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CO_2 Emission Reduction in the German Household Sector till 2050 – Barriers and Incentives

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Abstract

A shift in the German energy system which is mainly fuelled by imported fossil fuels has to be achieved over the next decades. Reasons for that are not just the insecurity of supply but mainly environmental problems such as climate change and legal commitments, demanding a decrease of emissions in the energy sector which is the main emitter of CO_2. A reduction of CO_2 emissions in this sector is highly based on the supply by renewable energy sources (RES) and a strong reduction of the energy consumption. Till 2050 (the timeframe of this research) a global CO_2 reduction of 50% is strongly advised by several reports (Enquete, Stern, IPCC). In the same time respecting development trends in production, consume and population in developing countries and acknowledging that the recent tremendous share of emission comes from industrial countries, further advices are aiming for a reduction of 80% in developed countries (e.g. Germany) within the same timeframe. This can just be reached with a major supply by RES and with a reduction on the demand side of 50%.

The building sector in Germany accounts for about half of the national energy consumption (48%) on the demand side and is consequently the biggest CO_2 emitter. Compared to the other hugely emitting sectors (transport with 27% and industry with 25%) the building sector has very likely the highest feasible potential for a fast reduction of energy consumption mainly due to a strong increase in energy efficiency but also influenced by a change of individual's behaviour. This assumption is the rational for a developed scenario that bases on advised demand reductions of 50% given by above scenarios as an average for all three sectors. The developed scenario takes the sectorial advantages into account and consequently aims for an energy demand reduction in the buildings sector of 70%.

The second part of the paper consequently investigates how to reach this aim. Thereby the focus is not on percentage points but on the general discussion of burdens and improvements. It is shown that the needed knowledge in the building sector exists and the potentials are already applied in some cases. But mostly not even the moderate legal German requirements (EnEV) are reached during renovations and new constructions and a huge environmental but also economical potential is basically unused.

This research is divided according to the four pillars of sustainability: ecological, political, social and economic issues are discussed as well as technical potencies. It becomes clear in this paper that all areas mentioned above offer huge potentials for improvements and that it is important not to focus on a single segment. So is the public opinion as well as economical interest highly important for political decisions which again are the main trigger for further reductions of minimal energy efficiency requirements in legal regulations. Support is also needed on financial side to overcome the burden of higher investment costs and to shorten the payback time of some 20 year. Also the user behaviour has to be influenced towards a reduction on the demand side. In addition further ideas and concepts are mentioned such as the implementation of the building sector in the Kyoto protocol, a LCA based economy or a national ecological tax reform.

Keywords: greenhouse gases, CO_2, emission reduction, building sector, housing sector, Germany, 2050, energy demand reduction, political, social, economic.

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Abbreviations

CDM	Clean Development Mechanism. A mechanism under the Kyoto Protocol to mitigate emissions
DEPB	Directive on the Energy Performance of Buildings (2002/91/EC) (EU). Directive has been in force since 2003. Implementation into national law mandatory for all member states
DHW	Domestic Hot Water
EEG	Renewable energy sources Act (The German “Erneuerbare Energie Gesetz”). German Law replacing the EFA in 2000 with a significantly broader scope (revised in 2004 and 12/2007)
EFA	The German Electricity Feed Act. Law from 1991 regulating obligatory feed-in tariffs (degressively structured fixed rates for renewable generated electricity) from decentralised production to be paid by the grid operator
EnEV	German Energy-Saving Ordinance (Energieeinsparverordnung). In effect since 02/2002. replaces all previouse heat-protection and heating-system laws. Shifted regulation of the heating requirements to a limitation of primary energy requirement.
EPT	Emission Permit Trading. A mechanism under the Kyoto Protocol to mitigate emissions
Fossil fuels	Coal, oil and natural gas. CO_2 was stored millions of years ago. The combustion of fossil fuel in present days releases this gas again into the atmosphere
GHE	Green House Effect
GHG	Green House Gas
JI	Joint Implementation

LCA	Life Cycle Assessment
LCC	Life Cycle Cost
Primary energy	The original energy source (lighite, hard coal, uranium, natural gas, biomass and others) employed to produce usable energy carriers (heating oil, petrol, electricity, district heat and others)
R&D	Research and Development
SBS	Sick Building Syndrome. Syndromes like allergies, fatigue, lack of concentrations and others deriving from time spent indoor of “sick” buildings. Probably connected to bad air quality.

1 Introduction

1.1 Background

During the last two and a half centuries mankind started to deplete fossil resources to satisfy its own hunger for energy. Due to the fast growing population and its exponentially increasing energy demand we nowadays face a not always perceptible risk of climate change. The profound influence of climate on our lifes lastly endangers global environmental and with it societal and economical stability. To mitigate these profound and generally accepted risks the reduction of green house gas (GHG) emissions is the primarily demanded action that has to be taken over the next decades since GHGs are the main trigger for climate change. Nowadays around half of the man-made GHG emissions derive from energy related factors (BMU 2006). CO_2 is the most emitted GHG which almost comes to 100% from combustion and other transformation processes in the energy sector. Consequently the reduction of CO_2 emissions within this sector is the most important but in the same time the most challenging factor to reduce the risk of climate change.

This reduction of emission can be reached on both sides in the field: the supply and the demand side. The production of energy (correctly speaking: the transformation) is nowadays almost exclusively based on fossil fuels. CO_2 neutral energy production from renewable energy sources (RES) can partly lead to a reduction. An increasing efficient use as well as a general reduction of the energy consumption are targeted on the demand side.

Since the anthropocentric influence on the climate has become accepted in research circles it also entered the international political agenda and is established in the United National Framework Convention on Climate Change (UNFCCC) since 1992. Five years later the Kyoto protocol was ratified by most states and defined hereby legally binding targets for the reduction of GHG emissions within ten to fifteen years. This ambition is a clear mitigation strategy while in the meanwhile, with a growing certainty of strong impacts from climate change, also adaptation strategies are developed. Energy demand reduction and a more nationally renewable generated supply are also adaptation strategies concerning a different risk: the risk of insecure supply. Since most countries are highly dependent on energy or energy fuel imports often from politically unstable countries and developing countries hugely start to compete with their growing demand on the energy market the situation became more and more fragile like it can be seen according to fuel related historical issues. It were the Middle East wars of the 1960s and 1970s as well as the OPEC oil embargo of 1973/74 that firstly rose the question of security of energy supply due to the finiteness of fossil fuels and the political will to deliver for the very first time in the post-war era. Further historical reminders of the scarcity and the high dependency on fossil fuel imports were the Iranian revolution of 1979, the Iran-Iraq war, the Iraqi invasion of Kuwait in 1991, the following wars in Kuwait and Iraq (Bell, Lowe, & Roberts 1996). Consequently a reduction of fossil fuel dependency is not just a political, social and economical threat for the future under a principle of precaution but also an important issue nowadays.

Talking about a demanding action it also should be mentioned that additional advantages (discussed in this paper) are to expect since energy efficiency in this huge sector also encouragingly supports society and stimulates the economy. Therefore legal, social and economical incentives for the building sector have to be reviewed and improved, handicaps on all levels must be minimized to fulfil the basic demands of an ecological system that gives space for society and consequently the economy.

To the urgently needed reduction of energy demand the building sector can highly contribute since its share on an European level accounts for around 41% of the total energy demand, in Germany even for 48% of the national consumption (EC 2006). Germany is one of the leading countries on the market of efficient building what can be used as a global advantage and also an international responsibility. This fact becomes perhaps more valid with the example that till 2020 some 300 million people in China (almost the population of the USA) are expected to move to cities why enormous efforts are made nowadays to supply enough living space. Coming back to the issue of climate change: if the existing energy efficiency standards will not be improved (keeping in mind that the lifetime of a building is estimated to some 70 years) the environmental burden for the whole world will be colossal (UNEP 2007).

The essential motivation for this topic can be summarized with the following points: (1) Mitigation of climate change and compliance of legal agreements (Kyoto protocol); (2) Issues about energy supply security; (3) National advantages generated by higher energy efficiency in the sector; (4) International demand for knowledge and development in the sector.

1.2 Objectives and Research Question

Energy in the building sector accounts for a large part in the whole energy field. To understand the ambition and the target of this paper and to give it a sense of completeness this has to be embedded into a huger context why even global energy issues and transboundary ecological treats are looked at in the first part. Consequently one of the objectives of the paper is a more holistic understanding of the connection between global issues and the main research topic.

The overarching aim of the paper is to exploit how energy savings and the slow development towards energy efficiency in the German building sector can be reached and speeded up. The specific research questions

1. *"What are the barriers and burdens to reach a tremendous CO_2 reduction in the German energy sector?"* and
2. *"What factors and actions can be improved to reach the target?"*

need two previous definitions deriving from the following questions:

a. *"What are the targets for a German emission reduction?"* and
b. *"What are the sectorial targets for the building sector in Germany on the demand side?"*

While the question (a) is generally answered by recommendations from literature the second sub-question (b) has to be answered by evaluation and assumptions wherefore a scenario had to be created.

The basic main conception for this scenario is that the three huge emitting sectors (industry, transportation and buildings) do not offer the same potential to reach the reduction in emission and energy demand corresponding to the national defined target. Literature review showed that the largest potential is located within buildings wherefore this sector is consequently more stipulated for emission reduction.

The main research questions (1 and 2) are defining the main objective of the paper which factors are important to be considered to reach the sectorial target previously defined in the scenario. Therefore ecological, technical, political, legal, social and economical measures and improvements will be discussed to stay on this track. A concluding outlook will give some further inspiration.

The basic structure of the argumentation is*: CO_2 from fossil fuels (around 94%) - fossil (and nuclear) share of the German energy supply (of some 95%) - energy demand in buildings (of some 48%), energy demand for heating (around 87% in the 34% of national demand in the housing sector)*. Energy reduction potential on demand side: *space heating (around 80%+), energy reduction potential for electricity (around 50 to 75%).* Emission reduction on supply side*: (estimated to some 40 to 70% till 2050).*

1.3 Limitations

Energy issues in the building sector are discussed within thousands of books while most literature is focusing on a single aspect within this huge topic. Since this paper discusses various points with different focuses and basically gives an overview, no in-depth discussions (neither in specific nor between the viewpoints) are possible within this work. The basic focus of the discussion is on the demand side in the housing sector. Another restriction deriving from the focus of the paper is the limited review of the transport and industrial sector which is valid to define sectorial differences.

1.4 Methodology and Materials

The main chapter is basically divided into a technical explanation and an investigation under the different viewpoints of sustainability: ecology, politics, society and economy. Therefore an interdisciplinary view, an integrated assessment communicating "knowledge of diverse scientific disciplines from the natural and social science" is applied (IPCC 2001). Quantitative but mainly qualitative methods are used to investigate the research topic from these different angles. In the beginning a scenario analysis is used to develop general further targets which are later on investigated with descriptive parts based on an extensive literature review, and analytical, explanatory parts discussing the barriers and opportunities under the given perspective.

The selected material is primary based on secondary literature and was largely accessible in one of the biggest national library for the building sector. Therefore reports, books, electronic sources, articles and hearings were reviewed. The focus of literature was between global and regional, general and specific and stresses different viewpoints and interests (such as legal, political, financial, social, technical or ecological). The reviewed literature was published between 1985 and May 2007.

1.5 Structure

The thesis is organized in four chapters beside this introductory part and will answer the research questions according to the following structure:

- Chapter 2 is about energy and climate change on a global level which in the same time will give the answer to the first research sub-question: *What are the targets for Germany?*

- Chapter 3 narrows the focus to a national issue, looking into details and finally defining the national, sectorial CO_2 emission reduction target for the building sector. For this purpose an assumption will be the base for an estimating scenario which leads to the answer to the second research sub-question: *What are the sectorial targets in Germany on the demand side?*
  General circumstances and connection between climate and the German energy demand in the building sector are clarified. Prerequisites to answer the essential research question are given.

- Chapter 4: The questions "*What are the barriers and burdens to reach a tremendous CO_2 reduction in the German energy sector?*" and: "*What factors and actions can be improved to reach the target?*" will be explored and discussed in the third chapter taking the four influencing factors for sustainability into account: Ecology, Politics and Law, Society, Economy. A technical chapter will previously give necessary information about the possibility in this field.

- Chapter 5: Finally the conclusion will summarize and condense the intense discussion and further ideas and inspiration will be mentioned.

2 Climate Change and Global Energy Issues

2.1 Environmental Concerns and a World Energy Roadmap

2.1.1 Industrialisation, Energy and CO_2 Defining Global Aims for Emission Reduction

The whole process of industrialization was almost exclusively based on fossil fuels. The close correlation between fossil energy fuel consumption and CO_2 emissions is proven. And so is the connection between man-made emissions from energy transformation such as combustion based on fossil fuels and climate change (Flade et al. 2003; Hauser et al. 2006).

Nowadays around half of the man-made GHG emission derives from energy related factors (BMU 2006). For CO_2 this share is even estimated to 94% (Malloth 2006). To reduce this huge risk factor of climate change even with a predicted growth of population the anthropocentric CO_2 production has to be reduced by 50% till 2050 based on 1990 levels (see Fig. 1) - equal to a CO_2 emission of fairly more than 1 t per capita and year (BMU 2006; Greenpeace 2007; Stern 2006). This reduction was already on the agenda of the climate conference in Toronto in 1988 (Borges, Lorenz, & Helmstädter 1997). For comparison: the 3rd part of the new IPCC Report (released in May 2007) even aims for a global reduction of 30 to 85% (on 2000 levels) to keep the risk of climate change below absolute uncertainties (IPCC 2007).

2.1.2 Global equality and National Consumptions Defining National Aims for Emission Reduction

Due to the fast growth of the energy demand in developed countries over the last centuries and especially the last decades their CO_2 emission account for a multiple compared to non-industrialized countries. In Germany we emit around 6.3t of CO_2 per person and year; in other states even more than the double. Striking is the fact that 18% of the world population (OECD countries) are responsible for more than 50% of global CO_2 emissions (BMU 2006). This social inequality has to be taken into account for a global CO_2 decrease of 50%. Consequently a reduction of 80% for the highly emitting industrialized nations till 2050 (see Fig. 2 and 3 for Germany) is recommended by several, recently published reports (BMU 2006; Greenpeace 2007; Stern 2006). The basic idea therefore was already developed in 1991 by the German Enquete Commission (Deutscher Bundestag 1991).

2.1.3 Strategy to Reach the Targets

This intense CO_2 reduction can just be reached by a holistic approach challenging all available potentials. A decreasing demand (due to energy savings) and a higher efficiency on the production and demand side pave the way for an energy production based on Renewable Energy Sources (RES) (see 2.2.1 Energy and Sustainability, p. 11). The basic idea is the same for the global scenario (50%) and the more ambitious scenario for industrialized countries (80%) with different proportions. On a global level this means that the tremendous decrease in emissions for industrialized countries gives non-industrialized countries the chance for development while simultaneously stabilizing their emissions (Greenpeace 2007).

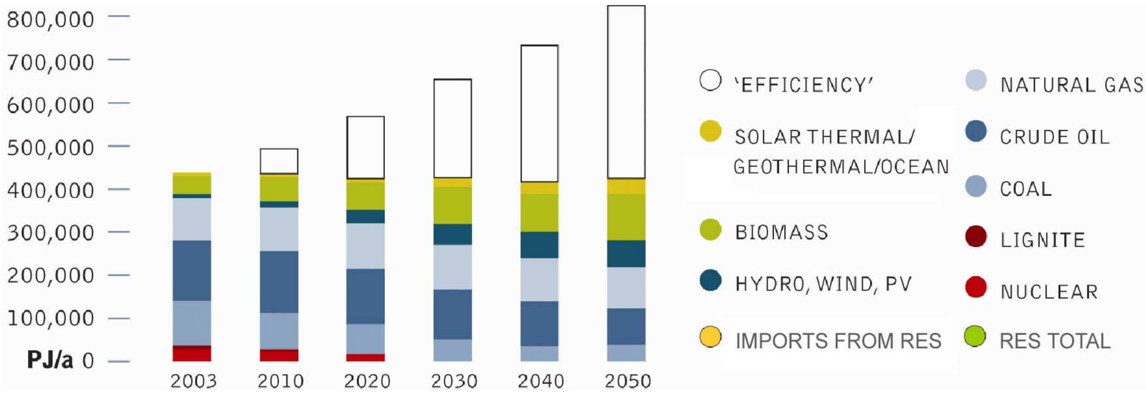

Fig. 1: Scenario of energy supply with 50% global reduction of CO_2 emissions till 2050 (Greenpeace 2007)

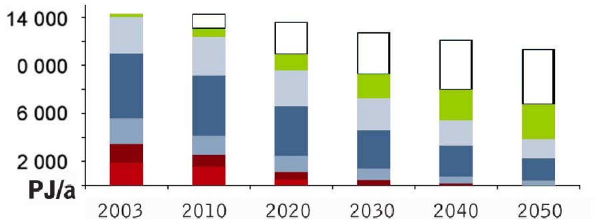

Fig. 2 : Sustainable energy scenario for Germany, based on energy savings, 50% efficiency and upgrading renewable supply aiming for a CO_2 reduction of 80% till 2050 (Umweltbundesamt 2007) (keys see Fig. 1)

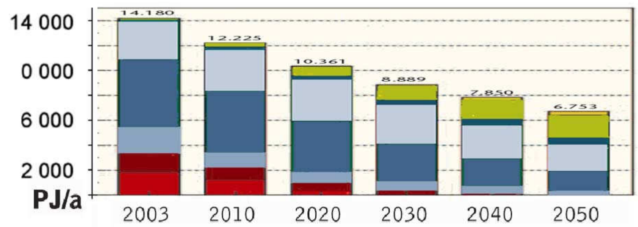

Fig. 3: see above (Fischedick & Nitsch 2002) (keys see Fig. 1)

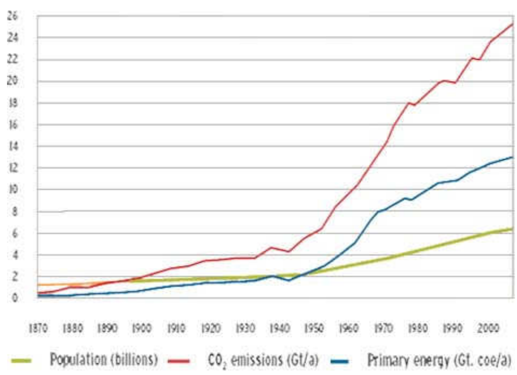

Fig. 3: Development of global energy-related CO_2 emissions since 1870 and the main causes: population growth and the combustion of coal, mineral oil, and natural gas (1 Gt. coe: 1 billion tonnes of coal equivalent corresponds to 29.3 EJ) (published in BMU 2006 p. 13)

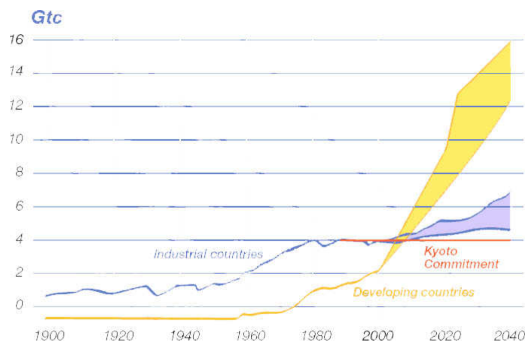

Fig. 4: Scenario: global CO_2 emissions till 2050 with the fast growing share from developing nations most emitting after 2015 (published in UNEP 2007)

2.1.4 Other Concerning Factors

2.1.4.1 Population Growth and Energy Demand

Since 1870 the world population has quadrupled to 6.3 billion people whereas the world energy consumption has grown by a factor of sixty (60) to 450 EJ/a; so did the consumption of fossil resources. The intense growth of energy demand started after 1950. Just between 1970 and 2000 the global energy consumption doubled (BMU 2006). This trend is expected to continue almost exponentially over the next decades this time mainly due to the giant energy hunger of prospering Asian nations unless convincing arguments might lead to a shift (see Fig. 3 and Fig. 4).

2.1.4.2 Fossil depletion and supply security

Another challenging factor for the global energy sector is the scarcity of fossil fuels and consequently the security for energy supply. The fast growing population and the rising energy demand led to a vast consumption of fossil fuels. The finiteness of most fossil resources is expected for this century what will unquestionably lead to tremendous rises in energy prices over the next two decades (Hauser, Hogrefe, Bradke, & Erhorn 2006). This trend will very likely get worse acknowledging the increasing energy demand of flourishing developing nations with no access to other energy sources.

Aggravating are the circumstances that 2/3 of the oil reserves are located in the “strategic ellipse” (area: Saudi Arabia, Iraq, Iran and Russia) (Hauser, Hogrefe, Bradke, & Erhorn 2006). The “[O]ver-reliance on energy imports from a few, often politically unstable countries and volatile oil and gas prices have together pushed security of energy supply to the top of the political agenda…” of many countries (Greenpeace 2007).

2.2 From Emission Reduction to Development

2.2.1 Energy and Sustainability

The availability of energy influences all fields of social, economical and political activities and its consumption has a major impact on the environment and the climate (BMU 2006).

Focussing on a “sustainable development” several main deficits in the energy sector can be identified:

- Emission and climate change
- nuclear risks and dangers
- diminishing and rising prices of fossil fuel reserves
- huge differences in energy demand between industrialized and developing countries
- intergenerational inequity by depleting resources as a key factor of sustainability
- Unjust contribution of environmental burdens due to transboundary pollutions

Consequently the energy sector can play a central role within a sustainable development. Therefore on one side the supply has to be guarantied by non-emitting and secure sources, on the other side the demand has to be strongly reduced to secure the worldwide supply by this stock.

Three main strategic elements can consequently be identified

- Consistency: consistency stands for the closing of the energy loop. Our current energy system is “open” (resource outtake and waste dumping) and has to be changed to a “closed” system
- Efficiency: an increase in efficiency can be seen as a basic element on the way to a “renewable energy supply”
- Sufficiency: this element is closely linked to the human demand and lifestyle issues. The addiction to a permanent growth has to be changed to a will to development. In other words “further, faster, and more” has to be replaced by “living better”. Or according to (Erich Fromm) “to be” instead of “to have”.

(BMU 2006)

2.2.2 Energy Savings, Efficiency, RES as a new Market

"The need to protect the environment has become accepted – almost as 'the establishment view'. But the hard part is an addiction to 'growth' on a finite planet…." (Ochsendorf 2004). In the energy sector this addiction can be shifted from growth to development. Countries with high standards have to play a key role to meet their ambitious goal towards a mostly CO_2 neutral economy. Growth has to be reduced, "increased efficiency of energy conversion and use" and "renewable energy" have to be addressed in equal ways (BMU 2006) as a switch from growth to a clean development.

Convincing for this shift is not just the ecological or social danger by climate change itself or the supply security for energies. A further valid economically and politically argument is in fact that prevention of climate change is estimated to be much cheaper than its resulting costs (Hauser, Hogrefe, Bradke, & Erhorn 2006; Stern 2006). Already an extra spending of 1% of GDP per year is estimated to be enough to mitigate environmental threats and to promote an environmental market change (Stern 2006). According to the 3rd part of the new IPCC Report (released in May 2007) climate change prevention will even fuel the world market or lead with a sustainable scenario to a almost neglectable decrease of 0.12% in GDP (IPCC 2007).

Politicians, industrials as well as economics in Europe and other parts of the world are about to realize that growing energy concerns foster a strong new market within a new branch. Technical innovations for energy savings and CO_2 neutral energy productions are believed to have a strong environmental, economical but also social impact.

2.2.3 Energy Consumption in Buildings

80% of the world's population lives in developing countries with a tremendous potential of an increasing pollution. More than 50% in cities, often densely populated (UN 2004). With an expected economical growth in most parts of the world construction activities never have been that intense like nowadays and are expected to grow according to above factors.

30-40% of primary energy is worldwide used in buildings (IEA 2005). The demand during the operational phase of the building again represents the major contribution with heating and cooling on top of the list (Hauser, Hogrefe, Bradke, & Erhorn 2006; UNEP 2007). Beside that construction, demolition, renovation and production of materials and the resource delivery are also factors to the energy demand of a building – during its lifespan. The growing energy consumption in buildings is enormous and "buildings can play a key role in combating climate change" (UNEP 2007).

In the building sector the reduction of the energy demand is the main trigger on the way to a CO_2 free society. Reductions have to be achieved by savings and by efficient use which does not mean to "freeze in the dark". Quite the converse according to improvements of standards (Greenpeace 2007). These standards can be reached by the most important options for energy saving: thermal insulation, buildings design, replacement of old heating systems and installation of high efficient electrical appliances (Greenpeace 2007).

2.3 Energy Issues in Europe

2.3.1 European Ambitions

In the EU live some 450 million people in 25 countries. The energy demand is annually continuously rising by 1-2% (Eurobarometer 2006a). Even with this growing demand European GHG emissions remained fairly stable over the last decade due to a continuing change from coal to other fuels (EEA 2004).

Already in the 1980s Europe was concerned by a growing awareness of environmental problems due to man-made pollution. This led in the early 1990s to the Kyoto protocol whereby the international community was lead by the European Union in defining the limits on the release of GHGs and other environmental aims. The targets for CO_2 emission reduction till 2008/2012 (based on 1990 levels) were defined globally with 5% and 8% on European level with individual national targets (e.g. Germany with 21%). The majority of European citizens (47%) are arguing for a European energy policy with a focus on "security of supply, market competitiveness and sustainability" (Eurobarometer 2006b). These are also the important factors given by "[the]

European Strategy for Sustainable, Competitive and Secure Energy" (European Commission 2006a). All these aims are consistent with energy efficiency, energy saving technologies and a renewable energy supply.

2.3.2 European Ambitions in the Buildings Sector

In Europe buildings account for 40 up to 45% of the total energy use with a significant contribution to the Green House Effect (GHE) due to huge CO_2 emissions (Hauser, Hogrefe, Bradke, & Erhorn 2006; UNEP 2007).

A study showed that in the European Union the application of existing technologies like insulation in buildings could reduce GHG emissions in the building sector excelling by far the total Kyoto commitments for all sectors (UNEP 2007) (see Fig. 5).

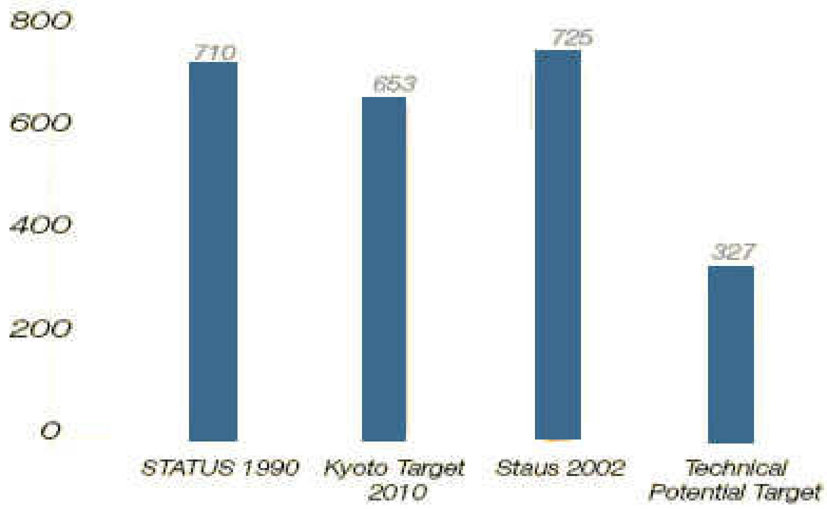

Fig. 5: CO_2 Emission in different EU scenarios and the technical potential of reduction in the building sector (published in UNEP 2007)

European's high energy import dependency as well as the commitment to the Kyoto Protocol initiated the European Climate Change Programme (ECCP 1 and 2) in 2000/2005 with the focus on cost efficient methods to reduce emissions. With regard to the building sector the following instruments were developed:

- The EU Emission Trading Scheme
- The legislation to promote RES
- The legislation to promote Combined Heat and Power generation (CHP)
- The legislation to promote the energy efficiency of buildings such as the "Directive on the Energy Performance of Buildings" (2002/91/EC) regulating the total energy demand of buildings

(EU 1992; UNEP 2007)

Additional methods (listed in UNEP 2007):

- SAVE Directive – deals with the reduction of CO_2 by better energy efficiency
- Hot-water boilers (Council Directive 92/42/EEC)
- Construction Products (Council Directive 89/106/EEC)
- Energy Labelling of household appliances (EU 2006).

Summary Part 2

*94% of the global CO_2 emissions derive from anthropocentric energy related issues mainly produced with fossil fuels. To reduce the risk of climate change the global CO_2 emissions have to be reduced by 50% till 2050 (around 1.3 t/capita*a) with a further reduction to 80% for industrialized countries (OECD) since they emit by far the hugest share of GHGs .This can be accomplished by a decline on the demand side of 50% and a fuel switch on supply side to over 60% RES (consistency). The tremendous decrease on the demand side can be addressed by energy savings (sufficiency) and rising energy efficiency. But for most developed countries this is more than just an ecological question. Reducing national energy import dependency (as a question of supply security, price stability and market stimulation), reducing environmental burdens and risks (climate threats but also from nuclear risks) and ease the time pressure concerning future energy political questions are other important effect on diverse levels (Stern & Oskamp 1987).*

The Kyoto protocol initiated by EU member states defines global emission reductions (5%) with a different distribution (Europe 8%, Germany 21%) till 2008/12. A huge potential for emission savings can be identified in the building sector that account for some 30 to 40% of the global primary energy demand and 41% in the EU. Therefore several European legal and other instruments were developed for this field.

3 Energy in Germany

Germany's ambitious goal to decline the CO_2 emission by 21% till 2008/2012 assented 15 years ago in the Kyoto protocol is already accomplished to a huge share. But the effect of energy savings was just realized between 1988 and 1992. trough increases in energy efficiency in almost all sectors, linked to national economical shifts and transformations during the reunification (Kohler, Kraus, & Hausladen 2006). In the meanwhile the second phase of the agreement covering the time frame between 2013 and 2017 is currently negotiated.

3.1 Energy Supply in Germany

3.1.1 Fuelling the Nation

On the supply side currently the heat market is predominantly fuelled by natural gas and oil while electricity generation is dominated by brown and hard coal with a growing share of natural gas. Nuclear, which is relatively CO_2 neutral, still accounts for 26% for electricity on national level but will be replaced by other sources after the phase-out during the next two decades (BMU 2006). Since Germany has just little fossil resources (hard and brown coal) it imports around 75% of its energy/fuels and is hereby highly dependent on prices, economical agreements and international political understanding. All of these are factors influencing the energy security of the German economy and the population (Hauser, Hogrefe, Bradke, & Erhorn 2006).

Concerns about the environmental impact and the supply security of European energy let the European Commission already in the beginning of this century adopted a Green Paper entitled "Towards a European Strategy for the Security of energy Supply". This paper presents the integration of RES and the distributed generation (DG) as the prioritized road map for the European energy supply of the 21st century. RES and DG can be installed nationally, are less or not based on fossil fuels and hence can be seen as a secure and more environmentally friendly energy source for a European and hopefully global energy supply (Sánchez-Jiménez 2001).

In the same time Germany promoted the development of renewable energies with its feed-in-tariffs for renewable energies which helped since the beginning of this century to develop one of the most flourishing markets for renewable energy technologies world wide. This strategy is further politically supported with the aim to increase renewable energy production to 12.5% (2010) and to 20% till 2020 (Kohler, Kraus, & Hausladen 2006). Combined Heat and Power Production (CHP) is also supported and is expected to increase from 14% to 30% of electricity production (BMU 2006). Fixed targets for the heat production from RES would mobilize a “sleeping giant” (Scheer 2007).

According to estimations by the Federal Ministry for the Environment (BMU 2006) the current German primary energy demand could be fuelled to 37% (5,200PJ/a) by renewable energies. With estimated high energy savings over the next decades this share might account for around 60%. Including with feasible imports of renewable energies the presumed energy demand can easily be covered completely by RES (BMU 2006). Other estimations even show a completely independent national energy supply (e.g. Scheer 2005).

Basic factors to achieve these aims are a “smart generation”, “distribution and consumption“, an „energy production closer to the consumer“ and „maximum use of locally available, environmentally friendly fuels“ (Greenpeace 2007). Eventually higher costs (around 5%) for a CO_2 neutral energy supply are even accepted by 40% of the (European) population (Eurobarometer 2006b).

The aspirated aim to double the energy productivity from 1990 to 2020 needs further encouragement. The reached gains in productivity of yearly 1.7% has to be more than doubled in the next years to 2.9 or even 3.5%. Helping might be that over the next 15 years around 40 to 70% of Germany’s power plants have to be replaced (Kohler, Kraus, & Hausladen 2006; Nitsch 2002). Hopefully by CHP or RES since this is a decision that lasts for the next 50 years (BMU 2006; Greenpeace 2007).

3.1.2 Energy Supply of Buildings

Germany’s energy production is highly centralized, based on large-scale units and slowly changing towards a more distributed generation (DG) with individual or local installations of Renewable Energies and small scale CHP production due to convincing incentives from guaranteed feed-in-tariffs. The aim is a feasible distribution between ‘off site’ (centralized), ‘on site’ (decentralized) and centralized or decentralized production on a unit scale systems (BMU 2006).

Since a detailed description of the energy supply in the building sector is too complex within this research the main energy market for the household sector – heating – will be discussed shortly.

As said before the current heat supply is hugely based on fossil fuels; mainly natural gas and oil. The distribution works primarily with fuel supply and combustion on a one-house base. The efficiency is highly dependent on the used system and the correct dimensioning and adjustments. Generally (90%) temperatures below 80°C are needed (Herkel & Strauß 2007). With an assumed decrease for heat and lower demand in temperatures mainly four supply systems (besides passive heating) will probably have the highest potential to supply the future demand for heat in a short run:

- Solar thermal panels (with relatively low temperatures in the heating season and a high dependency on climate conditions).
- Geothermal installations (with a reasonable demand for electricity for the heat pump)
- CHP production on a local or individual level (based on natural gas or biomass like wood/pellets)
- CHP with district heating supply (mainly based on fossil fuels, biomass, waste combustion or waste temperature form industrial processes)

While solar and geothermal supply is rather likely in sparsely populated areas the German settlement structure is generally predestined for district heat distribution (Nitsch 2002).

3.2 Energy Demand in Germany

3.2.1 Energy Issues in the German Transport and Industry Sector; Challenging the Reduction Targets for Buildings

In Germany almost half of the national energy demand is consumed in buildings (in the housing sector itself some 34%). Industries already reduced their share over the last 15 years (EC 2007). Further reduction will mainly be achieved according to emission prices in the European emission trading scheme. Therefore the avoidance cost will be much higher than in energy production or in the increased efficiency of buildings with a positive return (depending on price corrections and payback time).

The same can be expected for the transport sector which is still almost exclusively based on fossil fuels. A switch in the complex structure with its globally installed and multifaceted distribution net to renewable fuels or a fast and outrageous reduction in the demand is rather unlikely. Small steps like the CO_2 emission reduction to 120g/km till 2012 (including reductions on supply side) compared to currently 167g/km (Euractive 2007) are not reaching the needed and challenging effects.

These factors lead consequently to a hypothesis that a higher demand for reduction over the next four decades in the German building sector with its huge and feasible potential is urgently needed to fulfil the national reduction aim. This assumption is the basis for estimated projections defining a sectorial target for energy demand reductions in chapter 3.3.1. Very likely this basic concept can easily be transferred to most other European countries.

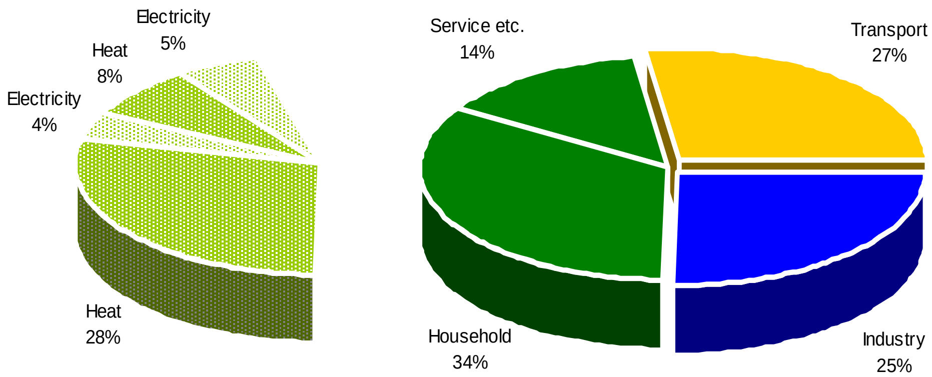

Fig. 6: Final German energy consumption by sectors in 2004 (right) and estimated share of heat and electricity in buildings (housing and service industries) (left) (EC 2006)

3.2.2 Energy Demand in the German Building Sector

In Germany around 48% of the energy demand is required within buildings (heat and electricity within the housing and service sector); the largest share of approximately 87% in private households during the operational phase as low temperatures (<80°C) mainly for space heating but also for the domestic hot water (DHW) (EC 2006; Herkel & Strauß 2007; Kohler, Kraus, & Hausladen 2006) what equals to around one third of the primary national energy demand (Hauser, Hogrefe, Bradke, & Erhorn 2006). In real numbers this means that the average space heating and DHW demand within the operational phase of buildings in Germany amounts to 225 kWh/m²a (Passivhaus Kompendium 2006). Further energy demands over the whole life-span of a building (cattle to grave approach) will be discussed later in chapter 4.1.1 (Life-Cycle-Assessment (LCA), p. 20).

The EnEV (the German implementation of the European “Directive on the Energy Performance of Buildings”) gives requirements for the heat demand (space heating and DHW) in the housing sector calculated on a primary energy basis. For new houses built according to the new building code (2002) the limit for space heating is set to around 100 kWh/m²a. Other "unofficial" standards demand much less (e.g. passive house standard: 15 kWh/m²a) or even 0 kWh/m²a (plus-energy house) (dena 2004; Flade, Hallmann, Lohmann, & Mack 2003). By several projects energy savings by a factor of 10 is proven to be achievable under normal market conditions for new buildings but also for the renovation of old houses which of course holds the highest cost-effective potency for CO_2 reduction (Kohler, Kraus, & Hausladen 2006; Nitsch 2002; Poxleitner 2006).

Consequently a very large and even economically feasible potential for the reduction of CO_2 emissions is available in the building sector in new developments but especially in the refurbishment of existing buildings.

3.2.2.1 Electricity

Even thou if the domestic energy demand is almost just dependent on heating electrical appliances, cooling and lighting will gain a growing importance with a hopefully decreasing demand for heating. The savings from energy efficient household appliances are estimated to account up to 3% per year. (BMU 2006). Already the energy demand during standby modes is likely to account for up to 13% of the electricity demand (EEA 2005) and with new energy efficient appliances standby power consumption can be reduced by up to 70% (Greenpeace 2007). The increasing amount of appliances on the other hand leads to a rise in power demand which will redeem the gains due to efficiency (EEA 2005; Mantzos et al. 2003; Rijkens-Klomp & Lieshout 2004). Improvements in power efficiency for electric appliances are in some literatures estimated up to the factor of 4 (Bell, Lowe, & Roberts 1996).

3.3 Reduction of CO2 and Energy Demand in the German Building Sector

3.3.1 Defining a sectorial Target

CO_2 Reduction in the building sector is highly efficient in many ways (see Fig. 7). (1) It will decrease the resource depletion, (2) it has a very high potential to reduce CO_2 emission while (3) the costs of prevention emission even have a positive feedback. For the (4) diversification of the energy supply the used source for heating and electricity is important and is much higher with the use of renewable energies. All the needed know-how and technology is there why (5) the practicability is enormously high. (6) The public value is also high but depends on other factors, too.

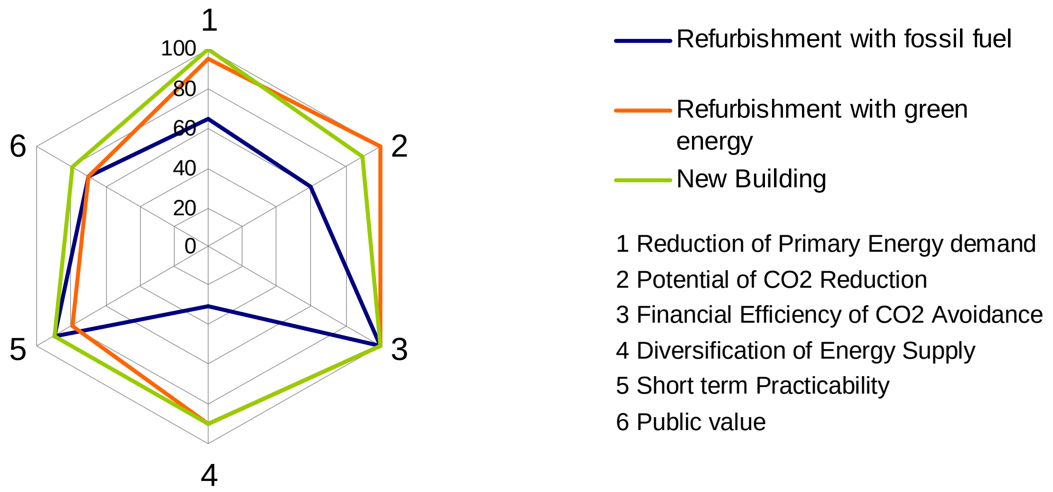

Fig. 7: Advantages of energy efficient measures in the building sector (Idea adopted from Hauser, Hogrefe, Bradke, & Erhorn 2006)

The aim of a total emission reduction is based on a reduction of the energy demand by 50%. Within this limits the supply side can probably fulfil the further emission reduction of 30% (60% according to the numbers in 2050- based ona 50% demand reduction scenario).

The energy demand is basically separated into the tree main categories: transport, industry and buildings (housing and services).

The industry sector: The share of industrial energy demand accounts for some 25%. Power savings of some 20% till 2050 are expected by more efficient production processes (Nitsch 2002) what sounds quite pessimistic.

In this scenario the reduction will follow the current efficiency improvements of 1.7% (Kohler, Kraus, & Hausladen 2006; Nitsch 2002) but reduced by a production growth of some 0.5%/a. These improvements will vary and slow down over the years, which results in a sectorial reduction till 2050 of some 65% down to a share of 17% (33% according to the numbers in 2050).

The transport sector: The transport sector accounts for 27% of the energy consumption in Germany. According to Nitsch (2002) the focus for energy reductions the transport are more promising in section. With a predicted growth in public transportation of 10% and a doubling of the share of transport by rail till 2050 a switch to gaseous fuels (still not based on renewables) will develop very slowly from 2030 onwards. Consequently energy efficiency is the most promising attempt in the transport sector (Nitsch 2002). But handicaps for an increase in efficiency are a strong lobby that tries to shift politically decided CO_2 reductions till 2012 of some 25% (including fuel sources) (Moutschen 2007) to later dates (Euractive 2007) and the unequal distribution of these reductions with higher emission tolerances for big cars (mainly produced and favoured in Germany). Moreover mandatory aims are just valid for new produced cars. Therefore a deceleration of probably 7 to 15 years can be expected to reach these aims as an average on streets. And finally the near past showed even with a reduction in fuel consumption per km a strong emission increase of some 25% over the last 15 years in the European transport sector due to a growing fleet and more need for commuting (Moutschen 2007).

In this scenario a reduction by 25% is calculated with a delay of around 10 years (2024). In the same time an increase in demand of around 1%/a reduces these improvements, slowing down after 2020. A slow change in fuel supply speeds the yearly improvements in efficiencies up to 1.7% as an average. Consequently the emission from the transport sector accounts in 2050 for 20% (40% according to the numbers in 2050) which equals to a reduction of 35%.

The building sector: This consequently leads to a needed reduction in the building sector of around 70% (based on current level) to fulfil the nationally aimed reduction of 50% on the demand side till 2050. A reduction of 70% energy demand in the building sector is consequently the quintessential motivation for the further research.

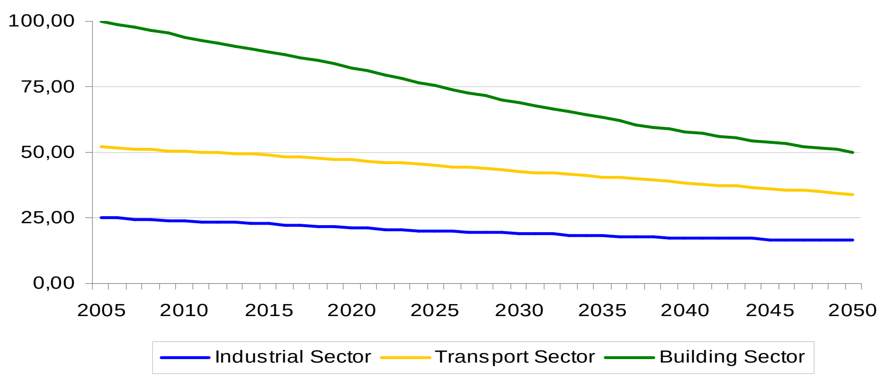

Fig. 8: Sustainable scenario for Germany (demand side) - A reduction on the demand side by 50% has to be achieved till 2050 to reduce CO_2 emissions by 80% (together with the supply). Industries and Transport can just aim for smaller reductions while the building sector with huge economically feasible potential can reduce its demand by almost 80%.

3.3.2 Measures to Reach the Targets

This ambitious aim should be generally based on a three-part strategy defining the framework for technical improvements and social shifts:

- **Legal**: building regulations and ordinances have to define and improve the minimum requirements for new and existing buildings and have to support ambitions (further discussed in 4.3 Legal and Political Aspects for Emission Reduction in the German Building Sector, p. 29)
- **Informative**: market oriented measures like the building pass as well as information campaigns, trainings and consultancy will increase (1) professional knowledge and (2) the public acceptance. A change in behaviour has to be established (further discussed in 4.4 Social Aspects for Emission Reduction in the German Building Sector, p. 35)
- **Financial**: Fiscal aid programmes like the CO_2-Building-Refurbishment-Programme offer additional incentives for investments in energy efficient technologies and measures (further discussed in 4.5 Economic Aspects for Emission Reduction in the German Building Sector, p. 39).

(Hauser, Hogrefe, Bradke, & Erhorn 2006)

Summary Part 3

The energy supply in Germany is highly based on fossil fuels and therefore dependent to 75% on energy and fuel imports. In addition the phase-out of the more or less CO_2 neutral nuclear power production has to be compensated within the next two decades. Due to the influence of the feed-in-law for RES Germany has a very flourishing market in that field and a shift to more RES and DG can be identified. In total the amount of existing RES (around 5%) as well as aimed 20% (2020) are by far behind the estimated feasible potential of 37% (BMU 2006).

The heat supply in the building sector (almost exclusively temperatures below 80°C) will hopefully also shift to more on- and off-side CHP production as well as supply by RES (centralized and decentralized).

Reduction on the demand side can mainly be achieved for heating (a factor of 10 is possible and economically feasible). Thereby the average demand for space heating and DHW of 225 kWh/m²a can be reduced to 15 kWh/m²a (plus DHW with around 12.5 kWh/m²a). Consequently the building sector holds a huge potential for a decrease of CO_2 emissions and current regulations with a heat demand (space and water heating) of around 100 kWh/m²a are no more very challenging.

To reach the given goal (in CO_2 emission reduction) of 80% according to given scenarios till 2050 huge efforts are needed on supply and demand side. Energy efficiency in the building sector is one of the main potentials for action and the reduction of its energy demand has to be much more demanding since other sectors (industry and transport) cannot compete for several reasons in the same timeframe (see 3.2.1, p. 16). The sectorial target for buildings should consequently aim for an energy demand reduction of 70%. Handicaps to reach this ambitious reduction can be identified on different levels what will be further discussed.

4 Barriers and Incentives for a Sustainable Energy Demand in the German Building Sector

The urgently needed reductions in CO_2 emission in the building sector aims for ecological rebalancing with political, social and economical efforts to support technical improvements and promote sustainable consumption patterns. Hence a sustainable scenario is targeted. Consequently the necessary changes and factors will be discussed in the following chapters according to the four pillars of sustainability (ecology, politics, society and economy). Due to the strong interconnection between these categories many topics might be discussed various times but with different viewpoints.

For simplification this research will focus from now on mainly on the demand side in the housing sector.

4.1 The Ecological Aspects for Emission Reduction in the German Building Sector

Issues concerning the environmental impact of buildings are various. GHG emissions are just a single important factor beside material extraction, land use, liquid and solid waste generation, problems with the reuse and recycling of building materials, transport of materials, water use and discharge, acidification, other pollutants, health concerns as well as the integration of buildings within a system of infrastructure and society (UNEP 2007).

4.1.1 Life-Cycle-Assessment (LCA)

Concerning CO_2 emissions and energy demand the following processes have certain impacts: the production of materials and components (embodied energy), the transport of materials (grey energy), the process of construction and installation (induced energy), the phase of operation during the occupation of the building (consequently called: operation energy), the demolition process at the end of the operational time (demolition-recycling energy). This complexity of factors which is hard to analyse is influencing the ecological balance and the energy consumption of buildings on a life-cycle approach. Several European studies estimate that buildings hereby account for 45% of CO_2 emissions (UNEP 2007).

The most demanding factor within a LCA is the time span it is based on (Mine & Geoff 2005; Rijkens-Klomp & Lieshout 2004). The operational time of buildings is usually 50 to 75 years (UNEP 2007) in Germany due to relatively high standards even longer. But with increasing energy efficiency during the operation phase of buildings the importance of other energies than operation energy grows. Hereby in a highly energy efficient house the energy demand on a LCA-basis during the operational phase can be limited down to 1/3 (Hastings & Wall 2007). Hence a shift to a LCA analysis is mandatory for ecological improvements within the material intense buildings sector. The approach of Live-Cycle-Cost can help with the implementation and the general acceptance.

4.1.1.1 Environmental Impacts from Insulation Production as an Example for a LCA:

For the ecological balance it is important which insulation material is used. Hence it is also important for insulation materials to focus on the energy demand during its production process (Passivhaus Kompendium 2006). But even a not very ecologically produced material like Expanded Polystyrene (made out of oil) is highly efficiently used as insulation on a LCA-basis. A research done in 2000 in a cooperation of the Austrian Institution for Building Biology and Ecology and the Donau-University in Krems (in Jandl 2006) clearly showed that recent insulation standards in the housing sector with an average maximum of 30 cm are far below the ecological break-even point. The research evaluated the energy demand, greenhouse effect and acidification during an average life time of 30 years for the envelope taking all additional factors like installation and deconstruction into account (Jandl 2006):

	Ecologically most favourable thickness of insulation (cm)
Energy demand	90
Greenhouse effect	125
Acidification	65

It has to be said that the economical threshold is much more limited and highly dependent on the energy price (Jandl 2006). An evaluation based on the Life Cycle Cost (LCC) would probably suggest an insulation of some 20 to 40 cm.

Life Cycle Cost (LCC) is the financial facet of an LCA and sums up all costs of a product or an object relevant during its cycle of use. Therefore secondary cost like reparation, renovation, replacement and dismantling have to be added to first investments. But also costs for the maintenance, administration and operation like energy (Albrecht 2006). With a potential implementation of externalities LCC will mirror the ecological burden of materials and products (see also 4.5.5.3LCC Life Cycle Cost, p. 42).

4.1.2 From Resources to Reuse

4.1.2.1 Material Resources

The construction and building sector accounts for the largest share of material extraction and in the use of natural resources by the use of land (UNEP 2007). In the same time the efficiency in the resource use is significantly low. “It has been estimated that only 6% of [the] vast flows of materials end up in products” (Natural Capitalism, 1999 quoted in Ochsendorf 2004). Even more concerning is that the prices for resources dramatically dropped during the last three decades due to new technologies, growing demand and new markets (Weizäcker et al. 1995).

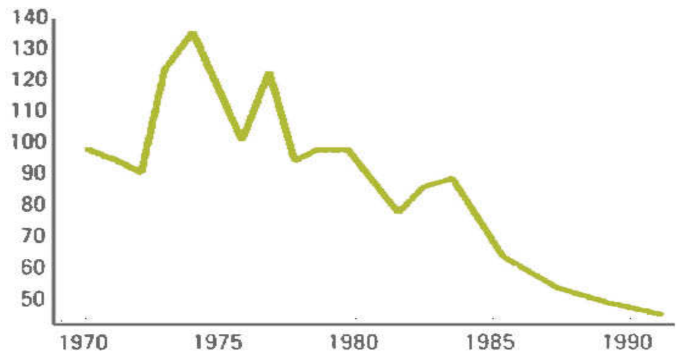

Fig. 9: Price development of raw materials from the during and after the oil crises (1974 -1991) (Weizäcker, von E.U., Lovins, & Lovins 1995, p. 220)

4.1.2.2 Production

Materials such as concrete, aluminium, steel and other metals are produced very energy intense thus have a large embodied energy and are correspondingly also responsible for a vast quantity of CO_2 emissions (Lawson 1996). The building sector heavily consumes these materials. The choice of materials during the design phase can tremendously reduce the embodied energy of the total complex and hereby decrease CO_2 emissions already in an early phase of the life-span of buildings.

A study by Petersen (Petersen & Solberg 2002) stated “that the total energy consumption in manufacturing of steel beams is two to three times higher and the use of fossil fuels is 6 to 12 times higher, as compared to the manufacturing of glulam (glue-laminated timber) beams. The waste handling of both materials can either give or use energy. Therefore, the difference in energy consumption over the life cycle between steel beams and glulam beams depends strongly on how the materials are handled after the building demolition” (UNEP 2007).

Consequently the reuse (in buildings or energy processing) or the recycling of materials is a further significant factor for the life-cycle energy balance.

4.1.2.3 Recycling and Reuse

The recycling potential of a building is as important as a minimisation of embodied energy in materials since the recycling and reuse of materials and components is equal to maintaining its embodied energy; partly or completely. Recycling of aluminium for example accounts just for 10% of its production energy why, generally speaking, materials with large embodied energy are nearly always recycled (Mine & Geoff 2005). The use of recycled materials in the building industry accounts for a reduction of embodied energy of up to some 50% (with huge variations between different studies). The reuse of building materials even up to 95% (Mine & Geoff 2005; Thomark 2000). Depending on the energy use history suggests two different sustainable solutions for constructions: temporarily highly ecological based structures like used by Incas and permanent Roman structures with a long life time but with material use and technical equipment. Depending on the reuse or the recycling of components and materials both can be sustainable (Ochsendorf 2004).

Material	embodied energy kWh/KG
Kiln dried sawn softwood	0.9
Kiln dried sawn hardsoftwood	0.6
Air dried sawn hardwood	0.1
Hardboard	6.7
Particleboard	2.2
MDF	3.1
Plywood	2.9
Glue-laminated timber	3.1
Laminated veneer lumber	3.1
Plastics - general	25.0
PVC	22.2
Glass	3.5
Aluminium	47.2
Clopper	27.8
Galvanised steel	10.6

Fig. 10: Typical figures of embodied energy for some building materials (Lawson 1996)

4.1.3 Planning Process

Building activities are influenced and limited by technical standards, mandatory safety regulations, esthetical considerations, architectural factors, health and quality standards and finally requirements concerning energy and the environment (UNEP 2007). All these factors have to be considered during the planning process. For a sustainable building concept it is useless to focus just on one area of consumption and therefore it is important to work on a holistic concatenation of all parameters: climate, building material, energy, insulation, water, ground, undeveloped area, and waste (Malloth 2006). Accordingly the following points have to be considered by architects:

- Sustainable site planning
- Energy efficiency and renewable energy
- Conservation of materials and resources
- Indoor environmental quality
- Life-time planning of the building (construction, operation, demolition)

(Ochsendorf 2004)

But not just during the planning procedure also during construction activities especially in huge projects many people and actors are involved. Even with accurateness in their own field the whole buildings might lack energy efficiency due to the separation of the participating crafts (UNEP 2007). According to this fact energy efficiency should be continually included in the planning and building process from the very beginning onwards as a core part of the basic concept of a building (Kohler, Kraus, & Hausladen 2006).

Summary Part 4.1

Energy in the building sector is primary demanded during the operational phase (within a highly efficient building this share might be reduced to 1/3). But also the material production, transport and installation as well as the demolition of the building account for enormous demands. Consequently a holistic approach calculating the energy demand as such has to be based on a LCA. A LCC analysis can help to implement this necessary, all-embracing concept. Further economical and political adjustments are needed (like internalization of externalities). A support for ecological and green insulation materials such as LCA-based financing or particular subsidies are tentative opportunities.

4.2 Physical and Technical Aspects for Emission Reduction in the German Building Sector

4.2.1 Basic physical Effects in Buildings

Oscar Wilde once should have said that if nature was comfortable men would not have invented architecture. This brings us back to the basic function of buildings: shelter and a stable, comfortable environment.

From a physical viewpoint several parameters are influencing the well-being of inhabitants. Highly important are: air temperature, surface temperature and other air qualities like humidity and air pollution. The average sensed indoor temperature should be around 19 to 20°C (depending on personal preferences; see paragraphs 4.4.3.2 and 4.4.3.4). It is normally calculated as the arithmetic middle between surface temperature and air temperature, which means that in bad insulated houses with cold walls higher air temperature is necessary to supply comfortableness. Surfaces of well insulated houses differ by 3 to 4 K the maximum. In general relatively low temperatures - and consequently a low demand for heating - already meet a high satisfaction in good insulated rooms (Schulze Darup 2003).

Energy efficiency in buildings can easily be achieved and is not a technical innovation. The general energy demand (mainly for space heating) and hereby the CO_2 emissions can easily be reduced by around 80% and even further to a factor of 10 (Feist et al. 1994; Kohler, Kraus, & Hausladen 2006; Schulze Darup 2003). Main factor is the reduction of the thermal transfer by a consequent, high level of insulation and the reduction of air leakage between the in- and the outside of the building by accomplishing air tightness of the envelope. The design of the house with solar irradiation (with the use of shades in summer against overheating) leads to a minimisation of active space heating. In addition mechanical ventilation with efficient heat recovery systems, efficient boilers, efficient pumps and lighting can reduce the energy demand further. Depending on the energy fuel for heating and electricity (fossil or renewable) the emission of GHGs from such buildings can be cut down to almost zero (Hauser, Hogrefe, Bradke, & Erhorn 2006)

In a nutshell these steps can be translated to the advised energy measures in the IEA Solar Heating and Cooling programme (UNEP 2007):

- energy conservation technologies
- passive solar
- active solar

4.2.1.1 Thermal Insulation and Air-Tightness

Good thermal insulation is mostly seen as the prioritised action to achieve a better energy efficiency of buildings. But especially during refurbishments simply adding of insulation does not automatically lead to a high-energy-performing house. In high insulated houses the effect from thermal bridges becomes even more important. Thermal bridges are thermal discontinuities in the envelope, the floor or the roof often originate from balconies, corners or connections of different compounds or materials (Feist 2001).

The other aspect is the air-tightness of the envelope. Its effect on energy savings but also on the durability of the construction is often underestimated. Furthermore, the better the thermal insulation of a house the more pronounced are the effects of even small fractions of energy gains (e.g. by solar radiation).

4.2.1.2 Design

The relation between surface and volume, insolation (orientation), window size and the aerodynamic of buildings have a high influence on the energy demand. Due to these factors like the compact building form and the orientation of the building, energy efficient houses have limited design opportunities.

4.2.1.3 Orientation and Windows

The orientation of the building for a good south faced solar irradiation and the window design is highly contributing to the energy efficiency of buildings. Solar energy without the additional use of technical support (as pumps or converters) is called passive solar energy. The primary example are windows facing south (BMU 2006). Passive solar gains can highly contribute to the heat supply during the heating season. Efficient and well planed solar protection is necessary against overheating during summer.

For the illumination the orientation of windows is more important than its size. But the insulation quality of windows is 3 to 10 times lower than that of walls. Therefore already with a proportion of 50% of windows the extra solar gains in winter time are no longer usable (Kohler, Kraus, & Hausladen 2006).

A good choice of glazing (kind of glass, size, orientation and shading) considers the right balance of thermal insulation, overheating, reflection of light and illumination depending on the outer climate, solar irradiation and indoor climate demands. Energetically this leads to a trade–off between additional lighting, heating and perhaps even air-conditioning (UNEP 2007).

4.2.1.4 Space Heating

Solar gains highly contribute to the heat balance of a building but additional space heating is still necessary in most cases in the German climate. With good thermal insulation and air-tightness (see 4.2.1.1) a reduction of the space heating demand (measured in kWh per m² and year) down to 15 kWh/m²a is economically possible. In addition to that, the heating load (maximal demand for heating at a time) can be drastically reduced to 10 to 20 Watts/m² which makes high temperatures for heating media (above 40°C) unnecessary. The results are lower temperature differences in the air, a better distribution of the heat in the air without stratification, reduction of draught and no more pyrolysis effects of dust which normally results in bad air quality. A drastically increase in well-being is the result (Schulze Darup 2003).

With a reduction below 10W/m² of heating load a water based heat system can be replaced by an air-heating system. No tubes and radiators have to be installed which leads to further benefits in air-quality and economics (Schulze Darup 2003).

4.2.1.5 Ventilation

During the 1980s air tightness of buildings often led to moulds, allergies and other effects associated with the Sick Building Syndrome (SBS). Good controlled ventilation is mandatory in air-tight buildings. The mechanical ventilation in passive houses for example guarantees an air-exchange of around 0.4 to 0.8 per hour which equals a manual ventilation every 90 minutes; also during night (see Chapter 4.4.4, p. 38 and Fig. 17) (Schulze Darup 2003). A further advantage of the controlled ventilation is the possibility for additional heat recovery. Good heat recovery systems achieve a performance rate of more than 80% and save hereby a huge amount of energy.

4.2.1.6 Lighting and Appliances

Even if space and water heating accounts for by far the largest share of reduction potential also lights and appliances offer a variety for improvements which is in some literature estimated with a factor of 4 (Bell, Lowe, & Roberts 1996). This becomes even more important since with huge reductions for space and water heating, electricity will potentially account for the largest share of domestic energy consumption. Very likely the demand for electrical energy will even rise due to its high quality (it can easily be transformed into almost all needed forms of energy, is scalable and is easy to transport) what is proven by the past. The fraction for space heating, water heating and cooking did not significantly change over the last 40 years while the energy demand for lights and appliances more than doubled (Shorrock, Henderson, & Brown 1992).

4.2.1.7 Synergy Effects

Energy efficiency has often a multiple positive effect (Greenpeace 2007).

Energy efficiency is not just necessary for a whole building but also for small appliances. The inefficiency in one system can have enormous effects on other systems in the building. The complexity of this issue can be explained by the example of exchanging normal light bulbs (which just use less than 10% for light and 90% for heat production) to highly efficient light systems (which reduces the share for heating to some percent. Consequently the cooling demand during summer can significantly be reduced. With respect of the positive ecological effect this is a clear win-win-win situation. How important the consideration of this factor is shows a study by Chalmers University (Sweden), finding that some modern office buildings in Sweden even need cooling at outdoor temperatures of -10°C (UNEP 2007).

4.2.1.8 Supply

Heat supply: CHP systems small or large-scale are reducing emissions by improving the primary energy based efficiency by 20 to 40%. The switch to renewable energy carriers like biomass or the use of solar thermal or geothermal energy brings further improvements for the primary energy balance (Schulze Darup 2003).

4.2.2 Urban Design

Orientation and design of the building is often not just an individual question and relates to urban or land-use planning with their strong influence on the location, the density and the design of neighbourhoods and individual dwellings. Thus, land-use planning "has a significant role to play in achieving sustainable development, and in particular in reducing the energy use of new developments" (Kohler, Kraus, & Hausladen 2006). So are issues concerning the management and administration of urban systems (Bell, Lowe, & Roberts 1996). An example to involve energy issues in the land-use planning process is expressed in a research showing that two development areas with different energy requirements and therefore different wall thickness also had a very different footprint. Increasing wall thickness reduces the energy demand of a dwelling but also reduces the available indoor space and limits the space for houses. In the given example the high wall thickness lead to 17% less erected houses with 22% less living space. But the authors argue that with the correct urban structure when wall thickness is included in the urban planning process, a passive house standard could be achieved without limitations in housing space (Ellis & Bell 2004).

During the EcoCity project patterns for sustainable cities were designed in several developments with a focus beyond the pure energy demand inside the buildings. Beside factors such as nature, community issues and genius loci, energy factors were extended to an urban level such as need for transportation, waste management and locally centralised CHP (UNEP 2007).

How important this holistic approach is can be identified with the following example taking quality of insolation, space demand, surface/volume ratio and need for comm uting into account:

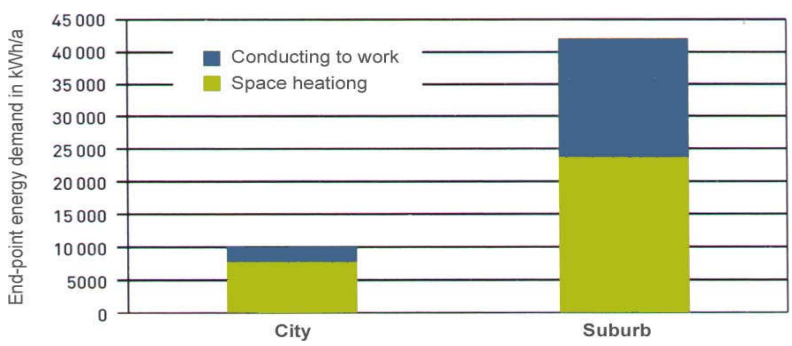

Fig. 11: Change in energy consumption of a family moving from a city apartment house to a detached house in the suburb (Kohler, Kraus, & Hausladen 2006, p. 87)

Fig. 11 shows the energy demand of a family living in a good insulated apartment house in the city with little need for commuting (5km by car/day). By moving to a bigger house with lower insulation outside the city (50km) the family will increase its energy demand by a factor of 4. (Kohler, Kraus, & Hausladen 2006)

4.2.3 Energy Standards for Buildings

Due to the crisis in energy supply since the late 20th century energy efficient standards were demanded by law since the late 1970s. These standards continually improved from ordinance to ordinance. Nowadays a heat demand (space heating and DHW) of some 100 kWh/m²a is required the maximum for new, non-commercial buildings (EnEV 2002) (see Fig. 12 and Fig. 13).

4.2.3.1 Definition: EnEV House

This standard is named by the German Energy-Saving Ordinance (EnEV) that basically regulates legally demanded regulations for the energy efficiency of a building. Consequently this standard corresponds to the recent German legislation. The maximal energy demand for space heating and DHW is standardized to around 80 to 120 kWh/m²a for new buildings and for older buildings during fundamental renovations with a 40% higher level. These requirements are evaluated on a primary energy basis.

4.2.3.2 Definition: Low-Energy Building:

Low-energy Buildings are generally buildings with an energy demand lower than the current building regulations (by definition a reduction of 30% or more for heating). Therefore the definition of “low-energy houses” varied over time and is depending on the official, national regulations. Low energy houses are normally built with standard solutions with an improved thermal insulation, glazing, air-tightness and ventilation with heat-recovery (UNEP 2007). Hereby the indoor comfort of the user can be highly improved.

4.2.3.3 Definition: 3 Litre House

A 3 litre house is defined by its demand for space heating (or space and water heating) of 30 kWh/m²a (equal to the energy content of 3 litre of oil) whereby the supply can be based on renewable or fossil fuel.

4.2.3.4 Definition: Passive House

The idea of a “passive house” is around 20 years old. Almost 15 years ago Feist (1994) calculated the individual possible and feasible reduction in domestic energy demand to 45 to 75%. With the use of renewable energies (like solar thermal or PV) the demand for fossil energies was estimated to be reduced up to 90 %. 1991 the first passive house was built in Darmstadt-Kranichstein, Germany (Passivhaus Kompendium 2006).

Nowadays the concept of the “passive house” (heated by passive heat) is probably the most popular nonofficial “low-energy house standard” in Germany and already exported to almost all European countries and also overseas.

A passive house provides a high indoor comfort and good air quality with the above measures. Thereby the space heat demand is reduced to a level that no active heating and cooling systems are required (in Germany <15 kWh/m²a for space heating; maximum heat load should be minimized to 10 W/m²). The resulting low demand for heat can be guaranteed and distributed by the anyhow needed ventilation system (Passivhaus Kompendium 2006). The total primary energy demand (including electricity and DHW) should not exceed 120 kWh/m²a what generally can be provided by RES. In general passive houses aim for a forth of current European energy requirements for new dwelling houses (UNEP 2007) (see Fig. 13).

4.2.3.5 Definition: Zero Energy House

The zero energy house produces on-site with RES the same amount of energy used by the building based on a yearly energy balance. Mostly the grid is used as a theoretical storage (feeding energy in and taking out the same amount when needed). But also a totally autonomous existence off the grid is possible. This attempt requires the state of the art in all kind of energy-efficient technologies and aims for minimal environmental impact of the building (UNEP 2007). Hereby the inhabitants have no further energy costs than the initial investments.

4.2.3.6 Definition: Energy-Plus Building

As the name already says: This building produces more energy by an increased amount of RES than it uses over the year (UNEP 2007).

Taking the embedded energy in building materials into account and calculating the energy demand of a building on a life cycle basis an energy-plus house might produce the total energy that is used over its life-span. Correctly speaking the definition of zero-energy and plus-energy houses should be evaluated on a LCA basis (see 4.1.1 Life-Cycle-Assessment (LCA), p. 20).

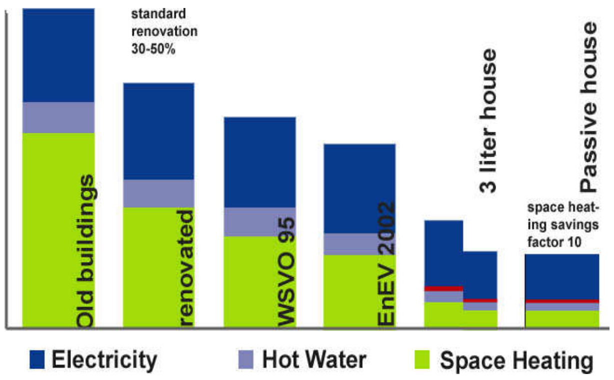

Fig. 12: German energy efficient standards for houses (Schulze Darup 2003)

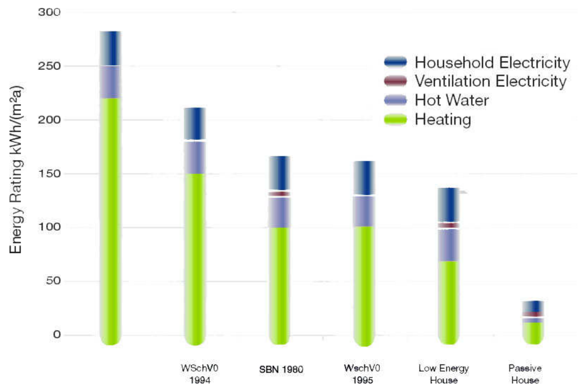

Fig. 13: Comparison of energy ratings of homes.
WSchVO=German Heat Protection Regulation
SBN=Swedish Construction Standard (UNEP 2007)

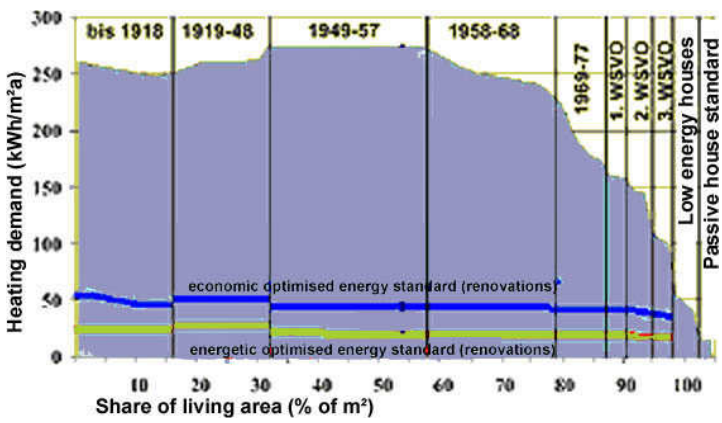

Fig. 14: Share of German buildings built according to energy ratings with the year of construction (Schulze Darup 2003)

4.2.4 Renovation

The average cycle for the renovation of buildings is around 40 to 50 years. Some 80% (32 million dwellings) of all dwelling houses in Germany were built before the first Ordinance for Energy Saving Requirement for Space Heating and Domestic Hot Water Devices (HeizAnlV) in 1979 thus without any limitations in their energy demand. Consequently the energy demand in these buildings is normally much higher than in newer buildings. Over 50% of the existing dwelling houses in Germany will fall due for refurbishments over the next two decades what is equal to 19 Million chances to reduce harmful CO_2 emissions (dena 2004; DKZ 2007; Passivhaus Kompendium 2006).

The average energy demand for space heating and DHW in existing buildings amounts to 225 kWh/m²a. 5% of the building stock in Germany even demands over 475 kWh/m²a (Passivhaus Kompendium 2006). Current studies show that up to 80% of energy can be saved by professional energy efficient refurbishment and the installation of modern building service engineering (4.2.4.1 Examples for refurbishments, p. 28) (dena 2004). Since the measures during standard refurbishments are very similar in most cases to specific action during energy efficient refurbishments the basic costs for such improvements are almost covered. The additional costs to reach a high energy standard (around 30 kWh/m²a) are estimated with 100 to 150 Euro/m² (Schulze Darup 2003). In the same time just every fifth building of the round 2.5% of yearly refurbished buildings in Germany is renovated with an energy efficient viewpoint (Kohler, Kraus, & Hausladen 2006; Nitsch 2002). Also concerning is that improvements achieved during renovations are often just half-hearted since the small extra costs for further enhancements (like heat recovery) were avoided. The effects are many-sided but mainly an economical and ecological dereliction for the next 30 to 50 years (Kohler, Kraus, & Hausladen 2006).

4.2.4.1 Examples for refurbishments

To test the implementation of high energy efficient measures during the renovation process of buildings and to develop hereby a marketable standard the German Energy Agency (dena) hosted a pilot project "low energy standards for existing buildings". Within this project 21 house building companies all over Germany refurbished 800 dwellings with 40,000 m² (dena 2004).

The requested energy values were set 30 to 50% below the demands for new constructions according to the recent ordinance (EnEV 2002) (Passivhaus Kompendium 2006). In most cases the aspirated targets were even excelled (dena 2004). The results of the project were evaluated by committees of experts and were summarized for the legislator (Hegner & Loga 2004). During this project (started in 2003) it was proven that reductions up to 80% of the energy demand can be achieved. The resulting low energy demand often was fuelled by renewable sources with support of solar thermal energy in almost 50% of all monitored buildings (Passivhaus Kompendium 2006).

Summary Part 4.2

It is technical possible to construct new buildings with no energy demand (probably even with a positive energy balance over its life-cycle). Necessary measures are a good site planning, the building design, its orientation, insulation and air-tightness, good solar irradiation over winter and shading over the summer as well as heat recovery and the use of renewable energies.

The average heat demand of 225 kWh/m²a mainly derives from the large stock of old buildings built before the first regulations of the energy demand in 1979 (around 80%). It is estimated that some 50% of all existing buildings in Germany need to be renovated till 2020. The yearly share of renovations of 2.5% has to be increased to reach this target. In the same time it is essential that refurbishments will aim for the highest technical and economical feasible energy efficiency. The technical know-how is present and the energy demand can be reduced by 80% during required renovations. A high reduction in energy demand will also lead to an even higher decrease for CO_2 *emissions in the sector as low energy demands can often be guaranteed by on-site RES.*

For a sustained development the improvement in existing buildings is even more significant than in new constructions (BMU 2006).

4.3 Legal and Political Aspects for Emission Reduction in the German Building Sector

The cut of global CO_2 emissions by almost 50% over the next four decades with massive reductions on demand side and RES on the supply side is feasible. All that is missing is the right policy support, not just on global level (Greenpeace 2007). Too little was done on the political stage over the last decades for a sector that demands some 40%+ of the total primary energy use (UNEP 2007).

4.3.1 Need for Political Support for Emission Reduction

In Germany "[m]ajor energy conservation potentials are found in buildings, […]" and because of their "long lives […] and the long periods between modernisation measures, energy conservation measures should be introduced immediately […]". But the political pressure is implemented too slowly for fasten up the development according to the given potentials of energy and emission savings. Although even some political advisors with environmental and market interests are arguing for a faster implementation: According to the Enquete Commission the average specific reduction of end-point energy consumption in recently renovated buildings down to 50 kWh/m2 has to be pursued up to 2020 (Deutscher Bundestag 2002). It is crucial to introduce further measures to promote energetic renovations in existing buildings.

4.3.2 Conflicts of Interest

The building sector is very different to other GHG emitting sectors: many, highly emitting units with a very long lifetime, many stakeholders in different levels. A complex structure with diverse concerns formed by various interest groups (UNEP 2007). In short: the complexity of the building sector with all involved people, producers and sub producers for materials makes this sector one of the most complicated target groups for environmental policies (OECD 2003). Environmental concerns are just supported by a very small lobby. Therefore where ever "protecting the climate conflicts with other social and economic goals, such as economic regeneration or the interests of particular local industries, any political will towards the former disappears". The helping argument of the win-win situation of such initiatives might result in the reduced implementation just of those measures which "constitute the lowest common denominator, leaving the majority of local emissions of greenhouse gases untouched" (Kohler, Kraus, & Hausladen 2006).

One of the systematic problems here is the differences in timescale. Typical political interests and commercial decisions are limited to 3 -10 years maximum. Changes in infrastructure, working lives, or lifetimes as well as factors of environmental damage are 10 times larger. Sustainability requires decision-makers to take even a longer view.

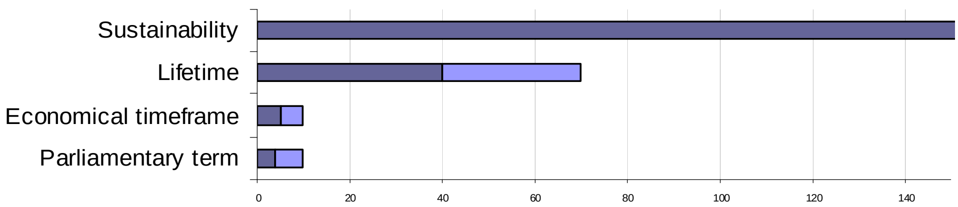

Fig. 15: Timeframes of different interests

Especially in this sector with diverse interest groups an its enormous demand for energy it is essential to reach a fast implementation of higher energy efficiency and saving wherefore political support is absolutely central. In the political arena two very basic factors have to be considered: the level (international, national, regional, local…) and the political measure.

4.3.3 Political Levels of Decision

The result of a survey about energy issues in the European Union by Eurobarometer (2006a) clearly states the demand for political action on all levels. 42% of all Germans think that political decisions about environmental necessities should be taken on a national level. Almost he same share sees this decision primarily taken on a common European level (40%). These numbers are also representing the European opinion with 42 to 39% (Eurobarometer 2006a).

4.3.3.1.1 International and national level:

The Kyoto protocol and its following commitment are acting on a global level. Several other political programmes and legislations are acting on a European scale. For example the European "Directive on the Energy Performance of Buildings" (2002/91/EC) (EPBD) (discussed in 4.3.4.1.1). The national implementation of the EPBD into German law is the German Energy Saving Ordinance (EnEV) (also discussed in 4.3.4.1, p. 31).

4.3.3.1.1.1 Local levels

On local level other instruments like the Local Agenda 21 (LA21) are highly important and basically independent of national levels. In addition local political levels can be strengthened by "transnational networks of local governments […] as a means through which to diffuse policy programmes, exchange best practice and lobby at a national and international scale" (Routledge Institute 2003). Local authorities' influence can be seen as vast since it includes land-use planning, building requirements, considerable experience in addressing environmental effect and implying energy efficient measures to own developments and stocks. In addition they "can facilitate action by others in response to climate change, both by lobbying national governments as well as by developing small-scale demonstration projects to illuminate the costs and benefits of controlling greenhouse gas emissions" (Routledge Institute 2003).

Some handicaps on local and also individual levels were identified within qualitative interviews in Danish municipalities concerning energy efficiency in schools to take place on economical and organizational stages but also issues about knowledge and behaviour. The main findings of this study are the following (UNEP 2007):

- Energy decisions are made as a link in political process, which not always is economically rational.
- Energy saving measures are often seen as an expense, and not as an economical investment. Economical incentives for this purpose are very disperse or not existing.
- Decisions about energy are given to the building management. Energy, technical and economy skills are not necessarily present combined with ignorance.
- Lacking knowledge on energy saving measures on institutional/local level combined with the "uncertainty" of theoretical effectiveness of energy saving measures.
- Prejudices exist about the impracticality to influence people's behaviour toward low energy issues; especially in shabby environments.

4.3.4 Political Measures/Instruments

In general political measures towards more ecological development are even supported by many residents: 47% of the German population was voting for more provided information, 45% for tax incentives and still 40% for higher energy standards (Eurobarometer 2006a). Political Instruments can be basically categorised as legislative and administrative (mandatory standards), economic (taxes, subsidies, tariffs) and informational (labelling, rating systems etc). The further they can be divided into stimulating (subsidy or agreement) vs. repressing (tax, prohibition). Another question is the focus; general (like taxes) or targeted (e.g. subsidies for PV) (Nilsson 2006).

Energy efficiency is a complex issue that has to be addressed by many instruments and measures what cannot be discussed in details. But basically the following political amendments have to be achieved:

4.3.4.1 Standards

Regulations for standards in the building sector can be basically found in the German Energy Saving Ordinance (EnEV). The limits of the current EnEV (2002) can be exceeded by far with available measures. Consequently higher limits have to be reached and to be proven.

4.3.4.1.1 European and German Standards: EPBD and EnEV

The introduction of the Ordinance for Energy Saving Requirement for Space Heating and Domestic Hot Water Devices (HeizAnlV) in the 1970s and its revises in the following decades had a huge impact on the energy demand in households for heating (Kohler, Kraus, & Hausladen 2006). Since that requirements were continuingly increased. The first common European directive on the “Energy Performance of Buildings” (EPBD) came into force in early 2003 with the following main points:

- Holistic approach for an energy balance calculation of buildings
- Minimal standards for new buildings
- Use of renewable energies for new buildings
- Minimal standards for huge scale refurbishments
- Energy passes for all buildings
- Inspection of boilers, other heating and air conditioning devices on a regular basis.

(European Parliament 2002; Malloth 2006)

The directive was developed with the aim to increase the energy performance in European buildings through cost effective measures by establishing a common methodology for building standards of its energy performance and by developing a convergence of basic requirements in the whole European Union with regard to climate and other regional conditions (UNEP 2007). This Directive had to be implemented into national law of all member states within 3 years after disclosure (EU 2006; European Parliament 2002). It was calculated that due to low demands, certain conditions and exclusions the possible impact of this directive has been shown to address just 10% of the technical potential (Eurima 2005).

The current German Energy Saving Ordinance (EnEV) was implemented in 2002 to prepare the market for the implementation of the European Directive. It refers to the annual primary energy demand for heating and combines consequently the energetic quality of the building envelope, the technical equipment for space heating and DHW, solar gains and utilized fuels (Hegner & Loga 2004). In commercial buildings air conditioning and lighting will also be included in the next EnEV in 2007 which will be comletly based on the European Directive. This demands an integrated planning process. Further improvements are that the energy pass will become mandatory for all buildings by 2008/2009 and a reduction of further 30% compared to the 2002 standards is deliberated these days (BMWi 2007).

4.3.4.1.2 Control of Standards

Demanded standards (like EnEV standard) are no longer controlled after construction or renovations why just every fifth building is renovated with an energy efficient viewpoint (Nitsch 2002).

An extensive study in the county of Baden-Württemberg exemplary pictured the huge deficit according to this missing control mechanism. (ifeu Institut & ECONSULT 2005). While the level of insulation strongly increased for new buildings, renovations and refurbishments on the envelope of old buildings mostly were carried out without any additional insulation. Lacking was also the communication and cooperation between the maintenance groups with a focus on energy efficiency. Generally the huge potential of energy saving in the household sector was just reached to less than 45% (in this example in Baden-Württemberg). The further, the regional economical potential of CO_2 emission reduction by improvements of insulation was reduced to even just a third. (ifeu Institut & ECONSULT 2005)

To guarantee the fulfilment of important requirements a control mechanism has to be implemented. At least on a sample basis of 1 to 2% since the evaluation of all buildings does not seem to be possible. Additional incentives to reach the required standards should be implemented as well. (Borges, Lorenz, & Helmstädter 1997; ifeu Institut & ECONSULT 2005).

Since energetic improvements often are not possible to prove immediately after taking measures (caused by billing times or seasonal conditions) energy consultancy should be mandatory during the whole construction process. This is often not to be achieved by the architect himself due to knowledge and economical reasons.

4.3.4.2 Labelling

Because of the growing importance of electricity in the domestic sector minimum appliance efficiency standards and strict labelling is highly important. Labelling will also be implemented for buildings themselves with the energy pass for buildings from 2008 onwards.

4.3.4.2.1 Energy Pass

The energy pass is also a part of the Ordinance 2002/91/EG of the European Parliament. The quintessential statement of the energy pass is the energetical quality of a building which will be communicated by a simple, comprehensible label. Further detailed information is also important and has to be included:

- dates and values of the energetical quality of the building's envelope and its technical equipment (with reference values for comparison)
- calculated CO_2 emissions
- Advices for energetical refurbishment under economical and technical view points

(Kohler, Kraus, & Hausladen 2006)

The energy pass itself is not saving energy. Energy is just saved by following the given advices. Hence they are an essential component for future improvements since they give tangible steps of action to improve the quality of houses and to boost market values (Hegner & Loga 2004; Malloth 2006).

Right now the energy pass is obligatory for all new buildings and for existing buildings during fundamental renovations and refurbishments. In 2008/2009 with the new EnEV 2007 it will become mandatory for all edifices (BMWi 2007).

The main goals of the energy pass for buildings can be seen in (1) the communication of the energy efficiency quality of the building; (2) inspiration for improvements; (3) the conservation and creation of value (added value), reduction of the dependency of energy imports will lead to a shift in qualification towards a more environmental friendly and sustainable real estate management (Malloth 2006). Hereby the energy pass can be translated to important key indicators for long term investments (Berger 2006).

In the future the concept of the energy pass for buildings could stepwise be extended by other important factors like: indoor air quality, access, noise emissions, comfort, environmental quality of materials, and highly important the LCC. Therefore it is important to create a common methodology to evaluate these values. The demonstration of low LCCs of buildings will increase their market value (Geissler 2006).

4.3.4.3 Political Economical Tools

Economical tools are mostly extremely powerful since financial considerations are often the first barrier to energy efficient improvements. Economical tools can be constraining (e.g. taxes, fees) or enabling (rebates, tax breaks, or cost neutral (UNEP 2007). The aim of economical tools should be an additional support to stimulate market based solutions towards a sustainable development. Concerning the development to a more sustainable attempt it is important to correct established market prices and to improve hereby the market transparency. The following two points (Subsidies and Internalisation of Externalities) are therefore highly influencing (4.5.5.2 Market Transparency, p. 42).

4.3.4.3.1 Subsidies

Subsidies (governmental financial assistance without a direct return) are often important to support the industry during innovative developments and during the market introduction of innovative products and techniques. In the same time a digression in the support strategy after introduction will give more need to new developments to become mainstream products (Schulze Darup 2003). During the last decades high levels of subsidies were given to many established and inefficient non-renewable energy sources. According to a study by the BEE (2004) 67 billions Euro flew into the nuclear, 164 billion Euro into the coal sector. Additional costs for the mitigation of external effects are not included.

4.3.4.3.2 Internalisation of Externalities

By definition external costs are not paid by the causer but by the general public (European Commission 2003). This generally happens when consequences of action are not regulated by right of ownership, legal regulations or market mechanisms and therefore the monetary value of these actions cannot be displayed transparently on the market (Geissler 2006). Costs appearing outside the production cycle (such as cleanup costs for pollutions) have to be shifted from a burden for society to a transparent cost for the producer and hence for the customer ("internalization of externalities"). It is important to recognize that the internalization of extra costs makes an economy more efficient and furthermore the country richer – not poorer (Weizäcker, von E.U., Lovins, & Lovins 1995).

An example of external costs from the energy sector is the estimated real production costs of electricity based on fossil fuels. According to estimations of the European Commission during the "ExternE project" the energy price from coal and oil produced electricity would double. Gas based production would still increase by 30% (Greenpeace 2007).

4.3.5 Other Political Fields of Action and Concepts

4.3.5.1 Indicators

Some EU-projects are working on Best Practice Guidelines and on Sustainable Indicators for the building sector. CRISP is such a programme, identifying indicators on global, national, regional, urban and building level (Geissler 2006). Such indicators have to become mandatory and more or less comparable at least on European level.

4.3.5.2 Ecological Tax Reform - CO_2-Taxation

The idea of an ecological tax reform goes back to the 1920th when the idea was firstly published by the British economist Arthur Cecil Pigou. Weizäcker (1995) presented his idea of an ecological tax reform in 1995. The basic concept is the taxation of pollutants such as CO_2 replacing some existing taxes on income and crating added value. Since environmental taxes are just charged on energy and goods, services are more or less not affected which basically means: Development is to increase, production and material consumption to decrease (Weizäcker, von E.U., Lovins, & Lovins 1995).

For the building sector and its dependent industries this gives growing incentives for renovation instead of replacement according to rising prices on good and decreasing prices on services (Weizäcker, von E.U., Lovins, & Lovins 1995). In addition this means economical incentives for energy savings and a shorter pay back time for complex improvements in efficiency (Borges, Lorenz, & Helmstädter 1997). A customs duty on embedded energy will limit the disadvantages of national producers. This duty is a decision on national basis and should not collide with GATT/WTO agreements (Weizäcker, von E.U., Lovins, & Lovins 1995) (further discussion in 4.5.6 Ecological Tax Reform – Economical Aspects, p. 44).

4.3.5.3 Kyoto

The great potential of energy savings in the building sector could be used to mitigate CO_2 emissions under the three forms of the flexible mechanism of the Kyoto protocol.

- Emission Permit Trading (EPT)
- Clean Development Mechanism (CDM)
- Joint Implementation (JI)

(UNEP 2007).

The idea of emission trading is already described in Weizäcker's book "Faktor 4" (1995) as a part of his ecological tax reform idea. The Stern Report generally considers carbon trading (under the EPT scheme) as an very powerful tool for a worldwide pricing of carbon (Stern 2006). From the UNEP it is also evaluated as a good option for the building stock (UNEP 2007). The best practise for implementation on a national level in Germany would be a pooling of buildings based on a baseline and credit model. A "pool-manager" is in charge for its administration; certificates are given according to the baseline, credits can be handed out for improvements (Hohmuth 2005).

To include buildings as a whole in the Kyoto process it would be essential:

- To define benchmarks for energy efficiency on the basis of common energy performance standards
- To establish monitoring systems to measure energy savings on an annual basis
- To develop a methodology according to the Kyoto protocol under international and national law.

(Hohmuth 2005; UNEP 2007).

Further inclusion of the building market into the Kyoto mechanisms is basically possible on an international level (see 4.3.6 Global Incentives, p. 34).

4.3.5.4 R&D, Innovation Support

Three main driving forces were identified for the next decades to support technical and socio-economic research in the energy sector by the Energy research programme of the EU Energy, Environment and Sustainable Development (EESD). Thus research is needed

- To reduce pollution and to increase efficiency of fossil fuel based technologies.
- To develop and to establish a market for clean, renewable sources of energy
- To strengthen European competitiveness and to foster market advantages by renewable energies.

(Sánchez-Jiménez 2001)

Long-term aspects and considerations of risk need more reflection in the political and financial scene. A keystone here fore is research and development (R&D). Research is the central element for innovation in the energy sector and innovation matures in the interaction of science and industry (Hauser, Hogrefe, Bradke, & Erhorn 2006). The building sector, based on innovative technologies can hugely contribute to and profit from more support of R&D.

4.3.6 Global Incentives

New technologies also in the building sector have to prove their marketability and practicability in the developed countries to help to solve global problems on an international level. But in the same time fast developing countries need to embed ecological and energy efficient aspects in their basic conceptualisation.

The export and the knowledge-transfer to developing countries can be of high value ecologically but also politically and economically. These processes can be implemented under the Kyoto protocol mechanism CDM and JI (UNEP 2007) (see 4.3.5.3 Kyoto, p. 33). In the same time the promotion of export of energy efficient technologies also brings cost reductions in production and therefore also advantages for national users (Hauser, Hogrefe, Bradke, & Erhorn 2006).

Summary Part 4.3

The political influence on the reduction of emission due to energy savings by behaviour and efficiency is very crucial. On all political levels measures can be taken and political instruments can influence behaviour patterns and engagements towards energy efficiency in the building sector. Bargaining about environmental targets will often lead to the lowest common denominator, leaving major emissions untouched wherefore the political time scale has to be changed to a long term planning (perhaps with a national, superior sustainable panel).

The political obligation is to build up the legal and general framework to support a useful development. Primarily a social consensus for the importance of energy efficiency is needed and irrational and economically motivated preconceptions and burdens have to be dismantled. Thus, research projects are essential and have to be coordinated. Information flow guaranteed and "light house" or "poster" projects have to be initiated and transferred to common standards.

Standards have to be minimized to the highest, feasible levels (passive house standard) and control mechanisms with mandatory energy consultancy during all planning and construction processes have to be implemented. In addition the energy pass has to include more values in the future like LCA, LCC, electricity (lighting and air-con), air quality and others. A set of mandatory indicators might be of help. Finally the Kyoto protocol should be opened for the building stock with its three major tools EPT, CDM and JI.

The correction of energy prices, internalisation of externalities, terminating subsidies, market transparency, stimulation of market based solution and a market transformation is achievable the easiest by aiming for an ecological tax reform. "A deprivational conservation policy" (Bell, Lowe, & Roberts 1996) will not succeed unless consumption is reduced with draconian measures.

4.4 Social Aspects for Emission Reduction in the German Building Sector

4.4.1 Important Social Aspects for Energy Savings in the Housing Sector

The largest share of national energy is demanded inside of houses. This aspect becomes even more valid due to the phenomenon of the "Verhäuslichung" (an increasing amount of time spent indoor) (Nokielsky 1985). Nowadays in Central Europe people spend around 90% of their time in buildings (Geissler & Bruck 2004). This is often linked back to the decreasing outdoor quality due to strong increases in traffic. According to this fact the quality of the indoor climate became significantly important for the health of individuals and the wellbeing of society. To increase indoor qualities and to reach demanded reductions of the energy consumption in households in the same time two main factors are crucial: "changing consumption habits" and "using energy in a \`greener´, more diverse and more efficient manner" (Eurobarometer 2006a). The pure regulation by price is not feasible since private households in general do not prioritize economical advantages. Hereby psychological models and concepts gain importance such as environmental awareness and environmental friendly behaviour. (Spada 1990 in Flade 2003). In the same time it has to be addressed that especially individuals and the society have high advantages from energy savings, energy efficiency and the accordingly necessary increase of standards (such as wellbeing, productivity, comfort, monetary savings, cleaner environment and a saver neighbourhood etc.).

A study focussing on the socio-psychological aspects in passive- and low-energy houses showed that energy efficient houses were judged as more comfortable than the normal standard control houses. Almost all inhabitants in passive houses were very pleased and would recommend this house type. In addition most inhabitants believed to have changed there live style towards more awareness concerning energy problems. The willingness to decrease comfort for environmental reasons was as low as in the beginning of the research (Flade, Hallmann, Lohmann, & Mack 2003). Consequently, beside the technical advancements (like high energy efficiency) the attitude and the behaviour are the next important factors. In a European research programme about the "Energy-efficient behaviour in office buildings" (EBOB 2006) different main factors of the user activities lead to a decreasing energy efficiency also in low-energy houses. Even though the motivation and the behaviour pattern might differ between commercial and private buildings the main findings can also be adopted to the housing sector. Thus, the most problematic aspects were the low level of energy concerning education and the lack of user information as well as the unmotivated attitude and problems to motivate users (what lead to a higher internal heat load than predicted) (EBOB 2006). Consequently it is the information, interest and the resulting behaviour that triggers energy efficiency on the user side the most.

4.4.2 Public Information

The need for information actually can be separated into three categories: *first*, the missing information resulting in disinterest and inefficient behaviour for individuals (end users). *Second*, the missing information on a professional level; from decision makers to architects and crafts men. *Third*, the missing transparency on the market (discussed in 4.5.5.2 Market Transparency, p. 42) (Kohler, Kraus, & Hausladen 2006).

The individual level: In most developed countries so in the EU and in Germany energy efficiency is supported by a majority of citizens. But even with a positive attitude the relationship between behaviour, emissions and environment does not seem to be understood. This might come from the “woolliness” of many adopted concepts and the complexity of the problems. Interviews showed that individual action can often not be linked to environmental damage. The problem of ignorance of facts but also the ability and the will to understand the complexness of the issue could also be identified (Bell, Lowe, & Roberts 1996).

For individuals the general knowledge about energy issues is often limited to the own fuel and electricity bill (Bell, Lowe, & Roberts 1996) and the power consumption of appliances is mostly estimated according to size and function (UNEP 2007). But to achieve an energy efficient behaviour on the basis of environmental concerns a high level of understanding is important (Bell, Lowe, & Roberts 1996).

Comparatively most European citizens (43%) would like to get more information about how to save energy especially for financial reasons (Eurobarometer 2006b). Even if the access to information will not automatically lead to an energy-efficiency behaviour (UNEP 2007) information and education leads to knowledge and knowledge can contribute to a sense of personal responsibility and empowerment. Exemplary the feedback strategy for energy use during a monitoring study – the monitored energy demand according to the user’s behaviour was made transparent to himself - showed an tremendous drop in energy demand by up to 20% (Stern & Oskamp 1987).

The discordance-theory (“Dissonanztheorie”) especially the basic idea of the “Foot-in-the-door” technique (Wortmann, Stahlber, & Frey 1988 cited in Flade 2003) offers an interesting argument for the importance of socio-psychological education and information. The aspiration for consistence is a strong and central psychological motivation (Cialdini 2002 in Flade 2003) and basically says that a person who is convinced to make even a little effort to save energy will try to keep the consistency in its behaviour. This strengthens the self-control mechanism on the one hand and creates a positive attitude towards energy saving. Generally a higher share of passive- and other supra-low-energy houses would be necessary not just for the purpose of energy saving but also as a trigger for a higher awareness (Flade, Hallmann, Lohmann, & Mack 2003).

The professional level: In the professional world information about energy values are also missing why for example even professionals still doubt the concept of space-heating free houses (passive house) in Central Europe. The lack of additional training and education in sustainability and energy saving technologies is another barrier. This deficit is a major problem that involves all levels of actors; from the client to the workman (UNEP 2007). The interest of the client is often based on recommendations from neighbours and friends and what they have seen and heard. Workers as well as architects and planers often stick to proven and experienced workmanship. Information has to be mandatory during all planning processes for all involved parties. Thereby it is important to provide up-to-date information for the effective implementation of energy efficient measures in buildings (UNEP 2007) since this field is highly based on R&D and underlies fast improvements.

4.4.3 User Behaviour

Important factors influencing the behaviour are the grade of information, the awareness and the attitude. Interesting hereby is that the energy saving behaviour of people, their awareness and their attitude about environmental problems are often not consistent (UNEP 2007). As shown in some studies the relation between the individual attitude and the behaviour is much stronger when the broad focus (e.g. climate change) becomes an immediate personal meaning (e.g. concerning health or economical incentives). Hence Williams et al (1985) for example suggest that the concept of energy efficiency might be easier to communicate with the personal incentive of a rise in comfort (in Bell, Lowe, & Roberts 1996). Generally these personal and specific concerns are much more likely to lead to energy efficiency investments and not just curtailment actions as likely from restriction and promoting energy efficiency as an individual responsibility (Bell, Lowe, & Roberts 1996).

4.4.3.1 Landlord-Tenant Conflict

A problem influencing the individual behaviour and motivation (for energy efficient refurbishments) derives from the landlord-tenant conflict in Germany with a high share of rented houses since investment costs are normally not fully adopted by the consumer (tenant) and incentives (well-being and savings) are not paying off for the investor (owner) (further discussion in 4.5.3.2 Landlord-Tenants/Ownership, p. 41).

4.4.3.2 Rebound Effect

A flipside of the coin from energy efficient renovations or efficient behaviour in one field is that the rise in comfort often leads to a change in behaviour patterns which completely compensates the accomplished savings. This "rebound effect" or as (Wortmann, Stahlber, & Frey 1988) says the "boomerang law of energy conservation" is based on the theory that a clear conscience and financial savings from less energy demand leads to a higher life stile, more spending in other matters and hereby again to energy consumption. Examples here are the rise in indoor temperature compensating for the luxury of wearing less warm cloths (Malloth 2006) or the rise in space demand (see 4.4.3.3 Increasing Demand of Living Space, p. 37).

4.4.3.3 Increasing Demand of Living Space

The living space demand per person and the increasing numbers of dwellings leads to a growing demand of land and an increasing energy demand especially for space heating. Since 1970 the request for indoor space in Germany has doubled from around 1.5 Billion m² to 3 Billion m². This development has been counterproductive for any achieved improvements in efficiency. The result of this trend on the energy demand can be seen in the following Fig. 16 (Kohler, Kraus, & Hausladen 2006).

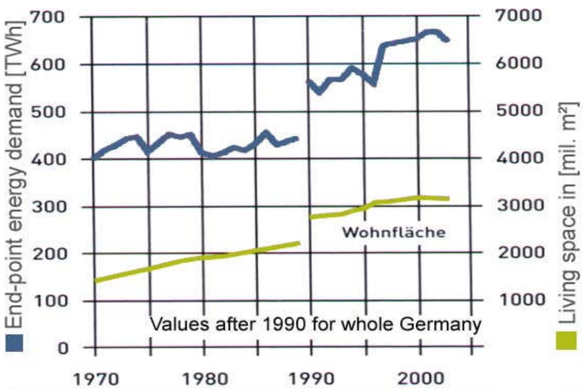

Fig. 16: Increase in demand for living space and energy since 1970 (Kohler, Kraus, & Hausladen 2006)

4.4.3.4 Other Socio-Demographic and Psychological Factors Influencing the Indoor Energy Consumption

Gender, age and socio-demographic conditions play also an important role within consumption patterns and behaviour (UNEP 2007).

- For example the energy demand of women in households is generally higher due to higher indoor temperatures to feel comfortable. Elderly people are also more dependent on warmer rooms but do not use that much warm water (UNEP 2007).
- An interesting stimulus-to-action-correlation can be found in the stimulation by close interest groups such as neighbours and friends as an important factor for motivation (McMakin, Malone, & Lundgren 2002).

- The level of energy demand is generally also growing with the income and hence with the demand for living-space (see example 4.2.2 Urban Design, p. 25) (UNEP 2007).

4.4.4 Wellbeing and Health Effects

"…[E]nergy efficiency is to a large extent a ‚no-regrets' option" since it has more positive side effects than just the reduction of CO_2 emissions. The positive health issue for inhabitants and their wellbeing by a rise in standards (e.g. less financial burdens for heating or better air quality) is also an important result (Bell, Lowe, & Roberts 1996).

Indoor wellbeing is mainly influenced by the following factors: daylight, illumination, temperature(s), humidity, air exchange rate, air speed, pollution of air, noise, visual contact to a natural outdoor environment and electromagnetic fields. Some of these factors are dependent on the site and the surrounding, most on a good architectural planning, others on good standards and technical equipment. So is for example the Sick Building Syndrome (SBS) influenced by many factors like bad air quality, humidity, lighting or electromagnetic radiation (Noeren 2006). It was proven in several studies that a high CO_2-concentration in the air leads to an increase of significant symptoms associated with SBS (Geissler 2006). Other studies showed a major correlation between the air exchange rate and the general wellbeing of interviewees (Wargocki et al. 2000). According to Kohler et al (Kohler, Kraus, & Hausladen 2006) this subconscious contact to outdoor is extremely influencing the well-being and hereby the productivity of users. Nowadays with a well planed house and with a good dimensioned ventilation system the comfort for inhabitants can be tremendously improved as stated before (see also 4.2.1.5 Ventilation, p. 24). In addition the benefit of not being forced to open windows for a better air quality and the noise reduction as a further consequence have to be acknowledged. This becomes even more important over night when manual ventilation mostly cannot guarantee to compensate high pollution by CO_2 and other substances (Schulze Darup 2003) (Fig. 18).

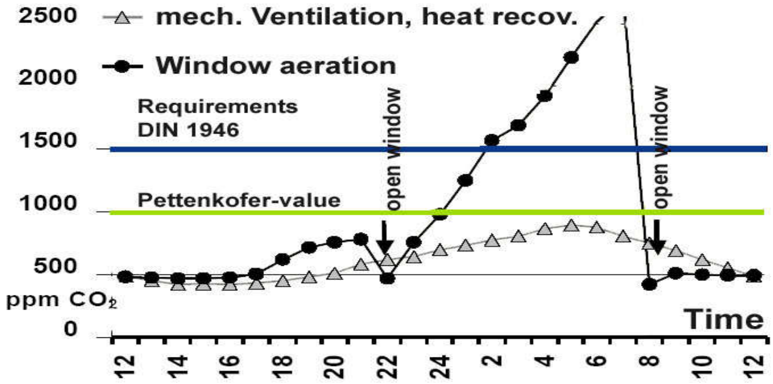

Fig. 17: Characteristic CO_2 concentration over the day in a sleeping room (with window aeration and regulated ventilation (Schulze Darup 2003)

Generally it can be said that values influencing the wellbeing and hereby the health of inhabitants, are not yet to quantify since too many individual variables also give an important stimulus. In the future it will be important to qualify these variables and to quantify the resulting effects more precisely than just with the decreasing number of sick days and the increase in performance (Geissler 2006).

4.4.5 Basic Socio-Ecological Approaches

Community-based activities such as car sharing, education, eco-communities or simply shared accommodation can be important initiatives to reduce the environmental impact from households nowadays (EEA 2005). An approach that is going much further is the idea of an eco-society: "The goal of eco-societies is to embrace the ethos of 'energy-saving cities,' involving conservation and reuse at a number of levels. The modalities are similarly multifaceted: technological innovations have been at the forefront of developing sustainable energy generation and low-energy approaches […]; and public attitudinal changes are increasingly seen to be central to shifting society to a more conserving basis." (Dendrinos et al. 1992). This shift is closely linked to the human demand and lifestyle issues regulated over a new definition of sufficiency.

Summary Part 4.4

The user behaviour is dependent on information, motivation and responsibility. All these factors have to be addressed by several instruments like incentives for energy savings (e.g. financially), energy consultancy (as mandatory during construction and installation of appliances) and information given by campaigns, publications, workshops, feedback projects (energy demand per hour/saving potential by behaviour) and lighthouse projects to increase information and interest since the general public opinion is important to trigger the consumer's behaviour which plays a major role for individual energy savings (Eurobarometer 2006a). This effect can also be achieved by labelling systems (like accomplished with the LEED system for buildings in the USA). The coming energy pass will rise the awareness on all fronts and will increase the consciousness of all stakeholders (UNEP 2007). Technical equipment has to convince users to the "best-action" from an energy perspective. Comfort optimisation due to a informing and adequately design interface should be in the centre of technical innovations (EBOB 2006).Social common activities like car-sharing also should be promoted since they influence consumption and can shift attitudes.

On a professional level also lighthouse projects are important to spread generated knowledge from such projects. Meetings, trainings, design guidelines, best-practice-brochure and -examples (with focus on concepts, technologies, costs, experiences) hold a huge potential (Hauser, Hogrefe, Bradke, & Erhorn 2006). Training sessions in this field have to become mandatory. Local learning networks in Switzerland for environmental advisors of industries were very successful and lead to CO_2 savings of around 10% over 4 years and doubled in the same time the technical efficiency of the monitored industries compared to the last 15 years. (Hauser, Hogrefe, Bradke, & Erhorn 2006). In general it can be said that further research is needed in the field of the social and natural sciences to identify parameters but also factors for behaviours.

4.5 Economic Aspects for Emission Reduction in the German Building Sector

The building sector is hugely based on economical considerations within a framework of regulations and standards to suit individual and social needs. Hereby mostly monetary short term reflections are prioritized and long term or even life span issues and sustainable arguments are rather rarely looked at.

To encourage stakeholders in the building sector to include long term thinking into their financial interest, economic instruments and incentives are very important means. Reduced tax rates as political instruments, increased rates of return on (efficiency-) investments or improved loan conditions are exemplary economic tools. In the same time market conditions can be changed hereby to the benefit of energy efficient buildings (UNEP 2007). Generally energy savings in the building sector can be put into practice with the best cost-benefit ratio (Kohler, Kraus, & Hausladen 2006; Schulze Darup 2003) what leads to a win-win-win situation especially during renovations of existing buildings: Reduction of climate impacts, financial savings for the user/tenant, (economical long term investments from owner perspective) and a better market development for the national economy (Kohler, Kraus, & Hausladen 2006).

4.5.1 National Economy

Typically the construction and building sector provides 5 to 10% of the market's employment, generating 5 to 15% of GDP (UNEP 2007). In Germany the building industry had a market decrease of 57% over the last 10 years (Kohler, Kraus, & Hausladen 2006) which of course had a strong negative effect on the national economy. With a shift to a CO_2 free economy this decrease can be compensated due to the huge demand of renovations in the building stock. 85,000 to 200,000 jobs can be generated by energy efficient measures in the building sector. In all related branches (supply and demand side) these numbers are estimated to some 400,000 to 600,000 new positions. The losses on the other side in fossil fuel related industries have to be acknowledged but can be realized under socially acceptable manors (Nitsch 2002). This positive development would have enormous consequences for the national economy and for the potential for further development.

4.5.2 Costs and Benefits

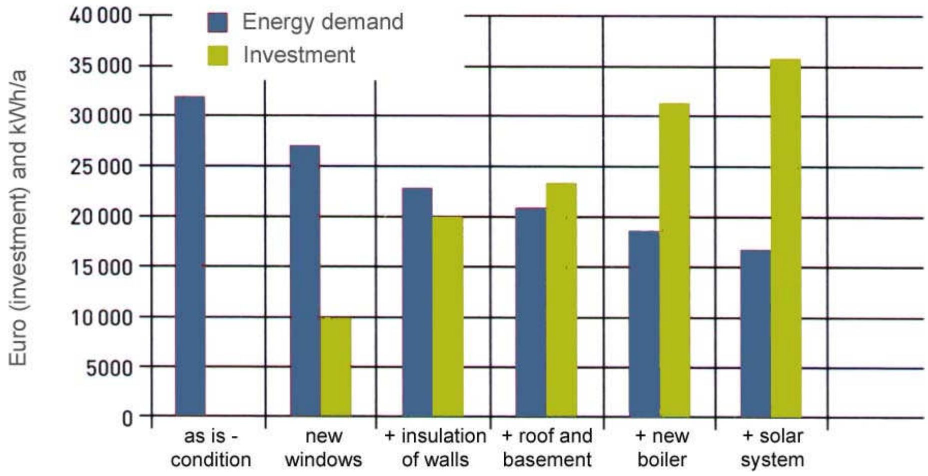

Fig. 18: Investments and energy efficient improvements (Kohler, Kraus, & Hausladen 2006)

Mostly for older buildings measures during standard refurbishments are very similar to specific action during energy efficient refurbishments. Therefore the basic costs for energy concerning improvements are almost covered. The additional costs to reach a high energy standard (around 30 kWh/m²a) were estimated (in 2003) with 100 to 150 Euro/m² (Schulze Darup 2003); the additional investment costs to reach a passive house standard with 200 Euros/m² of living space (BMU 2006). For new buildings the additional costs are also just slightly higher than the standard investments.

On an average investments for refurbishments are needed after 40 years what can be seen as the basic definition of the depreciation period. With estimated rises of energy prices an economical payback time of some 20 years can be taken as a basis. Consequently energy efficient refurbishments also have a direct economic benefit (Schulze Darup 2003).

Important is the question which barriers have to be reduced and which inducements are needed to motivate for more ambitious investments.

4.5.3 Financial Burdens for Investments in Energy Efficiency

4.5.3.1 Initial Investment Costs and Payback Times

One of the major problems to establish energy efficient improvements are high investment costs and the focus on very short amortization times on a liberalized and globalised market (BMU 2006). This is the same for private households with generally little financial margins, for public authorities and contractors with primary financial interests and consequently high prioritizing of short payback times or generally low initial investment costs.

The basic concept for private households is not to keep running costs but the initial investment costs low. The same behaviour was identified during a research by Thunselle et al. (2005) in 9 EU countries on a municipality level also with a focus on short time spans (see 4.3.3.1.1.1 Local level, p. 30). It was clearly shown that higher investment costs are the main reason to decide against high energy efficiency in buildings especially during retrofittings. Even if life-cycle costs were taken into consideration the initial investment was determining (Thunselle et al. 2005).

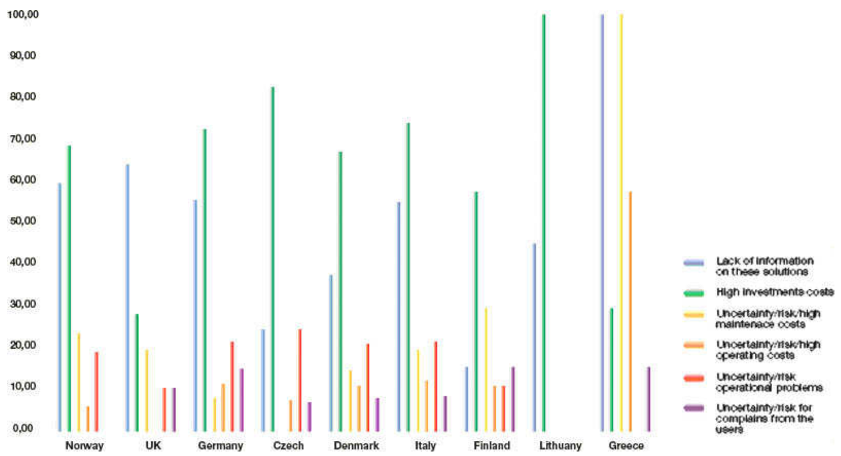

Fig. 19: Results of interviews in European municipalities; Main reasons for not choosing low energy solutions (Thunselle, Erhorn, Morck, Ferrari, Fuentes, & Manuel 2005)

Same factors are most decisive for contractors with a clear interest in profit-maximisation. Short pay back times (less than 5 years) might still be acceptable. But generally capital costs are more important than revenue savings (Bell, Lowe, & Roberts 1996). Another factor is the insecure prediction of increasing energy prices.

Summarizing the willingness to invest in energy efficient measures and refurbishments is low for medium or long term payback times for private owner but is even lower for building speculator acting on a huge scale (Hegner & Loga 2004).

4.5.3.2 Landlord-Tenants/Ownership

Also the landlord-tenant dilemma or more generally the investor-user-problem can be a barrier for energy efficient improvements (BMU 2006). This conflict of interests is still very valid in the housing industry when it comes to refurbishments of non-owner occupied houses. The investments for energy efficient improvements for buildings resulting in lower expenses in energy and higher standards are mainly advantages for the user since the rent in Germany normally excludes the expenses for energy (“Kaltmiete”). Lower energy costs are therefore no incentive for owners and acceptable increases of rents are mostly below the owner’s expected return of investment (Hegner & Loga 2004). Consequently the interest for energy saving measures is much higher for inhabitants or home owners living in their own house.

4.5.4 Incentives

4.5.4.1 Financial savings and gains

The most obviously economical incentives are financial savings (within a short time frame) and even financial gains on a long run since the payback time is shorter than the time of efficient savings. In addition health effects and accordingly lower spending on this issue as well as higher productivity can lead to financial advantages (Hegner & Loga 2004).

4.5.4.2 Increase in Value

The value of buildings is evaluated by its financial and its speculative value based on subjective assumptions such as the belief of increasing value, pension planning, independency or virtue (Schuler-Büchel, Rutzer, &

Mätzler 2003). Hereby renovated and especially energy efficient renovated buildings have a clear market advantage (due to its added value). This effect will probably become more obvious with a higher acceptance of energy passes for buildings (see 4.3.4.2.1 Energy Pass, p. 32). Also conservation of value for existing buildings is a valid argument (Malloth 2006).

4.5.4.3 Market Advantages

A general rise in indoor living standards and rising energy prices will lead to higher requirements by users. Especially since a decreasing population size in many areas has changed the real-estate market from a supplier to a demand market (Kohler, Kraus, & Hausladen 2006). Hence, depending on the location and the situation on the local real estate market refurbishments of higher standard can have an economical benefit if hereby market advantages can be achieved such as avoiding vacancy and prolonging cycles of reparation (dena 2004; Hegner & Loga 2004).

4.5.5 Economic Tools

To minimize existing barriers and to improve the acceptance of urgently needed action in the sector the following tools should be introduced or improved:

4.5.5.1 Commissioning and Contracting

Contracting models concerning the energy demand of buildings can be highly successful. Hereby a third party pre-finances technical improvements and profits from the resulting savings over a predefined time. Therefore the energy expenses have to be fixed or linked to increasing fuel prices to secure the investment’s revenue. The advantages for the user/owner are (1) no investment costs, (2) predictable and stable expenses (similar to previous energy costs) over a defined time span and (3) further benefit from improvements after the contract term (Agricola & Seifried 2005). This model is very common in larger edifices like hospitals or industries but can be transferred to the private sector. A drop of bitterness is the purely financial focus that consequently promotes improvements with the highest profit margin and excludes more ambitious attempts. This idea is further developed in the so called commissioning. “Commissioning means a systematic process guaranteeing that a building performs as designed and required by the functional need of users.” In a energy perspective this aims for an optimized performance of energy systems over the whole life-cycle (UNEP 2007).

4.5.5.2 Market Transparency

To make RES and energy efficiency more competitive the transparency of the market is essential. Therefore several political decisions are needed like the internalisation of externalities and the phase out of subsidies for established, inefficient ways of energy production (e.g. coal and nuclear) with the result in rising energy prices for fossil fuels. Consequently energy efficient measures will become more remunerative and payback times will decrease (see 4.3.4.3 Political Economical Tools, p. 32) (Borges, Lorenz, & Helmstädter 1997). Another advantageous step towards market transparency is the calculation based on the life span of goods; LCA.

4.5.5.3 LCC Life Cycle Cost

LCC is the sum of all costs of a product or an object during its cycle of use. Therefore secondary cost like reparations, refurbishment, replacement and dismantling have to be added to first investments. But also costs for the maintenance, administration and operation (such as energy) (Albrecht 2006). Consequently LCC approach makes additional or follow-up spending transparent and shifts the focus of initial investments to a long-term approach.

The minimization of initial investments is still evaluated as most important and LCC analyses are hence very unusual. Sustainable and hereby ecological buildings could be most persuasively under a Live Cycle perspective (Geissler 2006) since it is estimated that in the building sector a proportion of 1:1 to 1:2 of initial investment to follow-up costs normally leads to the lowest LCC. (Albrecht 2006).

Even though if LCC often promotes a long life time of appliances and materials it does not automatically lead to less emission, waste and energy use like a LCA does. Just with an internalisation of externalities for all materials a LCC analyses will economically mirror the results from LCAs. But as said before: the implementation of LCC assessments might lead to a higher and faster acceptance for a lifecycle-based approach according to LCAs (see also 4.1.1 Life-Cycle-Assessment (LCA), p. 20).

4.5.5.4 Energy Audit Programme

Generally an energy audit identifies the energy demand and consumption, potentials for (cost efficient) improvements and reports the findings (UNEP 2007). The energy pass for buildings in European countries can be seen as an energy audit. It will become mandatory for all buildings within this decade (see 4.3.4.2.1 Energy Pass, p. 32). Since the energy pass also includes advices for economical feasible energy efficient measures for the building this will lead to more transparency of energy costs, investments for improvements and saving potentials.

4.5.5.5 Rating Systems

A rating system is another opportunity for more transparency on the market (UNEP 2007). Therefore common levels have to be defined. In Germany no official acknowledged rating system for energy efficient buildings exist. The different standards (see 4.2.3 Energy Standards for Buildings, p. 26) like EnEV-building and passive house can be seen to a certain extent as a decentralized rating system.

4.5.5.6 Financial Support and methods

4.5.5.6.1 Remuneration of planners and consultants

The current payment system for architects and civil engineers (HOAI) is just related to the economical volume of a development and is therefore a miss-conception from times where further costs and externalities did not have to be calculated and regarded in the planning process. To reallocate the focus to a more ambitious, long-term and user-friendly approach the planner's remuneration has to be decoupled from total costs of a building and should be linked to the potential savings for the future user (construction and life time – in the best case based on LCC) (Kohler, Kraus, & Hausladen 2006). This concept is easy to adopt from billing habits of most consultants.

4.5.5.6.2 Financial Assistance – Private and Governmental (KfW)

Since the initial investment and the long payback times seem to be the basic restricting elements, financial incentives are highly important to stimulate the general interest in energy efficient houses and refurbishments. In the meanwhile many funding systems have become established from local governments and from private banks.

This financial support should be adjusted according to the met emission savings. While it has to be acknowledged that "solution packages" are much more efficient than partly or stepwise solutions (Borges, Lorenz, & Helmstädter 1997). Therefore the CO_2 Building Rehabilitation Programme, the most popular attempt to regulate loans and subsidies according to the emission savings, was realized by the German government. With a volume of 1.5 billion Euros over the next four years (exalted from 360 million euros per year) this programme has a huge potential for emission reducing investment supports (Kohler, Kraus, & Hausladen 2006). The financial volume is administered by the KfW promotional bank (Kreditanstalt für Wiederaufbau) and is used within two different kinds of financial support for energy efficient refurbishments for existing buildings (erected before 1984/1994): First, the well-tried credit with low interest rates; and second, subsidies introduced in 2007. The new package of measures is highly efficient and almost available for anybody. Basically the amount of financial support is dependent on the targeted energy efficiency after refurbishment and varies between 5 to 17.5% (one-time subsidies) and 2.5 and 17.5% amortisation grant (credit) (DKZ 2007).

Concluding it can be said that the weighing is shifted from renewable energies to efficiency of facilities. The demanded insulation is increased but a switch to renewable energy carrier is no longer demanded neither the calculations for the CO_2 reduction why RES like biomass lose there powerfulness (Chudy 2006).

4.5.6 Ecological Tax Reform – Economical Aspects

An ecological tax reform is basically a shift from a tax inhibiting the creation of value and of work (like taxes on income and creation) to an income-neutral taxation (on energy and goods). Therefore services are rarely affected which means a further shift from a producing to a service society. A study by the Washington World Resource Institute from 1992 calculates the shift of taxes from "Gütern" (things that create value e.g. human work) to "Schlechter" (things that demand consumption e.g. use of resources) with a politic economic incentive of 45 to 80%. In other words: each dollar of tax income from "Schlechter" instead of from "Gütern" leads to a market bonus of 40 to 80 Cent (Repetto and Dower 1992 quoted in Weizäcker, von E.U., Lovins, & Lovins 1995). Further merits are:

- Its minimal need for bureaucracy. Further more it can lead to a deregulation with the little need for administration
- Slowly but predictable rising energy costs which is much better to cope with than rapid and unexpected price explosions. Consequently a slowly rising tax to internalize mentioned externalities is much better for the economy than jumping price rises hence to energy shortage or crisis in fuel exporting countries.
- A predictable increase of energy prices will lead to a continuing investment in efficiency improvements
- A ecological tax reform is the easiest and most transparent way how to manoeuvre an economy to a sustainable direction

(Weizäcker, von E.U., Lovins, & Lovins 1995)

4.5.7 Supply Side

The prices for oil and gas have almost doubled during the last two years in the EU (European Commission 2006b). Beside a worldwide rising demand for energy fuels also the growing scarcity and the increasing costs for production are promising a further boost in fuel based energy prices (Greenpeace 2007). In the same time with a politically decided increase of RES (see 3.1.1 Fuelling the Nation, p. 14) the energy prices for renewables will further decrease. With the needed internalisation of externalities and the ending of subsidizing fossil fuels (see 4.3.4.3 Political Economical Tools, p. 32) this development towards environmentally neutral energy sources will be implemented much faster. Thereby the free market based solutions are biased by economic-political instruments.

A political correction was established with the German feed-in law. The German feed-in-tariffs for renewable energies are a highly effective economic market instrument to regulate emissions, renewable shares and market developments towards more RES and decentralisation. This tool was a milestone for the success of new sources of energy, new technological developments and hence also for energy efficiency in private and commercial buildings since building integrated installation of renewable energies has become worthwhile and a shift towards RES makes energy prices more predictable (BMU 2006).

But the real challenge is an extension of the feed-in law to the heating market. Other scales, structures and ideas have to be adopted but the huge potential of the heating sector and the tremendous share of emission should give enough incentives to wake up the "sleeping giant" (Scheer 2007). With the needed growing share of CHP district heating should supply around 2/3 of the future heat demand (Nitsch 2002) and will consequently become an increasing market like in other countries. To create the needed infrastructure is an economical chance for huge supply companies in times of a strong decentralisation; especially in cities where other forms of supply might be unavailable or installation more complicated (e.g. limited space of storage for biomass or no geothermal potential).

Summary Part 4.5

The economic positive effects of energy efficiency in buildings are manifolds and happen on different levels. On a national level, positive effects will be achieved with economic impulses from a lower unemployment rate and with less dependency on energy imports and a reduction of future costs from environmental problems. Financial incentives for individuals are the reduction of energy related expenses and the increasing wellbeing and productivity due to a higher living standard and air quality; the further the conservation or creation of value and linked advantages on a competitive market. Needed economical action to reduce the burdens and barriers for the high initial investment costs are located on the political stage for more market transparency (like ending of subsidising fossil fuels, internalisation of externalities, introducing a rating system next to the energy pass). But also direct financial tools can be used for corrections and improvements. Contracting models should be extended to reach more emission reduction potentials; internalisation of energy spending in rents can solve the landlord-tenant conflict due to a shift from providing "living space" to "living service". This concept leads self-explaining to more sustainable thinking and gives owners incentives for energy efficient improvements.

An important aspect comes with the internalisation of operation and follow-up costs within a LCC approach. This shift is essential and can prepare the market for LCA attempt. Also payments of planners and consultants should be based on achieved lifecycle savings; same for financial support systems (like KfW credits). On a long term a fundamental and holistic approach based on an ecological tax reform would give new impulses and a greater understanding why "[s]pending on climate change is a pro-growth investment" (Stern 2006).

5 Conclusion

In Germany like in most EU countries buildings and especially heating (space heating and DHW) demands a large share of the national energy. The potentials of reduction are proven to be economically possible with a factor of around 10 (90%). An estimated need for a sectorial reduction in energy demand (according to the hypothetical scenario) aims for 70% which positively answers the technical side of the question of feasibility. But to reach this aim in reality over the next four decades it is essential to improve the situation immediately within all discussed areas; (keeping the long renovation intervals of around 40 years in mind) for environmental but also for economical and social reasons.

Many influences are important from various sides (as discussed in chapter 4). But concluding it has become clear that just a holistic concept can lead to a sustainable change in this sector. Therefore all factors, all mentioned categories have to be linked and must act together. The political action is given top priority. To overcome political, legal and administrative barriers, multidisciplinary action on social and economic level is required and further scientific research is essential. Beside political stimulation the user behaviour is important to support these mandatory targets. Information, motivation and responsibility have to be challenged towards a sustainable change. This has to go hand in hand with economic support and incentive and finally an economic shift to more development and long time thinking.

Thereby a strategy to support higher efficiency in the building sector has numerous advantages.

- On a **national and international level**: A significant reduction of the fossil fuel demand will lead to a decrease in natural resource use and to a global balance of interests as a basis for a peaceful, sustainable development. In the same time a sustainable social economy with less dependency on energy imports can be created. Less emission reduction (not just CO_2 but also other gases, heat and other pollutants) will reduce future costs from environmental problems with a very good cost-benefit ratio. The German construction industry can reduce its economic deficits from the last decades creating employment as a result of increased activity by a growing amount of energy efficient refurbishments that also help to upgrade unattractive urban developments form the 1950s/1970s. Higher standards for old buildings and new developments will give the industry a vast potential for innovations.

- The **individual level** is mainly affected by a higher living standard leading to an improvement in comfort and air-quality resulting in more wellbeing, better health and higher productivity. Beside the relatively long payback time financial savings and an appreciation of assets due to the reduction of energy related expenses can be a promoting factor. Additional the conservation or creation of value and the increase in reliability are further positive side effects.

What is needed or can help to fasten up this urgent development was shown in the last chapters. Summarizing this can be condensed to the following concluding advices:

It is essential to build up the legal and general framework to support a sustainable development. In the building sector with its complex structure influenced by a wide range of influences form diverse directions (authorities, financers, customers, researchers, developers etc.) the problem is not the lack of access to technologies or concepts but a lack of signals to its stakeholders. Therefore as the primary necessity from the political side (1) the yearly amount of renovation has to be almost doubled and (2) the given minimum energy requirements in legal regulations (EnEV) have to be approached to an “up to date” or even “state of the art” level since no real pressure is given to build or refurbish with high levels of energy efficiency. (3) A control mechanism about the implementation of standards is necessary at least on a random basis of some percent. Since mechanisms have to be supported by the involved stakeholders governments have to respect input and should develop tools in consultation with these players.

Therefore it is important to dismantle irrational and short-sighted economically motivated preconceptions and to influence the general public opinion since it is the indispensable trigger of the consumer’s behaviour which again plays a major role for individual energy savings. Ways to overcome these burdens can be addressed by information, motivation and responsibility. More information has to become mandatory for professionals during meetings, training sessions, design guidelines, best-practice-brochures and –examples and local learning networks which leads to a higher qualification and finally also to better networking between knowledge partners. For individuals information also can be communicated with above tools especially feedback projects should be prioritized to reduce unawareness. Also energy consultancy which should become mandatory during all phases of construction, refurbishment and installation of appliances will lead to immediate improvements and to a change in consumption over time. This advising role of control has to be separated from the duties of architects. Payments of planners and consultants should be based on achieved emission savings.

A good tool to increase awareness and to supply information is the energy pass that will enhance the attentiveness on all fronts and increases the consciousness of all stakeholders. In addition the energy pass could include more information and values in the future like indoor air quality, access, noise emissions, comfort, environmental quality of materials, and highly important: LCC. Therefore it is necessary to create a common methodology to evaluate these values. Common European standards or a set of applied indicators will help to compare ambitions, targets and saving potentials above national borders.

A further advantage is the positive impact on an innovative market by a stronger support for R&D. In general visions to implement the idea of “green” into the building sector are needed (Ochsendorf 2004). As important trial and error are for scientists as important are show cases and models for the public. In “light house” projects innovations can be tested and promoted. New developments will also challenge given standards.

Barriers for the high initial investment costs can be limited with further financial support to minimize the financial risk. Subsidies will be returned with fiscal and employment effects and will generate an estimated 10 times higher investment (Schulze Darup 2003). For energy savings and efficiency financial incentives and political/legal support like credits, opportunities for depreciation and compensation for landlord/tenant-relation (for refurbishment) has to be improved and regulated. Even additional incentives for voluntary measures above required standards should be implemented. Contracting models should be supported influence or regulated to reach more emission reduction potentials.

5.1 Further ideas

Further inspiration for a long term development in the building and related sectors might be challenging but probably appropriate to the situation.

5.1.1 Sustainability as a Core Concept

Like already discussed before the internalisation of operation and follow-up costs within a LCC approach can prepare the market for a holistic and challenging LCA attempt. On this way towards sustainability as a core principle of the market the first step in the energy sector would be the correction of energy prices by the internalisation of externalities, termination of subsidies and more general market transparency. This will also stimulate market based solution and a fundamental market transformation in the energy sector becomes achievable.

Finally the holistic concept of an ecological tax reform is probably the easiest way to reverse the trend towards less consumption and more development. This would also partly solve the problem of different time scales (politics, market, live-time, sustainability) and would support a shift towards more social common activities (shared goods and provided services).

5.1.2 Knowledge/Technology Transfer

On the one side a growth of the gross global product by the factor 12 and an increase of energy demand by the factor 5 which is nowadays based to 80% on fossil fuels are expected. On the other side exponentially growing environmental problems have to be solved. Since these problems can be identified on a worldwide level and action is needed immediately, this tragic can be seen as a huge chance for new technological innovations of advanced developed countries like Germany (Hauser, Hogrefe, Bradke, & Erhorn 2006). New technologies have to prove their marketability and practicability in the developed countries to be feasible and applicable on an international market, also in developing countries.

Beside EPT inside Europe the building sector could also be useful with the mechanisms of knowledge transfer and Clean Development (CDM) under the Kyoto protocol. Most of the current 1500+ CDM projects are located on the production and very little on the demand side. Here is a huge potential for the building sector (UNEP 2007). With efficient technology the sectorial energy demand in Russia for example easily could be reduced by more than 50%. In China policies for efficiency in the building sector could tremendously thwart the rapidly increase in primary energy demand (Kohler, Kraus, & Hausladen 2006).

The transnational transfer of environmentally sound technologies (EST) might include the following points (Metz 2003; quoted in UNEP 2007):

- “government financing for incentives for the construction of more energy-efficient and environmentally-friendly homes;
- building codes and guidelines, and equipment standards developed in consultation with industry to minimize adverse impacts on manufacturers;
- energy and environmental performance labels on consumer products;
- government programmes for more energy efficient and environmentally-friendly buildings, office appliances and other equipment;
- demand-side management programmes to promote energy-efficient lighting and equipment; and
- R&D to develop products in the building sector that meet community priorities”

5.2 Concluding Words

Energy related activities are globally the biggest CO_2 emitter. Energy efficiency and energy savings on the demand side especially in the building sector can contribute to a very large share to reduce emissions what can no longer be handled like an “option”, it is a “duty”. “Without action, climate change will undermine growth” (Stern 2006) with tremendous influences on social and global stability.

In general the reduction of emissions according to the given targets should be seen as steps on the way to a completely emission free energy sector and perhaps even to an emission free society. This is a dramatic change that basically turns existing structures upside down. Therefore it is important to keep ecological and social but also economical parameter in focus from the very beginning onwards (Nitsch 2002).

6 References

Agricola, A. C. & Seifried, D. 2005, Energiespar-Contracting als Beitrag zum Klimaschutz, Ratgeber für Energiespar-Contracting in öffentlichen Liegenschaften, Umweltbundesamt - Federal Environment Agency, Berlin, Germany.

Albrecht, J. 2006, "Ein Wettbewerb setzt neue Massstäbe. Minimierung der Life Cycle Cost in der Gebäudetechnik", HK GEBÄUDETECHNIK, vol. 4, no. Nr.11, pp. 72-79.

BEE. 2004. Subventionen für die Kernenergie und die Stein- und Braunkohle. [Online] http://www.wind-energie.de/fileadmin/dokumente/Themen_A-Z/Subvention/BEE_Subventionen_Energie.pdf . 2004. Bundesverband für Erneuerbare Energien e.V. Ref Type: Electronic Citation

Bell, M., Lowe, R. J., & Roberts, P. W. 1996, Energy Efficiency in Housing Avebury, Ashgate Publishing Limited, Hants, UK.

Berger, T. 2006, "Energieausweise in Österreich: Stolpersteine auf dem Weg zu zukunftsfähigen Gebäuden", Wohnbauforschung in Österreich.wbfö no. Nr.2, pp. 10-13.

BMU 2006, Renewable energies - Innovations for the future, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety - BMU, Berlin, Germany, 2nd edition.

BMWi. 25-4-2007. Bundesregierung beschließt die Einführung von Energieausweisen für Gebäude (Press release). [Online] http://www.bmwi.de/BMWi/Navigation/Presse/pressemitteilungen . 25-4-2007. Bundesministeriums für Wirtschaft und Technologie (BMWi). 28-4-2007. Ref Type: Electronic Citation

Borges, H., Lorenz, G., & Helmstädter, E. 1997, "Energieeinspar- und CO2-Minderungspotentiale im Wohngebäudebestand der neuen Bundesländer bis zum Jahr 2005. Kurzbericht", Kurzberichte aus der BAUFORSCHUNG, vol. 38, no. 4, pp. 209-212.

Chudy, M. 2006, "KfW-Kredite 2007", Informationsdienst Bauen + Energie, vol. 1, no. Nr.12, pp. 141-143.

Cialdini, R. B. 2002, Die Psychologie des Überzeugens Huber, Bern, Swizerland.

dena 2004, Besser als ein Neubau, Deutsche Energie-Agentur GmbH (dena), Berlin, Germany.

Dendrinos, D. S., Inoguchi, T., Newman, E., & Paoletto, G. 1992, "The Dynamics of Cities: Ecological Determinism, Dualism and Chaos (Introduction)," Taylor & Francis, London, New York.

Deutscher Bundestag 1991, Protecting the Earth: A status Reprot with Recommendations for a New Energy Policy. Third Report of the Enquete Commission on Preventative Measures to Protect the Earth's Atmosphere. Bonn, Germany.

Deutscher Bundestag. 2-7-2002. Enquete Commission on Sustainable Energy Supply Against the Background of Globalisation and Liberalisation (Summary of the final Report). [Online] http://www.bundestag.de/parlament/gremien/kommissionen/archiv14/ener/schlussbericht/engl.pdf . 2-7-2002. 27-4-2007. Ref Type: Electronic Citation

DKZ 2007, "Zwei Möglichkeiten: Zuschuss oder Darlehen. Mehr Variabilität im KfW-CO2-Gebäudesanierungsprogramm", INSTALLATION DKZ, vol. 127, no. Nr.1/2, pp. 28-31.

EBOB. 2006. Energy efficient behavior in office buildings. [Online] http://www.ebob-pro.com . 2006. 11-4-0007. Ref Type: Electronic Citation

EC. 2006. ENERGY & TRANSPORT 2006 IN FIGURES. http://ec.europa.eu/dgs/energy_transport/figures/pocketbook/doc/2006/2006_energy_en.pdf . 2006. European Commission, Eurostat. 16-5-2007. Ref Type: Electronic Citation

EC. 2007. DEUTSCHLAND - Factsheet Energie-mix. http://ec.europa.eu/energy/energy_policy/doc/factsheets/country/de/mix_de_de.pdf . 2007. European Commission, Eurostat. 12-5-2007. Ref Type: Electronic Citation

EEA. 2004. Analysis of greenhouse gas emission trends and projections in Europe 2004. [Online] http://reports.eea.eu.int/technical_report_2004_7/en . 2004. EEA, Copenhagen, Denmark. Ref Type: Electronic Citation

EEA 2005, Household consumption and the environment, European Energy Agency, Copenhagen, Denmark.

Ellis, R. & Bell, M. "cobra 2004 - The international construction research conference of the Royal Institution of Chartered Surveyors", Rics Foundation and Leeds Metropolitan University, UK.

EU. 1992. The Kyoto Protocol. [Online] http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/06/74&format=HTML&aged=0&language=EN&guiLanguage=en . 1992. 13-2-2007. Ref Type: Electronic Citation

EU. 2006. [Online] http://ec.europa.eu/energy/demand . 2006. 12-3-2007. Ref Type: Electronic Citation

Euractive. 16-5-2007. Carmakers ask for CO2 cap delay[. [Online] http://www.euractiv.com/de/verkehr/autohersteller-fordern-aufschub-co2-begrenzung/article-163829 . 16-5-2007. 18-5-2007. Ref Type: Electronic Citation

Eurima. 2005. Cost-Effective Climate Protection in the EU Building Stock. [Online] http://www.eurima.org/downlads/leaflet_with_keypoints.pdf . 2005. 10-3-2007. Ref Type: Electronic Citation

Eurobarometer 2006a, Energy Issues, Eurobarometer, European Commission, 258.

Eurobarometer. 2006b. Eurobarometererhebung: Europäische Bürger befürworten eine europäische Energiepolitik. http://europa.eu.int/comm/public_opinion/index_en.htm . 2006b. Ref Type: Abstract

European Commission 2003, External Costs. Research results on socio-environmental damages due to elecricity and transport, European Commission.

European Commission. 2006a. A European Stategy for Sustainable, Competitive and Secure Energy. [Online] http://ec.europa.eu/energy/green-paper-energy/index_en.htm . 2006a. 11-1-2007a. Ref Type: Electronic Citation

European Commission. 8-3-2006b. Fuelling our future: the European Commission sts out its vision for a Energy

Stategy for Europe. [Online] http://europa.eu/rapid/pressReleasesActioin.do?reference=IP/06/282&format=HTML&aged=0&language=EN&guiLanguage=en . 8-3-2006b. 11-1-2007b. Ref Type: Electronic Citation

European Parliament. 2002. Directive of the Europena Parliament and of the council of 16 December 2002 on the energy performance of buildings. Directive 2002/91/EC. 2002. Ref Type: Bill/Resolution

Feist, Dr. W. 2001, Gestaltungsgrundlagen Passivhäuser Das Beispiel GmbH, Germany.

Feist, W., Jäkel, M., Sturm, H. J., & Werner, J. 1994, Lüftung im Passivhaus. Passivhausberich Nr. 8 Institut Wohnen und Umwelt, Darmstadt, Germany.

Flade, A., Hallmann, S., Lohmann, G., & Mack, B. 2003, Wohnen in Passiv- und Niedrigenergiehäusern aus sozialwissenschaftlicher Sicht, Institut Wohnen und Umwelt GmbH (IWU), Darmstadt, Germany.

Geissler, S. 2006, "Wert und Preis von Nachhaltigen Gebäuden", Wohnbauforschung in Österreich.wbfö no. Nr.1, pp. 10-14.

Geissler, S. & Bruck, M. 2004, Total Quality Planung und Bewertung von Gebäuden. Projekt im Auftrag des österreichischen Bundesministeriums für Wissenschaft und Verkehr, des österreichischen Bundesministeriums für wirtschaftliche Angelegenheiten und des österreichischen Bundesministeriums für Umwelt, Jugend und Familie., Österreichische Bundesministerium für Wissenschaft und Verkehr, Austria.

Greenpeace 2007, Global Energy [R]evolution, a sustainable world energy outlook.

Hastings, S. R. & Wall, M. 2007, Sustainable Solar Housing - Vol. 1; Strategies and Solutions, Earthscan (IEA, SHC, ECBCS), London, UK.

Hauser, G., Hogrefe, J., Bradke, H., & Erhorn, H. 2006, Die Energie der Zukunft - Intelligente Ideen für den effizienten Umgang mit einem kostbaren Gut Hogrefe,J.;Bradke,H., Stuttgart, Germany.

Hegner, H. D. & Loga, T. 2004, "Erste Schritte zur Einführung von Energieausweisen im Gebäudebestand", BUNDESBAUBLATT, vol. 53, no. Nr.2, pp. 24-30.

Herkel, S. & Strauß, P. 2007. Solares Bauen - Gebäudehülle und Systemtechnik. Solares Bauen.[Online] http://www.fv-solarenergie.de 2007[01], 26-29. 2007. Berlin, Germany, FV-Solarenergie. Ref Type: Electronic Citation

Hohmuth, T. 2005, "Emissionshandel mit dem Energieausweis? Wie Gebäude(eigentümer) am CO2-Zertifikatehandel teilnehmen könn(t)en", TGA Fachplaner, vol. 4, no. Nr.7, pp. 30-32.

IEA 2005, Key world energy statistics 2005, International Energy Agency, Paris, France.

ifeu Institut & ECONSULT 2005, Evaluation und Begleitung der Umsetzung der Energieeinsparverordnung 2002 in Baden-Württemberg, ifeu Institut, Heidelberg und Econsult, Rottenburg, Germany.

IPCC 2001, Impacts, Adaptation & Vulnerability. IPCC - Intergovernmental Panel on Climate Change, Cambridge University Press: Cambridge, UK.

IPCC. 4-5-2007. IPCC Fourth Assessment Report, Working Group III - Summary for Policymakers . [Online] http://www.ipcc.ch/SPM040507.pdf , 1-32. 4-5-2007. Swizerland, IPCC - Intergovernmental Panel on Climate Change. Ref Type: Electronic Citation

Jandl, J. 2006, "Welche Dämmdicken sind ökologisch noch sinnvoll", Wohnbauforschung in Österreich.wbfö no. 3, pp. 22-34.

Kohler, S., Kraus, F., & Hausladen, G. 2006, Energieeffizienz von Gebäuden, 1 edn, Wüstenrot Stiftung, Ludwigsburg und Karl Krämer Verlag Stuttgart, Zürich.

Lawson, B. 1996, Building materials, energy and the environment: Towards ecologically sustainable development RAIA, Canberra, Australia.

Malloth, T. 2006. Gesetzliche und wirtschaftliche Rahmenbedingungen des Energieausweises. Wohnbauforschung in Österreich.wbfö 2, 4-9. 2006. Ref Type: Magazine Article

Mantzos, L., Capros, P., Kouvaritakis, N., & Zaka-Paschou, M. 2003, European energy and transport trends to 2030, European Commission Directorate General for Energy and Transport. Office for official Publications of the European Communities, Luxembourg.

McMakin, A. H., Malone, E. L., & Lundgren, R. E. 2002. Motivationg residents to conserve energy without financial incentives. Environment and Behavior Vol. 34, 848-863. 2002. Ref Type: Magazine Article

Metz, B. 2003, Methodological and Technological issues in Technology Transfer, Interngovernmental Pannel for Climate Change - IPCC.

Mine & Geoff. 2005. Australia's guide to environmentally sustainable homes. [Online] http://www.greenhouse.gov.au/yourhome/technical/fs31.htm . 2005. 3-2-2007. Ref Type: Electronic Citation

Moutschen, E. 7-2-2007. Press Release: Die Europäische Kommission plant Rechtsrahmen, um die Erfüllung der EU-Ziele für geringere CO2-Emissionen von Kraftfahrzeugen sicherzustellen. [Online] http://ec.europa.eu/luxembourg/docs/press/057-2007_de.doc . 7-2-2007. European Commission, Representation in Luxembourg. 11-5-2007. Ref Type: Electronic Citation

Nilsson, J. 12-9-2006. Energy Policy. 12-9-2006. LUMES, Lund University, Sweden. Ref Type: Hearing

Nitsch, J. 2002. Strategien für eine vollständig solare Energieversorgung. FVS Themen 2002, 105-111. 2002. Berlin, Germany, Fachverband Solarenergie. Ref Type: Magazine Article

Noeren, D. 3-5-2006. Sick Building Syndrome and Moulds. The Sick Building Syndrome and other Effects on Humans from Indoor Pollution by Moulds. 1-5. 3-5-2006. LUMES - Pollution and Human Health 2006, Lund University; Lund, Sweden. Ref Type: Unpublished Work

Nokielsky, H. 1985, "Straße als Lebensraum? Funktionalisierung und Revitalisierung spzialer Räume," in Kommunale Sozialpolitik, J. Krüger & Pankoke, eds., R. Oldenbourg, München (Munich), Germany.

Ochsendorf, J. 2004. 1.964: Design for Sustainability. [Online] http://ocw.mit.edu/OcwWeb/Civil-and-Environmental-Engineering\1-964Fall-2004\LectureNotes\index.htm [Lecture 1-3]. 2004. MIT Open University; Massachusetts Institute of Technology; USA. 11-12-2006. Ref Type: Slide

OECD 2003, Environmentally Sustainable Buildings: Challenes and Policies, Organization for Economic Cooperation and Development - OECD, Paris, France.

Passivhaus Kompendium 2006, Passivhaus Kompendium Laible Verlagsprojekte, Allensbach, Germany.

Petersen, A. & Solberg, B. 2002. Greenhouse gas emissions, life-cycle inventory and cost-efficiency of using laminated wood instead of steel construction. Environmental Science & Policy 5/2002, 168-182. 2002. Ref Type: Magazine Article

Poxleitner, J. 2006, "Energieeffizientes Bauen", bau intern no. 3/4, pp. 2-3.

Rijkens-Klomp, N. & Lieshout, M. 2004, 'Housing', background paper for the EEA report on household consumption and the environment, International Centre for Integrative Studies (ICIS), Maastricht, NL.

Routledge Institute 2003, Review of Cities and Climate Change: Urban Sustainability and Global Environmental Governance; Routledge Studies in Physical Geography and Environment; 4, Routledge, London, New York.

Sánchez-Jiménez, M. 2001. Energy, Environment and Sustainable Development (EESD). FVS Themen 2001, 151-157. 2001. Berlin, Germany, Förderverein Solarenergie. Ref Type: Magazine Article

Scheer, H. 2005, Energieautonomie Verlag Antje Kunstmann, Munich, Germany.

Scheer, H. 30-1-2007. European Renewable Energy Policy Conference, The Renewable Energy Roadmap. 30-1-2007. EREC - European Renewable Energy Council, Brussels, Belgium. Ref Type: Hearing

Schuler-Büchel, S., Rutzer, M., & Mätzler, D. 2003. Methoden der Liegenschaftsbewertung. http://www.llb.li/lb2003.nsf/Files/FCOBerichte/$File/LLBFinancialConsulting03052003.pdf . 2003. Lichtensteinische Landesbank AG. 10-1-2006. Ref Type: Electronic Citation

Schulze Darup, B. 2003, Energetische Gebäudesanierung mit Faktor 10, Dr. Schulze Darup, [Online] http://www.ea-nrw.de/_infopool/page.asp?InfoID=2718&find=.

Shorrock, L. D., Henderson, G., & Brown, J. H. F. 1992, Domestic Energy Fact File., Building Research Establishment Report, Watford, UK.

Spada, H. 1990, "Umweltbewusstsein: Einstellung und Verhalten," in Ökologische Psychologie. Ein Handbuch in Schlüsselbegriffen, L. G. C. F. Kruse & E. D. Lantermann, eds., Psychologie Verlags Union, Weinheim, Germany.

Stern, N. 2006, "The economics of risk", Environmental Finance, vol. Dec. 06/Jan. 07, p. 20.

Stern, P. C. & Oskamp, S. 1987, "Managing scarce environmental resources," in Handbook of environmental psychology, Vol. 2 edn, D. Stokols & I. Altman, eds., Wiley, New York, USA.

Thomark, C. 2000. Enironmental analysis of a building with rused building materials. International Journal of Low Energy & Sustainable Building 1/2000. 2000. Ref Type: Magazine Article

Thunselle, K., Erhorn, H., Morck, O., Ferrari, S., Fuentes, & Manuel 2005, Bringing Retrofit Innovation to Application in Public Buildings - BRITA in PuBs. Deliverable D5 - Socio-economic Analysis on Barriers and Needs.

Umweltbundesamt. 15-5-2007. Primary energy consumption in Germany. [Online] http://www.env-it.de/umweltdaten/public/theme.do?nodeIdent=2326 . 15-5-2007. Berlin, Germany, Umweltbundesamt - Federal Environment Agency. Ref Type: Electronic Citation

UN. 2004. World populations prospects; The 2004 Revision Population Database. [Online] http://esa.un.org/unpp/ . 2004. United Nation Population Devision. Ref Type: Electronic Citation

UNEP 2007, Buildings and Climate Change, UNEP - Unitde Nations Environment Programme.

Wargocki, P., Wyon, D. P., Sundell, J., Clausen, G., & Ganger, P. O. 2000. The effects of outdoor air supply rate in an office on percived air quality, Sick Building Syndrome (SBS) and productivity. Indoor Air 10, 222-236. 2000. Ref Type: Magazine Article

Weizäcker, von E.U., Lovins, L. H., & Lovins, A. B. 1995, Faktor 4. Doppelter Wohlstand - halbierter Naturverbrauch Wuppertal Institut, Wuppertal, Germany.

Williams, D. I., Crawshaw, C. M., & Crawshaw, A. J. E. 1985. Energy Efficiency and the Domestic Consumer. The Journal of Interdisciplinary Economics 1, 19-27. 1985. Ref Type: Magazine Article

Wortmann, K., Stahlber, D., & Frey, D. 1988, "Energiesparen," D. Frey, C. Hoyos, & D. Stahlberg, eds., Psychologie Verlags Union, München (Munich), Germany.