 2),* already 50% lower than the calculated figures *(DQ 4r)*. This goes even as far down as ca. 3.5 kWh/m²*a *(DQ 2)*, a reduction of almost 85% of the 21 kWh/m²*a baseline *(DQ 4r).* On the other hand, the consumption figures go up to approximately 650 kWh/res.*a, an amount similar to the calculated figures of 21 kWh/m²*a of the ENEV. The low consumption can be predominantly attributed to behavioural aspects such as reduced hot water temperature [Ebel et al., 2003] but these extreme figures cannot be expected to be generally feasible at least not in the short run.

8.1.3 Power

The relative consumption of power is very much dependent on household size. In general, it can be said that the average German resident consumes 1000 kWh/a. These figures can be reduced by using gas stoves for cooking. This would reduce the average power consumption of the tenants like in the Münster case by 20% [Based on Dzulko, 2003]. As technical devices consuming power are mainly purchased and used by the tenants, concepts of behaviour change applied to these could achieve the highest conservation results. Individual metering in the Wiesbaden case displayed here again a lower average of 891 kWh with minimum energy consumptions of ca. 500 kWh/res. *a and maximum of 1500 kWh/res.*a *(DQ 2)* [Ebel et al., 2003]. Therefore, reductions of energy consumption by approximately 20 % or more can be obtained here, even if these figures are hard to calculate exactly.

8.1.4 Fuel

As already mentioned in section 3.2.6, increasing the energy efficiency of a system such as a household is one way to reduce the environmental impacts of energy services consumption. The other way is to generate the consumed energy with as few environmental impacts as possible. These two modes should not be seen as complementary or as competing with each other.

The generation of heat energy by renewable fuels, such as wood, instead of fossil fuels, like natural gas, reduce GHG emissions by more than 50% *(DQ 3)*. The generation of heat from solar collectors is almost CO_2 neutral [Öko Institut, 2001]. This solution is usually designed to cover 60% of annual hot water consumption, so that a boiler can be switched off during summer *(DQ 5)*. Public support programs for solar heat collectors are designed in such a way that integration of solar heat collectors should be the standard of newly built houses and heating modernizations.

Beside the generation of heat by renewable fuels, the generation of power by renewable sources also shows great potential to reduce GHG emissions. Power supplied by wind turbines and PV, that can be purchased at almost identical tariffs to that of current power, reduces GHG emissions of power use by more than 80%, when compared to the present German mix *(DQ 3)* [Öko Institut, 2001]. The cogeneration of power and heat from gas reduces emissions by around 60% *(DQ 3)* [Steimer, 1999] compared to the German mix, by achieving cheaper tariffs than of the usual power supply.

8.2 Analysis of CO_2 emissions

The reduction of CO2 emissions is the goal of the various conservation concepts that are studied here. How far the individual cases achieve this goal shall be analysed here. To show the emission reductions achieved by the different projects, the following table lists the various cases divided into technical improvements and tenant integration. This summarises a general evaluation of the achieved emission reductions of conservation concepts. As the exact conservation of tenant integration is difficult to calculate, these figures have been separated. The results should be viewed in light of the German average emission of ~4000 kg $CO_{2\,Eq.}$/resident*a *(DQ 5)* (see section 1.2). This level is assumed based on, that an average German produces 12 tons of CO_2 annually and one third of the German energy is consumed within households (see sections 1.2 & 1.3).

Table 6, Comparison and CO_2 emissions of the cases (DQ 4r)[11]

Project	Technical Improvements	Tenant integration	CO_2 Emissions [kg/res.*a]
Sennestadt	Insulation, Glazing, GCH and CHP boiler, Solar collectors, PV, (See section 6.2)	Information sessions, Information centre	1400
Berlin	Roof insulation, Change oil to GCH boiler, Solar collectors	Information	1400
Freiburg PH	Newly built Passive house CHP (Wood&natural gas), Solar heat, Power supply (65% CHP+Solar) (See section 7.4)	Tenants involved in planning and execution, Tenants association, Energy consultancy, Power conservation support, 15% subsidies for efficient devices, Settlement centre, Survey	350
Freiburg NEH	Newly built NEH, CHP (Wood& natural gas), Solar heat, Power supply (65% CHP+Solar) (See section 7.4)	Tenants involved in planning and execution, Tenants association, Energy consultancy, Power conservation support, 15% subsidies for efficient devices, Settlement centre, Survey	450
Gelsenkirchen Lindenhof	Insulation, Glazing, Ventilation, GCH boiler, Solar collectors	Information	1150
Hannover	Newly built NEH, CHP and Solar collectors, Wind turbines and PV, (See section 7.3)	Information, Lessons, Information centre, Survey	650
Münster	Insulation, Glazing, CHP, small flats (See section 7.2)	Tenants involved in planning and execution, Tenants association runs CHP boiler, Survey	900
Köln	NEH Insulation, GCH and Wood pellet boiler, Solar collectors	Information, Lessons, Move tenants out of flats during the renovations	950
Wiesbaden	Newly built Passive houses, (See section 7.1)	Information, Survey, Energy conservation weeks,	800
German average	See section 1.2		4000

Figures of Table 6 from Berner, 2003; Bischoff et al., 1999; Ebel et al., 2003; Flade et al., 2003; Kühn, 2003; Landesinitiative Zukunftsenergien NRW, 2003; Merkschien & Brieden-Segler,

[11] The calculations are described en detail in Appendix 2 and Table 11. Here also the individual outcomes of conservation aspects can be seen and the link between energy efficiency, renewable fuels and CO_2 emission reduction is displayed.

n.D.; Meyer, 2003; Michelsen & Danner, 2001; Ries, n.D.; Rumming, n.D.; E. Schneider, 2001; Sperling, 2002; Sperling et al., 1999; Öko Institut, 2001

The CO_2 emissions are only calculated based on technical improvements. If flat size and population was not known, the average household was used instead. The figures of CO_2 emissions should not be taken in absolute terms, as the calculations incorporate uncertainties. The exact figures depend upon boiler design, heating system design, outside temperature, exact share of fuels for power production, heat values of fuels, transportation distances of fuels, flat size, flat population, etc. Therefore, the figures are rounded to the nearest 50 kg CO_2. They should give a hint as to whether or not a project is efficient.

8.3 Potential savings

Based on the above shown cases and reduction results here a general case is created to display the energy conservation potential of tenants by cost efficient methods proven feasible.

The potential savings of an assumed household of 66m² inhabited by two tenants and consumption figures are as follows:

Table 7, Figures of the supposed household (DQ 5) (see Table 2)

Size / Cold Rent	66 m²	4.17€/m²
Space heating (Gas)	250 kWh/m²*a	4,2 Cent/kWh
Hot water	25 kWh/m²*a	
Power	3000 kWh/a	15,5 Cent/kWh

Table 8, Potential of conservation (DQ 4r)

Segment of conservation	Operation	CO_2 Emissions
Space heating	Reduction of the heat consumption to 55 kWh/m²*a[12], supplied by a wood pellet boiler	290 kg/hh
Hot water	Central heating by solar (60%) and wood pellet (40%)	80 kg/hh
Power	Regenerative production as proposed in Section 3.2.9	300 kg/hh
Behaviour changes and use of efficient devices	20%+ reduction in all fields	

As already mentioned, the concrete results of conservation behaviour changes are difficult to calculate. Based on the limited figures found, behavioural conservation can be assumed to be of a magnitude 20% and above [see figures of Bell et al., 1996; Dzulko, 2003; Ebel et al., 2003; Flade et al., 2003; Meves, 2003; Sexton et al., 1987; Siero et al., 1996; Walker, 1979]. However these figures should definitely be reconfirmed by further research before use.

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[12] Level of Multi Story Low Energy Houses (see section 3.2.3)

Together, with these assumed savings of 20% *(DQ 5)* due to behavioural change, is a total emission level of 270kg/tenant a *(DQ 4r)* achieved. This is a reduction of more than 90% of the average household based emissions of 4000 kg/Pers.*a of today. If it is assumed that the shares of the energy consumption in a sustainable world will be the same, so that the household sector is again producing between one quarter and one third of the permissible 1.2 tons of CO_2 emissions, a maximum emission of CO_2 of 300-400 kg/res.*a (See section 1.2) *(DQ 4r)* is achieved. Therefore, it can be said that the CO_2 emissions of the household mentioned above would be less than the maximum emissions allowed for a sustainable lifestyle. It is already conditionally possible to reach this total level with technical options alone. However, some of the improvements cannot be incorporated into every household. Supply with power produced from regenerative sources is limited, as well as the possibility to fuel boilers with wood pellets. The discussion of the accessible amount of renewable energy is quite complicated so this issue will be only briefly touched in section 8.5 to give a vision of a prospective outcome but mainly left here to other research.

Even, when the possibility exists to reduce the emissions of particular houses under the level of sustainability only with technical solutions, a concept of behaviour change needs to be integrated in every modernization concept. The reason for the necessity of this reduction surplus in the implementation cases is the limited possibility of implementing all technical solutions in all cases and the limited motivation of some tenants to reduce consumption and of some landlords to modernize their houses. In addition, the found aspects of behaviour change can be implemented apart from renovation works.

The expected savings would lead to a reduction of market-based energy-costs from 1230€/hh*a to 380€/hh*a, savings of 70% *(DQ 4r)*. Of these reductions, 120€/hh*a is based on changed tenant behaviour, a significant motivator not only for the households with low income. In the Sennestadt case, the BGW calculated the average renovation costs to be 320€/m^2. Of this, 30% was assumed to have been allocated for the modernization works [Kühn, 2003]. To spread the technical conservation of 730€/hh*a between tenants and housing companies would give a payback period of 19 years (undiscounted). A higher share for the housing company would decrease this payback time to minimum 8.5 years *(DQ 4r)*. These figures are calculated without incorporating public support. These pay back times are too long. Therefore, solutions with lower costs should be developed or the price of energy should be increased. Because of this, the aspects of behaviour changes show great potential as they create low implementation costs and show relatively good saving potential. They could in general be used to open initiatives to modernize the housing stock to a sustainable emission level by starting over behaviour changes and improving the technical layout of the flats as fast as technical and financial possible.

Due to a lack of knowledge and motivation, a large number of renovations are performed nowadays without improvements in energy efficiency and wherein tenant integration is just to satisfy legal information requirements. When modernization occurs, standard improvements raise energy efficiency by a factor of 1.5, and good cases published in journals (and used in this study) show improvement factors of between 2.5 and 4. The higher improvements noted here as success stories show that improvement factors of between five to ten are achievable. To what extent factors higher than five can be reached with Passive House Renovations should be revealed in further surveys. The average newly built house should have emission levels of around 1600 kg/res.*a (Factor 2.5). Here improvements can achieve sustainable emission efficiencies of Factor 10 and higher.

However, these remain as unique cases. The problem can be solved technically, but integration aspects have to be improved and the general dissemination of these concepts needs to be state of the art.

8.4 Discussion of the findings

The traditional focus on the heat losses of houses is too limited. Modern insulation techniques do make it possible to reduce heat losses to minute levels. In cases when heat losses are under control, the supply of the required residual heat and hot water has to be secured with sustainable technologies. Apart from this, developing energy conservation concepts should focus on power consumption and the sources of this power. For this purpose, Steimer recommends four steps for the design of energy conservation concepts:

1. The reduction of heat losses [and power consumption],
2. The optimal collection of solar radiation,
3. Energy efficient equipment, and
4. Optimal coverage of the remaining energy needs. [Steimer, 1999]

This should also include aspects of tenants behaviour that pertain especially to points 1,3 and 4. Point 2 is only conditionally possible to achieve when an old building is renovated, but all other points can be realized in a renovation project as well.

The settlement in Freiburg Vauban demonstrates impressively that tenant integration is possible on a large scale. The project also has the lowest CO_2 emissions of established projects that can already be rated as sustainable, if the figures of Schmitt-Bleek are used to define a "level of sustainability". The project gives emission reductions of around a factor of 10 (see section 1.2). These low emission values are based upon low consumption figures that are lower in turn, than what good insulation alone can promise, as well as the possibility to create power and heat with renewable fuels.

The second lowest figures were achieved by the settlement Hannover Kronsberg. This is mainly due to power production from renewable fuels. The lesser insulation levels do not have a significant impact. The project shows emission reductions by approximately a Factor of 6. With more integration efforts, this settlement could also obtain the emission levels of Freiburg. Unfortunately with the closure of KUKA, the municipality of Hannover missed this chance.

The third lowest emission values are achieved by the equally impressive Passive Houses of Wiesbaden, Lummerlund. The settlement displays emission reductions by around a Factor 5 compared to the German average. The consumption of electric power could be reduced here by energy conservation weeks by a further 20% *(DQ 2)* [Flade et al., 2003]. This could lower emissions to the level of Hannover. With power generation from similar sources as Hannover and Freiburg, this dwelling area would also achieve sustainable emission levels. The consumption figures for hot water in this case are, with 180 kWh/resident*a *(DQ 2)* [Flade et al., 2003 p.73], very low. These figures (when correct) give an impressive example of the potential of behaviour-based conservation.

The low cost renovation of houses in Münster achieved the lowest emission value of all the renovation projects. This is definitely based on the power consumption from the resident

CHP, a solution that would not have been possible without a living tenants network. The dwelling achieves emission reductions of a factor of 4.5. Based on the assumptions of Loske & Bleischwitz, this level can almost be declared as sustainable [Loske & Bleischwitz, 1996]. Thus, it can be shown that the best results of newly built as well as renovated houses are gained by projects that intensely integrate the affected tenants.

The reason why some conservation concepts in the comparison show significantly lower CO_2 emissions than others is mainly due to the type of power production of these projects. This shows that the traditional concept only incorporates point 1 and sometimes point 2, of the above mentioned list. Chiefly the purchase of efficient devices (point 3), and then partially reduction of heat losses and the purchase of fuels (point 1 & 4) are covered by aspects of use- and purchase-behaviour, and this reveals the value of optimal integration of the residents. The house has to be seen as a system consisting of technical parts as well as residents using it. Therefore, a conservation concept is only able to achieve sustainable energy consumption and emissions when the conservation concept focuses on the system in entirety, and not only on one section.

As the settlement in Bielefeld Sennestadt was the core of this study, calculations were performed to determine what could be achieved in Sennestadt to optimise conservation. Following the structure of Table 6 above, the following results appear to be possible.

Table 9, Optimal emission values of the Sennestadt case (DQ 4r)

Project	Technical Improvements	Tenant integration	CO_2 Emissions [kg/resident*a]
Sennestadt	Insulation, Glazing, GCH and CHP boiler, Solar collectors, PV, (See section 6.2)	Information sessions, Information center	1400
Sennestadt+	Insulation to NEH level, renewal power supply, Wood pellet boiler, Solar collectors,	Tenants involved in planning and execution, Tenants association	350

As displayed, the achievement of a sustainable emission level is also possible for other settlements. The cost efficient measures of improvement used to create the fictitious case Sennestadt+ could be implemented with integration of the tenants in the concept planning stage, the willingness to use renewable fuels for heat and power, and a slight improvement of the housing insulation values. This improvement would not be possible to this extent, as this incorporates tenants having to decide about the supply of heat and power, having to change their behaviour to reduce consumption and having to leave their flats during the work to permit certain works.

The projects showed a $CO_{2Eq.}$ emission level of 1.0-1.4 tons/res.*a *(DQ 4r)* if the conservation concept did not focus on power production, and a level of 0.4-0.9 tons/res.*a *(DQ 4r)* when power was produced from renewable sources or CHP. In this latter segment the insulation level was no longer that important. Only the Passive Houses of the Wiesbaden Lummerlund project had significantly lower CO_2 emissions than the other projects in which power production was not emphasised, but these also showed lower values of power consumption. When the residents of these houses purchase renewable power - running heat-pumps also with electrical power - the CO_2 emissions would only be approximately 100 kg per capita and year *(DQ 4r)*. Therefore, as power purchase is the responsibility of residents, it is crucial to integrate them into following energy conservation concepts, even when it should be noted here that all concepts result in significantly lower emissions than the German average of 4 tons.

On the other hand, these figures indicate that criticism over the growth in average flat size does not deal with the key-point of reduction in CO_2 emissions. This leads to the assumption that the last steps of insulation improvement are not as important to emission levels as so often stated by architects and researchers.

8.5 Prospective outcome

The goal of energy conservation and emission reduction is, as already described in section 1.2&1.3, to create a sustainable lifestyle with as little emissions as the environment can compensate. For this goal the CO_2 emissions of the whole world have to be halved in the next fifty years. As 80% of these emissions happened in the developed countries, an emission reduction of a Factor 10 is necessary to compensate the prospected economic growth of the developing countries.

The housing situation in Germany in fifty years will presumably be governed by a decrease of the german population and an increase of the average flat size per resident. The prospected population will than be 76 Mio. instead of today's 82 Mio., a decrease of 7.5 % while the average flat size per capita will increase already in the next 20 years by 8% [Hofer & Aehlen, 2002]. Therefore, it can be assumed that the total flat size of Germany will increase by around ten percent until 2050.

The average consumption of heat energy of the houses today is 200kWh/m^2*a. This is the amount of heat energy that an uninsulated house, which was built in the 1950s, consumes. As today annually around 1-2% of the german housing stock are build anew and also 1-2% are retrofitted it can be said that the turnover time for the whole housing stock will be around 30 years. Assuming that the demanded heat insulation for retrofitting will rise further but the heat insulation level of new build houses is almost reached it can be assumed that the heat losses of the housing stock in fifty years will be 50-70 kWh/m^2*a. This is one third to one fourth of today.

As the calculations in the standards are giving the consumption of hot water based on the flat size it is likely that the consumption of hot water will increase due to lifestyle based hygiene habits. The assumption can be stated that this will show a similar growth as the flat size as both are dependent on lifestyle and economic growth. Therefore, the average hot water consumption per square meter flat size will stay in the same area.

The supply of heat energy for the hot water and space heat will most probably shift towards a higher percentage of renewable fuels. Already today it is cost efficient to install solar heat collectors and the prices for oil and gas are presumably increasing by 50% till 2030 [IEA, 2004]. Also is it unlikely that taxes will decrease on these fuels. However, as the supply of wood is limited the use of other biogenic fuels like biogas and agricultural residues is promising.

In the use of electrical power it is also likely that the used amount will increase. Hofer and Aehlen are discussing two scenarios, a) that the technology of the end consumer remains the same will lead to an increase of the power consumption of ten percent or b) that the technology will improve will lead to an overall reduction of 20% [Hofer & Aehlen, 2002]. This leads to the basic conclusion that the technology and the growing demand will keep each other stable so that the power consumption will stay almost the same. This is also stated by

Nakicenovic, Gruebler, & Donnald, [1998] that are expecting for Western Europe a development of the energy consumption of plus 50% to minus 20% until 2050 dependent on the chosen scenario.

Apart from this is it necessary to understand that the production of energy will probably shift from today's 80% fossil fuels towards a greater percentage of renewable fuels. The growth of the dominating renewables in Germany Onshore Windturbines and Large Hydrodams almost reached its limits as land space is limited. Also is the supply of wood limited, but the use of agricultural residues and other organic wastes is promising as well as the installation of Offshore Windturbines. This will prospectively lead to a share of renewables of at least 20% in the German Energy Production in the year 2050 [Nakicenovic et al., 1998]. Other studies even say that 50% is possible [Allnoch et al., 1999]. In addition, can it be expected that fuel cells, Cogeneration Boilers and Steam- and Gas-Turbines will lead to a higher efficiency of the production of end energy. However, these higher efficiencies are already included in both studies. Therefore can it be expected that in the end a lower number of people in larger flats will consume less heat and more power. These energies will be created with lower environmental impacts than today. However, the reduction of the total household based emissions to one tenth will by far not be reached. Therefore, everything should be done to reduce the energy consumption and emission of CO_2 to a minimum.

It is indeed not realistic to expect to be able to supply the entire German housing stock with solar panels and wood chip cogeneration boilers; however, it should be shown that the conservation potential of already existing technologies with reasonable use and purchase behaviour is huge. The broad implementation of these technologies needs huge investments. When the financial support programs granted by the government are used by a larger number of landlords these programs will fast be exhausted. Without public support, the high level improvements are not feasible in the current market situation. When even the environmental conscious residents of the Passive Houses counted the energy conservation mainly as a reduction of costs it will be impossible to implement the energy conservation aspects on a large scale without public support. In addition, the broad implementation of these measures needs qualified engineers and workers to build in the improvements. When Hanke et al. are speaking of 430.000 potential new jobs [Hanke et al., 1999] in this field this 430.000 workes have to be trained and employed first. However, the german construction industry has laid off more than 13% of its employees in the last ten years [Kröger & Muscheid, 2003; Tab. 3.5.1], so in general a potential stock of personal is available even when the implementation of these new jobs would take some time. The resources for the production of a larger amount of insulation materials are also available. These materials are mainly made from oil, recycled glass or recycled paper; materials that are available in larger amounts than needed. Similar is the expected availability of energy efficient devices. A higher demand can always lead to shortages of one or the other material, but in general and over a timeframe of 50 years, there should be no problem of supply. In total can it be assumed that the demand for energy efficiency improvements will grow slowly but constantly when the political aspects of the financing, like energy taxes and public support programs, are not changed.

Therefore, as technical aspects to limit the general implementation of energy efficiency aspects are not expected and the positive outcome for the national economy is not criticised it is crucial to motivate the consumer, tenants and landlord to improve the energy efficiency of the dwellings. But as the most limiting factors of the models are dependent on the lifestyle of the consumers it will be crucial to increase the efforts to influence there behaviour to more sustainable consumption patterns.

9 Conclusions and recommendations

This final chapter concludes this study with answering to the research questions that arose in section 2.3 and discussing the answers. Than an actors perspective is chosen to give recommendations to the different actors having a stake in conservation concepts (see section 9.2). These recommendations are based on the observed situation of the actors. In this section, crossactors aspects are displayed in three textboxes (TI-III). Finally, I use the last section to take a critical look at the opinion of some of my colleagues (see section 9.3).

9.1 General Conclusion

The general conclusion of this study is that the german housing sector shows a great potential of energy conservation and emission reduction. These aspects today can reach a sustainable emission level and some of these aspects are cost efficient already under the current market situation. With public support programs, the financial feasibility of these solutions is even better. However, now it is the normal case that the efforts done to conserve energy and reduce CO_2 emissions are often too low. The main problem is not technical, but the motivation to improve the energy efficiency is too low. To improve this situation, the information level of the involved actors has to be raised. Apart from this, a single technical improvement will not alone compensate the aspects of a growing consumption based on the economic growth. Here once again behaviour aspects are crucial: the general limitation of consumption and the willingness to use efficient technologies.

However, today behavioural aspects that show interesting saving potentials are mostly not integrated and the understanding is limited that energy conservation aspects are necessary, can be done cost efficient and are technical feasible. This low level of understanding and the limited motivation of various actors, to increase the information level, can be seen as one of the largest blockades to generally improve the situation.

Therefore, it is possible to answer the raised research questions (see section 2.3). A large potential of energy conservation can be achieved by housing companies by various technical approaches and by influencing the behaviour of the tenants. These aspects could be broadly displayed in the chapters 3&4. The potential outcomes could be shown in the chapters 6, 7&8. In these chapters, it was also possible to show the larger conservation potential of tenant integration in planning and conduction of the concepts. The exact conservation figures of the individual aspects of tenant integration cannot be displayed as research is limited and the individual cases show individual outcomes. In summary, it can be said that technical actions as well as changes in tenant behaviour are promising for this reduction goal. The actions can be undertaken individually, but the outcome is far more promising when technical improvements are combined with attempts to change tenant behaviour. The best results can be achieved when tenants are involved in the planning and execution of the improvements. In these cases a sustainable emission level can be reached.

Consequently, the initial hypothesis can be emphasised that larger conservation potential can be obtained with a conservation concept also focussed on the potential of tenants.

9.2 Actors perspective: observations and recommendations

The different actors involved in conservation concepts show different interests in the conservation and different behaviours. To understand the drives of the actors is crucial to be successful in a multi actor concept. These observations are shown here and to utilize the findings of this study recommendations are given to the different important actors:

- Housing companies and landlords;
- Tenants;
- Political actors;
- Power supplier;
- Architects and engineers;
- Construction companies and craftsmen; and
- Researchers.

The recommendations provided here should help these actors to improve energy conservation concepts.

9.2.1 Housing companies and landlords

Observations:

Schneider et al. illustrate in their survey that housing companies and landlords show different attitudes towards energetic modernization. While large housing companies are quite open to renovation works so long as they receive reasonable payback on investments, private landlords and also house owners are conservative with respect to modernization [L. Schneider et al., 2003]. Housing companies attempt to maximise their profits, therefore modernization works should always have this in focus that proactive housing companies can improve their competitive advantage within the housing market. To maintain high rentability of flats, housing companies have to focus on the tenants' perception of the flats. This perception can be improved by cost reduction and by promoting higher identification with the flats. Automatic transfer of rent and secondary costs together is currently convenient and involves low transfer costs, but tenants' information level of heating costs is marginal, especially when this is compared with the information obtained from a separately sent power bill.

An integration of tenants in modernization concepts will most probably increase the identification with the dwelling. This identification and improvements in tenant behaviour contributes to increased values of flats and can reduce the running costs of a dwelling after improvements are undertaken.

Recommendations:

- Improve energy efficiency of the flats,
- Market the conservation works as cost reductions,

- Deliver clear and open financial figures of modernization works and energy aspects to the tenants,
- Improve information level of tenants,
- Integrate tenants in the planning and execution of conservation concepts,
- Motivate tenants to organize themselves,
- Demand ecological rent mirror.

T I Positive side effects of integration

The integration of tenants in the planning and execution of modernization works create costs for the coordination of these efforts. Dzulko guessed the costs for the coordination and integration of tenant aspects and the accompanying research of the project Münster Am Breul to approximate 20,000 – 50,000 € [Dzulko, 2003]. The dwelling incorporates 20 flats. This included tenant integration in the planning phase and the coordination of the support works on the construction site. Besides this an extensive study was performed on the project that was designed as an experiment. Therefore, the costs will presumably go down once certain standards are established. However, irrespective of these costs and the higher emission reductions, the efforts at integration had additional other positive side effects.

Thus, tenant identification with the houses is stronger in Freiburg and Münster, tenant turnover is relatively low and the demand for flats within the projects is higher than the supply [Dzulko, 2003; Sperling, 2002]. In the Münster project, 40 of 42 tenants moved back into their houses after the renovation works, a significantly high number. The level of trust in the dwelling is so high that most of the doors are perpetually open. Furthermore, one extra purpose of the tenants association - the collection of rent for forwarding onto the owner – is to buffer rent shortages of poor tenants [Dzulko, 2003]. The dwellings in Münster and Freiburg Vauban are mainly inhabited by highly educated, environmentally concerned people that prefer an alternative lifestyle. These people are also the main drivers of integration networks [Dzulko, 2003; Sperling, Forum Vauban, & Öko-Institut, 1999]. However, a higher level of trust and identification will probably also be obtainable with more average tenants.

In addition to these 'soft' aspects, lower running costs of the housing companies could be noted by tenant integration and the establishment of tenant associations. These can take on a significant proportion of administration and accordingly lower its costs [Bischoff, Ingenmeyer, Russ, & Wilke, 1999]. The same can be predicted for maintenance: as the tenants familiarise themselves more with the dwelling, they are more likely to fix small defects without calling an expensive craftsman. Lastly, based on higher tenant identification and stronger social control, the cost of vandalism will probably drop.

9.2.2 Tenants

Observation:

The tenants predominantly pay for energy consumption and accordingly are those to mainly profit from conservation efforts (see sections 5.1.2 & 5.2.2). This potential profit is not always understood by tenants as well as that, conservation concepts from which tenants profit and that are financed purely by housing companies or political players are seldom introduced.

Beside this lack of information and initiative, a stronger identification of tenants with their dwellings promises better conservation results. The ultimate conservation outcomes are dependent on various facets of tenants, of the houses and the outside players. Therefore, the extent of conservation cannot be generally predicted. The same can be said about the exact costs and savings of tenant integration concepts.

Recommendations:

- Organize themselves in tenants associations,
- Demand informations about energy and cost related issues,
- Improve knowledge about energy and cost aspects of living in a flat,
- Demand modernizations of the houses,
- Inform landlord about the wishes and needs that should be covered in a modernization,
- Take part in planning and implementation of modernization concepts.

9.2.3 Political actors

Observations:

The public support programs of the KfW or the federal banks do not have integration aspects yet and it would be worthwhile to research further if this would lead to higher acceptance and higher conservation results than achieved by the purely technical aspects already mentioned.

Presently conservation concepts are mostly planned to reach the margins of support programs or of the respective ordinances and standards. An integration of aspects of tenant involvement into future public support programs and ordinances should be performed to motivate housing companies and landlords to focus on this sector.

Recommendations:

- Inclusion of behavioural aspects and tenant integration into the national ordinances, standards and public support programs,
- Implementation of the ecological rent mirror, demand research about the integrated rent mirror, and change of the payment regulations of the german rental law, to make validate the costs of both an integration and technical improvements of the houses interesting for the companies,
- To use the influence on municipality owned housing companies and power supplier to create energy conservation efforts and to support proactive tenants,

- Change of the HoAI (Honorarordnung für Architekten und Ingenieure, National Ordinance on the salary of architects and engineers) to cover the larger workload of an integration of tenants and to make aspects of greater energy efficiency more interesting in the planning phase.

T II Integrated rent mirror

The demand for modernizations to a sustainable emission level is too low. Ecological or integrated rent mirrors are a way to increase the motivation of housing companies and tenants to modernize their houses. This tool will create higher demand.

A chance to create the motivation for modernization, from which the actors above will profit, can be to implement the 'ecological rent mirror' created by researchers of the Institut Wohnen und Umwelt (IWU) (see section 5.2.4). This rent mirror would shift a portion of a conservation concept's profits from the tenants to the landlords, making it more appealing for landlords to modernize their estates. Additionally, the ecological rent mirror reduces the rent level of unrenovated buildings, creating pressure on landlords to modernize them. The implementation of this tool has to be done at a national level, as rent law would have to be changed. Despite the raised criticism on the ecological rent mirror (see section 5.2.4), this appears to be a good way to motivate landlords. The implementation of this ecological rent mirror would result in that some landlords would lose money through lower rents, so long as they do not improve their properties. To lose money is usually more strongly motivating than to gain it [Wortmann, Stahlberg, & Frey, 1993 quoted in section 4.4.5]. Therefore, the ecological rent mirror would create significant demand. Tenant integration could also be incorporated within an integrated rent mirror.

To make it possible for tenants to design and profit from their own modernizations, it should be determined if a modernization's profit margins could be offered to such proactive tenants (see Figure 9, blue area). Consequently, they would be able to create with their investment savings from which they would profit. This is an interesting option for tenants of conservative landlords who are less willing to improve, or when tenants are particularly proactive, such as those in the Münster case (see section 7.2). This option would create a competitive situation, in which the tenants could opt for cheaper modernizations that better fit their needs. For this tenants and landlords would have to improve their knowledge, need to communicate adequately with each other and agree on the exact form of the modernization. An integrated rent mirror would increase the demand for modernization works even more so than the ecological rent mirror, and in turn reduce the social costs of energy use (see section5.2.1) and create a significant amount of jobs [Hanke et al., 1999].

As the ecological and integrated rent mirrors are essentially the same - just with different actors profiting - and as these tools are predominantly still in research phase, only the ecological rent mirror is named in these recommendations. The exact design of the tool needs further research before being implemented.

From the viewpoint of politicians, the ecological rent mirror would be especially useful as it is not a subsidy. Therefore, a regulatory effect appears without the use of tax money, which is traditionally in short supply, especially within municipalities. Therefore, even if they cannot decide upon the implementation of this tool, municipal politicians should use their influence at a federal and national level to encouragement the implementation of it or something similar.

The possible means of implementing an ecological rent mirror or integrated rent mirror should be an aspect of further research. This tool appears to have great potential to create motivation to modernize existing housing stocks. It should therefore be evaluated and tested in case studies, noting the risks that could hinder its implementation.

A competitive situation such as this would require competition rules, as although landlords should have a chance to modernize their estate, tenants also should be guaranteed the chance to modernise in order to reduce their energy bills. However, a higher demand will not be created solely by financial tools such as higher energy costs and a better payback period; it will also demand marketing aspects. To create financial support and marketing aspects demands a will to improve from the side of decision makers. The display of this will is sometimes too limited to truly believe in it; however this study discredits the excuse of an 'empty purse'.

9.2.4 Power supplier

Observation:

In Germany, the market for power-generation is dominated by four large companies. Besides these companies, most municipalities own traditionally power supplier that deliver the power to the end consumer that are usually called "Stadtwerke". The large companies are strongly interested to take over these municipal power suppliers. Municipalities are often interested to have political influence on the power supply, however the financial problems of the municipalities lead to the result that most of the "Stadtwerke" are already taken over or at least threatened to become taken over. As the large power supplier are able to outcompete the small companies on the price these companies should more focus on quality, service and environmental aspects. The prices for production of power from paid off old power plants are low, but until 2020, 70% of existing power plant capacity will be exchanged in Germany. [Fischedick et al., 2002]. This will create a demand for power from efficient, flexible and small plants that can provide peak-load power and heat to surrounding dwellings. This can strategically be a successful niche for a small power supplier or Stadtwerke that would currently have problems competing with large players only on price.

Recommendation:

- Transfer information openly and clearly to consumer as to from where their power is derived and how power prices are structured,
- Market these information as honesty to keep customers,
- Erect modern and efficient CHP plants and support customer associations to do so,
- Sell heat and power in packages and offer contracting.

9.2.5 Architects and Engineers

Observation:

The salary of architects and engineers is governed in Germany by the HoAI. This ordinance is limiting the salary and makes it dependent on the cost volume of the construction works. Therefore, the motivation to reduce costs is limited and the salary for the energy conservation concepts is also too low to allow an integrative approach. Anyhow, is today the market situation for architects specialized on new building extremely bad.

Recommendation:

- Incorporate tenant integration aspects in offers to tenants and landlords as a way to create a new field of business,
- Market improvements as cost reductions,
- Found or use associations to motivate landlords, housing companies and tenants to create higher awareness and knowledge to improve the conservation levels of their buildings. Marketing performed in this field by architects associations will not come into conflict with existing advertising prohibitions especially not when the association also includes craftsmen and other actors.

T III Impacts on the employment in the construction sector

As already mentioned in the description of the social costs of conservation measures (see section 5.2.1), renovation projects create significant benefits due to job creation. Hanke et al. proposes the creation of 430,000 new jobs by doubling of the present rates of renovation efforts *(DQ 3)* [Hanke et al., 1999], and Bringezu´s assumption parallels this recommendation [Bringezu, 2001]. Renovation works have significantly higher proportions of labour costs than the construction of dwellings. These jobs would mainly be created within construction companies (174,000 new jobs until 2020 *(DQ 3)* [Hanke et al., 1999]), an industry sector that has declined since 1996 annually by approximately 4% *(DQ 3)* [Statistisches Bundesamt (Hrsg.), WZB, & ZUMA, 2002]. A larger demand for modernization works will particularly create more employee positions within construction companies; however the engineers and architects involved will also profit. This potential of conservation works should be clear to the involved actors. A crucial point beyond financially promoting motivation to modernize is improving the knowledge levels of landlords and employees.

Landlords show a lack of knowledge in this field, a lack of motivation to become informed and when requesting information from their main sources, craftsmen and engineers received wrong and too little informations [L. Schneider, Steinmüller, & Vohmann, 2003]. Therefore, the players interested in an increase of modernization activities should create a constant, clear and open transfer of reliable information and establish an understanding of how they and other players will profit from this information. The profiting actors include: the taxpaying public that will profit from reduced social costs, tenants that will profit from lower energy costs, architects and craftsmen in receipt of new job opportunities, and landlords that obtain higher rentability for their properties, and thereby an competitive advantage. Besides the employment opportunities of the modernization works already considered, the low scale integration and information programmes also create job opportunities. Sperling states that already in Vauban 170 jobs were created *(DQ 3)* [2002]; of those four were in the local association and three in the municipality, working purely on these coordination aspects. Coordination aspects in Münster also provide at least one person with full-time work, [Dzulko, 2003] paid for by earnings of the project, wherein tenants pay lower costs for heat and power.

9.2.6 Construction companies and craftsmen

Observation:

The information level of craftsmen is too low and their willingness to increase it is also limited. The understanding of energy consumption as running costs is not spread. Apart from this is the employment and market situation in the german construction industry very bad. The construction industry had a decreased market volume of one third over the last eight years and has laid off more than 13% of its employees in the last ten years [Kröger & Muscheid, 2003; Tab. 3.5.1]. Therefore, the conservation concepts can offer new business opportunities.

Recommendation:

- Increase information level about energy conservation and try to understand the motivation of other involved actors,
- Develop quality guaranties of modernization works by establishing a defined job as insulation worker,
- Establish networks of craftsmen and other actors.

9.2.7 Research

Observation:

Research in the field of tenant integration and the possible resultant energy conservation is limited. As shown, tenant behaviour and integration are good conservation opportunities. Therefore, it will become necessary to evaluate the results of these “soft” issues in comparison with the technical “hard” facts and to create standards of tenant integration.

Recommendation:

- Evaluate the results of integrative conservation concepts and behavioural aspects,
- Create a concept of implementing an ecological rent mirror,
- Do further research on the potential of an integrated rent mirror.

9.3 A personal word about Architectural publications and attitudes

I permit myself here a personal word about a topic conditionally related to the content of the study, and that already lead to extensive discussions with colleagues.

In most architecture and engineering books, journals, websites and competitions the main focus is upon the house, sometimes the ensemble or the detail. Even in the renovation handbooks I used for this thesis, the technical section is overwhelming large. The resident, owner or renter is only a figure in the “Off”, if a chapter, at all, focuses on them. This chapter about tenant behaviour very often only includes giving information brochures to tenants regarding, for example, how to ventilate correctly. This lack is also criticised by other experts [Eberle, Steinmann, & Humm, 2002; Schwarzhoff, 2000].

Planners should always have in mind that they are planning for the inhabitants, and that the house will be inhabited, on average, for 80 years. This means that residents will move in and out, décor trends will change and scientific knowledge will increase. Eighty years ago, in 1923, when the first automobiles were used en masse, the future density and noise of traffic in modern cities and the importance of information and communication technologies were unknown. To create a building that will last the next 80 years means to create a building that fits the current needs of tenants, is flexible, has such low social and ecological impacts for that it will not be demolished in ten years and is not designed as per current trends, as these change too fast.

Therefore, the design of a sustainable house should be humble with regard to costs, social aspects, technical constraints and the environment, and also flexible to change.

The tendency for architects and planners to appear in journals today only when they build houses that look 'en vogue' is not sustainable and reveals the incorrect focus of a small group of people. That a very large group of my colleagues perceive tenants only as disturbance of their beautifully planned houses, is dangerous. Houses that do not fit the needs of tenants are harmful to the environment, ultimately create higher costs for society and the inhabitants, and even can endanger their health. It should not be necessary to teach the residents how to live; it should be the goal of planners to create a house that fits to the anticipated needs of tenants, now and in 80 years. However, sadly a very general opinion of tenant integration held by planners and decision makers is to "write a booklet on how to use the house and then hopefully 5% will read it." So long as tenants are perceived as disturbances, it is my hope that they will disturb more intensely until decision makers lose their arrogance. The positive outcome of such a disturbance can be seen in some of the comparison cases. When this study results in sufficient numbers of disturbances, I will have reached my goal.

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Abbreviations

a year (annum),

BGW Bielefelder Gemeinnützige Wohnungsbaugesellschaft (Communal housing company of the municipality Bielefeld,

Bio. Billion,

CH_4 Methane,

CHP Combined Heat and Power Plants,

CO_2 Carbon Dioxide,

CO_2 Eq Value to calculate the different intensity of =>GHG,

DBU Bundestiftung Umwelt (Federal Environmental Foundation),

DM German Mark (Deutsche Mark) currency in Germany till December 31st, 2001, consisting of 100 => DPf,

DPf Pfennig, 100 Pfennig were comprising =>1 DM,

€ Euro, currency in Germany and other European states (ECU) since January 1st, 2002. One € has the value of 1.93 =>DM. One € consists of 100 cents,

EJ Exajoule 10^{15} Joules,

ENEV Energie Einspar Verordnung (Energy saving ordinance, 2002), replacing the => WSVO,

EU European Union,

GCH Gas Condensing Heating System,

GHG Greenhouse Gases,

IWU Institut Wohnen und Umwelt (Institute Housing and Environment),

KfW Kreditanstalt für Wiederaufbau (Bank for Reconstruction, owned by the German state),

KUKA Kronsberg Umwelt Kommunikations Agentur *(Kronsberg Environmental Communication Agency),*

kWh Kilowatt-hour,

kWh/m^2*a Value to calculate the energy efficiency of a building, same as 3.6 =>W/m^2,

m^2 Square meter,

MFD Multi Flat Dwelling,

NEH Niedrig Energie Häuser (Low Energy Buildings),

NRW Northrhine Westfalia, a federal state in Germany,

PH Passive House (Houses with a heat loss of under 15 => kWh/m^2*a),

ppm Parts per Million,

SFD Single Flat Dwelling,

U-Value Value of heat transfer trough a layer [W/m^2*K](former k-Value),

WSVO Wärmeschutzverordnung (Heat saving ordinance, 1995),

W/m^2 Value to calculate the energy efficiency of a building, same as 0.28 =>kWh/m^2*a.

Appendix

Appendix 1 Tenant interviews

A. Outline of the interviews

Based on the chosen framework, tenant interviews were performed between June 24th -26th 2003. Tenants were notified of the interviews via letters sent out on June 17th; these informed the tenants about the topic and also used the official name of the BGW to support the interviews. The letters were sent out to all households in the so-called First Construction Section of the Sennestadt settlement. This Section includes 141 flats in 12 houses of types I and II. Of this section houses 10 and 16 had already been renovated in 2001 and houses 17, 30 and 34 were already undergoing renovation whilst the survey was performed.

The households were visited by the author during 10 a.m. and 8 p.m. 38 of the 141 households were interviewed. Fifteen tenants refused openly to participate in the interview, and no one from the remaining households answered their door. The interviews were performed in German and the findings later summarized in English. Two Turkish tenants were not able to speak sufficient German, and in these cases the adult sons of the tenants translated the interviews.

The interview began with an introduction wherein the author explained that he is working together with the BGW but not for the BGW, that the interviews are anonymous and that the tenants could refuse the answers without giving a reason.

The questions were directed in an order reflecting how the author expected tenants to best understand; that is, there were no jumps between political issues and cost issues, power consumption and heat consumption, knowledge and behaviour. The questions therefore are not ordered in accordance with the background framework. The questions used in the questionnaire were largely qualitative, and to a lesser degree quantitative. As the study was the first performed by the author and tenant reaction was expected to be unpredictable, a pure quantitative study was perceived as too risky. In future this ratio can be shifted more towards the quantitative questions if further surveys are to be undertaken in other settlements. In the preparation phase, a general concern over the length of the interviews made the author divide it into two parts, the first section containing all questions definitely requiring answers and a second where further questioning depended on the motivation of the interviewees. The concern that the interviews would be perceived as too long by the tenants was unfounded. Only two interviewees were perceived as not really willing to respond to the second section, and only one interviewee refused to answer the political questions.

B. Questionnaire

Questionnaire German

Energieverbrauch und Nutzerverhalten

Mieterbefragung Sennestadt

Fragebogen Mieter

Allgemeines

1.1 Wohnen Sie gerne in Ihrer Wohnung?

1.2 Anzahl der Haushaltsmitglieder Anzahl der Kinder

1.3 Wohnungsgrösse

Kenntnis über den eigenen Energieverbrauch

2.1 Wissen Sie die Höhe ihres Strom-/Gasverbrauch?

2.2 Schätzen Sie Ihren Energieverbrauch im Vergleich zum Durchschnitt?

2.3 Können Sie mit den Begriffen kWh, kW etwas anfangen?

2.4a/b Wissen Sie die Kosten einer kWh Strom/eines Kubikmeter Gas?

2.5a/b Welche elektrischen Geräte benutzen Sie? Wie lang täglich?

2.6 Welcher Geräte verbrauchen am meisten Energie in Ihrem Haushalt?

2.8a-c Benutzten Sie den Standby Mode? Wie lang täglich? Warum?

2.8d Wissen Sie wie viel Strom dieser verbraucht?

2.9a-c Haben Sie energieeffiziente Geräte? Welche? Warum?

2.9d Sehen Sie die Kosteneinsparung trotz höherer Anschaffungspreise?

2.10a-c Wie viel Wasser verbrauchen Sie im Bad? Wie oft nehmen Sie ein Vollbad? Würden Sie wassersparende Armaturen verwenden?

2.11a Schalten Sie die Heizung ab wenn Sie schlafen?

2.11b Wenn sie wegfahren?

2.11c/d Wenn Sie lüften? Wie lüften Sie?

2.12 Welche Temperatur haben Sie im Winter in Ihren Räumen? Tags/Nachts

2.13 Fühlen Sie sich durch Raumklima, Zugluft, kalte Oberflächen, Schimmel, Stickiges Klima in Ihrer Wohnung gestört?

Angebote

3.1 Sind Sie informiert und einverstanden mit den geplanten Renovierungsarbeiten?

3.2 Würden Sie es bevorzugen wenn technische Geräte Ihnen die optimale Schaltung von Licht und Heizung abnähmen? (Zeitschaltuhren, Bewegungsmelder, Temperaturschalter)

3.3 Kennen Sie Angebote die Ihnen das Energiesparen erleichten sollen?

3.4 Nutzen Sie diese? Warum?

3.5 Wie könnten sollche Angebote aussehen, damit Sie sie mehr nutzen?

3.6 Werte und politische Einstellung

4.1 Ist Ihnen der Begriff Nachhaltigkeit bekannt?

4.2a-fGeben Sie bitte folgenden Aspekten einen Wert von 1 (unwichtig) bis 5 (sehr wichtig)

Wirtschaftliche Entwicklung	
Sicherheit des Arbeitsplatzes	
Klimaschutz	
Sicherheit	
Gesundheit	
Energiesparen	

4.3a/b Wie schätzen Sie die Situation der Umwelt ein? Warum?

4.4 Wie weit sehen Sie Ihren Energieverbrauch als Kostenfaktor in Ihrem Haushaltsbudgets an?

4.5 Wie weit sehen Sie Ihren Energieverbrauch als Teil dieses globalen Problems an?

4.6 Sollten Ihre Nachbarn/ die BGW mit Energiesparmassnahmen anfangen?

4.7 Ist dies ein Problem das auf politischer Ebene gelöst werden muss?

Ab hier nur weiter wenn Interviewpartner motiviert ist und Zeit übrig ist

Akzeptanz von Regelungen

5.1a-c Wären Sie bereit Ihren Energieverbrauch zu reduzieren?Wie viel?Wie?

5.2 In welchem Bereich sollte die BGW den Energieverbrauch reduzieren?

5.3 Würden Sie mehr energiesparende Geräte nutzen wenn diese bezuschusst würden?

5.4 Wie viel mehr wären Sie bereit zu zahlen für Energie aus regenerativen Quellen?

Medienkonsum

6.1 Über welche Medien beziehen Sie Ihre Informationen?

Haben Sie das Gefühl über Umweltaspekte genug informiert zu sein?

6.3 Haben Sie das Gefühl über die Renovierung genug informiert zu sein?

Fragen über die wirtschaftliche Situation des Haushaltes

7.1 Ausbildungsstand

7.2 Arbeitsverhältniss

7.3 Einkommen

Questionnaire English

Energy consumption and behaviour of tenants

Tenant-interview Sennestadt

Questionnaire Tenant

General

1.1 Do you like to live in your flat?

1.2 Number of people in the household/ of kids?

1.3 Size of dwelling

Knowledge about the own energy consumption

2.1 Do you know how much power /gas you are consuming?

2.2 How high would you guess your energy consumption in comparison to the average?

2.3 Do you know the terms kWh, kW?

2.4a/b Do you know the costs of one kWh power/ one cubic meter gas?

2.5a/b Which electrical devices are you using? How long daily?

2.6 Which appliances have the highest energy consumption in your household?

2.7a-c Are you using the Standby Mode? How long daily? Why?

2.8a-c Do you own energy-efficient devices? Which? Why?

2.9d Do you see a cost reduction of these devices?

2.10a-c How much water are you consuming in the bathroom? How often do you have a bath? Would you use water-saving armatures?

2.11a Do you switch of the heating when you are sleeping?

2.11b When you are driving away?

2.11c/d When you open the window? How do you ventilate?

2.12 Which temperature do you have in your rooms in the winter? Day/Night?

2.13 Do you feel disturbed by indoor climate, draught, cold surfaces, mould in your flat?

Offers

3.1 Are you informed and do you agree on the planed renovations?

3.2 Would you prefer that technical devices do the optimal use of light /heating? (Timer/movement detector temperature sensors)

3.3 Do you know programs/policies/devices that should make energy saving easier for you?

3.4 Do you use these? Why?

3.5 How could such programs look like that you would use them more frequently?

Values and political opinion

4.1 Do you know the term sustainability?

4.2a-f Please give each of the following aspects a value of 1 (not important) to 5 (very important)

Economic development	
Job security	
Climate protection	
Security	
Health	

Energy saving	

4.3a/b How would you say is the state of the environment? Why?

4.4 How far do you see your energy consumption as a cost factor for your budget?

4.5 How far do you link your energy consumption as a part of the global problem?

4.6 Should your neighbours or the BGW start with energy saving first?

4.7 Does this problem have to be solved on a political level?

From here only if tenant is motivated and some time is left

Acceptance of regulations

5.1a Would you reduce your energy consumption?

5.1b How much? How?

5.2 In which area should the BGW reduce the energy consumption?

5.3 How much more money would you pay for energy from renewable sources?

Consumption of media

6.1 Which media are you primarily using to get information?

6.2 Do you think you have enough information about environmental aspects in the information you receive through media ?

6.3 How many of your neighbours do you know?

6.4 Would you like to have more contact with your neighbours?

6.5 Do you have a feeling of security in the settlement?

6.6 What do you miss here? What would you make better if you could?

6.7 What should be done to reduce the energy consumption?

Questions about the economic situation

7.1 Occupancy

7.2 Employment

7.3 Income

C. Summary of the findings

General

The first questions concerned general tenant satisfaction with the flats. 29 tenants reported to be satisfied with the flat, 2 were indifferent and 7 were not satisfied. Of the latter, 2 were unhappy with the renovation work and one criticised the cold walls, so this will be settled after the renovation will be finished (Question 1.1).

The flats housed on average 2.42 inhabitants each (Question 1.2). The average size of a flat was 65.9 m^2, ranging from 45m^2 to 85m^2. This equates to an average space per capita of 27.2m^2, ranging from 11.4 m^2 per capita to 76m^2 per capita (Question 1.3).

Tenants were asked to specify their household income qualitatively, as compared to an average household income of 2,000€/month. This income was exceeded by three households, two counted themselves as average and 33 announced themselves as earning lower than the average (Question 7.3). Interestingly, none of the interviewees refused to answer this question. 15 of the households were inhabited by pensioners, in 13 of the households at least one person had a paid job and in 9 households the tenants were living on welfare money. One interviewee did not reply to this question (Question 7.2).

Information

22 interviewees could say how high their power bills were, 4 knew where they had to look for this information, and 12 did not know what their power consumption was. The average cost of power consumption was 49.40 € per household and month with a range of between 14 to 80€. (Question 2.1).

16 interviewees did not know what the terms kW and kWh mean, and three did know that these terms are linked to electricity but not how. 19 interviewees knew the terms (Question 2.3). But only three tenants claimed to know the electricity price of one kWh. Here the opinions ranged from 13 and 14 c/kWh, up to 22c/kWh (Question 2.4).

Most interviewees had a favourable perception of their electricity consuming devices; only the hot-water boiler was occasionally forgotten. Also knowledge of the primary power consuming household appliances was good. Ten interviewees counted the hot-water boiler as the biggest consumer, twelve nominated the stove, seven the fridge/freezer, five the washing machine, four the TV, one his dryer and one the computer. Interestingly, none of the interviewees rated lighting as a very high consumer (Question 2.5&2.6).

16 tenants were always using standby mode when switching off the TV, Stereo or Computer, and five were switching the devices off overnight. The reasons for this were usually commodity. That devices consume power in standby mode was known by approximately half of the users of this mode, but none of them knew how much power. One reason given for turning off the TV at the power point was that its power consumption was presumed to be high. Also, some older tenants, who usually unplugged the TV overnight, mentioned the fear of lightning strike (Question 2.8a-c).

8 tenants had energy efficient devices and 7 had energy efficient light bulbs. Most others had never thought about it; only one person gave the higher price of the devices as a reason for not buying them. Two tenants claimed to have energy saving devices/lamps that actually

were only the normal variety. 9 of the tenants that had bought energy saving devices/lamps claimed to have realized a cost saving as a result of the devices. (Question 2.9a-d).

On average, a tenant takes 1.65 baths per week (Question 2.10).

23 tenants turn off the heating in the winter when they are sleeping, 7 turn the heating down and 8 tenants let it run overnight in some rooms (Question 2.11a). When leaving the house during winter, 25 tenants turn the heating off, 4 turn it down and 8 let it run (Question 2.11b). The behaviour is almost exactly the same in these two cases. 22 interviewees were ventilating rooms by fully opening windows and turning heating down or off. 16 were only partially opening windows (and leaving them so permanently). Some elderly people were leaving windows fully open for an hour (Question 2.11c/d). The tenants guessed the air temperature in their flats during winter to average 19.8 °C, and here a range from 16 to 25 °C was given. One tenant had 9°C in his bedroom (Question 2.12).

Mould is a significant problem in the surveyed flats. 19 tenants were complaining about mould on the walls, 15 had uncomfortably cold walls during winter, and 8 tenants reported draughts from windows and between boards in the roof. The two tenants that were living in flats under the roof also complained of unacceptably hot temperatures during the summer. 10 tenants had no problems with the climate in their apartments. In houses that were already renovated (See Figure 11; House 10&16) three tenants reported that mould had disappeared after the renovation and two had no problems. One further flat had mould on the walls (Question 2.13).

Incentives and offers

29 tenants were satisfied with the level of information level conveyed by BGW concerning the renovation works. 8 were not satisfied and 1 was partly satisfied. 23 of the tenants agreed with the intent of the renovation, and 15 did not agree or criticised parts of the work. Three criticised the rent increase, and four complained about the noise of the works (especially where they worked nightshift) or had required better storage possibilities during the work. Two claimed the insulation and roof windows were better. 8 tenants claimed that their satisfaction levels were irrelevant, and that the renovation would have been performed anyway (Question 3.1).

Asked for their opinion on technical devices for optimising room temperature, ventilation or lightning conditions, 16 interviewees said that thermostatic controllers or feedback devices would be good, three only wanted to get devices if rent would not increase further and 19 said they would not need such devices (Question 3.2).

Only one person knew of information programs regarding energy consumption reductions (Question 3.3). 18 tenants claimed that they would need more information, 1 wanted better feedback, 1 demanded financial incentives and two wanted to get better electrical devices. 2 claimed that they were already doing best practice and 16 did not know what more they would need to do in order to reduce their energy consumption (Question 3.5). Asked if the interviewees consider themselves well informed about environmental aspects, 14 answered yes, 21 answered no and three did not answer. Of the 18 interviewees demanding information about energy saving, 14 were also saying they had too little information about environmental aspects (Question 6.2).

Values and political opinion

The term 'sustainability' was known by 2 tenants and a further three had heard this term previously but did not know its meaning (Question 4.1). Only two said that generally the environment is in a good condition, and then only within Germany. They claimed that in the rest of the world the environment is in bad condition. Four said that the state of the environment is improving and three were saying that it was neither good nor bad. However on this question, the majority answered negatively. Two tenants claimed the state of the environmentI is not bad yet, but if nothing is done it will become so, 19 said the state of the environment is not good and six were even calling it a catastrophe. Two had no opinion about this question. Interestingly, a correlation can be found between the answers "the state of the environment is good" and "the renovation is necessary". This seems illogical as if the state of the environment was good, the renovation would not be necessary (Question 4.3).

The link between environment and own consumption of energy was generally not perceived. 18 tenants answered the question of whether they think a link exists between the state of the environment and their consumption of energy with "No". 8 said "Yes" and 6 "Only a little bit". 5 answered that they did not know. Furthermore, 24 interviewees said that this problem has to be solved at a political level. Of this group, 3 answered so because they perceived a higher effectiveness of political decisions in protection of the environment. 7 tenants said that in addition to political decisions everybody has to act responsibly. 6 claimed that they did not know (Question 4.5).

Contrary to the environmental aspect of energy consumption, 18 tenants said that their energy consumption is a significant share of their household's budget. 3 said that it is a small proportion, and 13 did not care or said it is not important within their budget. 2 had insufficient information about how their welfare organization was paying energy bills, or had only moved in shortly before the interview. One did not answer this question (Question 4.4).

The assumption that tenants with a low income do not care about the environment - such that interviewees with a low perception of the environmental impacts of their energy-consumption have a high perception of the costs and vice versa - could not be found. There were 15 occurrences of the first question answered with yes and the other with no. The answers corresponded 17 times.

As expected, tenants answering Question 4.3 more positively or with "I don't know" also more frequently answered that their energy consumption has no environmental impact (Question 4.5) and gave the aspects of climate protection and energy conservation (Question 4.2) low values. Also, this group of tenants responded that more action has to be taken by politicians (Question 4.7).

Asked for the importance of political issues on a scale of 1 (low importance) to 5 (high importance), tenants generally answered as follows:

Table 10, Average importance of political aspects

Health	4,71
Employment security	4,61
Economic development	4,27
Climate protection	4,24

Security	4,20
Energy conservation	3,80

These answers show that some tenants had difficulties in rating aspects lower. Of 222 responses to these questions only 34 times was a 3 given and 2, only 4 times. Some interviewees said that all aspects are very important (Question 4.2).

Acceptance of changes

The question "Would you be willing to reduce your energy consumption?" (Question 5.1) was removed from the questionnaire during the interviews. The answers to this question were predominantly"Yes sure", but most had no idea as to how.

How the BGW could further reduce the energy-consumption was answered with the suggestions of an exchange of the hot-water boiler (9 tenants), optimising the heating system and turning it off during the night (3 tenants), better insulation in roofs (2 tenants) and using timer-switches and movement-detectors in basements (6 tenants). 18 tenants had no idea how the BGW could save more energy (Question 5.2).

To the question if they would use more energy efficient devices if they were subsidised, 24 tenants answered "yes", but some were sceptical, claiming that this would never happen. 9 tenants answered that a subsidy is not necessary and 5 did not know (Question 5.3.).

A willingness to pay more for power produced from renewable sources was expressed by 9 tenants with acceptable higher costs of 10-20%. The range here was from 5% to unlimited. The majority of the 24 tenants were not willing to pay more for power from renewable sources, and 5 didn't know (Question 5.4).

Media consumption

The media from which most tenants received information was mainly the TV (34 tenants) newspapers (19 tenants), radio (9 tenants), Internet (5 tenants) and Videotext (1 tenant) (Question 6.1).

D. Discussion of the findings

General

The flats were, on average, inhabited by 2.42 inhabitants, larger than the average German household size of 2.21 (1995) inhabitants[13] [EEA, 2003]. The number of inhabitants ranged from one to five people per household (Question 1.2). That almost 40% of the interviewed tenants were pensioners and a further 24% were dependent on welfare money (Question 7.2) perhaps indicated that the timing of the interviews was ill chosen, as it is likely that employed people would only be reached during evenings. But these figures were confirmed by Mr. Kühn who, although having no exact figures, agreed pensioners and unemployed constitute a

[13] If the trend of the EEA figures goes on, the average household size in Germany would be today around 2.1 inhabitants/hh.

very high percentage of the settlement's inhabitants [Kühn, 2003]. He also confirmed that the average income given was accurate.

Information

Only 5% of the tenants understood the term sustainability, and a further 8% had heard of it (Question 4.1). This is significantly lower than the German average of 28% and even lower than the 17.9% comprehension that could be found in the lowest educational class [Bauer et al., 2002]. This low information level has also been found amongst similar projects [Brieden-Segler, 2003] and seems to be the primary barrier to more energy efficient behaviour. Most tenants demanded additional information, and 63% of the interviewees admitted that they had too little environmental knowledge (Question 6.2) or did not answer the question. Also 47 % demanded more information about energy conservation programs and a further 42 % did not even know what they would require for energy conservation; therefore information seems to be the crucial point, even whilst it is only one element of behaviour change models. On Question 3.3, only one person knew that the "Stadtwerke", the communal energy supplier, offers information programs on reductions in household energy consumption. The BGW gives information brochures to every new tenant. This highlights how information does not reach tenants if provided in brochures. A far more promising way to reach tenants is by personal contact with people they trust. This can only conditionally be achieved by the BGW as the company is perceived as prejudiced. As, anyhow, a situation of trust is hard to locate within the settlement, this knowledge would be best transferred by outsiders.

The average household annually consumes approximately 600 € for power and 760€ for gas. Based on BGW figures and my own calculations, these figures will be reduced to approximately 380€ for gas and 510€ for power by the renovation and the change from hot-water heating to gas central heating. It is understandable that the costs of power consumption is high for a household with an income under the approximate German average of 24.000 €/a. That the even greater costs for gas consumption are not known also reveals the lack of sufficient data.. This leads to strange and problematic situations in which some tenants do not accept sufficient heating during winter but also do not ventilate correctly. This is one reason for mould in the flats, in addition to the poor insulation of the old walls. It is crucial that the correct way to ventilate be taught to the tenants, especially as it is easy to perform and directly affects their health.

The level of power costs is dependent on household structure. A slight correlation between power consumption, flat size and number of inhabitants is noticeable. As expected, singles are proportionately high consumers, but this cannot be accepted as a generalisation. Older singles especially have very low power bills. A reason for this is that pensioners use less energy consuming devices such as a computer or microwave. Furthermore, older people said in the interview that they use the bath and shower less frequently. And generally they have a higher motivation to save energy. A lot of the interviewed pensioners were trying to save as much energy as possible in many very creative ways. They were sometimes baffled as to why more people were not sleeping without heating during winter (in an uninsulated house).

Knowledge about the technical aspects of power consumption was also quite limited. Most tenants were able to identify the appliance consuming most power in their household, but the general power costs and the exact consumption of devices were not known. Once again the pensioners showed the highest motivation to save energy. Turning off stoves before food has finished cooking in order to utilize the heat of the plate was mentioned frequently as well as unplugging the TV overnight (although this was only done to reduce the risk associated with lightning strike). That an average TV set annually consumes 20-30€ of power in standby mode was not known, just that it consumes was considered reason enough.

Only 18% of tenants had energy saving light bulbs in their flats. This is also significantly lower than the German average of 53% [Lebot et al., 2003] to 72% [Bauer et al., 2002]. Also use of other energy efficient devices is by far lower than the comparable literature figures. Only 21% of the interviewees had other energy efficient devices, and the reason for purchasing these devices was lower costs. This is typical behaviour, as mentioned in the study of Bauer et.al [2002]. Here 64% of the interviewees were willing to buy energy efficient devices if the lower consumption pays dividends. Furthermore, 20% were willing to pay more under any circumstances [Bauer et al., 2002]. The tenants that had not bought these devices had actually never considered to do so. Here again the lack of information surfaces. No correlation between income level and willingness to buy energy efficient devices could be found, as the income level was not sufficiently widespread. Also, no significant correlation is visible between the purchase of energy efficient devices and the perception of energy costs as a high proportion of one's budget (Questions 2.9 & 4.4). Only if costs are not considered relevant is the number of devices correspondingly low. .

A large range in bath/shower use is evident: twelve tenants only take showers or only use the shower of their bathtub. Other tenants take a bath daily. Interestingly there exists no correlation between frequency of bathing and power-consumption costs. A reason for this could be that a high frequency of bathing is associated with lesser knowledge of one's power bill. Due to this, no correlation can be found. Four tenants had water saving devices connected to showers or faucets, and most of the others were willing to use them (Question 2.10).

Tenants perception of their room temperatures was criticised by Mr. Kühn [2003] even when the stated average temperature is only slightly higher than the average temperature he predicted in the first interview (See section 4.4.8). He claimed that many tenants of the BGW in general maintained too low room temperatures in winter and were ventilating too seldom. He proved this by exhibiting data collected by the BGW when tenants registered complaints. In these instances, dataloggers are placed in the flat for two or three weeks to measure air temperature and humidity. The graphs shown represent the majority of these cases. The graphs note an average temperature of 16.5 to 18 °C and a relative humidity of ~70%. Only two ventilations can be noticed during the three weeks of datalogging. It is clear that these climate conditions can create mould. In cases like these only a better insulation layer would help to keep the climate and energy consumption at sufficient levels, as improved ventilation behaviour of tenants would evidently raise energy consumption. A correlation between the Questions 2.12 & 4.4 (Perception of the energy costs and Temperature of the rooms) cannot be shown. The problem with the data of the data logger is that the BGW uses approximately five (one per service team) continuously during wintertime. One logger stays for two to three weeks in a flat. So during the normal heating period (November to April) a maximum of 65 measurements are done. Spreading these measurements over 11,000 flats leads to strictly conditional generalisations.

The average winter indoor temperature as guessed by tenants complaining about mould and cold walls was not distinctly different to the general average temperature. It should be determined if such temperatures are being correctly guessed. In general tenants have a good perception of the level of temperature in their flats [Haas et al., 1998]. The two tenants who said that they had 25°C in their rooms also mentioned they would prefer cooler rooms. This could also be a signal that these tenants could not correctly guess their temperature (Question 2.12).

Incentives and offers

The main incentive to change already exists for most of tenants: energy consumption costs are perceived by the majority as high. This is called a negative incentive or punishment. In the years between 1998 and 2001, energy prices rose by 60% due to green taxes and other factors [Kühn, 2003]. This seems to be already a striking reason for tenants. When tenants were told after the interviews that an average TV in standby mode consumes 30-50€ of power annually, the TV was switched off immediately. However for reasons other than economy, the motivation to save was low. The Stadtwerke offer energy measurement devices and information brochures to all consumers at a location very central to Bielefeld, through which most tenants have to commute to reach the city. Furthermore, the BGW and the Stadtwerke run a small pavilion directly within the settlement where information and support can obtained as needed. The weekly meetings are usually attended by around ten tenants. But as 79 % of the tenants guessed their energy consumption as lower than or equal to the average (or had never thought about it) (Question 2.2), and 63% demanded politicians to act first on environmental problems (Question 4.7), the general motivation to act on these issues can be considered as low. Also 63% are not willing to pay more for renewable energy (Question 5.4) and would demand for energy efficient devices to be subsidised (Question 5.3).

These demands are interesting in view of the renovation. The renovation was mostly accepted by the tenants. The tenants living directly under the roof claimed that they did not get anything and demanded better insulation. These flats were built in the 1990s in the previously disused roofspaces of some of the houses, and during these works, an insulation layer of 12 cm was added. This is 4 cm less than the 16 cm of insulation added to roofs without flats today, and the workload to change the insulation in the existing flats would be high, as the boards in the roof would have to be displaced. The improvement in insulation would amount to a change from the existing U-Value of 0.27 W/m^2K to 0.22 W/m^2K [Energiepass-Service GmbH, 1996]. Also 8% of tenants complained that rent would rise. This percentage, and the 8% complaining about noise and dust, can be considered as low. However the work proceeded in only one quarter of houses, so only a small number of tenants was affected directly. These low numbers could be connected to a general lethargy in the face of the renovations, as suggested by the 21% of interviewees answering that "we cannot do anything" when asked if they agree with the renovation (Question 3.1). This would also explain the demand for external support and political action with corresponding personal inaction. Schwarzhoff speaks about this behaviour when the unsure, undemanding late "War- and After War Generation" feel helpless within processes where they should otherwise be integrated [Schwarzhoff, 2000].

A correlation between low educational level and a missing link between the environmental condition and the own consumption (Question 4.5) can be found. The 18 tenants that answered Question 4.5 with "No" 10 had a lower education degree (Hauptschule) and three had no degree. On the other hand, tenants with high school degrees had answered this question with "Yes" (2) and "I don't know" (2). Also, four of the tenants that answered positively about the state of the environment (Question 4.3) had a low degree. This corresponds to the findings of Bauer et al. [2002].

Values

The deficiency in tenant knowledge has already been criticised above. The environment is assigned a relatively low value as compared with other political aspects (Question 4.2). Hübner & Hermelink also point out in their study that the tenants rated a clean environment as important, but the importance of energy saving was lower. A link between the global value of environmental protection and the own behaviour cannot be shown [Hübner & Hermelink, 2001]. This is also found in the opinion that environmental problems should be solved on a political level (63%, Question 4.7), and also in the generally low willingness to pay extra for energy conservation and renewable energy (Questions 5.3 & 5.4.) and the stressing of the cost savings of energy saving devices. As already mentioned above, the potential financial values is the most striking way to reach tenants. Interestingly, security rated relatively low on the agenda of political values. The values of security and climate protection are almost identical (Question 4.2). When so many interviewees do not link their own power consumption to the global environmental problem (47% no; Question 4.5), it can be assumed that even fewer perceive their own consumption of fossil fuels as a reason for the current global security situation. However health could be used as an interesting aspect to convince the tenants to adopt more energy conserving behaviour. Health is rated on average as the highest value with 4.71 points (See Table 10). Families with children rated health even rated (4.81 points; Question 4.2). As half of the tenants complained of mould and similar problems, the renovation (and corresponding elimination of this problem) could have been used as a trigger to reach the tenants. A perception of the link between their own energy consumption and their own health could be easier to build than the link between the own energy consumption and the abstract global problem of climate change. Therefore health appears to be a worthwhile value to raise along side financial aspects.

Appendix 2 Calculation of the emissions

The emission values shown in Table 6 are calculated as following:

If no other figures were known, the size of an average household as displayed in Table 2 is used. These figures do not represent an absolutely typical household, but they better reflect the average household of a rented flat in a MFD.

The emission values of the heating boiler and of power production were taken from the GEMIS Program Version 4.1 [Öko Institut, 2001]. The emission values of the program are displayed in n E6 kg CO_2/1000 TJ. This leads to emission figures of 0.0036*n kg CO_2/kWh. The emission values of heating systems are displayed in Table 3.

The emissions of the heating system were calculated by:

*Heat losses [kWh/m²*a] * flat size per resident [m²/resident] * emission value of the heating boiler [kg CO_2/kWh]*

The emissions of the hot water consumption were calculated by:

*Hot water consumption [kWh/m²*a] * flat size per resident [m²/resident] * emission value of the heating boiler [kg CO_2/kWh]*

The emissions of the power consumption were calculated by:

*Power consumption per resident [kWh/resident*a] * emission value of the power*

If no other values for power consumption were known, consumption was assumed as 1000 kWh/resident*a. This is rather high for a large household, but normal for households of one or two inhabitants like the household of Table 2. Emissions of a CHP were calculated as the total amount of heat created by the CHP multiplied by the related emission factor. Power production is calculated based on heat. When the electrical power created by the CHP does not meet demand, a proportion of normal power had to be bought, usually the 'German mix'. When the CHP produces more power than consumed by tenants, the emission level is not reduced by the surplus.

The sum of these three figures is displayed as the CO_2 Emissions per resident in Table 6. These figures are higher than the figures found in some of the publications utilised, as the authors did not take the CO_2 emissions of power consumption into consideration. There is no requirement for the calculation of the energy efficiency in Germany based on the calculation method of the ENEV (see section 5.1.1)

The consumption figures of the Sennestadt case are taken from Kühn, 2003; Merkschien & Brieden-Segler, n.D.. Heat supply by GCH (70%), CHP (30%). Hot water supply by electrical boiler (17%), 40%GCH+60% Solar (17%), CHP (30%), GCH (36%). Power supply by CHP (30%), German Mix (70%).

The consumption figures of the Berlin case were taken from Berner, 2003; Ries, n.D. Heat supply by GCH boiler. Hot water supply by Solar collector (30%) and GCH (70%). Power supply by German Mix.

Table 11, Emission values of the cases

Case		Sennestadt	Berlin	Freiburg PH	Freiburg NEH	Gelsenkirchen Lindenhof	Hannover	Münster	Köln	Wiesbaden
Heat	[kWh/m2*a]	100	100	15	50	65	55	70	53	10
	Creation	GCH boiler (70%), CHP (30%).	GCH Boiler	CHP (80% Wood, 20%gas)	CHP (80% Wood, 20%gas)	GCH Boiler	CHP (Gas)	CHP (Gas)	GCH+ Wood Pellet boiler	El. Heat Pumps (80%+)
	Factor	0,24	0,2	0,1	0,1	0,2	0,33	0,33	0,14	0,21
Hot Water	[kWh/m2*a]	21	24	500/res	500/res	21	21	21	21	180/res
	Creation	Electrical boiler (17%), 40%GCH +60% Solar (17%), CHP (30%), GCH (36%)	GCH boiler (70%), Solar collectors (30%)	40% CHP(80%/20%), 60% Solarcollector	40% CHP(80%/20%), 60% Solarcollector	40% GCH, 60% Solarcollector	40% CHP, 60% Solarcollector	CHP (Gas)	40% GCH+ Wood Pellet boiler, 60% Solarcollector	El. Heat Pumps (80%+)
	Factor	0,3	0,15	0,06	0,06	0,1	0,15	0,33	0,07	0,21
Power	[kWh/res.*a]	1000	1000	1000	1000	1000	1000	810	1000	970
	Creation	CHP (30%), German Mix (70%)	German mix	CHP, PV,+German mix	CHP, PV,+German mix	German mix	CHP, Wind, PV	CHP (Gas)	German mix	German mix
	Factor	0,49	0,7	0,25	0,25	0,7	0,01	0	0,7	0,7
Emis-sions	[kg CO2/res.*a]	**1400**	**1400**	**350**	**450**	**1150**	**650**	**900**	**950**	**800**
Figures from		Kuhn, 2003, Merkschien & Brieden-Segler, n.D..	Berner, 2003; Ries, n.D.	Sperling, 2002; Sperling et al., 1999	Sperling, 2002; Sperling et al., 2000	Berner, 2003, Landesinitiative Zukunftsenergien NRW, 2003; Meyer,	Michelsen & Danner, 2001; Rumming, n.D.	Dzulko, 2003; Bischoff et al., 1999	Meyer, 2003;	Ebel et al., 2003; Flade et al., 2003

The consumption figures of the Freiburg cases were taken from Sperling, 2002; Sperling et al., 1999. Heat supply by CHP (80% Wood, 20% Gas). Hot water supply by CHP (40%), Solar (60%). Power supply by CHP (60%), PV (5%), German Mix (35%).

The consumption figures of the Gelsenkirchen case were taken from Berner, 2003; Landesinitiative Zukunftsenergien NRW, 2003. Heat supply by GCH. Hot water supply by GCH (40%), Solar (60%). Power supply by German Mix.

The consumption figures of the Hannover case were taken from Michelsen & Danner, 2001; Rumming, n.D.. Heat supply by CHP (Gas). Hot water supply by CHP (40%), Solar (60%). Power supply by CHP (90%), PV&Wind (10%).

The consumption figures of the Münster case were taken from Bischoff et al., 1999; Dzulko, 2003. Heat supply by CHP (Gas). Hot water supply by CHP. Power supply by CHP.

The consumption figures of the Köln case were taken from Meyer, 2003. Heat supply by GCH (50%) & Wood pellet (50%). Hot water supply by GCH (20%), Wood pellet (20%), Solar (60%). Power supply by German mix.

The consumption figures of the Wiesbaden case were taken from Ebel et al., 2003; Flade et al., 2003. Heat & Hot water supply by Heat pump. Power supply by German mix.