Sino-German Cooperation Project

Qualification of Key Actors in the Building Energy Efficiency Sector (KABEE)

Training textbook

German Experiences to obtain Energy Efficiency Gains in Cities through Green Buildings

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1 Introduction

The building sector represents a significant share of national energy consumption and thus a primary target for a concerted effort to reduce a nation's greenhouse gas emissions. The sector may yield enormous energy savings potential achievable through numerous options.

The aim of the textbook is to holistically summarize the German energy efficiency efforts in the building sector. The report starts with building energy consumption, potential of saving energy, and co-benefits associated with measures of building energy efficiency. It then outlines the state and trends regarding residential buildings in Germany and Europe. Next, it explores the different types of low energy buildings and highlights life cycle costs. It then explores the techniques and technologies of promoting energy efficient buildings. Given the high relevance of green buildings to China, it also includes a chapter on green buildings in Europe. Finally, it addresses policy and measures that drive the up-taking of building energy efficiency technologies.

The textbook is the first attempt to draw synergy between ***KABEE***- Qualification of Key Actors on Energy Efficiency in the Building Sector and ***bigEE***-Bridging the Information Gap on Energy Efficiency in Buildings (www.bigee.net). Thus, this textbook was developed largely based on bigEE content, namely, Chapter 5, Chapter 6, and Chapter 8.

2 Context

2.1 Status Quo

Energy efficiency in buildings is crucial for sustainable development, climate and resource protection and a low-risk worldwide energy system. The buildings sector accounted for approximately 32% of global final energy consumption, 19% of energy-related CO_2 emissions, and 51% of global electricity consumption in 2010 (IPCC 2014). Expressed in carbon emissions, the building sector caused emissions of 9.18 giga-tons (Gt) of CO_2 equivalent in 2010 (IPCC 2014).

On the other hand, large savings in energy use (75% or higher) are possible both for new buildings and existing building stock. Currently, even conventional new buildings in OECD countries with a history of building codes save about 50 % of energy, in comparison to average buildings in the building stock. Numerous studies confirm that enormous energy saving potentials – up to 80 to 90 per cent – can be realised by improving building and appliance energy efficiency. IPCC (2014) claims that mitigation opportunities in the buildings sector are significant and are more cost effective compared to other measures. At the same time, significant co-benefits, for example, housing comfort and healthier indoor climate can be generated.

Taking a closer look at energy consumption in buildings, space conditioning and water heating account for roughly half of global building final energy use (Figure 1). Thus energy efficiency of buildings is a basic requirement for any renewable energy supply implementation strategies. Yet, to make this happen, policy is needed to help the actors in the building value chain overcome their various barriers to harness energy efficiency and to strengthen their market-inherent incentives. The goal is to make energy efficiency as easy and attractive as possible, sometimes to make it feasible at all, and ultimately to make it the standard choice.

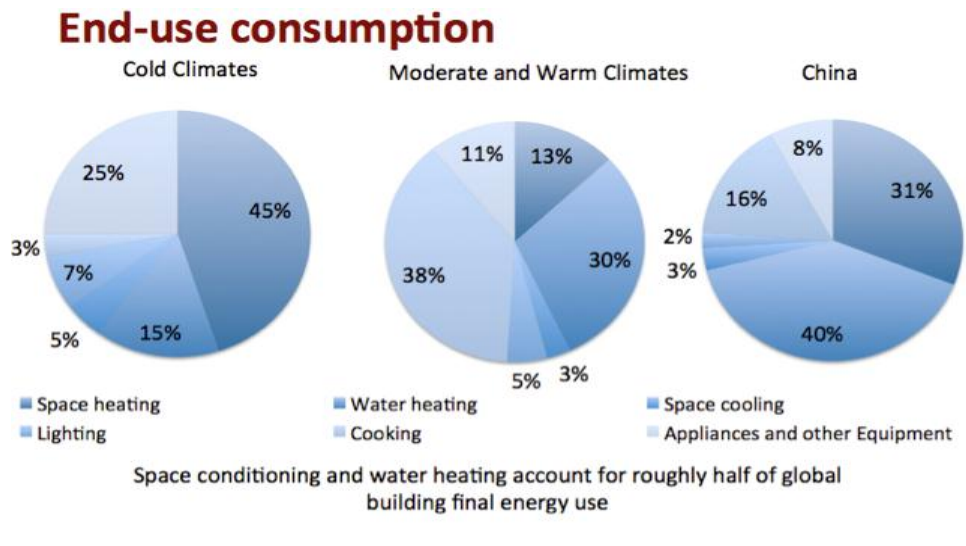


Figure 1 Energy end-use consumption in buildings

2.2 The potential for energy savings is high

New Ultra-Low-Energy Buildings needing 60 to 90% less final energy for heating and cooling than conventional new buildings can be constructed cost-effectively in most parts of the world. Retrofitting existing buildings can bring similar improvements, i.e. 50 %–75 % (IPCC 2014: 686). Extensive energy-efficient renovation measures ("deep renovation") can be profitable investments if done as part of typical refurbishment cycles and if the energy costs savings during the life cycle are considered (GEA 2012).

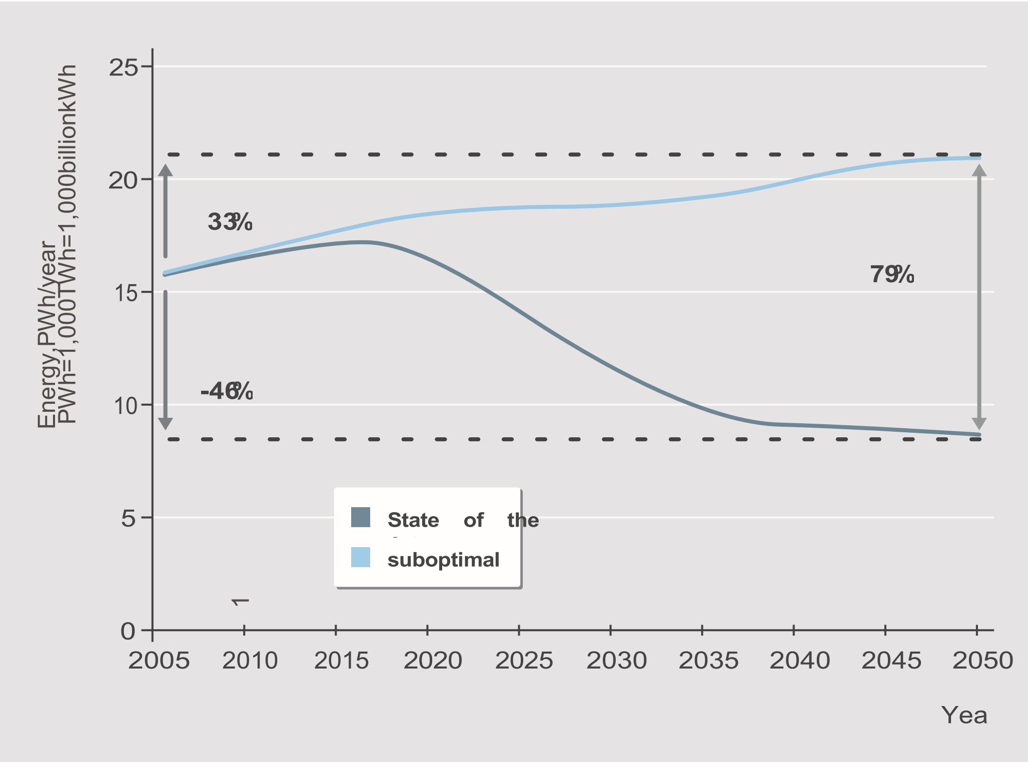


Figure 2 World space heating and cooling final energy use, 2005 – 2050, suboptimal and state-of-the-art energy efficiency scenario

(Source: GEA 2012)

Most recent scenarios (Figure. 2) show that state-of-the-art energy-efficient renovation and new buildings could result in worldwide overall energy savings of 46% in 2050 compared to 2005. For a suboptimal scenario this could save up to 60% of the energy consumption expected in 2050 expressed in final energy demand for heating and cooling. Despite growth in the building stock, this translates into an absolute decrease in energy consumption from 15.7 PWh (15,700 TWh) in 2005 down to 8.5 PWh (8,500 TWh) in 2050. GEA (2012) estimated that the approximately US$57 trillion of cumulative energy cost savings until 2050 in avoided heating and cooling energy costs alone substantially exceed the estimated US$15 trillion investments that are needed to realize this pathway. Such a transition will only be achieved with early, comprehensive and systematic implementation of state-of-the art energy efficiency measures in design, construction and technology in both new and existing buildings. These measures are urgently needed because policy that only encourages suboptimal improvements will lead to considerable "lock-in" effects. Once renovated or built, it will not be cost-effective to further upgrade the energy efficiency of these buildings for several decades. In other words, inadequate action now means losing cost-effective opportunities for long-term investments, energy and carbon emission reductions.

2.3 Co-benefits of energy efficiency

Improving building energy efficiency does not only save energy and contribute to climate change mitigation but also has various co-benefits. The most interesting of these co-benefits are improvements in health, higher workers' productivity through better indoor climate and lighting, and higher living standards by making energy bills affordable. Co-benefits increase social and/or individual welfare and come as a free add-on to the direct benefits of energy efficiency for investors and policy, which are reduced energy costs and climate change mitigation.

Box 1 Co-benefits of energy efficiency

Investors

- Higher price premium for energy-efficient buildings
- Enhanced competitiveness of suppliers of energy efficiency solutions
- Improved public image for companies that make their buildings state-of-the art in terms of energy efficiency
- Improved productivity in commercial buildings and reduced sick leave times due to health and comfort benefits

National economy

- Increased energy security by reducing dependence on imports of depleting supplies of fossil fuels
- Economic development in emerging economies like India and China by reducing energy demand

Society

- Poverty alleviation by using surplus energy to connect more areas to energy grid
- Reduced dependence of low-income households on social benefits or subsidies on energy price
- More jobs for skilled workers in new construction and building renovation and indirect jobs to meet demand of products and services created due to extra money at users' disposal

Environment

- Contribution to mitigating climate change
- Increased resource efficiency and reduced demolition waste of energy-efficiently designed buildings
- Ecosystem protection, reduced pollution of indoor air and related damage to soil, water and crops

Health

- Healthier, more comfortable indoor environment
- Reduced noise and increased day-lighting

- Increased thermal control
- As a result: Improved productivity and reduced sick leave times in commercial buildings

3 Residential Building Sector in Europe

According to the BPIE (2011) study there are 25 billion m2 of useful floor space in the EU27, Switzerland and Norway. Of this about 75% or 18,75 billion m2 is residential floor space alone (Figure 3). Many countries within the EU have however actually recorded a decrease in residential floor space mainly due to the current financial crisis. The residential stock is varied ranging from terraced housing to flats and detached houses with the largest sector being the single family building. Apartment blocks may accommodate several households typically ranging from 2-15 units or in some cases more than 20-30 units (e.g. social housing units or high rise residential buildings) (BPIE 2011)

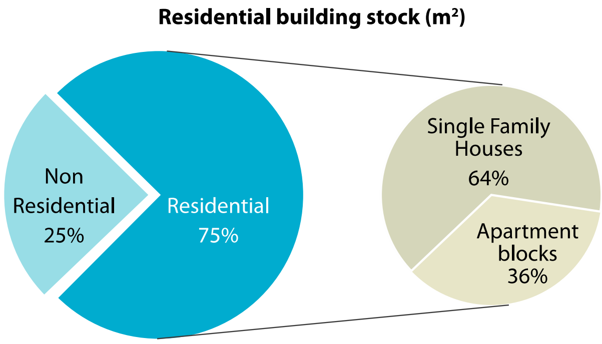


Figure 3 Residential Building Stock in Europe

(Source: BPIE 2011)

A large share of the stock in Europe is older than 50 years and many buildings are even older (some buildings are hundreds of years old). Many buildings have been constructed before the 1960s (more than 40%) without strict building regulations (Figure 4).

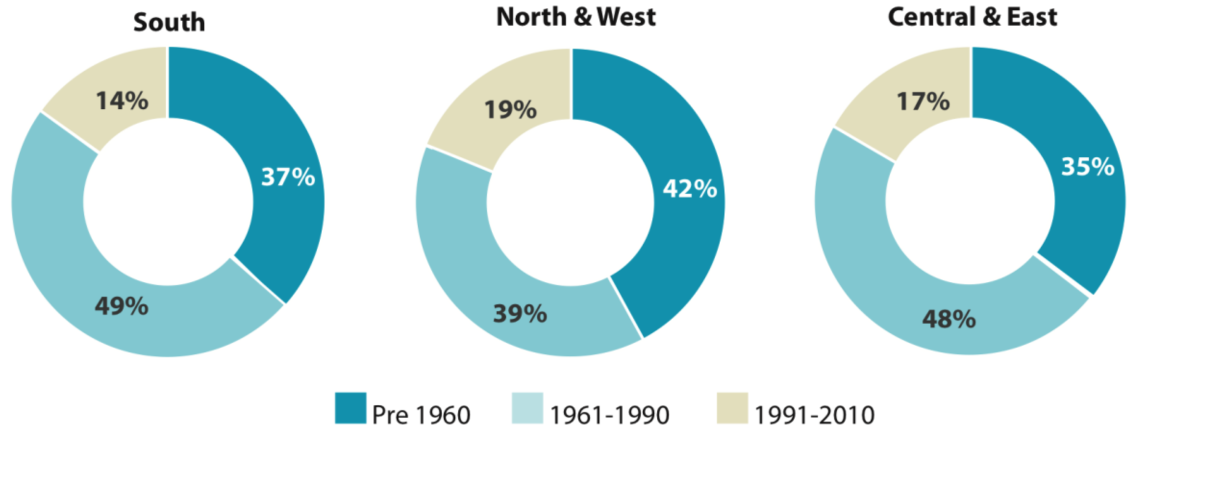


Figure 4 Age categorisation of housing stock in Europe

(Source: BPIE 2011)

The building sector is the largest consumer of energy in Europe, accounting for almost 40% of the total consumption (EC 2013).

The greater part of energy use in the residential sector is at present for hot water and space conditioning (heating and cooling) (as shown in Figure 6). With the ever-improving insulation standards the influence of the space conditioning becomes less and less and that for hot water grows in importance.

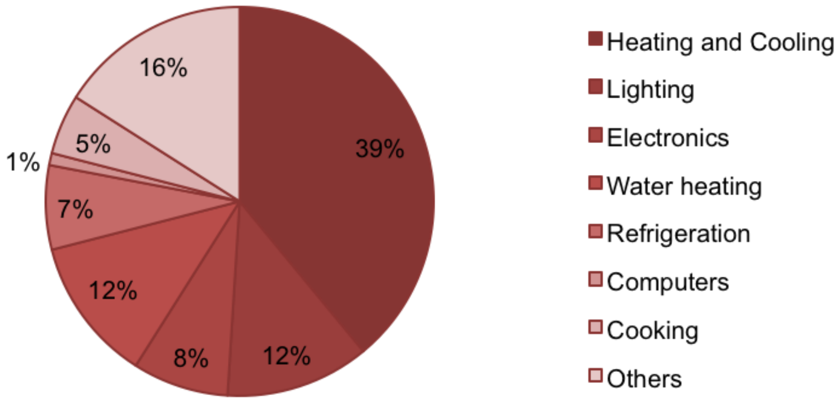


Figure 5 Energy use in the residential sector

(Source: BPIE 2011)

The energy consumption of conventional new residential buildings in Europe is between 80 - 150 kWh/m^2. A large part of the new buildings are however already under this level well below the required values from code and many are already nearly reaching passive house standard using less than 50 kWh/m2a (BPIE 2011). However, a substantial amount of the existing building still has poor energy performance, which constitutes the largest potential for energy saving in Europe (BPIE 2013).

4 Residential Building Sector in Germany

Residential building sector has a substantial share in Germany. There are 19,06 million residential buildings with around 41,29 million residential units (Statistische Ämter des Bundes und der Länder 2011).

As in Europe there are a wide range of living styles in Germany – single-family, multi-family and to a lesser extent high rise buildings. Of this 65% are single family buildings, with 17% double family, 12% with more than 3 apartments and only 6% are large multifamily buildings with more than 7 apartments. The large multifamily sector accounts for over a third of all apartments and is just as large as the single family building sector (Statistische Ämter des Bundes und der Länder 2011).

The ownership pattern of residential buildings is diverse in Germany. About 85% of residential buildings are owned by private persons. In addition, rental housing has a high share with 52% of all dwellings (IWU 2014) (Figure 6).

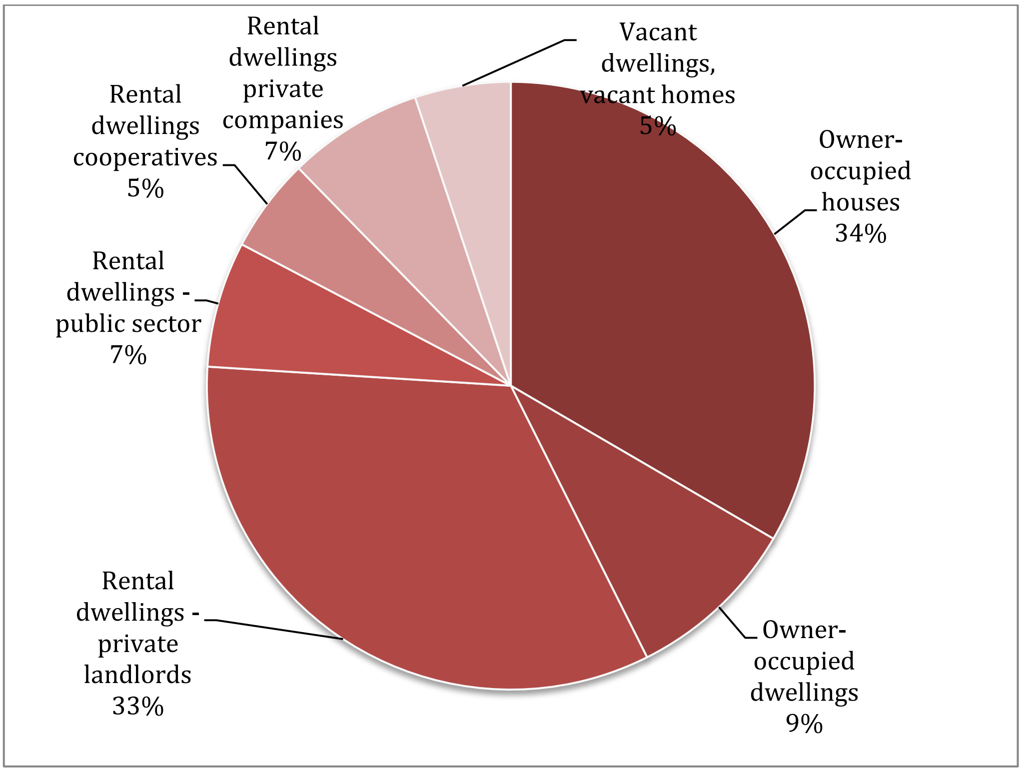


Figure 6 Residential property ownership 2011 (dwellings)

Similar as the situation in Europe, Germany´s buildings were built before any formal energy performance requirements with about two thirds all residential buildings in Germany were built before 1980 (Figure 7). The rate of new buildings lies around 1%.

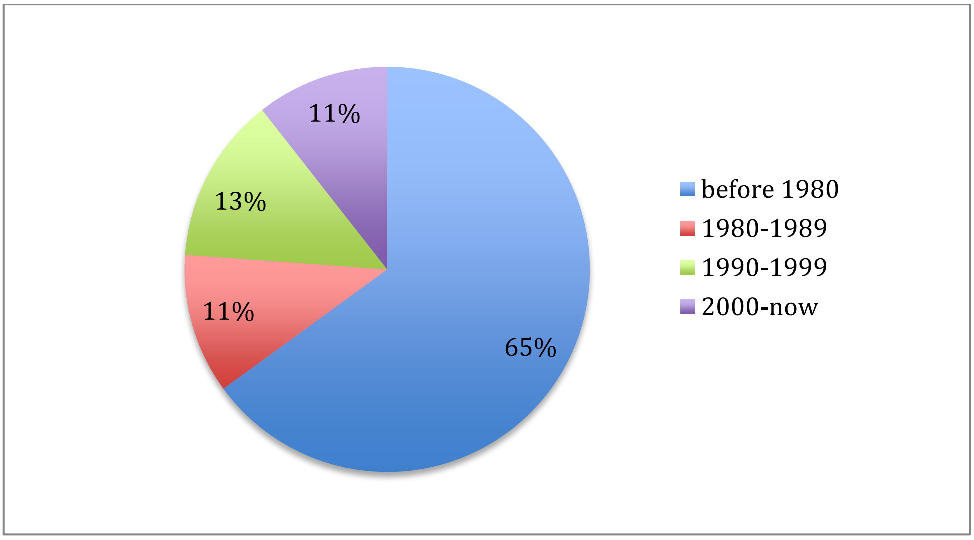


Figure 7 Residential buildings according to its ages (data 2011)

Energy consumption in buildings in Germany in 2011 was given as 75 Terawatthours (TWh). This represents around 31% of the total energy consumption in Germany, of which only 12,7% or 95 TWh was from renewable energy sources.

Climate in Germany can be described as a warm, temperate and wet climate with westerly winds. The summers are moderate and the winters are mild. Extreme temperature fluctuations occur rarely. As per Köppen classification, it features a mix of humid continental climate in the East, with Oceanic climate in the West with polar and alpine climate towards the South of the country.

Accordingly, space heating accounts for a significant share of building energy. The average specific final energy consumption for space heating taking into account the adjustment for different yearly temperatures was around 133 kWh/m2 (Umweltbundesamt 2014).

On the other hand, since the first energy efficiency standard was first implemented in 1977, 75% of energy consumed by residential buildings is from buildings constructed before 1979 (Umweltbundesamt 2014). This calls for energy efficiency renovation in existing building stock.

5 Energy Efficient Buildings

This chapter starts with introducing holistic approach and strategic approach to integrated building design. It further indicates energy consumption of energy efficient buildings in Europe and Germany. Then it presents different types of energy efficient buildings, including passive houses, (nearly) Zero Energy House, and Active House. Finally, it addresses the cost and cost-effectiveness of energy efficient buildings, e.g. passive house.

This chapter is largely based on the content of bigEE (www.bigee.net).

5.1 Holistic Approach

Buildings are extremely complex. Each component can be improved upon but none can bring about energy efficiency in buildings on their own. There are combinations of different options for improving energy efficiency in buildings. The Strategic Approach follows the premise of first implementing load-reducing "Passive Options" for building design, followed by energy-efficient "Active Options" for thermal conditioning and ventilation as needed and then fine-tuning building operation through "User Behaviour and Energy Management". At first glance they all seem independent of each other. However all energy efficiency options are interdependent to some degree and therefore an integrated design approach is indispensable to ensure that the architectural elements and the engineering systems work effectively together. Changing or improving one aspect might have great impact on another. Focusing on individual pieces of equipment or design features generally only brings limited improvements. Analysing the building as an entire system can however lead to altogether different design solutions. This can result in new buildings that use much less energy but are no more expensive than conventional buildings (IPCC 2007). This integrated design process can achieve improved building performance at lower costs and ensures fewer troublesome changes during the later stages of the project. The sum of the whole is more than the sum of the single components. This integrated three-part process can reduce the primary thermal energy demand of a building to low or even ultra-low levels, depending on the levels at which these are implemented at. Adding on-site renewable energy technologies for heating and cooling and / or for power generation (CHP / CHCP, PV cells etc.) can turn the primary energy balance of a building to the positive side, with the building becoming a net producer of energy over the year.

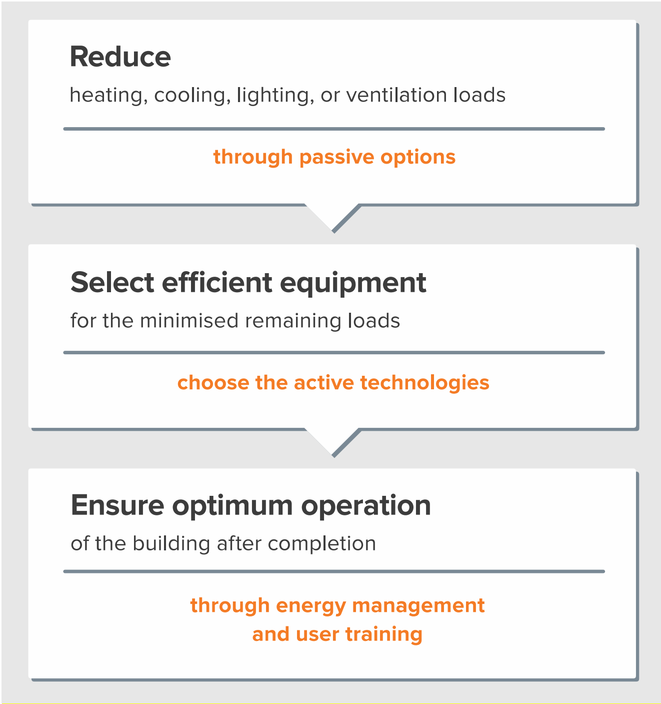


Figure 8 Holistic approach of building energy efficiency

The holistic approach is very important and Figure 8 illustrates for implementation of appropriate strategies. The later they are accommodated in the design process the more costly the end result for the client. Lifecycle optimised planning although, slightly more costly in the beginning brings great savings in the end.

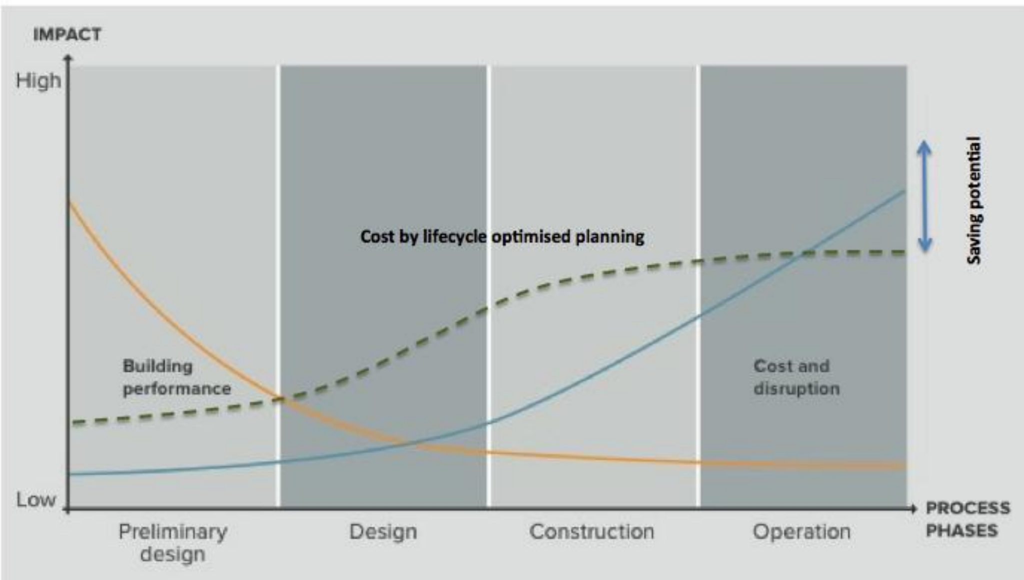


Figure 9 Building Phases and their impacts

(Source: www.bigee.net)

5.2 Strategic Approach

A Strategic Approach to integrated building design is the key to achieving high-energy savings at low or no extra cost in residential buildings. Although it includes an Easy-Efficiency Approach as well as an Advanced-Efficiency Approach the first step will not be sufficient to reach long-term climate protection goals. It is thus necessary to implement and support an Advanced Approach at the earliest to avoid lock-in effects (Figure 10). This would otherwise result in less efficient houses than achievable continuing in use for decades because of long building lifetimes.

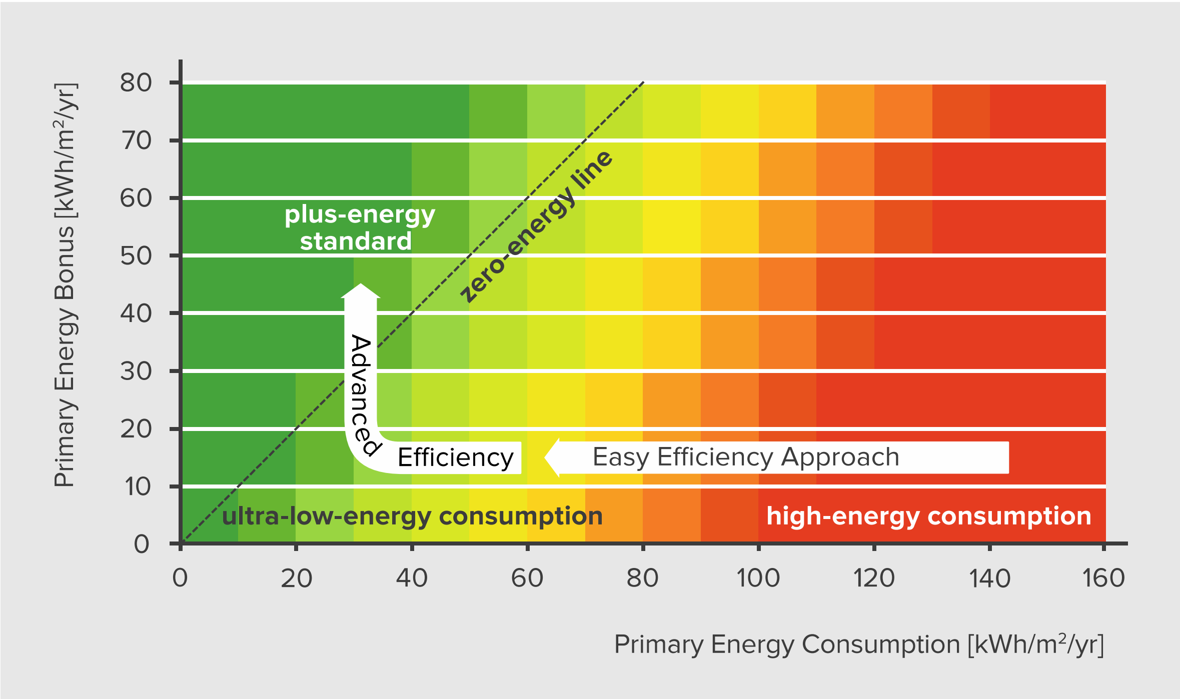


Figure 10 Strategic Approach to integrated building design

5.2.1 Low-Energy buildings

The Easy-Efficiency Approach or Low-Energy Building (LEB) is characterised by an intelligent (holistic/integrated) building design in combination with an appropriate choice of efficient technologies for heating, cooling, hot water production, lighting etc. By fulfilling basic rules of energy-efficient design especially passive options, any incremental capital costs incurred are compensated by energy cost savings within a few years and certainly provide returns over the lifetime of the buildings. Thus the most important advantage of these buildings is that they are – as a rule – economically attractive over their lifetime as they make use of the 'low hanging fruits' of energy efficiency options.

5.2.2 Ultra-Low-Energy Buildings

The Advanced-Efficiency Approach or Ultra-Low-Energy Buildings (ULEB) is a further development of a Low-Energy Building, requiring up to 90% less primary energy consumption than a conventional new building. The Ultra-Low-Energy Building maximizes a building's energy efficiency potential. An Advanced-Efficiency Approach is needed to attain these low levels of energy consumption. Ultra-Low-Energy Buildings set more ambitious energy efficiency standards, using the most-energy-efficient components and systems available to reduce the energy consumption. This energy consumption should preferably be covered by renewable energy sources such as solar energy, ambient and geothermal energy, sustainable biomass etc. It can be cost-effective, depending on the trade-off between incremental capital costs and long-term energy cost savings but this may not always be the case.

5.2.3 (nearly) Zero-Energy Buildings and Plus-Energy Buildings

The (nearly) Zero-Energy Building (nZEB) and the Plus-Energy Building (PEB) concepts are based on the Low-Energy Building or preferably the Ultra-Low-Energy Building concept described in the Strategic Approach. This building standard requires on-site energy generation from renewable energy sources or the use of Combined Heat and Power (CHP) systems in addition to an already high energy-efficient building. As on-site generation is normally more expensive the best possible measure is to minimize energy consumption. If the amount of on-site produced energy (converted in primary energy equivalent) is roughly equal to the annual primary energy consumption, the building can be described as a (nearly) Zero-Energy Building. If energy production exceeds the consumption, the term Plus-Energy Building will be used.

5.3 World wide recommended energy consumption levels

The climate classification for the building sector within the bigEE project differs from that of the Chinese Building Standard climate definition. The bigEE climate definition is that of a degree-day system. This is based on both the heating degree-days, cooling degree-days as well as the humidity. For simplicity the world's climate was divided into four major climatic zones, ***Cold, Temperate***[1], ***Hot and Humid and Hot and Arid*** (Box 2). Each of these regions or zones has different requirements with respect to heating and cooling energy needs. The focus of energy-efficient measures therefore varies between different climatic regions (Figure 11).

Box 2 bigEE climate definition

Cold (Climatic regions with a high heating load)

Cold climates have a high heating demand for all or part of the year and no or little cooling demand. Climatic conditions are cool with four distinct seasons cold to very cold winters, with cool to warm summers and variable spring and autumn conditions.

Heating Degree Days18°C ≥ 1000, Cooling Degree Days10°C < 1000

[1] This is not the same Temperate as in the climate definition for China according to the Chinese Energy Building Standards

Temperate (Climatic regions with a medium heating load and low cooling load)

Temperate climates have both a heating and cooling demand for all or part of the year. Climatic conditions are with four distinct seasons cool to cold winters, mild to warm summers and variable spring and autumn conditions. These climatic regions require no or very little cooling in summer.

Heating Degree Days18°C ≥ 1000, Cooling Degree Days10°C ≥ 1000

Hot and Dry (Climatic regions with a high cooling load and low humidity levels)

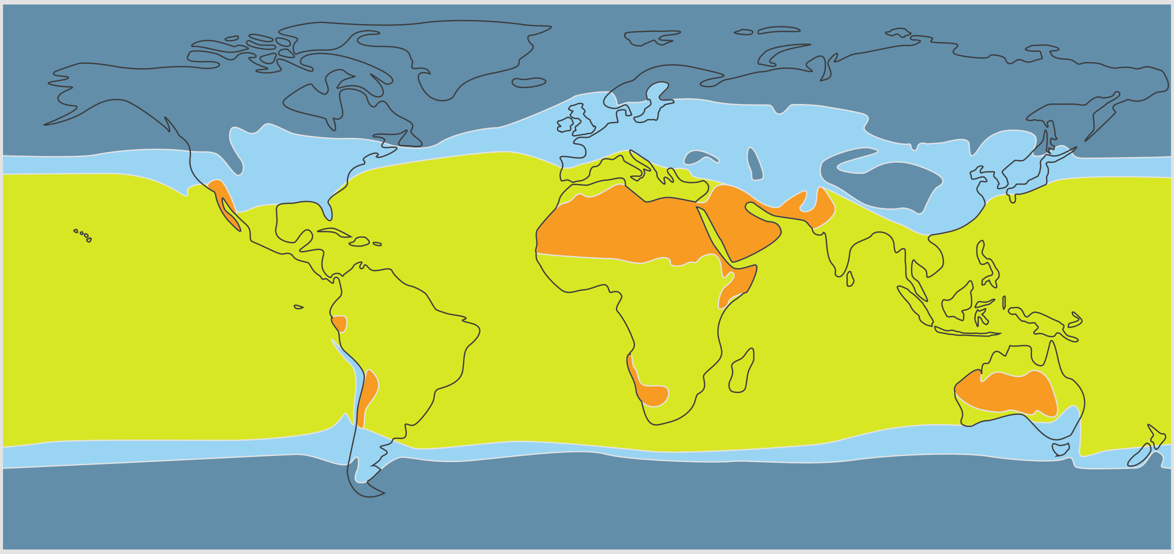
Hot and Arid climates have a cooling and no heating demand throughout the year as well as low relative humidity levels throughout the year. These climates have hot to very hot summers with little rainfall and low humidity throughout the year. In addition to this the solar insolation tends to be extremely high. The difference between diurnal and nocturnal temperature is quite high. Depending on location the temperatures can become cool during the winter.

Heating Degree Days18°C <1000, Cooling Degree Days10°C ≥ 1000, Humidity ≤ 50%

Hot and Humid (Climatic regions with a high cooling load and high humidity)

Hot and Humid climates have a cooling and no heating demand throughout the year as well as a high humidity level throughout the year. The summers are hot to very hot with humidity levels of over 50%. They often require no or very little heating in winter depending on the geographical location.

Heating Degree Days18°C <1000, Cooling Degree Days10°C ≥ 1000, Humidity > 50%



Climate	LEB	ULEB	nZEB	PEB
Cold	80-40 kWh/m^2_{TFA}yr	40-20 kWh/m^2_{TFA}yr	20-0 kWh/m^2_{TFA}yr	++
Temperate	80-40 kWh/m^2_{TFA}yr	40-20 kWh/m^2_{TFA}yr	20-0 kWh/m^2_{TFA}yr	++
Hot and Humid	150-100 kWh/m^2_{TFA}yr	100-50 kWh/m^2_{TFA}yr	50-0 kWh/m^2_{TFA}yr	++
Hot and Arid	100-50 kWh/m^2_{TFA}yr	50-25 kWh/m^2_{TFA}yr	25-0 kWh/m^2_{TFA}yr	++

Figure 11 World map showing bigEE climate zones and recommended specific consumption levels

5.4 Types of energy efficient Buildings

5.4.1 Energy efficient buildings in Europe

Energy efficient or low energy building has no standard definition in Europe and can therefore include various design and technology options. High levels of insulation, energy efficient windows and technologies as well as low levels of air infiltration define these buildings in general. The most important advantage of these buildings is that they are – as a rule – economically attractive over their lifetime because they make use of the 'low hanging fruits' of energy efficiency options. It can be generally accepted that this approach is about 40 to 60% more efficient than the current new building according to standard. Many of these low energy developments can be seen as having a light house effect guiding the masses in the right direction. Due to the varying climatic conditions there is however no exact definition.

As can be seen from simulations and case studies carried out at the Wuppertal Institute as well as the Passive House Institute low energy buildings, Passive Houses as well as near and zero energy buildings form well in temperate climates such as those found in Europe despite the extreme variation in climatic extremes varying from South Portugal to North Sweden.

Table 1 gives some examples of different low energy building categories in Europe.

Table 1 Examples of low energy building categories in Europe

Austria	Annual heating energy consumption below 60-40 KWh/m²
Belgium	Low Energy Class 1 for houses: 40 % lower than standard levels Very low Energy class: 60 % reduction for houses
Denmark	Low Energy Class 1 = 50% lower than standard levels
Finland	Low energy standard: 40 % better than standard buildings
France	New dwellings: than 50 kWh/m² (in primary energy). (40 kWh/m² to 65 kWh/m²)
Germany	Between 60kWh/(m²•a) and 40 kWh/(m²•a Passive House = ca. 40 kWh/(m²•a)

Source: SBI (2008)

5.4.2 Energy efficient buildings in Germany

Measures to reduce energy consumption and bring down CO_2 emissions in the building sector have been on the political agenda for years.

5.4.2.1 Germany (among others)

Various standards and/or benchmarks that are prevalent in Germany in the domain of energy efficient buildings are given in Table 2.

Table 2 Various standards and/or benchmarks of energy efficient buildings in Germany

Plusenergiehaus	(Plus Energy House)	Disch	1994

PassivHaus	(Passive House)	PHI	1996
Nullenergiehaus	(Zero-Energy House)	BUW	2008
Niedrigstenergiehaus	(Low-Energy House)	EPBD	2010
Effizienzhaus Plus	(Energy Efficient House Plus)	DENA	2011

A number of leading German building firms with the help of the BMBVS have joined together to form the next generation of energy efficient buildings. There has also been the creation of a Federal Benchmark the Energy Efficient House Plus (in German: Effizienzhaus Plus).

The buildings of the Energy Efficient House Plus must have a negative final energy consumption as well as negative primary energy consumption. Numerous buildings have already been built throughout Germany by several companies. All of them are buildings in which people live and not prototype buildings.

Table 3 provides a comparison of primary energy consumption in buildings as per various energy efficiency standards in Germany.

Table 3 Comparison of primary energy consumption in buildings under different standards in Germany

Standard	Primary energy consumption
EnEV 2014	ca. 75 kWh/(m²•a)
KfW 115	ca 86 kWh/(m²•a) (only for retrofitted existing buildings relevant)
KfW 100	ca 75 kWh/(m²•a) (only for retrofitted existing buildings relevant)
KfW 70	ca 53 kWh/(m²•a)
KfW 55	ca 40 kWh/(m²•a)
KfW 40	ca 30 kWh/(m²•a)
Passive House	ca 40 kWh/(m²•a)

Similarities and differences of sustainability features between these various energy efficient building standards can be seen in Table 4.

Table 4 Similarities and differences of sustainability features between various energy efficient building standards

Building Type	Passive House	Niedrig-energiehaus	Null-energiehaus	Plus-energiehaus
Waste recycling of electrical appliances	✔	✔	✔	✔
Insulation of roof and exterior walls	✔	✔	✔	✔
Energy demand met through own production		✔*	✔	✔
Generation of surplus energy for storage or public grid				✔

In addition, to promote energy efficiency, government and leading building firms have set up energy efficient exhibition centres for example in Cologne (which is the largest) or Wuppertal. Here prospective buyers can see first different energy efficient buildings. This helps to remove fears of the buyers and shows buildings which are cost effective and not much more expensive than the building norm.

5.4.2.2 KfW program

Incentives are given by the German Government through the KfW Bank Group to build building better than the required minimum standard.

The "energy-efficient refurbishment" KfW-programme, introduced in April 2009, together with its predecessor programme, saved 2,679 million kWh/yr of final energy and reduced greenhouse gas (GHG) emissions by 955,000 tons of CO_2eq/yr in 2009. In combination with the "energy-efficient construction" programme, the two programmes reduced annual GHG emissions by 1.2 million tonnes of CO_2eq/yr in the same year. 111,000 person-years of employment were created or secured by the refurbishment programme. The German federal government provided €2.0 billion to KfW for the programmes in that year. Using these government funds and further funds raised from capital markets, KfW made €8.9 billion available as soft loans with reduced interest or as grants in 2009 to promote energy-efficient investments for new and existing buildings. After the 2009 stimulus programmes, recent years saw government allocations of between €0.9 and €1.3 billion for the programmes, stabilising at €1.5 billion/yr recently. The state offers further financial incentives to make use of energy advice to avoid lost opportunities. The programmes promote an integrated optimisation of whole-building energy performance and are also linked to energy performance certificates.

Further details of KfW programme can be found in Section 8.4.4.

5.4.2.3 EnEV Standard [2]

The energy savings ordinance ENEV (Energieeinsparverordnung) Standard first came into force on 01.02.2002. The main purpose of the ordinance is to bring all components related to energy efficiency under its ambit. It started by merging "the Thermal Insulation Ordinance (WSchutzVO) from 16.08.1994" and "the heating system regulation "Regulation on energy-saving requirements for heating piercing engineering facilities and hot water systems from 04.05.1998" into ENEV 2002 After a series of amendments and up gradation in the following years in ENEV2004, ENEV2007 and ENEV2009.

The ordinance essentially sets out standards for installation and operation for various building components and technical systems with an aim to reduce the primary energy requirements (energy efficiency) of newly built residential and non-residential buildings by 25 percent from 1.1.2016.

Essential standards of ENEV include:

[2] This chapter is based on (Dena 2013).

- DIN 4701-12: heating energy assessment and ventilation systems in existing buildings – Part 12: Heat generation and domestic hot water.
- DIN V 4701-10: Energy efficiency of heating and ventilation systems – Part 10: heating, water heating, ventilation.
- DIN V 4701-10: heating Energy efficiency and ventilation systems
- DIN V 4108-6: Basics of heat, humidity and rain protection
- DIN V 18599-1 to 11: Energy performance of buildings – Calculation of energy demand (useful, final and primary energy demand) for heating, cooling, ventilation, domestic hot water and lighting of buildings

In order to aid the practice and to help plan and calculate energy balance of residential and non-residential buildings to reflect the objectives of the ordinance, a software package called EnEV is being offered. This helps in predicting energy performance achieved by a building and makes a case for any incentivized programmes for energy efficient buildings like the KfW programme.

5.4.2.4 KfW / EnEV 2014

The idea behind the KfW is part of their promotion program for energy efficient buildings. The better the KfW level (lower the energy consumption) the higher the amortization grant, meaning less of the loan that has to be repaid. The level of the KfW is defined by the ENEV and the energy consumption qualities of the building.

The program funds newly built buildings or apartments (or first bought buildings) houses including residential, retirement and nursing homes. The program also funds buildings that have been converted to residential buildings (rededication). Holiday homes and weekend houses are not included in the program)

A KfW building is a building as defined by the KfW with a defined minimum energy efficiency level. This is based on the EnEV, in which the criteria for modern building built according to the minimum of ENEV for new buildings is defined. A building built to ENEV or KfW must thus meet a minimum standard as defined by the EnEV. The KfW 55 (including Passive houses) and KfW 40 (including Passive houses) must all be supervised through specialised planning and checked by a qualified and registered expert/appraiser.

New Buildings are subjected to a complete package of modernisation with the aim to achieve a KfW energy efficiency house level. The KfW Energy Efficiency House comes in 3 Standards for new buildings of:

- KfW 70 Energy Efficiency House
- KfW 55 Energy Efficiency House
- KfW 40 Energy Efficiency House

KfW 100 Energy Efficiency House

This building is equivalent to a house built to the minimum ENEV requirements.

KfW 70 Energy Efficiency House

This is a building in which the annual primary energy requirement (Qp) can not be more than 70% of the maximum value of the energy-saving for the reference house 100 or KfW 100 (ENEV minimum) amount (hence KfW Efficiency House 70). In addition, the transmission heat loss must be the maximum value of the Energy Saving Ordinance by at least 15 % below (not more than 85% of the maximum value).

KfW 55 Energy Efficiency House

This is a building where the annual primary energy requirement (Qp) (total energy consumption of a building) must not exceed 55% of the reference building according to the Energy Saving Ordinance 2009. The so -called HT - value (average, specific transmission heat loss) must be at least 45% below the peak value of the Energy Saving Ordinance.

KfW 40 Energy Efficiency House

In a KfW Efficiency House 40 primary energy demand must be at least less than / equal to 40% of the maximum value according to Energy Saving (2009). The transmission heat losses less than / equal to 55% must be the reference value of the Energy Saving Ordinance (2009).

In existing buildings, when modernising, the buildings are subjected to a complete package of modernisation with the aim to achieve a KfW energy efficiency house level or a combination of measures to help increase energy efficiency.

Similar to new buildings energy targets are fixed for existing buildings under the following categories:

- EH 115 Energy Efficiency House – total energy consumption of a building must not exceed 115% of the reference building according to the minimum EnEV requirements
- EH 100 Energy Efficiency House – total energy consumption of a building must equivalent to a house built to the minimum EnEV requirements
- EH 85 Energy Efficiency House – total energy consumption of a building must not exceed 85% of the reference building according to the minimum EnEV requirements
- EH 70 Energy Efficiency House – total energy consumption of a building must not exceed 70% of the reference building according to the minimum EnEV requirements
- EH 55 Energy Efficiency House – total energy consumption of a building must not exceed 55% of the reference building according to the minimum EnEV requirements

5.4.2.5 Passive House

5.4.2.5.1 Description

The most common and well-known archetype, with over 30000 buildings in Europe, of an ultra-low (near zero) energy building is the Passive House. Started in Germany in 1990, with the first pilot project Kranichstein Passive House by the Passive House Institute in Darmstadt, the Passive House Standard is one of the few constants throughout Europe as it is a standard defined by a central entity.

5.4.2.5.2 Passive House

The definition for a Passive House is: "A Passive House are buildings in which a comfortable temperature in winter as well as in summer can be achieved with only a minimal energy consumption." (Feist 2013). The basic idea of a Passive House is to provide high-energy efficiency/ performance with the use of good insulation, airtight construction and mechanical ventilation to achieve high indoor thermal comfort condition (ISO 7730) at low building cost (Janson 2008). The Passive House concept is however open to the choice of building materials including insulation, heating and cooling systems as well as the energy source.

Passive Houses for Germany (a cool temperate climate) are defined by an annual demand for space heating to 15 kWh/(m^2a) and a limit for total primary energy of 120kWh/m^2a as well as an air-tightness of at least n50 (50Pa) ≤ 0.6 h as tested by a blower door. With the next step in the building standard for Germany as well of many European countries all new buildings must be nearly passive house standard or better.

The calculation of a Passive House, that is to be registered, is through the Passive House Planning Package (PHPP). This is then certified through the Passive House Institute. The calculation of the building includes the space heat demand as well as the total primary energy consumption including household appliances and work equipment.

Table 5 shows parameters for residential passive houses new and existing in Germany.

Table 5 Parameters for Residential Passive Houses New and Existing in Germany

Building Envelope Insulation	U ≤ 0.15 W/(m^2K)
Windows	Ug ≤ 0.8 W/(m^2K), g-value (SHGC glass) > 50%
Mechanical Ventilation:	Ventilation with ≥ 75% heat recovery over total system ($\eta_{HR,eff}$ ≥ 75 %)
Pressurization Test Result:	max. 0.6 ACH @ 50 Pa (pressurizing and depressurizing)
Thermal Bridging	(near to) thermal bridge free
Heating load	max. 10 W/m^2
Space heating demand	max. 15 kWh/(m^2a)
Space cooling demand	max. 15 kWh/(m^2a)
Total primary energy consumption	max. 120 kWh/(m^2a)
Excess temperature frequency	< 10 5
Electricity consumption	Max. 0.45 Wh/m^3

5.4.2.5.3 EnerPHit (Certification Criteria for Energy Retrofits with Passive House Components)

If an existing building is renovated and meets the Passive House criteria then this building can be certified as a Certified Passive House (see above for more details). However it is often difficult to reach certified Passive House criteria in existing buildings for numerous reasons such as air tightness, thermal bridges or buildings that need to maintain certain criteria as they are a listed building (historical building). For such buildings Passive House has also developed a system called EnerPhit and EnerPHit[+1]. The EnerPHit+1 designation is applied if more than 25% of the opaque exterior wall has interior insulation.

If in existing buildings Passive House components and the appropriate insulation is applied and the building does not reach all the parameters for the Passive House certification than a building can still apply for the EnerPHit certification. This can take place either through the fulfilling of the heating demand or through the requirements for individual building components. For the building components they must either be Passive house certified or evidence must be provided that component criteria as laid out by Passive House is met. As with the Passive House certification the calculation of a Passive House, that is to be registered, is through the Passive House Planning Package (PHPP). This is then certified through the Passive House Institute. The calculation of the building includes the space heat demand as well as the total primary energy consumption including house-hold appliances and work equipment.

The EnerPHit certification can be obtained if the following criteria are obtained (Table 6):

Table 6 EnerPHit certification criteria

Heating Demand	Q_h ≤ 25 kWh/(m^{2}a) (as calculated by Passive House Planning Package (PHPP))
Exterior insulation	ft*[1] . U ≤ 0.15 W/(m²K)
Interior Insulation	ft *[1]. U ≤ 0.35 W/(m²K)
Thermal bridges	Should be avoided and under Ψext ≤ +0.01 W/(mK) where economically possible
Windows	UW,installed ≤ 0.85 W/(m^{2}K), g . 1.6 W/(mÇK) ≥ Ug
External doors	ft . UD,installed ≤ 0.80 W/(m^{2}K)
Mechanical Ventilation	Ventilation with ≥ 75% heat recovery over total system ($\eta_{HR,eff}$ ≥ 75 %)

Notes:

*1 where ft temperature factor:

in contact with the outdoor air: ft = 1

in contact with the ground: "ground reduction factor " from the PHPP "Ground" Sheet

5.4.2.5.4 Example of Passive House New Buildings

Lodenareal Passive House

Table 7 lists the general Information of Lodenareal Passive House

Table 7 General Information of passive house new building example (Lodenareal Passive House)

Building Name:	Lodenreal
Climate Zone:	Temperate
Project State:	New
Building Sector:	Residential
Building Type:	Multi-Family
Mode:	Closed
Energy Efficiency Level:	Ultra-Low-Energy Building (Passive House)
Year Built:	2009
Location:	Innsbruck
Municipality:	Innsbruck
State:	Tyrol
Country:	Austria
Geo. Latitude:	42.28 N
Geo. Longitude:	11.42 E
TFA:	26000 m^2
Treated Building Volume:	167000 m^2
Number of Dwellings:	482

Description

The Londenareal housing estate was built by the Neue Heimat Tyrol in 2009. The main aim of the developer is to minimize long term energy costs and rents for his customers, by applying modern architecture and a challenging technical management, as well as enhancing the public awareness of current energy issues and achieving a leading role in the sector of sustainable housing. It is the largest Passive House complex in Austria.

Initially, the biggest challenge was the required construction volume, which exceeded all the energy-efficient residential developments built in Europe up to that date. In order to comply with these requirements, the project was constantly surveyed and certified by the renowned Institute for Passive Construction Darmstadt under the aegis of Professor Wolfgang Feist. The development is the biggest completed construction unit in Europe that complies with the latest certified Passive House construction standards.

Energy experts and building specialist were included in the planning from the start of the design process. Weekly meetings as well as additional meetings were held, which greatly helped the "networked planning". Numerous site visits of buildings and producers of Passive House components (ventilation-, window-, insulation-manufactures etc.) were made and further education and training was carried out for all participants. Integrating all the necessary, interdisciplinary expertise into the early planning stage, allowed for the development of construction-technical systems and details, which strongly contributed to a minimization of the construction time. Through state-of the-art software and its parametric calculations, the digital planning data of all experts were synchronised in a time-efficient manner

To test all detail solutions such as windows, balconies, ventilation duct connections etc. a model apartment was built beforehand. The first blower test for the apartment reached air infiltration rates of n50 = 0.38 well below the maximum level set of n50 = 0.60. Never the less the weak points were carefully studied so as to improve these in the final construction.

Air quality control tests in the Lodenareal buildings have shown that the air quality in terms of temperature, humidity and $CO2$ is extremely good. Room temperatures under 20°C never occurred. Maximum room temperatures were never over 29° C.

With an energy consumption of 14,5 kWh / m²a (calculated by the PHPP), the utilization of groundwater heat, a wood pellet based heating system and solar collectors the building is actively contributing to climate protection.

Further objectives of this passive house project were to fulfil the specifications of the Kyoto Protocol and to implement the Tyrolean Energy Strategy 2020.

The Lodenareal Passive House Estate won the Energy Globe 2008 of the State of Tyrol.

Architectural Description:

The complex consists of four 5 storey L shaped buildings with two buildings each being placed against each other to form a quiet green courtyard. Each L-part was designed by different architect teams one by k2 , the other by din a4.

The apartments are planed so that they face either to the south or west. The building complex has 354 apartments in total. In the block planned by din a4 there are 189 energy efficient apartments, 57 one-bedroom apartments at 52.40 m2 each, 120 two-bedroom apartments at 81.30 m2 each and 12 three-bedroom apartments at 94.15 m2 each. The other 165 All apartments are built barrier free.

Each apartment unit has been assigned either a private garden, if situated on the ground floor, or balconies on both sides. Through its optimized site development concept, maximum exploitation of the available floor area was achieved. All the apartments stretch across the whole depth of the building, and are hence provided with sufficient daylight at all times

Building Envelope

The external walls are made of concrete and are heavily insulated on the outside with a 30 cm layer of expanded polystyrene (EPS) board to ensure Passive House standards for walls which is less than 0.15 W/(m2K). All the layers are joined together by using full scraping adhesive mortar and anti-cracking nets. The outer layer is made using Silicon bound render finish. Thick fire resistant rock wool insulation has been added above the lintel. The roof is a green roof and is insulated with a 30 – 36 cm sloped insulation. The parapet of the roof is insulated to prevent thermal bridging. Constructive separation of structural components such as supporting walls was used as a prevention of thermal bridges. Care was also taken that constructions such as balconies were thermally decoupled from the building. All ground floors are made up of concrete slabs insulated using 13,5 cm thick insulation between the screed and the with reinforced concrete floor, an additional 6 cm insulation is on the outside. All details were calculated and simulated before construction to remove the possibility of thermal bridges and were necessary then improved.

Triple glazed windows with insulated wood/aluminium frame have been used. All the doors that open to exteriors/unconditioned hallways are specially sealed for air tightness. A certified blower door test has been conducted to measure the air tightness of the house, to seal any potential leakages and to meet passive house standard of 0.2/h at n50 value. Variations of the solar shading were tested at an early stage of the project to ensure that optimum shading was reached.

All windows are Optiwin, Freisinger triple glazed windows in wood/aluminium construction. The windows were installed in the insulation layer. To some part the windows were fixed glazing. The U-Value of the doors was given as 1.8 W/m2K

Building Systems

The estates' heating is via district heating. The district heating station can be found between the two building complexes in the centre of the estate. 80% of the heating demand is covered by a pellets system supported by a solar system; a gas-condensing boiler covers the peak load. All exhaust fumes are conducted though 2 stainless steel chimneys on the façade to exit above the roof.

In each building module there are two substations. Each of these substations supplies one of the 4 L shaped buildings. In the sub-stations there are 6 buffer tanks with 2500 l capacity, each which are heated through the solar system as well as the district heating systems. A fully automatic temperature control, including integrated circulation pump and manifold, is located in each substation. To keep the heat loss in the buffer tanks to a minimum these were completely encased and the spaces insulated with cellulose insulation. Insulation of all piping in the basement is 1.5 times thicker than that required by norm. A two-pipe systems is used for the hot water as well as the heating distribution. First tests have shown that this is more efficient than a four-pipe system.

Special care was taken with the installation systems in the buildings. All installation systems were installed using insulated prefabricated duct systems. All the maintenance shafts are placed in common areas such as corridors or beside staircases, hence allowing for unobstructed technical maintenance. The prefab systems were covered with plasterboard and filled with cellulose insulation. In addition to the "normal" building services additional requirements for the building services, such as control consoles, ventilation etc. had to be integrated into the building.

In each apartment a so-called 2-pipe station is installed. This is a heat exchanger for heating water and a control station for the under floor heating. This has the advantage that a separate hot water line, including circulation can be omitted (from the heating centre) and thus significant Distribution and circulation losses are excluded.

The radiator system, an under floor heating system, was reduced to the critical peripheral room areas due to the low heating requirements. Only the bathrooms have under floor heating throughout. Room temperatures can be controlled by means of a room thermostat.

The solar share of the heating lay at 26% in the first year and 35% in the second year. The share of the gas (peak) system was nearly constant at 13.6 % in the first year and 14.2 % in the second year. The pellet boiler covered the rest share with 60.4% in the first year and 50.7 % in the second year.

The heat requirement was given at 14.5 kWh/m2a, The heat load at 9.1 W/m2. The total annual final energy demand in the first year lay at 1.733 MWh and 1.663 MWh in the second year.

The roof of the building complex has a 1050 m2 large solar hot water system for hot water and heating system assistance. The area of the solar hot water system corresponds to 3 m2 per apartment. The solar energy collected is stored in the 6 buffer tanks located in the sub-stations. Through the use of solar Hot Water systems the energy needed to heat the water could be reduced by 50%. The rest energy is provided through CO2 neutral biogene fuels in this case wood pellets. Through an innovative two pipe system 20% of the energy can be saved against a typical system.

The ventilation was through a semi-central ventilation system with heat recovery. In each stair well, in the basement, a comfort ventilation system was installed to guarantee the necessary hygienic fresh air as required. In total 18 of such systems were installed. Pre-heating in winter and pre-cooling of the air in summer of the air was through ground water from two ground water wells. The air-intakes are in the courtyards in a height of 3 m. The heat recovery is through a counter flow heat exchanger. In summer incoming air flows through an automatic bypass. The air distribution in the cellar is through metal ducts and is insulated with 10 cm insulation. All incoming air is filtered by a class F-7 filter thus ensuring high air quality levels.

Air enters the apartments through vents in the bedroom and living rooms; air exhaust is through the bathroom and kitchen. The sound level at the supply air is through the use of special silencers at about 22 dB. The kitchen vent has a removable fat filter. The room ventilation is controlled with an average air exchange rate of 0.34 (for the three and four room apartments) - 0.4 /h (for the two room apartments). If needed this can be increase by the inhabitants by 30%. This is automatically reduced after an hour to save energy. The air volume is between 1200 m3/h and 1900 m3/h. The energy consumption is 0.45 W/(m3/h).

Overall Performance

The project has set the stringent target of the German Passive House standard in contrast to conventional domestic standards for residential buildings in Austria. The measured final energy heated demand in the first year lay at 13,59 kWh/m²TFA in the second year at 14,55 kWh/m² TFA. This is below that of the Passive House Standard with 15 kWh/m²TFA. The building thus has a 80% lower energy consumption than comparable new buildings.

The heating demand according to the Austrian Energy Pass amounts to 7 kWh / m² usable area and year, which classifies the project "Lodenareal" in the category A++.

The household energy consumption was 32,55 kWh/(m²TFA*a) in the first year and 34,10 kWh/(m²TFA*a) in the second year. In comparison the energy (electrical) consumption of the ventilation system was 4,08 kWh/(m²TFA*a). The share on the total electrical energy consumption was 10%

The total primary energy consumption of the estate including household electrical energy consumption was 119,1 kWh/(m²TFA*a) in the first year and 123,3 kWh/(m²TFA*a) in the second year. Only 10% of the total primary energy consumption is for heating and hot water the other 90% is for electrical consumption alone.

Cost and cost effectiveness

The overall costs amounted to ca. 52 million € which is approximately 11% premium over the cost of constructing conventional efficient buildings. However 7 % of the extra costs were covered by subsidies and the remaining 4% are to be covered by the inherent energy savings offering a bargain for the extra premium.

Special Features

An approx. 8.200 m2 wide Park was designed as well as a boathouse at the north-west edge of the area. The course of the Sill to the river Inn will be redirected from east to west. A new bridge above the Sill offers an extra sidewalk and cycle way.

5.4.2.5.5 Example of Passive House Existing

Weingarten Bugginger Straße 50 Passive House

Table 8 lists the general Information of Weingarten Bugginger Straße 50 Passive House

Table 8 General Information of existing building passive house (Weingarten Bugginger Straße 50 Passive House

Building Name:	Bugginger Straße 50
Climate Zone:	Temperate
Project State:	Refurbished
Building Sector:	Residential
Building Type:	High Rise Building
Mode:	Closed
Energy Efficiency Level:	Ultra-Low-Energy Building (Passive House)

Year Refurbished:	2010
Location:	Freiburg in Breisgau
Municipality:	Freiburg in Breisgau
State:	Baden-Württemburg
Country:	Germany
Geo. Latitude:	47.99 N
Geo. Longitude:	7.81 E
TFA:	8473 m^2
Treated Building Volume:	248 m^2
Number of Dwellings:	140
Cost/m^2:	1680 €/m^2

Description

The building was originally built in 1968 a part of the housing estate Weingarten West in Freiburg, Germany. Before the refurbishment the building contained 90 apartments with some commercial use in the ground floor and had a total living floor area of 7200 m^2. Refurbishment of the building was started in 2009 and finished in 2010.

Of the original 90 units 45 were 2 room apartments of 65 m^2 each and 45 were 3 room apartments of 86 m^2 each. Energy consumption for the entire building was 68 kWh/m^2a. In the 1980s they building under went a superficial refurbishment of the ground floor and cement surfaces.

The current refurbishment came about in part as the heating and building services as a whole were in dire need of replacement. In addition to this the apartments were seen as being overly large especially in light of the changing demographics.

The renovation of the high rise required a complete gutting of the building and restructuring of the floor plans. Further measures included the renewal of the thermal envelope, sound insulation, fire protection, enclosure of existing balconies and supplement of new balconies.

Measures included:

- Floor plan restructuring
- Insulation of the façade, roof and cellar
- Improvement of the building air-tightness
- Removal of thermal bridges
- Replacement of the heating system
- Replacement of the old bathrooms
- Installation of ventilation systems with heat recovery
- Placement of the ventilation system on the roof

- Refurbishment of all electrical systems
- New entrance
- Photovoltaic on the roof

After the refurbishment and restructuring of the floor plans there were 139 apartments with an example refurbished floor having six 2 room apartments at 50 m^2 and three 3 room apartments at 70 m^2. The total living area was increased by 935 m^2 to 7750 m^2 in total. The total treated floor area is 8473 m^2. In the process of the restructuring the bath and kitchen were placed in the building interior opening the building façade.

Building Envelope

The external wall construction varies in with 3 different types. All walls are heavily insulated to ensure Passive House standards for walls which is less than 0.15 W/(m^2K). All external wall construction are made of concrete, two of reinforced concrete and one of aerated concrete and are heavily insulated on the outside with a thermal insulation composite system. Both the floor as well as the upper ceiling are also heavily insulated. Triple glazing was used throughout the project. Thermal bridges are avoided by using special details at all critical junctions. A certified blower door test has been conducted to measure the air tightness, with an air tightness of 0.2/h at n50 value, of the house, to seal any potential leakages and to meet passive house standard.

The windows used in the refurbishment are Rehau, Geneo triple glazing windows with a PVC Frame. The windows are in part fixed glazing.

Building Systems

The heating capacity of the refurbished building is also through district heating. There is a 3000 l buffer storage to reduce peak loads. The supply temperature of the heating system is 50°C. The pipes are however to some extent in un-conditioned rooms but have a 6 cm insulation with heat conductivity of 0.035 W/mK. The radiators can be controlled individually.

The building has 2 Universal II central ventilation units, from the firm Nova, with Heat Recovery with a 70 % efficient heat recovery capability. The units each have a maximum volume of 5000 m^3/h. The apartments can also be ventilated through the windows.

The hot water system is also supplied through the district heating system. The hot water pipes are a pipe in pipe system with warm water circulation.

Overall Performance

The heating load was 68 kWh/m^2a before the refurbishment. Energy consumption after the refurbishment was reduced to 15 kWh/m^2a a savings of 78%

Cost and cost effectiveness

Efficient envelope and systems for Passive House cost a premium of 30 % compared to conventional envelope and systems. The total costs for the building lie at 1680/m^2

The refurbishment bought with it a rent increase of 1.85 €/m^2 through the refurbishment the costs for heating have however been drastically reduced. The whole project was aided through subsidies from the Federal Government, the State as well as the town at 35% of the total costs.

5.4.2.6 (nearly) Zero Energy House

Zero energy buildings

A "nearly zero energy building" and/or "zero energy building" is a building that has a very high-energy performance with the low energy needs being covered by renewable sources whether onsite or nearby. At present there numerous definitions of zero energy buildings among them zero net energy buildings, zero energy stand-alone building and zero energy-zero carbon emission buildings. It should be noted that in zero energy buildings that appliances also play a major role in the energy consumption balance.

Zero net energy buildings

Zero net energy buildings can be autonomous from the energy grid supply, in practice however at some periods power gained from the grid and in other periods power is returned to grid (renewable energy sources are often seasonal).

Zero carbon buildings

Zero carbon buildings do not use energy that entails CO2 emissions, or balance, over a year, off-site fossil fuel use by producing enough CO2-free energy on site.

Zero stand-alone buildings

Zero stand-alone buildings do not require connection to the grid other than as a back-up. Stand-alone buildings have the capacity to store energy for night-time or wintertime use.

Plus energy Buildings

Plus energy houses are similar in concept to a zero energy house with the exception that it produces more energy, from renewable energy sources, than it consumes. This is achieved using combination of small power generators and low-energy building techniques such as passive solar building design, insulation and careful site selection and placement.

The main criteria for the Plus-Energy standard are:

- a negative annual primary energy requirement ($\Delta Qp < 0$ kWh/m^{2}a)
- an annual final energy consumption (including lighting and appliances) ($\Delta Qp < 0$ kWh/m^{2}a)

5.4.2.7 Active House

Active house is a concept that is based on "Buildings that give more than they take". Environment and comfort are considered equally important to energy in active house concept. Thus, this can be considered broadly as a green building rating systems than an energy only assessment system. The primary and building annual energy consumption should be as follows (Table 9) and the use of renewables is strictly mandatory.

Table 9 annual energy consumption and the use of renewables in active house

Annual energy demand	Annual primary energy performance	Origin of energy supply	Score'
40 kWh/m^2	0 kWh/m^2 for the building	100% or more of the energy used in the building is produced on the plot or in a nearby system	****
60 kWh/m^2	0-15 kWh/m^2 for the building	>75% or more of the energy used in the building is produced on the plot or in a nearby system	***
80 kWh/m^2	15-30 kWh/m^2 for the building	>50% or more of the energy used in the building is produced on the plot or in a nearby system	**
120 kWh/m^2	30 kWh/m^2 for the building	>25% or more of the energy used in the building is produced on the plot or in a nearby system	*

'* is only indicative of comparative performance and not the rating criteria issued by the active house standard.

5.4.3 Cost and cost effectiveness

Rising energy costs is one of the reasons that energy efficiency is becoming more and more imperative. Prices of energy efficient technologies fall as market penetration becomes larger and the costs for production become less and less (Figure 12).

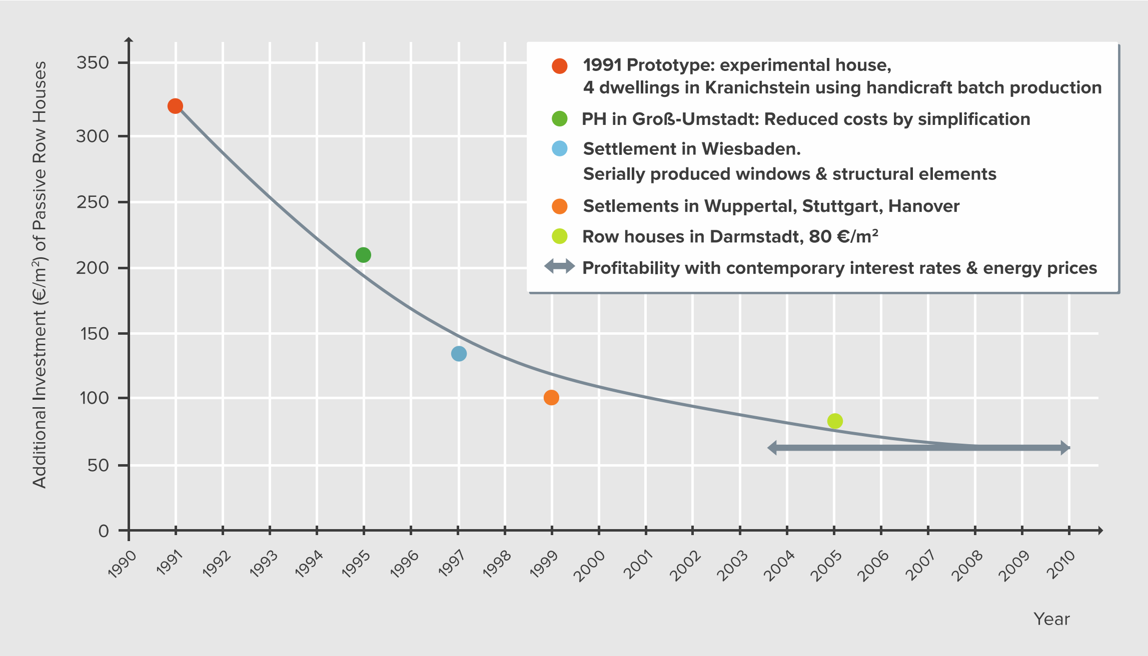


Figure 12 Learning curve of energy efficient buildings

Learning curve showing the progressive decrease (the increased energy performance of new buildings being taken into account) in the incremental cost of meeting the passive house standard for the central unit of row houses in Germany. These compare to costs for conventional buildings of ca. €1250 to 1750 per m2. Energy prices and interest rates being set for 2005. (Source:Wuppertal Institute (2012), adapted from Feist (2005))

Payback time in Europe for renovations is around 10 years (in many cases less than this). Chinese decision makers expect a 3.2 year payback on building efficiency measures. Average construction costs in China lie between 600-800 €/m^2 (in comparison construction costs in Germany lie between 800-1600 €/m^2. As energy cost is inexpensive in China compared to Germany, the payback time is usually higher than what is expected.

Energy efficient buildings are more costly than comparable building in the construction due to higher quality workmanship, more expensive planning, higher material costs among others. This gives the impression that energy efficient buildings are in general expensive. Based on a Life-Cycle Cost Analysis (LCCA), low energy buildings in many cases are more economically beneficial compared to conventional buildings, although the initial investments are higher. Due to high performance building components, such as triple glazed windows or heat recovery ventilation (HRV), low energy buildings such as Passive Houses built are 10-15% more expensive than a conventional building (Research Centre Jülich 2011). Additional capital costs differ from 3 to 10% in different European countries (in residential buildings) such as France, Germany, Italy, Spain and UK with total useful energy savings between 25-65% compared to conventional buildings[3] (Table 10). It is however difficult to transfer the costs from one country to another, as energy prices, labour costs, experiences and expertise differ.

[3] http://www.passive-on.org/

In general, the additional investment in Europe is in the range of € 100/m^2 with returns of less than 20 years. Furthermore costs are expected to further decrease in the future due to technological development. Low energy buildings offer considerable savings in energy bills over their lifetime compared to standard new constructions as they only use 15-25% of the energy required to run a conventional one (European Commission 2009). From a study of single residential buildings in Germany, the additional investment can decrease with time (from 8% in 2010 to less than 7% in 2011)[4]. The discounted payback time for Passive Houses varies from 4 to 19 years[5]. The cost effectiveness depends on the energy prices growth rates.

Table 10 Comparison of cost of a passive house against a standard house

		France	Germany	Italy	Spain
Standard House	€/m^2	1,100	1,400	1,200	720
Passive House	€/m^2	1,203	1,494	1,260	744,1
Extra Costs	€/m^2	103	94	60	24,1
Extra Costs	%	9	6.71	5	3.35
Extra Capital Costs	€	103	94	60	24.1
Extra Capital Costs	%	9	6,71	5	3.35
Energy Consumption Standard	kWh/m^2/a	70	90	101	80.5
Energy Consumption Passive	kWh/m^2/a	15	15	15	15
Total Energy Savings	kWh/m^2/a	55	75	86	65.5
Total Energy Savings	%	45	50	65.4	57.3
Extra Costs per saved KWH/m^2/a		1.87	1.25	0.7	0.37
LCC 10 Years Standard	€	143,731	184,716	193,817	101,828
LCC 10 Years Passive	€	152,621	190,104	190.437	95.676
LCC 20 Years Standard	€	160.343	204.942	221.148	117.928
LCC 20 Years Passive	€	160.552	200.579	198.458	103.647
Cost-Benefit Ratio	10 Years	-0.72	-0.48	0.39	2.13
Cost-Benefit Ratio	20 Years	0.02	0.39	2.63	4.94
Discounted Payback Period	Years	19.5	19	8	4

Source: http://www.passive-on.org/

In Germany, at present the Passive House standard presents itself as economically viable and zero energy buildings at the edge of this range. Studies have shown that Passive House buildings in Germany, Austria or Sweden are no longer significantly higher in costs than

[4] http://passipedia.org/

[5] http://www.passive-on.org/

normal buildings. This is due to the increasing competition in the supply of the specifically designed and standardised Passive House building products as well as technological advances. The Passive House Institute gives a range of extra upfront costs of 0 – 14 % for a Passive House building against a comparable building built to standard (see figure below). With economic aid from the side of the government these boundaries are pushed much further. Simulations have shown that zero energy buildings principles are feasible and reachable with already existing technologies (IEA 2011). It should be noted that with the higher efficiency in the buildings standard heating or cooling systems are no longer needed thus offsetting the extra costs for higher insulation. Care must be taken when transferring these potential savings to China as the local factors and market conditions must be taken into account separately. State should invest in building refurbishment and Incentives and policy are needed to guide the investments.

6 Energy Efficient Techniques and Technologies

This chapter presents various techniques and technologies to achieve energy efficiency, starting from holistic planning, to passive design (i.e. wall and roof insulation, windows, increasing air tightness, closing thermal bridging, surface coating, shading, workmanship and labour), to active systems (space heating systems, condensing heat boiler, space cooling, energy recovery ventilation systems, solar thermal systems and hot water supply, lighting, building energy management systems).

This chapter is largely based on the content of bigEE (www.bigee.net).

6.1 Holistic planning

Holistic planning presents itself as an easy approach to reaching energy efficient buildings.

There is a need to develop low energy, zero energy and plus energy buildings using a tight knitted holistic approach taking various aspects of the building design in account. Buildings are planned to maximise passive (solar/internal) energy gains and factors such as the average surface to volume ratio for low energy buildings is around 0.6. Building energy consumption simulation/calculation has become an integral part in the building design in Europe and is required by law. However, in order to achieve this building materials, technologies and all other components must of a high standard in terms of energy efficiency.

6.2 Passive Design and Active System

In Germany, the greatest potential for energy saving in buildings can be made through the following techniques and technologies (BMWi 2014):

- Oil and gas based heating especially by using condensing boiler technology
- Improvement of heat distribution by using efficient pumps
- Improvement of heat emissions
- Improvement of controls
- Ventilation technology for example through heat recovery ventilation systems
- Use of efficient air-conditioning technology
- Combined heat and power generation
- Heat insulation
- Lighting technology

In order to meet the energy demand in the building sector, it is strongly recommended that the fossil fuel energy sources be replaced by renewable energy sources such as:

- Solar thermal technology for domestic hot water
- Solar thermal technology for heating system support
- Photovoltaic technology for electricity production
- Innovative wood-burning technologies
- Heat pumps

- Geothermal heating and cooling

These techniques and technologies includes both passive design and active system.

6.2.1 Passive Design

The simplest way in reducing energy consumption in buildings is through good passive design. Energy efficient buildings rely on passive (solar) design techniques that take into account the climate of a region in order to maintain comfort conditions in the space. Passive design techniques, if implemented correctly, eliminates or minimize the need for mechanical and electrical systems to achieve appreciable indoor environmental quality. In Germany, buildings with good passive design, as often seen in well-planned Passive Houses, maintains quite comfortable indoor conditions for the greater part of the year. The indoor room climate in such buildings is near self-regulating or optimised through user intervention, if required.

The passive design criteria for Germany is achieved through:

- Compact design of buildings to reduce transmission losses
- Reducing Thermal Bridges to a minimum
- Optimising the surface area to volume ratio

Specific guidelines for winter:

- Reducing thermal losses through the appropriate insulation
- Reduction of ventilation losses through an air tight envelope
- Maximisation of solar heat gains through windows and skylights
- Make good use of internal heat gains

Specific guidelines for summer:

- Appropriate shading of window areas to reduce thermal heat gains
- Using natural and cross ventilation for space cooling
- Use of night ventilation to cool buildings and dissipate heat loads

6.2.1.1 Wall and roof insulation

In Europe, there is a significant north – south divide in terms of insulation. The average U-Value for the building envelope excluding window and doors was between 0.29 W/m^2K and 0.22 W/m^2K with the most stringent requirements in code in the Scandinavian countries. A good practice building such as a Passive House requires Insulation with a very low thermal conductivity of $\lambda < 0.035$ W/(mK) as well as a U-Value in between 0.12 W/m^2K to 0.15 W/m^2K. In Europe most new buildings have a U-Value of around 0.25 W/m^2K.

In Germany the thickness of the insulation has increased over the years owing to reduction in costs and implementation of new and improved standards. The implementation of the new standards can be seen in the jumps of the insulation thickness for example in 2007 and 2009.

The maximum U-Value for walls of residential buildings and heated zones of non-residential buildings with indoor temperatures should not less than 19 °C is ≤ 0.24 W/m²K. In Passive Houses the required U-Value for insulation lies at ≤ 0.15 W/m²K.

Table 11 shows a comparison of U-Value requirements for roof and wall as prescribed by various standards.

Table 11 A comparison of U-Value requirements for roof and wall in different standards

U-Value	EnEV 2014	Efficient House 70	Efficient House 55	Passive House
Roof	≤ 0.20	≤ 0.18	≤ 0.15	≤ 0.12
Wall	≤ 0.28	≤ 0.24	≤ 0.21	≤ 0.15

With the energy efficiency goals and the emphasis of 'passive design first', insulation represents a major market in Germany. Expanded polystyrene (EPS) is the most commonly used insulation material in Germany.

6.2.1.2 Windows

Overall Heat Transmission coefficient (U-Value) gives a measure of heat transfer through glazing systems. In recent years the performance of window design has developed from single glazing with a U-value as high as 5.6 W/m²K (indicating very low efficiency), to triple or even quadruple glazing with special treatment, achieving U-values as low as 0.4 W/m²K (indicating a very high efficiency). Single glazed windows have all but disappeared from European countries with double-glazing effectively being the standard. The German building standard has defined a minimum U-Value for windows as ≤ 1.3 W/m²K. However, triple glazing is also now moving from being a premium product into the mainstream, with special glazing such as vacuum and quadruple glazing now being considered premium. It has been shown that triple glazing in Germany has proven to be economically viable. Effective window U-Value for a low energy or better building in Germany should be ≤ 0.8 W/(m²K). The values for Passive House windows are set at ≤ 0.8 W/(m²K). One of the benefits of highly insulated and air tight windows is that of the even surface temperatures and that there is no need for heating elements near/under windows to reduce draft due to cold air.

Table 12 shows a comparison of U-Value requirements for windows as prescribed by various standards.

Table 12 U-Value requirements for windows in different standards

U-Value	EnEV 2014	Efficient House 70	Efficient House 55	Passive House
Window	≤ 1.1	≤ 0.90	≤ 0.90	≤ 0.80

Besides U-Value another important characteristic of glazing that determines its effectiveness is a factor called "shading coefficient (SC)". Shading coefficient is the value of the amount of direct solar radiation passing through a particular glazing divided by the direct solar radiation passing through a clear float glass. SC for a glazing is between 0 to 1. However, SC is giving way to a new factor that is referred to as "Solar Heat Gain Coefficient (SHGC)". SHGC, unlike SC, takes into account the amount of solar radiation passing though an entire window system including its frame. SHGC is roughly given as 0.87 multiplied by SC. Lower SHGC values can be obtained in typical double glazing units by applying tint or low emission coatings to the outer glass. However, SHGC requirements have also to be designed in accordance to the requirement of daylight levels, as special tints can minimize the daylight entering through windows.

6.2.1.3 Air tightness

As buildings become more and more energy efficient uncontrolled ventilation losses become one of the major sources of energy losses in buildings. Care should be taken to plan junctions and joinery in buildings with care. Details such as doors and windows where materials change and penetration points occur should be sealed carefully. Airtightness also helps in reducing damage to the building including structural damage, for example, by reducing points where condensation occurs. The air tightness of a building is measured using a blower door test (pressure differential test).

Blower door test are recommend by many European countries for new buildings and are a must for all low energy buildings. A blower door test is usually carried out with a pressure difference between the interior and exterior of 50 Pascal. A performance check with infrared camera is also usually made with a blower door test to check the building quality and identify and leaks. Passive House buildings have for example an air-tightness of at least n50 (50Pa) ≤ 0.6 h as tested by a blower door. Air tight buildings have been shown to save 10 % to 40 % of energy used (depending on climate and airtightness level) and represents a low cost method of reaching energy efficiency.

6.2.1.4 Thermal bridging

With the improvement in the Insulation levels in new buildings in Germany, minimizing thermal bridging has become very important. Careful design, planning and implementation should be made so that insulation levels are the same throughout the building. Points of thermal bridging such as concrete slabs, façade anchors or frames should be made free of thermal bridges or reduced to a minimum. Special products, such Isokorb for cantilever structural components such as balconies and shades, help to reduce thermal bridges.

In prevailing standards it is often required that calculations be made to evaluate potential heat loses because of thermal bridges. When calculating a building according to the building standard EnEV if no detailing is made for thermal bridges these are added to the calculations with an addition to the total U-Value with a value of ΔU_{wb} = 0,1 W/(m^{2}K). If however, care is taken and standard details are used such as those covered by the DIN V 4108-6: 2003-06 then these can be reduced in the calculations to 0,05 W/(m^2K). These can of course for EnEV calculations, be calculated exactly as defined in DIN V 4108-6: 2003-06 using the appropriate technologies and simulation software.

Many companies, publishers as well as producers of building materials and insulation have created catalogues with predefined construction details, which conform to Building Standards or independent standards such as Passive House, to aid architects and planners in the minimisation of thermal bridges.

Passive Houses must be built nearly thermal bridge free with values for thermal bridges kept to < 0.01 W/(mK). Passive House design construction details are readily available which if used eliminates the need to explicitly calculate heat loss through thermal bridges. Proof must however be shown that the construction has taken place in accordance with the prescribed details. Passive House construction details that are not pre-approved by Passive House have to include thermal bridge calculations which are then assessed by the Passive House Institute.

6.2.1.5 Surface coatings

One obvious and very low cost way to reduce cooling requirements is to use light-coloured rather than dark-coloured roofing materials. It is a well-known fact that light colours reflect solar radiation and dark colours absorb it. Thus much of the heat is reflected before it is to the interior. The term albedo is used to describe the reflection property of a material. High-albedo surfaces, i.e. light-coloured surfaces, will tend to be cooler than low-albedo or dark surfaces. The difference in temperature between a white roof and black roof in a desert area can be of about 40 °C. Cooler roofs might also last longer due to reduced thermal stresses. White glossy surfaces can reduce the energy consumption for cooling by up to 16-23 % in hot climates. Surface coatings have been proven to be low cost and easy approach to low energy buildings. Coatings with high solar reflectance reflect heat from the surfaces of buildings such as roofs and walls. Studies haven shown that savings of 10-16 % can be achieved in terms of cooling energy in southern Europe.

6.2.1.6 Shading

Provision of shading in buildings and the choice of colour for its surfaces is one of the initial priorities that have to be considered in the early stages of the design. Blocking/allowing the sun (and thus reducing/increasing the solar heat gain) before it reaches the envelope and reflecting large parts of that solar energy that cannot be blocked both have a considerable effect on the thermal performance of a building, its energy requirements and the thermal comfort of its occupants. Shading devices like awnings and louvers can reduce solar heat gain by 65% on equator facing facades and up to 80% on East and West facades (Harvey 2006). A shaded window transmits approximately depending on latitude longitude and orientation only a third as much heat compared to a window without shading.

Shading elements can be classified into purpose-built devices (fixed and adjustable) and non-purpose built shading elements such as trees and plants, as well as aspects of site and location and shading from other buildings. Orientation of the openings, combined with their size and tilt can modulate the solar gains passing through them. This must be taken into account when designing shading devices. Shading elements can also be architectural features of the building itself such as balconies, vestibules, integrated façade design or planters etc. Purpose-built shading devices are either fixed or adjustable. These can be further divided into

- Solar blocking devices (such as blinds)
- Solar and light blocking devices (such as shutters)
- Solar blocking and light enhancing systems (such as light shelves)

Fixed elements are often preferred because of their simplicity, low maintenance cost and sometimes low construction cost.

6.2.1.7 Workmanship and labour

Due to the high quality and low thermal stress on the building parts the lifetime of the building materials and technologies is also considerably longer. High quality workmanship for low energy buildings such as Passive Houses is however also not always easily available and requires extra training resulting in extra time consumption (Boqvist et. al 2010). Thus, higher market penetration rates of low energy buildings are mutually interlinked with increased demand for a competent workforce. Investing in new buildings as well as retrofitting can have a positive effect on the job market. In France for example, it was estimated that the work required to implement criteria set by the national Grenelle de l'Environment could create 220,000 jobs just in one year (CECODHAS, 2009). In German the KfW estimates that ca. 350,000 jobs could be created and retained within the building sector with energy efficient new buildings and retrofitting.

6.2.2 Active Systems

6.2.2.1 Space heating systems

As technologies and buildings become more efficient in Germany, inefficient technologies such as non-condensing boilers have all but disappeared in buildings. Since 1998 standard boilers in Germany are no longer permitted. Low temperature boilers are still in use but thy are also disappearing from the market. Fossil fuel based technologies are not being consistent with the ambition of the proposed nearly zero energy building principles. In Germany as well as in other European countries fossil fuel based technologies although still present, in high efficient variations are on the decline. With buildings minimising the need for heating through excellent passive measures such as insulation, traditional conventional systems have become too large and inefficient replaced by technologies such as heat recovery systems and efficient heat pumps.

6.2.2.2 Condensing Heat Boiler

Condensing boilers are the latest generation of boilers being used in Germany. The condensing boiler is in principle a low temperature boiler, in which an additional heat exchanger is connected in the exhaust stream. This second heat exchanger cools the gas to below the condensation point (natural gas: 56 °C / gas oil: 47 °C). Thus, in addition, the (so-called latent) heat that is released in the condensation of water vapour, can be used. The relative degree of efficiency (relating to the calorific value) can be raised in this way to about 100% for natural gas and 95% for heating oil. The gas condensing boilers are now considered to be best available technology (BAT). They can usually also be realized in existing buildings through the use of tight and acid-resistant chimney (such as plastic pipe use). Condensing boilers are extremely cost-effective with a payback time of just a few years. In terms of carbon emission savings this represents a savings of around 35% when compared to standard boilers and over 50 % when combined with solar power for heating and hot water. On the heat distribution side most condensing boilers in Germany are connected to two pipe radiator system.

An oil condensing system in Germany costs on average ca. 8,000 €. With heat prices at present of around 60 cents per litre and a consumption for a single – two-family house of around 4,500 litres (for heating and hot water) approximately 1,350 € can be saved annually thus guarantying a payback time of approximately 6 years (BMWi 2014)

Pellet Boiler

Alternatives for fossil fuel boiler technologies such as pellet boilers are quite common in Germany as well in the Scandinavian countries and Austria. In Austria pellet boilers represent 35% of the market in new buildings. Pellet boilers are often used in refurbishment projects where conventional fossil fuel based technologies are not wanted and technologies such as heat pumps are not effective. Pellet boilers although cost effective on their own are often subsidised to improve the move to non fossil fuel technologies. Carbon emissions from pellet boilers are high when one looks at the direct emissions but when it is taken into account that the energy source is from a renewable energy source this goes almost to zero with some emissions for processing, production and transport of the pellets.

Wood pellets are dried to a maximum of 12% residual moisture, and normalized as wood dowel shaped pellets from untreated wood waste. They are usually produced from sawdust and wood shavings and shaping of the wood processing industry. The pellets have a diameter of 4 to 10 mm and a length of 20 to 50 mm. To ensure quality, they should comply with harmonised standards, e.g. the European norm DIN EN 14961-2, DINplus, ENplus or similar. One advantage of the pellets is their high storage density and good transport logistics: Their energy content is 5 kWh/kg (≈ ½ litres of oil equivalent). Referred to the volume its energy density is about four times as large as the wood chips.

Heat Pump Systems

A heat pump is a device that transfers heat energy from a heat source to a heat sink against a temperature gradient. Typical heat pumps associated with GSHP are "water-to-air" systems. Heat pump operates through a DX vapour compression cycle similar to that of a room AC except that it is a reversible unit capable of reversing the cycle across the loop and thus providing both cooling and heating in different seasons using the same machine. The energy saving aspect in GSHP is that the condenser is replaced by the Earth heat exchange loop instead of the condenser exchanging the heat with the ambient air. Since the Earth heat exchange loop consists of water at a more moderate temperature than the ambient air the load on the compressor is significantly reduced thus operating the system much more efficiently than otherwise. With the move to low energy buildings in Europe the need for conventional heating systems is declining. With low heating requirements heat pump systems are extremely effective. However, care must be taken that such systems are used in highly insulated buildings. A good combination is the integration of the heat pump system with energy recovery ventilation and earth ventilation systems. Heat pumps at present in Europe have a COP of approximately 3.

Compared to air source heat pump, ground (or water) source heat pump operate more efficiently. Ground Source Heat Pump (GSHP) is potential source of tapping freely available geothermal energy for the purpose of space heating, cooling and domestic hot water. According to a 2009 report by the U.S. Department of Energy of the 15,400 MWt of estimated global installed base of GSHPs, about 56 % of this 'capacity' is installed in the U.S., corresponding to about 65 % of the GSHP 'unit' installations. Europe follows, with about 39 % of the installed capacity, and Asia has about 5%. In Europe, Sweden is the dominant player in the GSHP market, with almost 2,500 MWt installed— more than double of any other European country. Out of which, approximately 80% of GSHP installations found application in residential sector while the other 20% by small commercial sector (Goetzler et al. 2009). Compared to typical efficiency Air Source Heat Pumps (ASHP), GSHP saves approximately 25% - 50% of heating and cooling energy with a payback of 5-25 years (Navigant Consulting, Inc., 2009).

Combined heat and power and micro-combined heat and power

Combined Heat and Power also known as cogeneration is a process in which both power (in the form of usable electrical energy) and heat (typically in the form of steam of hot water) are generated simultaneously. CHP provides onsite generation of heat and electricity. The central idea is to tap the heat that is produced as a by-product of power generation and use it for beneficial purposes rather than emitting it into the atmosphere. CHP can be assembled in various configurations to best suit the purpose. Typical configurations include gas turbine or engine with heat recovery unit and steam boiler with steam turbine. Applications of CHP can be found in industrial facilities, Universities, Commercial buildings and at municipal levels catering as district energy systems for residential communities.

Conventional heating systems are often substituted by combined heat and power (CHP) plants in medium to large sectors such as bigger residential complexes and non-residential buildings. The use of gas or even biomass with CHP opens an economically higher attraction and can supply bigger utilities with small district heating grids more steadily. These have a high-energy efficiency and are seen as a good practice solution especially when using biomass.

District heating will increase energy efficiency and / or save fossil fuels, if the heat source is an efficient cogeneration of heat and power (CHP) plant, and / or uses renewable energies, or waste heat. Up to 100% or even more of energy savings on the heating side are possible. If the heat source is from fossil fuels without CHP, energy-efficient individual heating systems will be more energy-efficient than district heating.

Table 13 shows example heating systems under different standards

Table 13 Example systems under different standards

	EnEV 2014	Efficient House 70	Efficient House 55	Passive House
Example System	Condensing Boiler + Solar Hot Water	Heat Pump + Solar Hot Water	Heat Pump / Pellets + Solar Hot Water	Heat pump / Pellets + Solar Hot Water

6.2.2.3 Space cooling

Until quite recently space cooling was not a major factor in European climates. Most hot temperate climates of countries such as Portugal and Spain were able to use the diurnal temperature range for cooling. However, with the change in perception of thermal comfort, fluctuating summer seasonal peak temperatures, this has changed so much so that even in countries such as Germany cooling has become an important factor. However with the high diurnal temperatures and the ground coupling easy passive methods such as night ventilation and ground-coupled ventilation are becoming the norm. Space cooling constitutes 15% - 40% of the total energy consumption in a typical commercial building located in hot-arid and hot-humid climates (CEC, 2006). In the USA, a mature air conditioning market, space cooling accounts for around 8% of residential and 13% of commercial electricity US DOE/EERE (2009) consumption and 2% in the EU (IEA, 2010). Many high GDP growth regions of the world fall in climates that require cooling, and the markets there are far from saturation (McNeil & Letschert, 2007). In such a baseline scenario, energy consumption due to air conditioning is only expected to rise significantly in the coming years, and the search for avenues for efficient cooling mechanisms will become indispensible (GEA, 2012). However, energy-efficient design, components, strengthened by strong policy measures may save 12% (2,105.9 TWh/yr) of energy on space cooling (including ventilation) in the building sector (IEA, 2011) in the year 2050.

Unitary (DX) Air-conditioners

DX (Direct Expansion) Air-Conditioners (AC) use 'refrigerant vapour compression/expansion cycle' to produce cooling (in other terms, to remove heat from the space). The heat is removed from the space through natural or forced convection by an 'evaporator' unit that is usually located within the space (packaged units however, use ducts and big fans). The heat removed from the space is rejected to the outside atmosphere through a 'condenser'. Various configurations of DX units are in use such as window AC, split AC, heat pumps, Variable Refrigerant Volume/Flow (VRV/VRF) AC and also packaged ducted units.

There were an estimated 550 to 600 million DX units in the form of room air conditioners and packaged ducted air conditioners installed worldwide at the end of 2009 (IEA 2011). Annual sales of these air conditioners were around 55 million (including reversible units) in 2009 (IEA, 2010). The best split units have a COP of around 6 compared to average sales weighted efficiencies of around 3.5 or less. In simplistic terms this equates to a potential saving of around 40%, although savings in real usage could be more or less than this when seasonal efficiencies and regional variations are taken into account. The IEA estimated global energy consumption by residential air conditioning systems (chiefly DX systems) could be reduced by approximately 877 TWh/yr by the year 2050 with stringent policy action when compared to a 2007 baseline scenario (IEA 2011).

The world's most efficient residential air conditioners have nominal COP of approaching or even exceeding 6, with a theoretical maximum of around 6.5 today (CLASP 2011). This reveals significant scope for improvement compared to typical DX AC units with sales weighted averages ranging between 3 and 3.5 for most countries (CLASP 2011). For example, the best European products achieve a COP of 5.63 (Anette et. al. 2011) for units smaller than a capacity of 4 kW and a COP of 4.52 for units over a capacity of 4 kW. Multi splits achieve a COP of 4.97 but mobile units achieve a COP of only 3.22 (in Europe).

Electirc chillers

An electric chiller is a machine producing chilled water for air conditioning purposes. Chilled water is typically procured at 4 – 6 °C. It works on the principle of vapour-compression refrigeration cycle. Common refrigerants used in chillers are R 22, R 12, R 123, R 134A Ammonia. Commercially available chillers vary in capacity from 50 kW to 5 MW or even more in specialized conditions. Typical life expectancy of electrical chillers is approximately 25-30 years. Electric chillers are used to cool multiple dwellings in a residential complex, apartment building and commercial buildings. Chillers account for approximately 9.4% of the total cooling market by value (Holley 2013). Energy cost of operating chillers could be in the range of 50-90% of total life cycle costs. Overall energy savings potential by using BAT chiller against average chiller is in the range 10% to 30% annually with an incremental capital cost of 25% to 75% and a payback period of 3-7 years.

The core of any electrical chiller is its mechanical compression system (compressors) and heat rejection system (condensers). Popular compressor types are positive displacement compressors and dynamic compressors. Positive displacement compressors work by mechanically compressing the vaporized refrigerant to increase its pressure and include reciprocating, rotary and scroll compressors. While, dynamic compressors impart kinetic energy on refrigerant using a rotating impeller and there by increase the pressure of vaporize refrigerant and include centrifugal compressors. Centrifugal compressors are the state of the art compressors that can achieve highest efficiency. Improvement in compressor technologies include features like:

- High efficiency compressor
- Chillers with variable frequency drive
- Improved heat exchangers
- Improved and inverter driven (variable speed) fans
- Heat recovery chillers
- Water side economizers

The central cooling systems like chillers requires a means to reject the heat it accumulates (heat of condensation). The condenser is where bulk of this heat is rejected in a vapour compression machine. Condensers in chillers have two configuration of heat rejection mechanism- air cooled and water-cooled. Air-cooled condensers reject heat from the condenser to the ambient air using special fans. They may either be remotely located or be connected with the chiller (e.g., packaged chillers). Water-cooled condensers exchange heat with water, cooled through evaporation, using special heat exchangers called cooling towers. In water cooled condensers a secondary cooling circuit using water will be used to move the heat from the condenser to the outside.

Thermally driven and solar air conditioning

Solar cooling is a proven technology, but hasn't been widely deployed to date. As of 2009, only 113 large-scale solar cooling systems and 163 small scale ones were installed worldwide. In total, the installed cooling capacity of the 286 systems was just 15.7 MW (Sparber, 2009). The capital costs of these systems are substantially higher than conventional electric air conditioners, but can, depending on system design, virtually eliminate electricity costs. Future cost reductions could see solar thermal be-come competitive in niche applications, particularly where there are simultaneous cooling and water heating demand and available waste heat.

Solar or thermally driven air conditioners operate using heat as input energy instead of electricity as compared to electric chillers. The compression technology in such air conditioners is based on the principle of absorption or adsorption and can be divided into two broad categories as closed thermodynamic and open thermodynamic cycles. The efficiency (COP) of single-effect absorption chillers is typically between 0.5 and 0.75, significantly lower than that of vapour-compression systems which are typically in the range 3 to 3.8 for new units. Adsorption chillers don't have the opportunity to use double-effect configurations, so COPs of one or greater will not be achieved in the short to medium-term. It should be noted that comparing the COPs of thermally driven chillers and vapour-compression using electricity, as the driving energy isn't comparing like-for-like, as the efficiency of electricity production globally is just 40%. Thermally driven chillers have lower COPS, but use heat (solar, gas, waste heat, biomass, etc.) directly. A comparison of the primary energy use for a unit of cold production therefore gives a more valid indication of the efficiency of the two options at an overall system level. Assuming a primary energy factor of 2.8 for delivered electricity means that vapour-compression air conditioners with a COP of 3 consume around one unit of primary energy per unit of cold produced. Assuming that a thermally driven chiller is used for only cooling and it has a COP in the range 0.5 to 0.75 would mean that 1.3 to 2 units of primary energy would be required to produce one unit of cold. Compared to this, COP of an electric chiller is in the range of 3 to 6. However, this isn't a valid comparison, because vapour-compression air conditioners use electricity, as the driving energy and the efficiency of electricity production globally is low. A better metric would be Resource COP which takes into account source to site efficiency of the fuel and transmission losses. Thus a thermally driven chiller would require more final and primary energy to produce a unit of cold than a standard vapour-compression air conditioner. However, when using waste heat or heat from renewable energies, it will save fossil primary fuels such as oil or coal.

District cooling and CHCP systems

District cooling networks, like district heating networks, are mature, commercially proven cooling solution. Interest in district cooling systems is growing because of their energy and CO_2 savings potential, as well as their ability to reduce peak electricity demand. District cooling systems can take advantage of renewable sources that aren't always economically viable for individual buildings, such as deep sea or lake cooling, free-cooling from aquifers or abandoned mines, etc. By grouping cooling loads district cooling systems also experience more stable cooling load profiles, allowing better sizing of equipment, but also allowing more efficient operation of the cooling equipment. District cooling systems can reduce the energy required for cooling by 20% to 80%, but require relatively large, geographically concentrated cooling loads to be economically viable.

A distributed CHCP system is the provision of space heating and cooling, as well as sanitary hot water. A distributed CHCP system is located in or on the site of a building. The system consists of an electrical prime mover that generates electricity, with a heat recovery system, a thermally driven chiller and a heat rejection system. These are the minimum components of a CHCP, but they will usually include a hot water storage tank and cold water storage tank to help manage the system. A conventional boiler and air conditioner can be incorporated into the system to meet peak demand or for back-up in larger multi-family dwellings.

Distributed CHCP is an emerging solution to provide space heating, sanitary hot water and space cooling separately or simultaneously that can potentially support district cooling and heating systems. The combination of a CHP prime mover with a thermally driven chiller can provide and interesting solution to reduce energy consumption and CO_2 emissions, but the higher upfront capital costs mean that care must be taken in the design of the system and distributed CHCP will not make sense for all residential households. Distributed CHP will make the most sense in large multi-family dwellings, where the combination of sanitary hot water, cooling and space heating. Primary energy savings depend on the efficiency of electricity generation system, but typically range from 10% to 35%. Payback times can vary between 7 years and 13 years in cases where the systems are economic.

6.2.2.4 Energy recovery ventilation systems

With the high levels of insulation the need for conventional heating systems have become obsolete. With the low energy demand it becomes possible to keep buildings within the thermal comfort zone alone through the conditioning of the air required for good indoor quality. Many low and zero energy buildings are heated and cooled through energy recovery systems. This is often combined with ground coupling to reduce the temperature difference that needs to be bridge both in summer and in winter. Energy recovery systems in Passive housing has a recovery rate of at least 80%.

Ventilation of buildings though indispensible has an inherent problem of adding significantly to the cooling and heating loads in air-conditioned buildings. HVAC systems tend to reject considerable amount of heating or cooling energy that is vented out of the building in the form of stale/return air during the process of ventilation. By using Energy Recovery Ventilators the heat/cold from the return air can be exchanged with the fresh air that is drawn in into the system, thereby preheating/precooling the fresh air and thus reducing the ventilation load on the system. Popular technologies are thermal wheel type heat exchanger with a typical efficiency of 65 %-75 % and a maximum of 90 % and flat plate heat exchanger with a typical efficiency of 50 %-65 % with a maximum efficiency of 70 % (Carbon Trust, 2013). However, the efficiency does not only depend on the ERV systems but also on other factors like ventilation rate etc. In Northern Europe with a predominant heating requirement decentralized and dedicated heat recovery systems are more popular especially in Scandinavian countries. This is because heating in this part of the world is done through air water systems with radiators as indoor units. Sweden has clearly emerged as a major market due to the strict legislation and building energy codes.

6.2.2.5 Solar thermal systems and hot water supply

Solar thermal systems and hot water supply varies greatly throughout Europe and is highly dependant on building type and location. In northern countries hot water is most often combined with the heating system irrelevant of the building type however in southern Europe with high insolation levels this has been proven to be a cheap and cost effective way of supplying hot water even in middle rise buildings. For example in Central Europe, solar thermal systems have the potential to cover more than 20% of the total heat requirement (heating + hot potable water) of a traditional building or up to 50% regarding the most energy-efficient low-energy and passive houses (BINE 2005).

Solar Collector Systems

It was estimated that in 2011 there were ca. 1.7 million thermal solar collector systems installed with an area of ca. 15.3 million m^2. Solar hot water systems provide domestic hot water and also contribute to space heating using solar energy. The efficiency of rooftop solar water heaters depends on the type of collector and storage tank among other parameters. Evacuated tube collectors are among the efficient type of solar collectors available capable of delivering hot water temperatures up to 180 °C. According to data from the energy saving trust, UK typical carbon savings in the UK because of solar hot water heaters are around 230kgCO_2/year when replacing gas and 510kgCO_2/year when replacing electric immersion heating. Total solar thermal capacity installed worldwide in 2009 reached 152 GWth (IEA 2011). In terms of solar thermal installed capacity China is by far the leader, due to low costs and government support. The EU 27 is the second largest market, with the majority of installations located in the South (Bloombuerg 2011). When evaluating the SWH market on per capita basis the ranking changes completely. Small sunny countries like Cyprus and Israel dominate the scene (see market scenario below). Relatively higher rankings for Austria, Germany and Denmark prove that the availability of solar resources is not the only the important factor, supportive policies to encourage deployment need also to be in place.

6.2.2.6 Lighting

Lighting is one of the major end uses for electricity, and accounts for almost 15% of global power consumption worldwide (en.lighten). In the USA alone in 2012, lighting in residential and commercial sector accounted for about 461 billion kWh (EIA). By switching efficient lighting technologies it is estimated that globally 939 billion kWh of electricity can be saved annually which is approximately five per cent of global electricity consumption (en.lighten). According to the IEA, by adopting a "Least Life-Cycle Cost" strategy energy policy, electricity consumption in the year 2030 can be reduced by 38.4% compared to a reference scenario limited to current energy policy (base year 2006). Global lighting electricity consumption has increased steadily and it will continue increasing in future, if the current energy policy is not changed. Without a change in energy policy, global electricity demand for grid-based lighting will further grow over the next years and decades. The en.lighten initiative of UNEP is expecting that over the next 20 years global electricity consumption for lighting will increase by 80%.

All lighting systems, no matter how complex, are made up of three or four basic components:

- Lamp – the source of the light, for example, a bulb or a Compact Fluorescent Lamp.
- Luminaire – a light fitting that incorporates a lamp, ballast, mirror and louvre to direct the light
- Ballast – a device used to limit the amount of current, which is necessary for all discharge lamps
- Controls – manual or automatic switching equipment, that operates the lighting system.

Replacing inefficient lamps is the simplest method to save electricity. If incandescent or halogen lamps are installed, a reduction of electricity consumption of 60 to 85 percent can be achieved. As shown below, even if high quality products like a T5 lamp are installed, additional saving potential are possible through more efficient T5-lamps (Master TL5-ECO, Philips). In practice it should always be proved, if a better solution can be reached through optimizing the whole lighting system (including luminaire, lamp, ballast, control system) instead of only changing the lamp.

Lighting sector is often regarded as one of the low hanging fruit of energy efficiency, as it can be both retrofitted easily and also provides an option to chose from the most efficient technologies irrespective of climate and building type, especially for general indoor lighting. Improvements in lighting can be therefore done by choosing or replacing existing low efficient lamp technologies by most efficient ones and by assigning appropriate lighting controls. However, a holistic lighting design is also very important to supplement efficient lighting technologies.

6.2.2.7 Building Energy Management Systems

Building Energy Management (BEM) is a systematic process to monitor, control and benchmark the energy consumption of a building and its systems, to implement energy efficiency improvement actions, and to optimise the operation of the building in order to minimise energy use. These systems control, monitor and optimize energy consumption of comfort systems, lighting, hot water and appliances in a building over time and augment energy savings already obtained by the use of passive and active measures. An important tool for BEM is Building Automation & Control systems (BAC)/Building Energy Management systems (BEM), which is the focus of this bigEE section. By complying to 'Class A'(high energy performance) classification of the standard EN 15232 (Energy performance of buildings - Impact of Building Automation, Controls and Building Management) there can be potentially up to 30% energy and cost savings with added benefits of thermal comfort and safety (Siemens 2010). Other studies (Becker, Bollin, & Eicker, 2010) show that by employing building automation and energy management techniques 60% of annual energy savings could be obtained with a pay back period of 2-10 years (Becker & Knoll) in commercial buildings.

Energy consumption in a building can be optimized only if it is measured effectively. Monitoring and measurement represents a very important function of the BEM system and is done through advanced metering techniques using appropriate sub meters and smart meters. Sophisticated facility monitoring and control systems allow monitoring of various end uses in real time. The Efficiency Valuation Organization (EVO) publishes the International Performance Measurement and Verification Protocol (IPMVP) to increase investment in energy and water efficiency, demand management and renewable energy projects around the world. It lays special emphasis on the use of Energy Management Systems and allows building owners, energy service companies, and financiers of energy efficiency projects to quantify the energy savings performance of energy conservation measures (ECMs).

The energy consumption output data that are available from central monitoring and measurement unit can be analysed periodically for optimizing various processes. The analysis typically takes into account external weather data, occupancy schedules, automation schedules, user behaviour data and system performance. Based on this data a schematic step-by-step approach is followed in order to optimize one or all of the above described parameters in conjunction or in isolation. In some cases the whole system can be optimized by just recalibrating the system and adjusting the controls to suit updated user behaviour patterns.

7 Green Buildings in Europe

This chapter depicts the history of green buildings and energy efficiency in buildings Europe and compares different green building certifications in Europe, namely, BREEAM (Building Research Establishment Environmental Assessment Method) from UK, DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen e.V./ German Sustainable Building Council) from Germany , and HQE (Haute Qualité Environnementale/ High Quality Environmental standard).

7.1 History of green buildings and energy efficiency in buildings Europe

Most European countries have a long history of mandatory energy standards but do not have a long history of green building certification e.g. Germany, with DGNB which first started in 2007, as it has stricter environmental regulations and higher green standards. Conversely, where there are a higher numbers of certifications, as is in US, the green standards are considerably lower (Deutsche Bank Research 2010). In Europe the focus is on energy efficient buildings with the development of stringent and compulsory energy standards. In the past Europe was highly dependant of external energy sources as compared to other countries. As economics can be seen as a major driver, this is one of the reasons that the focus in Europe is more on energy efficiency and thus direct cost savings rather than green buildings. It must be noted that energy prices in Europe have been higher than for example USA or China (the electricity rate in Germany is 0.24 Euro/kWh while in China it is 0.06 Euro/kWh (Schwede 2012). One of the reasons being the added tax on fuels.

Various energy efficiency measures have thus been adopted by individual Member States to improve building energy performance since the 1970s (in response to the oil crisis), with some form of minimum requirements for thermal performance of building envelopes. As one of the first, the Swedish government launched a project in 1977 to estimate energy savings in homes based on utility bills and building characteristics (Santamouris 2005). Throughout the 1980s and 1990s the Building Research Establishment (BRE) of the UK conducted numerous energy audits across the UK, which served to produce the Domestic Energy Model, a predecessor of current energy rating tools. A further tightening of the requirement was witnessed from around 1990s (BPIE 2011). One of the first countries requiring energy assessments was Denmark and, although progress was slow at first, it has now spread around the world. Denmark launched its mandatory energy rating systems for commercial and residential buildings in 1992 and 1993, respectively.

Momentum increased following the European Union's Energy Performance of Buildings Directive (EPBD, 2002/91/EC) in 2002, which caused national-level energy rating policies to emerge in 31 European countries. This directive acts as Europe's foremost and main policy driver related to energy use. The mandatory framework directive (EPBD- Energy Performance Buildings Directive) has the obligation for its member states to set minimum energy performance standards (MEPS) for significant reductions in the energy consumption of buildings. This serves the purpose of reducing Europe's greenhouse gas emissions as defined in the "Kyoto" targets. The Directive has been recast in 2010 (EPBD recast, 2010/31/EU) making its goals more ambitious (towards nearly zero energy buildings (nZEB) for new public buildings by 2018 and all new residential and commercial buildings by 2020).

In addition to this energy efficiency in the building sector is often aided through various specific policies and measures such as regulation, transparency and information, incentives and financing, capacity building and networking, promotion of energy services and RD&D and BAT promotion (bigEE 2013). Regarding financing, in Germany, for example, energy efficiency in the building sector has added incentives through the KfW Bank (Kreditanstalt für Wiederaufbau), which offers preferential loans for energy efficient buildings. Similar programs can be seen in countries such as the UK and France as well as other European countries.

Historically, in Europe buildings, are also expected to have a long lifetime (c.a. 100 years). This also means that systems tend to be more robust and that the running costs tend to make up a larger part of the total lifetime costs. As a result more emphasis is placed on energy savings to reduce running costs.

The effort to decrease the amount of operational energy to reach higher energy efficient buildings is certainly important. However the embodied energy and carbon are also an important consideration that takes into account the building material resources (material intensity and recycling options (EIO 2011)). For example, in UK, the ratio between operational and embodied emissions used to be around 80:20 (Lane 2007). However, with the improvement of energy efficiency in buildings this ratio has a shift closer to 60:40 for an average building (EIO 2011). It emphases that embodied energy can carry a greater percentage in a low-energy building's total lifetime (due to insulation and other (sophisticated) building materials). Therefore, the present issue in Europe is to look beyond operational energy efficiency and cover resource efficiency such as material efficiency, embodied energy, water efficiency and sustainable use of land (RICS 2013). Regarding material efficiency, the German construction industry has demonstrated that of the 13.0 million tonnes incurred in construction waste, 0.3 million tonnes were recycled (2.3%) and 12.3 million tonnes (94.6%) were supplied for another utilization and only 0.4 million tonnes (3.1%) were disposed of in landfills (Kreislaufwirtschaft Bau 2013).

Studies have shown that countries, which already have high levels of energy efficiency in buildings, have little benefit from green building schemes (Nelson 2008). As seen above the energy efficiency movement in Europe has also been through strict regulation standards whereas for green buildings in Europe this is not directly the case. It can be noticed that countries in Europe with stricter energy regulations in the building sector often have a shorter history of green building certificates. Germany for example first introduced the DGNB in 2009.

Green buildings as a holistic approach covers the issues aimed at mitigating impacts from the built environment through sustainable design. On a voluntary basis, third party labelled green building certification systems are widely used in Europe for both new and existing buildings. Most of the member states in EU have individual green building certification systems such as BREEAM (Building Research Establishment Environmental Assessment Method) from UK (since 1990), DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen e.V./ German Sustainable Building Council) from Germany (since 2007), HQE (Haute Qualité Environnementale/ High Quality Environmental standard) from France (since 2004) whose weightings for criteria and rating system differ (see Table 14). They are either limited to each (founder) country or widely used internationally. In addition to these the internationally acclaimed LEED (Leadership in Energy and Environmental Design) (originally from US) is also used in Europe. Figure 13 and Figure 14 shows the evolution of these green building certification systems in Europe (and other countries). Among these certification systems, higher numbers of buildings are certified in BREEAM (see Figure 15), this is however due to the fact this is a mandatory certification in the UK.

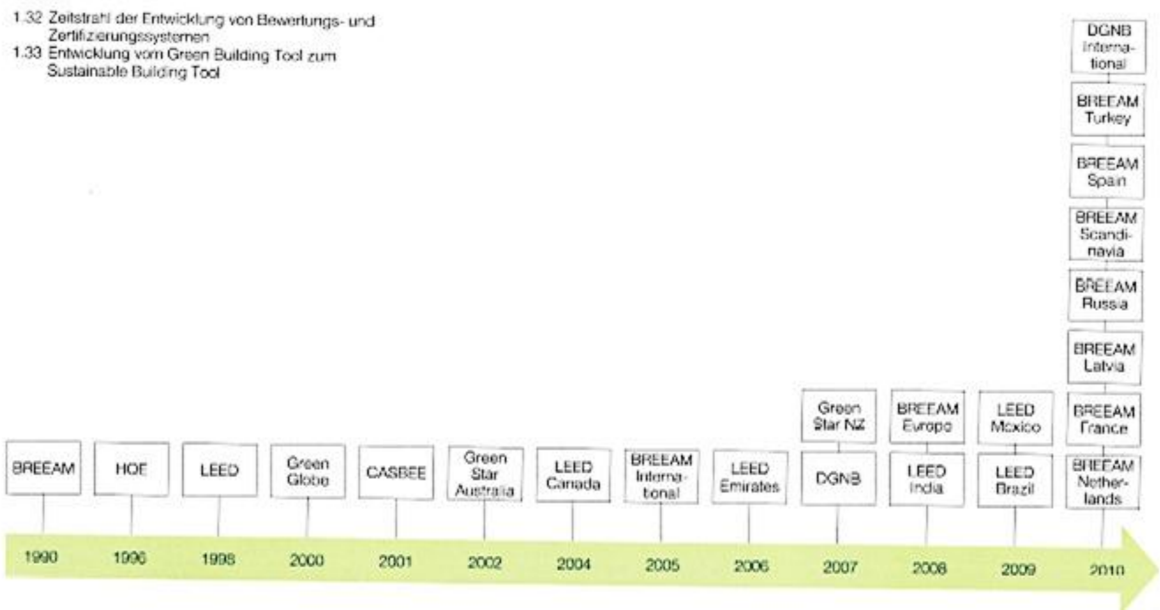


Figure 13 Evolution of green building certificates

(Source: Ebert et al. 2011)

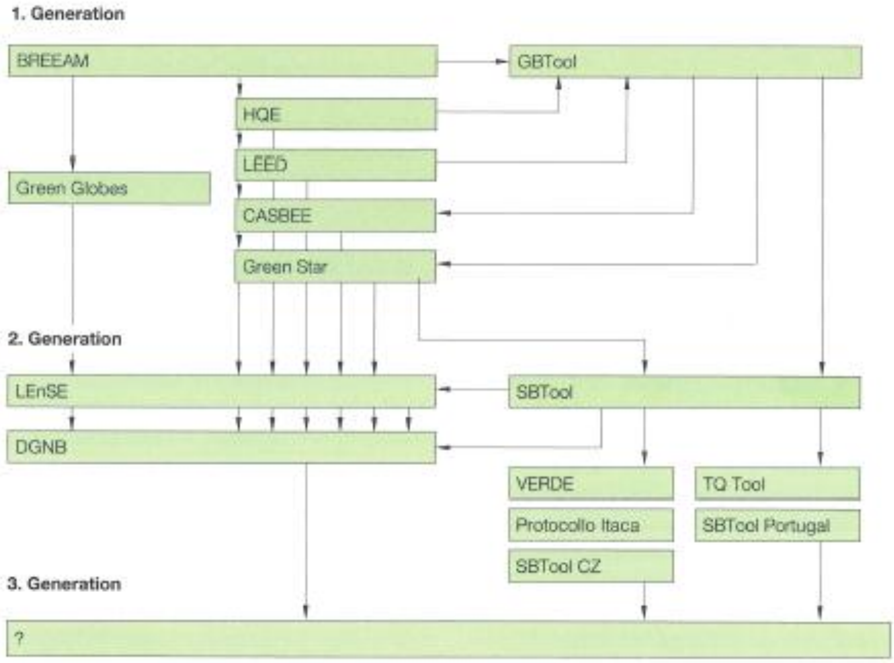


Figure 14 Evolution of green building certificates and their relationship
(Source: Ebert et al. 2011)

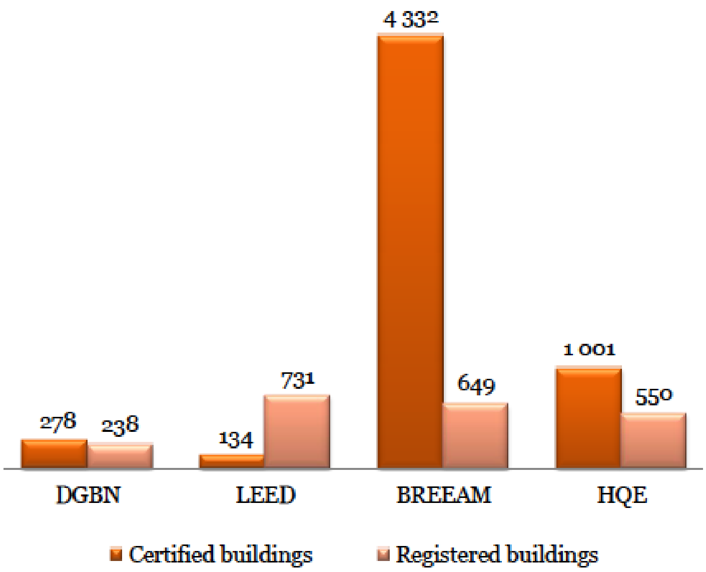


Figure 15 Certified and registered buildings in Europe until May 2012
(Source: RICS 2012; LuxReal FORUM Sustainability 2013)

7.2 Green building certifications in Europe

7.2.1 Green building certifications in Europe

Green building construction is growing fast in Europe along with a growing number of Green Building councils (GBCs) – 24 GBCs till date in World Green Building Council (WorldGBC) (WorldGBC n.d.) (see Figure 16). Among various green building certifications in Europe, this textbook focuses on BREEAM, DGNB, HQE and LEED, and their consideration on energy and material efficiency. See Table 14 below for their detail comparison.

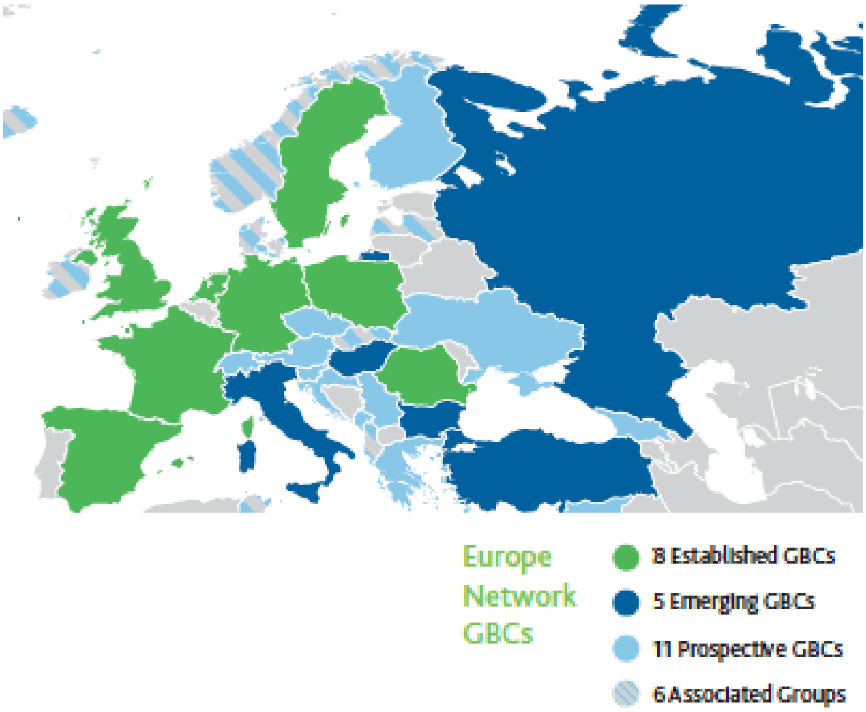


Figure 16 Green Building Councils in Europe

(source: World GBC n.d.)

BREEAM

BREEAM, the world's first environmental/ green building certification system, originated in the UK in 1990 and was developed by the Building Research Establishment (BRE). It was established to address environmental and sustainability issues of buildings. It encourages building stakeholders (designers, clients and others) to think about low carbon and low impact design, minimising the energy demands created by a building before considering energy efficiency and low carbon technologies (BRE Global 2010-2013). See Table 14 for detail.

DGNB

DGNB, established in 2007 by DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen e.V./ German Sustainable Building Council) together with BMVBS (German Federal Ministry of Transport, Building, and Urban Affairs), covers all aspects of a building's life cycle. It is a meritocratic rating system that covers all relevant topics of sustainable construction. It was developed to respond for a society that faces a wide range of challenges such as climate change, resource scarcity, as well as the financial crisis. It includes ecological, economical and socio-cultural issues in the planning, construction, and operation of buildings for sustainable buildings (DGNB 2012). See Table 14 for detail.

HQE

HQE, launched in 2004, was developed by the French Green Building Council and HQE Association (QUALITEL and Certivéa). It is a performance and function-oriented system that looks at how a building actually performs (e.g. energy performance and acoustic properties) (SWEGON AIR ACADEMY 2012). It aims to attain high environmental quality by controlling the impact of a construction or renovation project on the external environment and on the comfort and health of users, whilst managing the operational processes related to the scheduling, design and implementation phases (Certivéa 2012). See more detail on HQE in Table 14.

LEED

LEED, developed by US Green Building Council in 1998, is one of the largest environmental/ green building certification systems in the world. In 1993, USGBC realized that the sustainable building industry required a system to define and measure 'green buildings'. From this LEED was developed, providing building owners and operators with a framework for identifying and implementing practical and measurable green building design, construction, operations and maintenance solutions. It intends to use resources more efficiently than conventional buildings (USGBC 2009). See Table 14 for detail.

Table 14 Comparison of some of the different green building certifications in Europe

	BREEAM	DGNB	HQE	LEED
Origin country/ Website	UK (http://www.breeam.org)	Germany (http://www.dgnb.de/de/)	France (http://assohqe.org/hqe/)	US (http://www.usgbc.org/leed)
Established	1990	2007	2004	1998
Responsible	BRE Global (under BRE Trust)	DGNB together with BMVBS (German Federal Ministry of Transport, Building, and Urban Affairs),	France Green Building council and HQE Association (QUALITEL and Certivéa)	US Green Building Council
Internationalization of the certification system	Netherlands, Norway, Spain, Sweden and (other countries)	Austria, Bulgaria, Switzerland and Thailand (co-operation agreement China, Brazil and Russia (on the process)	Belgium, Germany, Great Britain, Italy, Luxemburg, Morocco, Algeria and Brazil	Argentina, Brasil, Canada, Chile, Colombia, South Korea, India, Italy, Jordan, Mexico, Norway, Poland, Romania. Russia, Spain, Sweden, Turkey and UAE
Target buildings	New Building, Extension, Existing building, Major renovation, Shell and Core	New building, Existing building, Renovation	New building, Renovation, In-Use	New building, Extension, Existing building, Major renovation, Shell and Core
Criteria in the certification system	Management, Health and well being, Energy, Transport, Water, Materials, Waste, Land Use and Ecology, Pollution, Innovation	Ecological quality, Economical quality, Socio-cultural quality, Process quality, Site use	Eco-construction, Eco-management, Comfort, Health	Sustainable site, Water efficiency, Energy and Atmosphere, Materials and Resources, Indoor environmental quality, Innovation and Design process
Energy efficiency	BREEAM bases parts of the results on carbon dioxide, which means that energy is recalculated to carbon dioxide equivalents to make it possible to give points to some of the issues in the energy category (SWEGON AIR ACADEMY 2012).	DGNB takes into account total primary energy demand and the proportion of non-renewable primary energy within the building (SWEGON AIR ACADEMY 2012) and it should fulfill the requirement up to or above the level of EnEV (Energiesparverordnung/ German Energy Saving Ordinance) (latest e.g. EnEV 2009). EnEV is Minimum energy performance standard (MEPS) for Germany which has stringent energy consumption baseline.	HQE, with performance-oriented approach, focuses on the reduction of energy use (minimum 10% saving compared to reference level of consumption) through good building design, reduction of primary energy use and reduction of the creation of emissions to the atmosphere	LEED certification requires at least or above the level of ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) standard 90.1-2007 for energy efficiency. ASHRAE is the energy code in US which is updated every three years.

Material efficiency	BREEAM considers reuse of existing building façade, building structure, recycled aggregates, minimize construction waste and use of low embodied and environmental friendly materials determined by Green Guide Rating.	DGNB focuses on avoidance of construction waste by the design that are ease of deconstruction, recycling and dismantling; use environment friendly materials that have Green Product Certification; and design alteration with resource saving.	HQE considers using locally available materials, proper type and construction process, and waste management (from the worksite and activity) based on local recycling/ treatment options. It uses construction products with European standard prEN15804 or international standard ISO 21930 (Certivéa 2012).	LEED emphases on building material reuse and promote recycling; manage the construction waste and use regional environmental friendly materials with Green Product Certifications.
Ratings	Pass (≥30%)/ Good (≥45%)/ Very Good (≥55%)/ Excellent (≥70%)/ Outstanding (≥85%)	Bronze (50-64.9%)/ Silver (65-79.9%)/ Gold (above 80%)	Pass (0 Star), Good (1-4 Stars) Very good (5-8 Stars), Excellent (9-11 Stars), Exceptional (12-16 Stars)	Certified (40-49 points)/ Silver (50-59 points)/ Gold (60-79 points)/ Platinum (80 and above)
Scheme	Voluntary	Voluntary	Voluntary	Voluntary, consensus-based, and market driven, performance based
Local or International standards/ Codes taken into account **(baseline standards)**	EPC, EU Code of Conduct on Data Centers, CIBSE	EnEV 2009, DIN EN ISO 14040, DIN 4108, DIN EN 12207, FSC, HOAI, EPC	EPC, European standard prEN 15804 (material), ISO 21930 (material), FSC or PEFC-certified wood (material), ISO 9972 (air permeability)	ANSI/ASHRAE/IESNA standard 90.1-2007, ASHRAE Standard 62.1-2007, Chartered Institution of Building Services Engineers (CIBSE) Applications Manual 10: 2005, ASHRAE Standard 55- 2004, ANSI/SMACNA 008-2008
Number of certified buildings in total	115,000 certified buildings 700,000 homes and buildings registered (until June 2011-including all building types)	160 certified buildings (until June 2011-including all building types)	7,200 certified buildings (till the end of 2011)	7052 certified buildings (within US) (until June 2011-including all building types)

7.2.2 Green requirements under energy certification systems and vice versa

Various energy certification systems have been introduced in Europe such as the German Passive House Standard (Passivhaus) and the Swiss Minergie standard. In such highly efficient buildings, where the operation phase is characterized by low energy requirement, decreasing embodied energy plays an important role in reducing the environmental impact (Dutil et al. 2011 in Hennicke et al. 2012). Among various types of the Swiss Minergie certifications, Minergie-P-ECO allow high demand on energy performance and the same demand on the choice of building materials, recyclability and indoor quality (SWEGON AIR ACADEMY 2012).

In green buildings, as the energy baseline depends on a country´s energy standard such as ASHRAE for LEED and EnEV for DGNB, the operating energy use is higher than in energy certified buildings such as Passive House (Eian 2011), but their material efficiency is more stringent which leads to lower embodied energy than in energy certified buildings. Therefore, in Europe, green building certifications reinforced through highly energy efficient buildings (such as Passive House), must be seen as a stepping-stone in reaching energy and resource efficiency in the building sector (Hennicke et al. 2012).

7.2.3 Effect of mandatory standards and voluntary certifications in market transformation

As European countries have mandatory energy standards, this helps to prevent construction of inefficient buildings in terms of energy consumption. Voluntary green building certification systems (BREEAM, DGNB and HQE) and energy certification systems (Passive House) act as an incentive for manufacturers to differentiate themselves from their competitors and stimulate the introduction of efficient buildings (World Energy Council 2008). Therefore the introduction of voluntary certificates and mandatory standards pull the market towards more energy and resource efficient buildings and can support introduction more stringent energy standards in Europe.

7.2.4 Material efficiency and green material lists and information in Europe

7.2.4.1 Material efficiency/ embodied energy in Europe

The overconsumption of limited resources in buildings construction is one of the greatest environmental challenges of the 21st century (EIO 2011). Material and/or resource efficiency in general refers to using fewer natural resources to achieve the same or improved output i.e. more from less (use resources more effectively and reduce the amount of resources) (EIO 2011). Attention should thus be given to all phases in the product's/material's life cycle, i.e. from the extraction of natural resources, via the production process, and use, right through to disposal or recycling which orient to limiting the environmental impact of products throughout their entire life cycles (Proesler 2008).

Some of the green or eco-materials are already in use in Europe among them alternatives for the mostly used construction materials such as cement, steel or metal, glass and wood. For example Eco-cement, as a replacement of Portland cement, reduces the embodied CO2 of the average structure by 25% (ecocem n.d.). It uses industrial waste materials such as blast furnace slag and fly ashes or reduces calcium content through technology called Celitcement (under examination at a pilot plant in Germany) (EIO 2011).

Moreover, metal recycling has major benefits for the environment as less energy is needed to produce steel or copper products from recycled scrap metal than from virgin ore. Urban mining has larger potential in Europe that helps to utilize 'forgotten resources' in the most efficient way e.g. Aluminium (EIO 2011). In Germany around 485 000 tons of aluminium are used for construction use, with an end of life collection ratio for construction of around 85% (Radlbeck 2005 in EIO 2011) while the energy needed to produce recycled ingot from scrap is only about 5% of that needed to produce primary aluminium (EIO 2011).

Likewise, multi layered high performance glazing with timber frames, which are widely used in Europe, results in lower embodied energy. Double-glazing is a well-established product in Europe (except perhaps in only a few un-renovated building stock which still have single glazing) (Glass for Europe n.d.). The study by Glass for Europe (n.d.) shows that the greater use of high performance double and triple glazed units using Low-E insulating glazing in all new and existing buildings across the EU 27 could save as much as 97 million tones of CO2 per year by 2020. Beside this glass with certified ISO 14001, through the reuse of broken glass reduces embodied energy e.g. Saint-Gobain Glass Products (Saint-Gobain Glass 2012).

Another option to reduce a building´s embodied energy is through the use of wood from sustainable sources. Building with wood has been increasing over the last decade in Europe, both in single storied and multi storied buildings (EIO 2011). An empirical study by Mahapatra and Gustavsson (2009) shows that the use of wood for multi-story building construction varies widely among European countries. The market share of such construction reached about 15% in Sweden and there is an encouraging growth in UK and Ireland (but less in Germany). These differences might be due to procurement policy of legally certified wood products and regarding concern on fire safety and durability of wooden buildings, which exists in UK, Germany and Netherlands, but not in Ireland and Sweden (Mahapatra and Gustavsson 2009).

7.2.4.2 Green material lists and information in Europe

To categorize green building materials, various voluntary Green Product Certifications such as Cradle-to Cradle (C2C), Forest Stewardship Council (FSC), Natureplus, European Ecolabel and the Blue Angel are used in Europe. C2C (website: http://www.c2ccertified.org) has over 300 certified products by 2010 of which 80 are building products such as concrete, insulation materials and floor covering. FSC (website: https://ic.fsc.org/) is a widespread label for sustainably obtained wood, wood products and paper, while Natureplus (website: http://www.natureplus.org) is a bio-ecological label for building materials and materials for interior design (150 products are Natureplus certified of which 70 are available in Belgium). European Ecolabel (website: http://www.eu-ecolabel.de) is a consumer-oriented label, which has limited labels for building products such as paints, varnishes and floor coverings (Debacker et al. 2011). The Blue Angel eco-label (website: http://www.blauer-engel.de/index.php), created in 1978 on the initiative of the German Federal Minister of the Interior and approved by the Ministers of the Environment of the federal government and the federal states, labels the products for environmental and health protection benefits. Some of the products are for furniture, laminate flooring, panels, linoleum and insulation materials (Umweltbundesamt 2013). See Table 15 for short detail on these Green Product Certifications.

Table 15 Comparison of some of the Green Product Certifications

	Cradle to Cradle	Forest Stewardship Council	Natureplus	European Ecolabel	The Blue Angel
Website	http://www.c2ccertified.org/	https://ic.fsc.org/	http://www.natureplus.org/	http://www.eu-ecolabel.de	http://www.blauer-engel.de/index.php
Awarding body	MBDC (McDonough Braungart Design Chemistry)	FSC accredited certification bodies. Accreditation Services International (ASI) is responsible for checking certification body.	International Association for future-oriented building and accommodation - natureplus e.V. (in EU and associated countries)	European Eco-labelling board (EUEB)	Umweltbundesamt (German Federal Environment Agency), RAL – German Institute for Quality Assurance and Certification)
Created in	2005	1993	1998, launched in 2001	1992	1978
Type	Not classified	Type I according to ISO 14020	Type I according to ISO 14020	Type I according to ISO 14020	
Scope and Range	The products includes building materials, interior design, paper and packaging, textile and fabric and other products	- Promote environmentally appropriate, socially beneficial, and economically viable management of the world's forest. - Responsible forestry management and products originating from responsible forestry management - There are 3 types of FSC certificate: Forest Management Certification, Chain of Custody Certification and Controlled Wood.	Ecological building products from renewable raw materials	- Products and services, consumer-oriented - Building products included: Paints, varnishes, heat pumps, wooded floor coverings, soft floor coverings and textile floor coverings	Products and services which – from a holistic point of view - are of considerable benefit to the environment, at the same time, meet high standards of serviceability, health, and occupational protection.
	400 products (until 2013), 80 building related (until 2010)	-20,000 Forest management and Chain of Custody Certification in 2011 -129.35 million hectares of certified forests in over 80 countries	30 types of building products, 150 products	560 companies, 2000 products (2007)	11,700 products and services in circa 125 product categories
Criteria determination	Criteria in 5 categories: -Material Health	10 principles and 56 criteria	Minimum certification requirements for building	-Aiming at achieving feasibility for 30% of the	Criteria under product groups and services. The group that:

	-Material Reutilization -Renewable Energy and Carbon Management -Water Stewardship -Social Fairness Product certification is awarded at five levels (basic, bronze, silver, gold and platinum)		products: - Minimise energy consumption and material usage over the complete product life-cycle - Maximise the use of environmentally-friendly, renewable raw materials and regenerative forms of energy. - Minimise the processing steps and the contents. - Minimise emissions/ harmful substances. - Maximise the factors promoting well-being. - The highest possible fault-tolerance in their use and application. - Maximise the longevity and ease of repair. - Products reuse - Products recycle or disposed of without any danger	products on the market -Criteria determination on the basis of lifecycle analysis	-protects environment and health -protects climate -protects water -protects resources
Certification	- Runs via MBDC and possibly EPEA	The certification is carried out by independent organizations called certification bodies. These certification bodies assess forest management and chain of custody operations against the applicable Forest Stewardship Standards. Only FSC accredited certification bodies are authorized to issue FSC certificates.	- Research request to Natureplus, definitive product test, factory visits and sampling. - Life cycle analysis and laboratory trials	-Runs via a third party, National Competent Body (PFS Product Policy for Belgium) -Product testing by accredited laboratory	- German Federal Environment Agency (Umweltbundesamt) which develops the technical criteria - expert hearings involving representatives from industry and other expert groups - Environmental Label Jury composed of representatives from HDE (Central Association of German Retail Trade), BUND (Friends of the Earth Germany), BDI (Federation of German Industries), NABU (Nature and

					Biodiversity Conservation Union), DGB (Confederation of German Trade Unions), vzbv (Federation of German Consumer Organisations), SWR (South West German Broadcasting Corporation) as well as Stiftung Warentest (Foundation for comparative product testing), churches, state ministries of the environment, local authorities and science, decides on the award of a Blue Angel - RAL which organizes the award with the label users - German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, the supporting organization of the Blue Angel
Validity	Annual revision	FSC certificates are valid for 5 years and the FSC accredited certification body will conduct annual surveillance audits.	Valid for 3 years	Valid for 3-5 years	

Source: Debacker et al. 2011; Umweltbundesamt 2013 and individual websites

Moreover, there exist numerous websites in Europe that provide lists database and information on efficient building materials in Europe. Some of then are discussed shortly below based on the information available in their respective websites.

Greenbuildingproducts.eu (website: http://www.greenbuildingproducts.eu)

Greenbuildingproducts.eu lists the database of products assessed in terms of LEED and DGNB and is provided by HOINKA GmbH, Germany. The criteria included in LEED are Indoor Environmental Quality (IEQ Credit 4.1, 4.2, 4.3 and 4.4) and Materials and Resources (MR Credit 4, 5, 6, 7). Likewise, the criteria included in DGNB are Criterion 6 Risk for the local environment and Criterion 8 Sustainable Resources.

Greenspec (website: http://www.greenspec.co.uk)

Greenspec, a UK based and in conjunction with BRE, is dedicated to disseminating information about green building materials and construction techniques. It identifies and endorses green building products, systems and services using the PASS (Product Assessment Screening System) and includes a directory of endorsed products along with supporting environmental and specification data.

Ökobaudat (website: http://www.nachhaltigesbauen.de/oekobaudat/)

Ökobaudat is a database published by the German Ministry for Transport, Building and Urban Development. It contains about 950 datasheets of building materials and construction and transport processes of the environmental effects for the categories such as mineral building materials, insulation, wood products, metals, coatings and sealants, plastic building products, components of windows, doors and curtain walling and building techniques. The latest one is Ökobaudat.dat 2011.

WECOBIS (website: http://www.wecobis.de/)

WECOBIS is a database published by the German Ministry for Transport, Building and Urban Development. WECOBIS provides comprehensive, structured processed, vendor-neutral information on health and environmental aspects including possible application areas for the major building product groups and materials. This information is provided for the life cycle phases of raw materials, production, processing, use and end of life disposal.

Ecoinvent (website: http://www.ecoinvent.ch/)

Ecoinvent lists product databases provided by the Swiss Center for Life Cycle inventories. It holds the world's leading database with consistent and transparent, up-to-date Life Cycle Inventory (LCI) data (current version Ecoinvent version 3). The data are available in the 'ecoSpold2' data format and are compatible with most of the Life Cycle Assessment (LCA) and eco-design software tools such as LEGEP Software tool (LEGEP Software GmbH, Germany), GaBi (PE International/ LBP-GaBi, University of Stuttgart, Germany) and Umberto (ifu Hamburg/ ifeu Heidelberg, Germany).

The Blue Angel (website: http://www.blauer-engel.de/en/blauer_engel/)

As mentioned above, the Blue Angel is eco-label with brand character that provides a building product database according to products, brands, suppliers and basic award criteria.

7.3 Conclusion

European buildings have a longer life history of energy efficiency achieved through higher implicit standards of design and construction with stringent/ appropriate codes and standards. Energy prices have also been much higher in Europe, making the conservation of energy in design and operation an economic issue (Yudelson 2009). Therefore, energy efficiency has been a major priority in Europe, with the building standards moving towards nearly zero energy buildings. Green building certificates in Europe (such as BREEAM, HQE, DGNB and LEED), though not having a longer history, are widely used to minimize the resource consumption and environmental impact. Resource/material efficiency is also a greater concern in Europe. The rate of use of green or eco-materials, material recycling and reuse are also growing. Databases of green building materials are easily available through various websites (e.g. Ecoinvent, Greenbuildingproducts.eu, Greenspec, Ökobaudat, the Blue Angel and WECOBIS) which provide the options to choose eco-materials. Lastly, as European buildings are moving towards highly energy efficient buildings a greater concern to resource efficiency in such buildings is a wise step to reduce buildings' adverse environmental impact. Numerous good practice examples exist in Europe that shows the leading path towards energy and resource efficient Europe

8 Polices for Buildings Energy Efficiency

This chapter addresses the policy dimension of building energy efficiency, i.e. how policies can promote the up-taking of various building energy efficiency techniques and technologies. It includes a recommended policy package for energy efficiency in new buildings and renovation, its components, and guideline for designing energy efficiency policies for buildings. In addition, it takes Germany as an example to illustrate how the policy package and a specific policy instrument, kfW soft loan programme, promote building energy efficiency in Germany.

This chapter is largely based on the content of bigEE (www.bigee.net).

8.1 Actors relevant to building energy efficiency

To realize energy efficiency in the building sector, it is essential that all members of the complex value chain act in favor of energy-efficient designs and choices, or else the energy efficiency chain will break. Our advice to policy-makers is to analyze the situation in their country to devise which support market actors need. This is important before designing and implementing policies for energy-efficient buildings.

The actor constellation in the building sector: New construction of a building is an extremely complex process. In each of the three main phases of development, construction, and operation, there are several interlinked steps in the value chain that have to be coordinated. This process involves a large number of different market actors, the most relevant of which are architects, developers, financiers, builders, contractors, component suppliers, and last but not least investors, building owners, tenants, and individual users. In addition, there are also some actors that are not part of the value chain itself, but nevertheless play important roles in influencing market decisions, such as public authorities, energy agencies, and energy service companies (ESCOs) – to name just a few. Processes for energy-efficient building refurbishment are quite similar to new build and involve many of the same actors, although they normally exclude the tasks and actors of property development and sale or letting. Such renovation processes and actor constellations are thus almost as complex as those for new build.

Table 16 and Table 17 shows which actors are involved in the different steps of the value chain or have an influence on the value chain. These items should all be considered for a thorough analysis to prepare the creation of an appropriate policy package for energy efficiency in buildings.

Table 16 Actors involved in the different steps of the value chain

Value chain links and corresponding actors	
Property development	• Property development companies • (Social) Housing companies • Investor-occupier

Financing	• Banks • Equity funders • Public-private partnership (PPP) • Insurances • Property valuers
Design	• Architects • Engineering consultants
Component supply	• General management companies • Construction companies and contractors • Manufacturers of pre-fabricated houses
Installation of systems	• System suppliers • Installation contractors
Sale/Letting	• Property development companies (as sellers or landlords) • Manufacturers of pre-fabricated houses • Housing corporations • Real estate agents • Landlords/landladies • Buyers, tenants
Commissioning	• Commissioning providers • Engineering consultants • Facility managers
Operation/Use	• Investor-occupiers • (as developers or as buyers of completed buildings) • Landlords/landladies • Tenants • Employees, customers, visitors, guests etc. • Facility managers

Table 17 Influencing factors and corresponding actors

Influencing factors and corresponding actors	
Governance framework Regulation Incentives	• National/local authorities • Building Permission Authorities • Energy agencies
Advice and research	• Consumer organisations • Science • NGOs
Supply of Energy Efficiency Services	• ESCOs • Energy agencies • Energy consultants/ assessors

8.2 Barriers and incentives

All members of the building value chain have their specific barriers but also immanent incentives for harnessing energy efficiency. Too often, however, barriers are stronger than incentives. This is why policy-makers should analyse the situation in their country to devise which support market actors need to overcome barriers and strengthen incentives.

Many studies have shown that even in spite of their cost-effectiveness, most possible energy savings are not realised by market forces alone, because of a variety of barriers and market failures. These obstacles are especially powerful and persistent in the building sector because of its complexity and the multitude of actors involved in it. Many different actors have to work together for an optimal outcome.

By knowing the barriers and incentives of each type of actor (Table 18), the policy package can be adapted to guarantee desired results and achieve the greatest possible energy savings. Table 3 lists common barriers and incentives for the actors in the building value chain.

Table 18 Barriers and incentives of actors

Barriers	Incentives
Economic/financial barriers • Capital constraints and risk-averseness of value chain actors in the building sector	**Saved energy costs** This will be an important incentive for investing in energy efficiency improvements, unless there are split incentives
Knowledge/information barriers • Lack of awareness of the energy saving options on the part of both building users and financiers	**Co-benefits** Health and comfort increases due to improved indoor climate, productivity gains in commercial properties due to better lighting and noise reduction are just some of the many positive side effects
Lack of interest and motivation for energy efficiency improvement • Low and unrealistic energy prices decrease motivation of majority of actors to reduce energy costs • High transaction cost of accessing information about energy efficiency solutions decreases actors' motivation to invest in energy efficiency	**Directly increased earnings or profits for suppliers** The price premium and additional investment in energy efficiency increase turnover and profits for the suppliers
The landlord-tenant, developer-buyer or investor-user dilemma • Investor-use dilemma where investor in	**Unique selling proposition for suppliers** This is a strategic benefit. It can lead to competitive advantages or even market leadership

building energy efficiency may be actual beneficiary of the savings that will occur. For example a building owner normally is the one who has to pay for the thermal insulation while it is his or her tenant whose energy bills are reduced.	with increased profits
Technical barriers • Solutions to energy efficiency may not be available yet or there may be uncertainties whether the new technologies will perform reliably	**Improved reputation** End-users as well as the environment benefit from energy-efficient solutions: they serve to underpin a company's Corporate Social Responsibility (CSR) goals, which also yields competitive advantages
Market distortions and regulatory barriers • Subsidized energy prices and lack of inclusion of externalities will distort energy prices and disguise the true value of energy efficiency	**Contribution to protecting the environment** This may be an intrinsic motivation for any actor
	Higher occupancy rates and market value of the property If the total rent (basic rent plus energy costs) is lower for energy-efficient buildings, it may be easier to find tenants

8.3 The role of policy

Energy-efficient buildings already exist in many countries. The technologies and the design know-how to cost-effectively build them are also available – what is still lacking is their wider dissemination.

Given the high energy-saving potential and co-benefits presented above, the challenge is for policy and market actors together to transform the building sectors in a way that efficient buildings will no longer be an exception but become the standard choice of market actors.

As we have seen, policy is needed to help the various actors overcome their respective barriers to harness energy efficiency and to strengthen their market-inherent incentives. The goal is to make energy efficiency as easy and attractive as possible, sometimes to make it feasible at all, and ultimately to make it the standard choice.

Having identified all relevant actors and their specific barriers the question is: How can policy assist market actors to overcome these barriers and how can policy strengthen their immanent incentives? The following chapter presents possible answers.

8.4 Recommended policy package for energy efficiency in new buildings and renovation

Looking at the potential energy savings in new build and the many benefits they bring, the goal for policy-makers should be to make Ultra-Low-Energy Buildings (ULEB) the mainstream standard. For renovation and operation of existing buildings, the goal is two-fold: pave the way for high energy savings in each retrofit and in operation, and for increased rates of energy-efficient retrofit. To achieve these goals, all actors in the complex building value chain with their specific barriers and incentives need to be reached through policy. This requires a well-combined set of policies and measures reflecting the national circumstances.

Value chains in the building sector are long and complex. Actors as diverse as property developers, financiers, contractors, building designers and architects, component suppliers, investors, owners and users/tenants all have inherent incentives to improve the energy efficiency of buildings. But they also face strong barriers to take steps for efficient buildings themselves. It is important for governments in each country to analyze the building sector value chains and specific barriers and incentives inherent to each actor before designing and implementing policies for energy-efficient buildings. As described above, these policies are needed to correct market distortions and reduce transaction costs for actors to access the information about available technologies and solutions for energy efficiency. A governance framework is required to provide an overarching structure to co-ordinate and implement energy efficiency policies and measures and manage their inter-relationships. Experience from advanced countries and an analysis of market barriers show that several instruments will need to interact and reinforce each other in a comprehensive policy package. Every policy or measure has its own function in the package, its advantages, target groups and specific operational mechanisms. Each is tailored to overcome one or a few certain market barriers and to strengthen the actor-specific incentives, but none can address all of these barriers and incentives. Therefore, the impact of well-combined policies is often larger than the sum of the individual expected impact (IEA 2005).

Different policies addressing the demand- and supply-side actors of markets should be properly combined according to national circumstances. This does not mean that governments seeking to improve the energy efficiency have to implement all possible policies in order to be successful, but they should combine a selection of instruments tackling the most important market barriers. As successful countries have demonstrated, a comprehensive and coherent policy package for energy efficiency in buildings will usually provide a sound balance between clear mandatory measures, incentives, information and capacity building or in other words, 'the sticks, the carrots, and the tambourines'.

Following the bigEE approach, the set of specific policies and measures for energy efficiency in buildings and the common governance framework policies needed to guide and enable the former are distinguished (Figure 17).

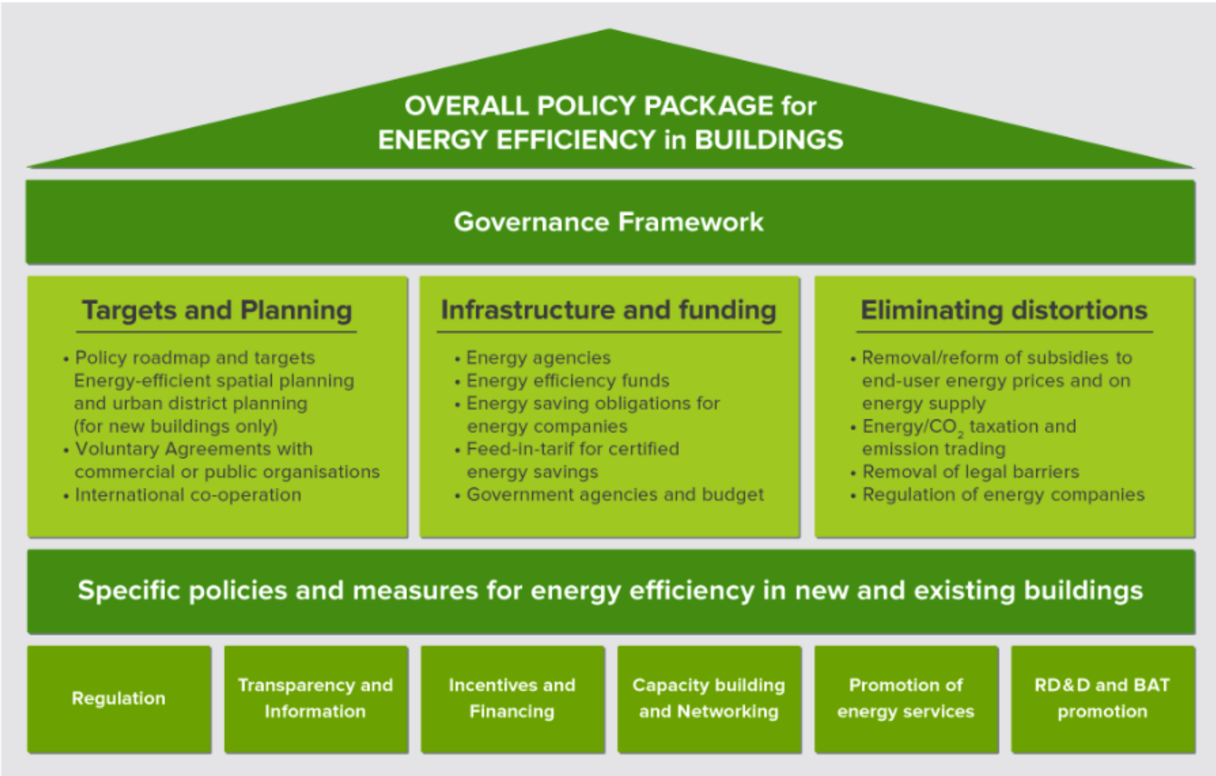


Figure 17 The bigEE recommended policy package

(Source: Wuppertal Institute 2013)

8.4.1 Interaction between building-specific elements of policy package

To achieve the goal of making **Ultra-Low-Energy Buildings (ULEB) the mainstream standard in new buildings,** a variety of policy instruments need to be combined and implemented as a package (Figure 18):

- Mandatory **minimum energy performance standards (MEPS)** for all new buildings (and building components where useful) are the most important policy for energy efficiency in new buildings. They should be created by law and then strengthened step by step every three to five years, to finally require energy efficiency levels equivalent to ULEB. MEPS reduce transaction costs as well as the landlord-tenant and developer-buyer dilemma by removing the least energy-efficient building practices and concepts from the market.

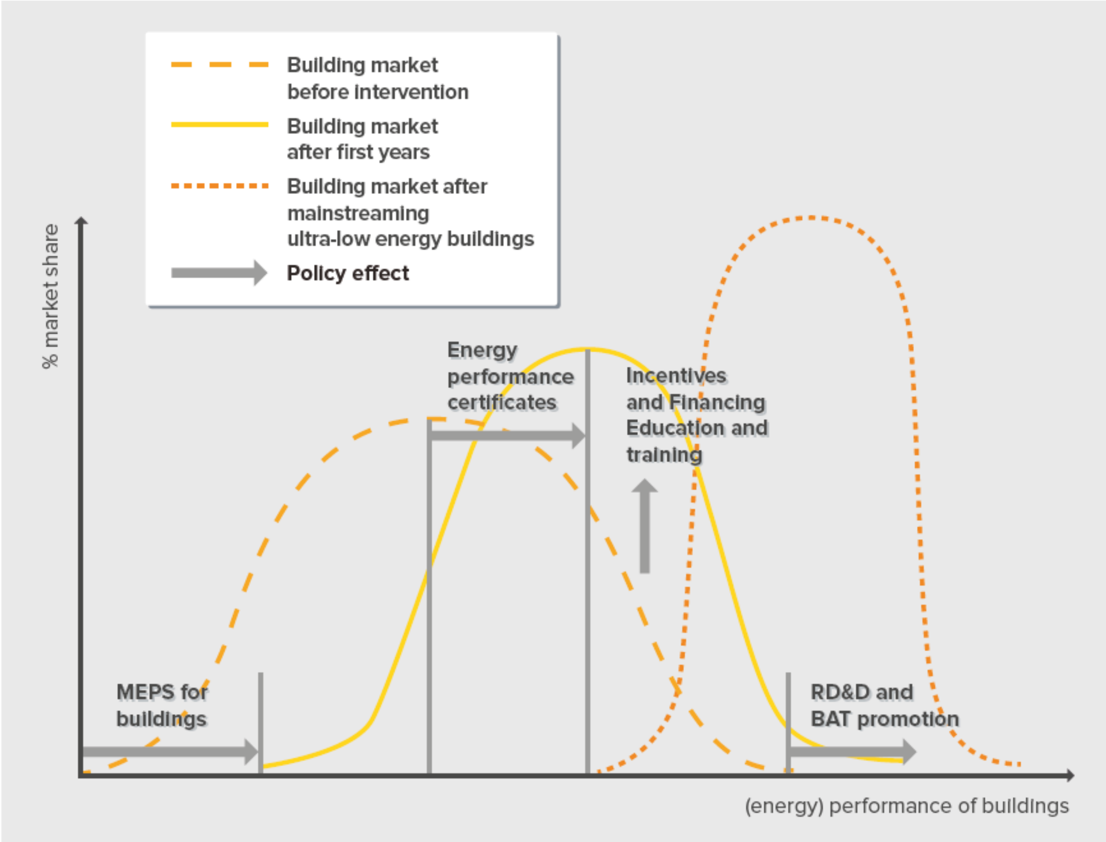


Figure 18 The interactions of policy instruments for energy efficiency in new buildings

(Source: Wuppertal Institute (2012), adapted from Klinckenberg Consultants (2006))

They should, however, always be at least as stringent as the energy performance level leading to least life-cycle costs. In order to be effective, compliance with MEPS must be controlled at the local level in both the design stage and after construction. In a transition period before a law can make MEPS mandatory, a voluntary standard may help. Preferably, **other statutory requirements** such as individual metering, energy management for larger buildings and building portfolios, or regular inspections of heating, ventilation, and air conditioning systems would complement the legal framework.

- **Education and training** of building professionals (architects, planners, developers, builders, building and installation contractors, financiers and other relevant market actors) is essential to prepare introduction and further strengthening of MEPS regulation up to ULEB. Easy-to-use tools for energy-efficient building design and for life-cycle cost calculation are important for the training. **Certification** of successful participation to the training can make it more attractive for both the qualified market actors and their customers.
- The markets should, furthermore, be prepared for the next step(s) of MEPS regulation towards ULEB through policies tackling the substantial information deficits and financing barriers. These include building **energy performance certificates** (and energy labels for components where useful), **showcasing** of demonstrated good practice

buildings, **advice** and **financing support** for investors, and **financial incentives** – such as grants and tax incentives – for broad market introduction of ULEB. It is mainly for such information and financial programmes that energy efficiency funds or energy companies must contribute.
Promotion of energy services for energy savings and voluntary agreements with large developers to build more energy-efficiently than required by MEPS may also support market breakthrough.

- Once a certain market share of (Ultra-) Low-Energy Buildings of a specific energy performance level is reached, the professionals are trained and used to the required practices, and the cost-effectiveness of this energy performance level step is proven, this level can then be mandated by the regulation to become the new MEPS level. This would be one step of MEPS regulation towards ULEB in new build.
- Future steps of MEPS regulation towards ULEB should be prepared by innovation support through **R&D funding, demonstration** (including in public buildings), **award competitions**, and maybe also already by financial incentives for broad market introduction. The **public sector** should **lead by example** through energy-efficient public procurement and ambitious targets for its own buildings, thereby paving the way for the other sectors to follow.

The **existing building stock** provides larger potential for cost-effective energy savings than new construction. It is also the bigger challenge to retrofit the walls, roofs, windows, and heating and cooling systems of existing buildings to highest energy performance levels in an integrated way. The operational goal for energy efficiency in existing buildings thus has two dimensions:

- Achieving very energy-efficient and comprehensive, "deep" retrofits whenever a building is renovated, and
- increasing the rate at which buildings undergo such "deep" energetic renovations.

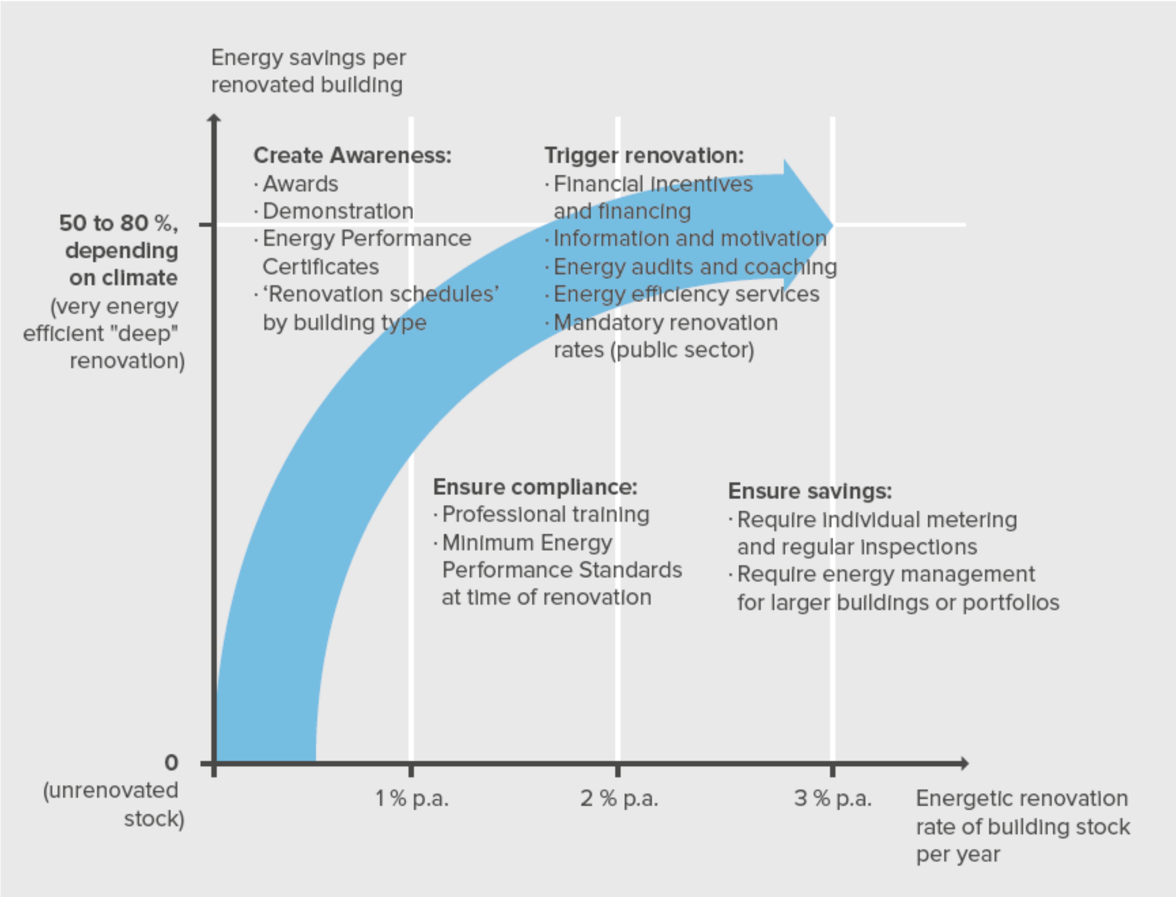


Figure 19 and the following text present the recommended combination of policy instruments for achieving this two-dimensional goal.

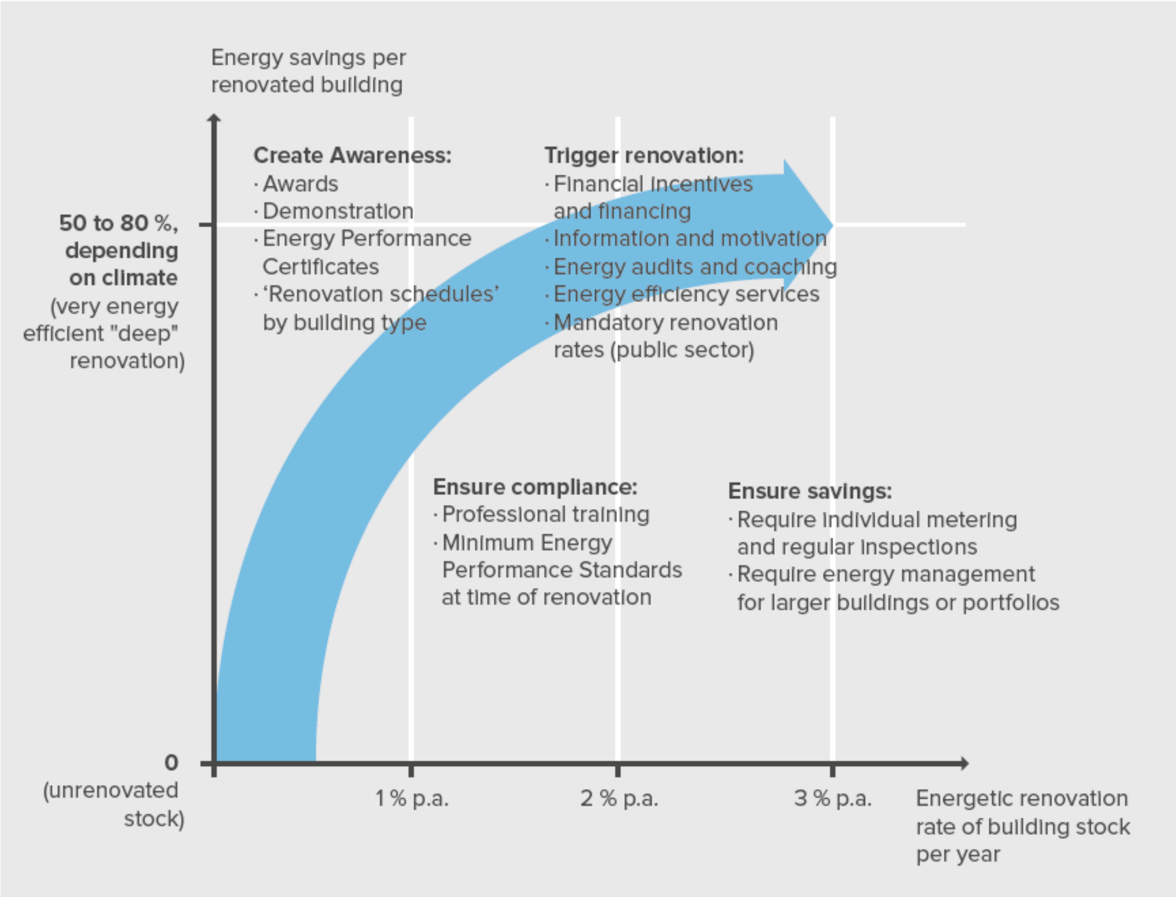


Figure 19 The interactions of policy instruments for energy efficiency in building renovation and operation (Source: Wuppertal Institute 2012)

Every year, many existing buildings undergo renovation for maintenance or beautification anyway. These opportunities should be harnessed to improve energy efficiency by adding thermal insulation or shading and using more energy-efficient windows, heating, and cooling systems, instead of just replacing paint, tyles, or windows as they were before. The reason for this recommendation is that it is very often cost-effective to add the incremental energy efficiency investment at the time of renovation but not cost-effective to repay the full renovation cost from energy savings. Renovation without improving energy efficiency therefore means a lost opportunity and will likely lock in high energy consumption until the next renovation.

- Mandatory **minimum energy performance standards (MEPS)** for existing buildings undergoing major renovation (e.g. more than 10 or 20% of the building shell or of the walls, windows, or roofs) as well as for building components and heating and cooling systems are therefore an important policy for *energy efficiency in existing buildings, too*. They should be created by law and then strengthened step by step every three to five years, to finally require energy efficiency levels equivalent or close to ULEB also for existing buildings when the technology is mature and cost-effective enough. MEPS reduce transaction costs as well as the landlord-tenant and seller-buyer dilemma by removing the least energy-efficient building practices and components from the market. They should, however, always be at least as stringent as the energy performance level leading to least life-cycle costs. In order to be effective, compliance with MEPS must be controlled at the local level in cases of major renovation. In a transition period before a law can make MEPS mandatory, a voluntary standard may help. However, for existing buildings it is much more important to accompany MEPS with individual advice as well as financial incentives or financing for meeting the MEPS requirements, since otherwise building owners may wait with major renovation. A possibility may be to mandate the rate at which the portfolio of large building owners has to undergo energy-efficient renovation each year, as the European Union has recently decided for national government buildings in its Member States.

- Preferably, **other statutory requirements** such as individual metering, energy management for larger buildings and building portfolios, or regular inspections of heating, ventilation, and air conditioning systems would complement the legal framework to ensure energy-efficient operation of buildings.
- The most important policies and measures for energy efficiency in existing buildings are those tackling the substantial information deficits and financing barriers, in order to first move markets towards very energy-efficient retrofit levels („deep renovation") and then to trigger energy-efficient renovation at all, to increase retrofit rates.
  These instruments include building **energy performance certificates** (and energy labels for components where useful) with mandatory display upon advertisement, rental or sale, **showcasing** of demonstrated good practice building renovations, and **award competitions** for very energy-efficient renovations, combined with **information and motivation programmes** to disseminate the results, to raise awareness for energy efficiency opportunities in renovation and to develop more energy-efficient and cost-effective technologies and concepts for building renovation. In addition to these instruments, **individual advice**, such as **energy audits** need to show building owners what they (or their tenants) can save and what is cost-effective, and **coaching** can be essential to assist investors in implementing the retrofits. Still, due to long pay-back times and/or lack of finance, **financing support** for investors, and **financial incentives** – such as grants and tax incentives – for broad market breakthrough of very energy-efficient retrofits. It is mainly for such information and financial programmes that energy efficiency funds or energy companies must contribute. Promotion of **energy efficiency services** for guaranteed energy savings and voluntary agreements with large developers to renovate energy-efficiently at an increased rate may also support market breakthrough.
  Only all of these instruments together are likely to achieve the double goal of very energy-efficient retrofits at increased rates.
- In addition, there must also be a sufficient number of skilled providers willing and able to perform the energy-efficient renovation tasks. **Education and training** of building professionals (architects, planners, portfolio managers, builders, building and installation contractors, financiers and other relevant market actors) is essential *to increase renovation rates and ensure high quality and very energy-efficient retrofit.* Easy-to-use **tools** for energy-efficient building design and for life-cycle cost calculation are important for the training. **Certification** of successful participation to the training can make it more attractive for both the qualified market actors and their customers.

- Once a certain market share of retrofits to a specific energy performance level is reached, the professionals are trained and used to the required practices, and the cost-effectiveness of this energy performance level step is proven, this level can then be mandated by the regulation to become the new MEPS level for major renovations. This would be *one step of MEPS regulation* towards energy efficiency levels equivalent or close to ULEB in existing buildings.
- Future steps of MEPS regulation towards energy efficiency levels equivalent or close to ULEB should be prepared by innovation support through **R&D funding, demonstration** (including in public buildings), **award competitions**, and maybe also already by financial incentives for broad market introduction. The **public sector** should **lead by example** through very energy-efficient renovations and ambitious energy savings targets for its own buildings, thereby paving the way for the other sectors to follow.

8.4.2 The components of the recommended policy package

A single policy cannot address all market barriers; rather it will address only those barriers for which it is created. A combination of policies in a policy package is therefore recommended to target different market actors and the respective barriers. A comprehensive policy package approach will provide a balance between clear mandatory measures, incentives, information and capacity building – "the sticks, the carrots, and the tambourines".

8.4.2.1 Overall governance framework for energy efficiency

As described in the previous chapter, the different policies addressing supply and demand side actors of the market need to be combined in a policy package in order to tackle the most important market barriers. Figure 20 outlines the basic components of bigEE recommended policy package: As a framework, clear vision and targets for energy efficiency need to be established at the highest government level. This should be accompanied by allocating finance and resources for implementation of sectoral policies and addressing market imperfections simultaneously. At the sector-specific level, policy instruments such as regulations, incentives and financing and capacity building are important components of a comprehensive policy package for energy efficiency in buildings.

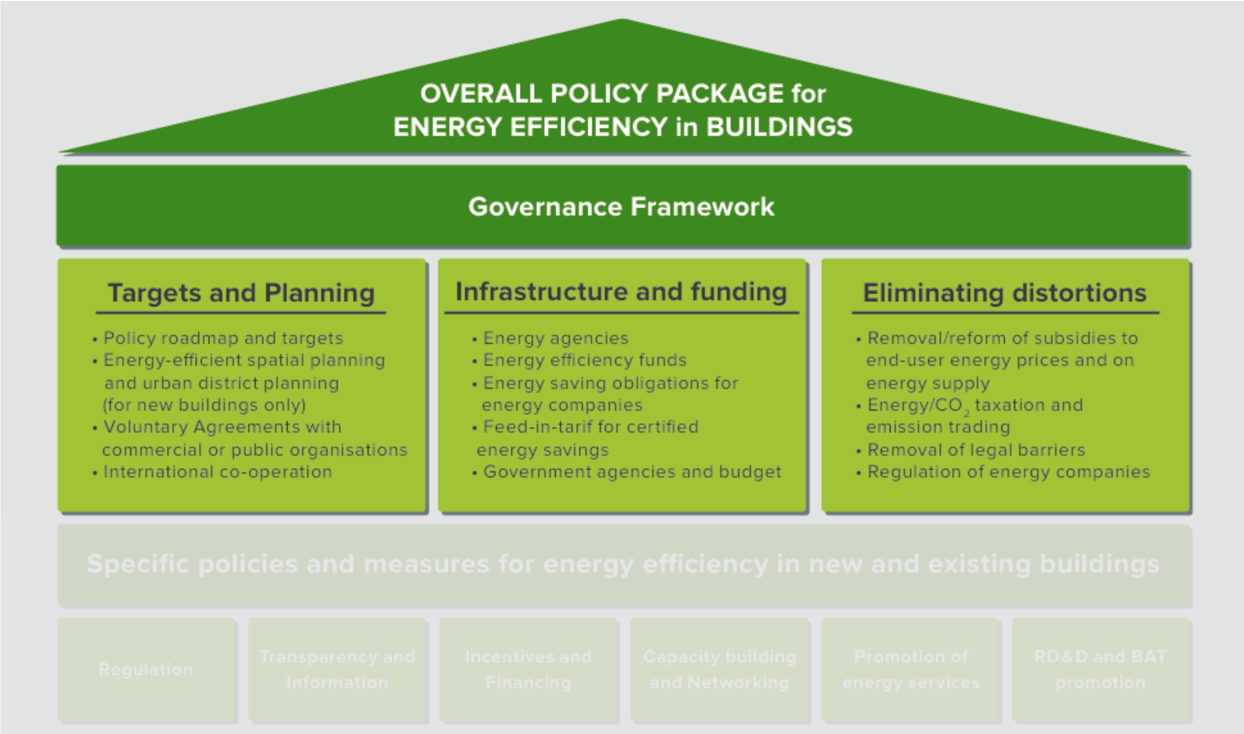


Figure 20 The bigEE recommended policy package: Governance Framework

(Source: Wuppertal Institute 2013)

In the bigEE recommended policy packages, the general governance framework serves to guide and enable implementation of the sector-specific policies, as well as to remove price distortions in energy markets that would make energy efficiency improvements appear less cost-effective than they are.

Energy efficiency targets and planning

- **Policy roadmap and targets for Ultra-Low-Energy Buildings**
  A clear political commitment to energy efficiency is the necessary basis for long-term investment decisions in the construction industry and building market. It will provide a reliable planning framework for market actors and will reduce investment risk for investors and suppliers of energy-efficient buildings and technologies. To make such a commitment credible, it is crucial to set ambitious, yet achievable energy saving targets and to develop comprehensive medium- to long-term strategies towards eventually making Ultra-Low-Energy Buildings (ULEB), the standard both in new build and retrofit (e.g. a long-term policy roadmap and short-term plans for developing advanced buildings and the related technologies, the market skills, and the MEPS, towards very low energy levels). Ideally, the roadmap and targets should be made statutory through an energy efficiency law, including provisions for a stable funding for energy efficiency policy.
- **Energy-efficient spatial planning and urban district planning**

Including energy efficiency considerations in spatial planning and urban district planning is an important means to harness the easy energy savings possible and reduce primary energy consumption through early design decisions such as for siting and microclimate, building form and orientation, integration of energy-efficient cogeneration of heat and power and/or renewable energy supply, etc. Apart from the energy used in buildings, these planning processes are highly relevant for reducing transport needs and optimising ways of transport, with their associated energy demand.

- **Voluntary Agreements with commercial or public organisations**
  Voluntary Agreements (VAs) on energy efficiency targets and actions can be concluded by the government with commercial or public organisations (e.g. developers, housing companies, local authorities). The organisations commit to reaching energy efficiency targets and or to implementing energy efficiency actions, e.g. retrofitting their building stocks or investing only in (very) energy-efficient new buildings. VAs can thus be a complement to regulations, e.g. for promoting higher energy efficiency levels than mandated by law. In order to make such agreements effective, they must include rules for independent monitoring and impose stringent penalties in case of non-compliance.
- **International co-operation**
  Countries can co-operate in many ways to learn from each others' experience in policymaking and policy success. The opportunities for international co-operation are diverse. For example, countries can jointly develop energy performance standards for buildings and equipment so as to create regional markets with higher volumes and economies of scale. Furthermore they can jointly develop test procedures for the energy consumption and create harmonised energy labels. Countries can also co-operate in professional training and in the development and application of evaluation methods for energy savings, costs, and benefits.

Energy efficiency infrastructure and funding

- **Energy agencies**
  For greater effectiveness of their energy efficiency policy, governments are likely to need an energy agency. Tasks of energy agencies typically include the co-ordination of policies and implementing parts of the policy package, such as provision of information and initial advice, initial energy audits, promotional activities, education, training, dissemination, co-ordination of energy efficiency projects and programmes, demonstration activities, network-building between market actors, awareness raising, and organising campaigns.
- **Energy efficiency funds**
  Energy efficiency funds are special entities founded and funded by the state for organisation and funding of energy efficiency programmes. These programmes typically combine information, motivation, financial incentives and or financing, capacity building, and RD&D/BAT promotion. Energy efficiency funds (or trusts) can implement such programmes as an alternative to, but also jointly with energy companies or the government itself.

Energy efficiency funds or trusts may be given greater flexibility in implementing energy efficiency programmes than government agencies, and may receive a stable funding by creating dedicated levies or taxes on energy to feed the fund or trust.

Several successful examples around the world show that energy efficiency funds can achieve gross energy savings equivalent to 2% per year and more of the target groups' energy consumption, of which up to 1.5% per year are additional to baseline trends of energy efficiency. Usually, these energy savings are cost-effective for consumers and society.

- **Energy saving obligations for energy companies**

  Energy supply and or distribution system operator companies can be mandated by law to save a certain amount of end-use energy (i.e. on the demand side, with their customers) and prove achievement of that target.

  The energy companies thus receive both the responsibility and the right of cost recovery for the organisation and funding of energy efficiency programmes. These programmes typically combine information, motivation, financial incentives and or financing, capacity building, and RD&D/BAT promotion. Energy companies can implement such programmes as an alternative to, but also jointly with an energy efficiency fund or trust, or the government itself.

  A potential but weaker alternative to a legal obligation could be voluntary agreements with energy supply, transmission or distribution companies to achieve a certain amount of energy savings.

  The most successful countries achieve gross energy savings equivalent to around 2% per year and more of the target groups' energy consumption through energy saving obligations.

  Up to 1.5% per year of these savings are additional to the baseline trends of energy efficiency. Usually, these energy savings are cost-effective for consumers and society.

- **Feed-in-tariff for certified energy savings**

  Feed-in-tariffs (FiTs) have already been implemented in the field of electricity generated from renewable energies in many countries. In a similar way, a country could also offer providers of standard energy efficiency programmes a fixed remuneration for every certified unit of energy saved. It could be an alternative to energy saving obligations for energy companies that creates more competition in the energy efficiency market.

  No countries have implemented energy efficiency FiTs yet. However, similar approaches, such as competitive bidding or standard offer schemes for capacity (not energy) saved through load management or energy efficiency, have been realised in a number of countries.

- **Government agencies and budget**

  The traditional way is that integrated energy efficiency programmes with financial incentives, information and individual advice are managed by existing government agencies and funded from the public budget. The advantage over other mechanisms is the direct implementation and budget control by government and parliament. Experience shows, however, that (1) appropriations for programmes in the government's budget are more subject to cuts and fluctuations or even "stop and go" effects than energy efficiency funds created via special levies or than targets under energy efficiency obligations and that (2) government agencies are often less flexible than energy efficiency funds and trusts or energy companies in the measures they can take to support consumers and market actors.

Eliminating distortions

- **Removal/reduction of subsidies on end-user energy prices and on energy supply**
  Energy prices should 'tell the economic and ecological truth' through full-cost pricing or the internalisation of external effects in order to discourage wasteful consumption of environ- mental resources. Therefore, existing inefficient subsidies for non-renewable energy production or on energy prices should gradually be removed – legislators and governments should rather use the budget saved to fund energy efficiency schemes for low-income households and small businesses, so as to keep their energy bills affordable instead of maintaining energy prices at artificially low rates.
- **Energy/CO2 taxation and emissions trading**
  Energy prices should 'tell the economic and ecological truth'. Consequently, energy or CO2 taxes, or an emissions trading system, should be introduced to internalise the external costs of environmental damage and threats to health into the final energy prices. By means of sending out the "right" price signal to market actors, both instruments – taxation and emission trading – improve financial gains from more energy-efficient behaviour and/or encourage energy efficiency investments. Revenue generated can be used to further increase the attractive- ness of energy-efficient solutions by means of providing information and/or easily accessible funding opportunities, grants, or tax credits.
- **Removal of legal barriers (if they exist)**
  Sometimes, law prohibits energy-efficient solutions. Examples could be the prescription of low maximum air temperatures, e.g. 20 °C, during hot days in offices or schools, or of minimum ventilation rates even if nobody or few people are in the room, or the prohibition of solar water heaters on the roofs of historic buildings. Such legal barriers to solutions that can save a lot of energy should be re-examined and if possible removed. However, no further general recommendations can be given, since such legislation is highly country-specific.
- **Regulation of energy companies**
  Regulation authorities should determine the allowed revenues of energy companies that are either natural monopolies (mainly grid companies) or are granted a monopoly of supply, such that they earn more by improving their customers' end-use energy efficiency and not by in- creased energy consumption. To this end, one important element is cost recovery for energy efficiency programmes that reduce customers' energy bills. Just as important an element is that annual revenues allowed by the regulator to the companies should not, or only to a very small extent, be based on the volume of energy or power sold or transported. By contrast, regulators should

mandate that energy bills to final consumers should depend on the volume of energy or power delivered as much as possible. This will provide an adequate incentive to save energy or power.

8.4.2.2 Specific policies and measures

A comprehensive sector-specific policy package needs to be designed and implemented within the conditions of the overall governance framework (Figure 21). A combination of specific policy instruments is needed: They range from regulations (e.g. Minimum energy performance standards), information instruments (e.g. building energy labels), monetary incentives or financing (e.g. tax benefits), capacity building (education and training programmes for relevant market actors), promoting energy services (e.g. private advice and support services for energy savings), research and development and demonstration (RD&D) and Best Available Technology (BAT) promotion (e.g. R&D funding and award competitions). These specific policies and measures are explained in Table 5. Priority elements are highlighted.

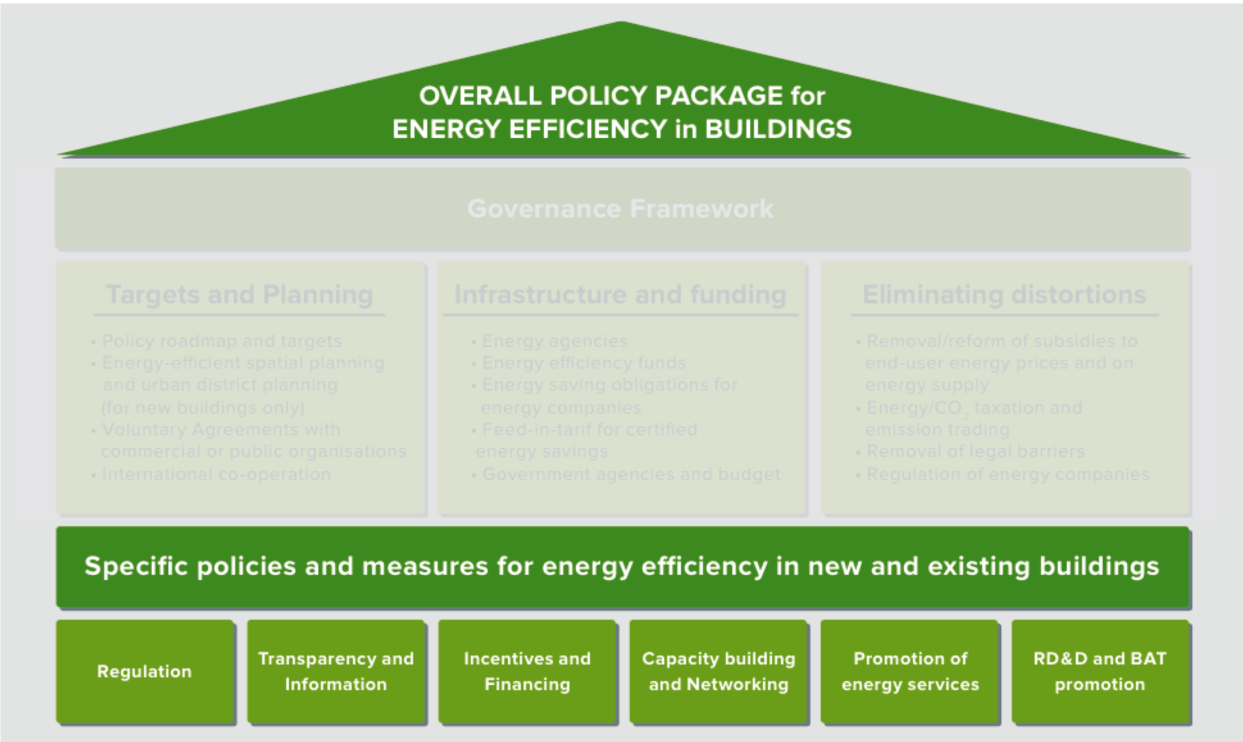


Figure 21 The bigEE recommended policy package: Specific policies and measures for energy efficiency in new and existing buildings.

Source: Wuppertal Institute 2013

Regulation

- **Minimum energy performance standards (MEPS) for buildings and equipment***

  By setting an upper limit for the allowed energy consumption of a building, Minimum energy performance standards (MEPS; also known as energy building codes or regulations) are used to exclude at least the most inefficient building concepts and technologies from the market. They are most important for new build but should also apply to major retrofits of existing buildings. While MEPS, at cost-effective levels, should be made compulsory by law, higher standards up to Zero Energy Buildings can first be established on a voluntary basis. MEPS should then be tightened step by step every three to five years, until after 10 to 15 years very low energy levels have been reached. Advanced countries have already achieved energy savings of 50 to 75% in today's new buildings as compared to conventional building practices of the past. An effective control and enforcement regime is essential to ensure compliance with the standards.

- **Other legal requirements**

  In addition to MEPS, a number of further legal requirements have a positive impact on the overall energy consumption of a building, either on their own or in enhancing other policy instruments in their impact to reduce energy use. For example, individual metering is an important feedback measure for occupiers of multi-unit buildings that may induce more energy-efficient user behaviour. Likewise, the requirement of appointing energy managers, regular inspections or building energy efficiency commissioning will help to detect incorrect installations or operational settings of energy systems and to frequently check energy-intensive building equipment (e.g. boilers, ventilation or air-conditioning systems).

- **Revision of landlord and tenant laws**

  Legislation that allows landlords to fully or partially recoup the costs for energy efficiency improvements of existing buildings or of energy-efficient vs. conventional new buildings from the tenants can help overcome the landlord-tenant dilemma. Rent increases must not exceed the energy cost savings the tenants can achieve, though. We further recommend mandating that rent plus energy costs must be disclosed to potential tenants, but that rent and energy costs must be charged separately.

Transparency and Information

- **Mandatory Energy Performance Certificates (EPCs) and equipment labels**

  Energy performance certification – sometimes also referred to as building energy labelling – aims to inform prospective buyers or tenants about the level of energy efficiency of a particular building compared to other buildings of the same kind. Energy performance certificates (EPCs) display the results of a professional assessment of a building's energy performance (also known as building energy rating), thus making energy use visible and raising awareness about energy saving potentials. The availability of EPCs to prospective buyers or tenants should be mandatory to enhance market transparency. Consequently, EPCs are an important means for establishing energy performance as a relevant purchasing, rental or investment criterion and can thus increase the demand for, and supply of, low-energy buildings.

- **Energy advice and assistance during design and construction**
  Energy advisers and consultants are essential to inform home-builders and investors about energy efficiency and its benefits in general but also to help them identify concrete energy saving opportunities, assess the related costs and benefits, and ultimately take adequate action. Policy should ensure free basic advice and consider providing grants for consultancy to stimulate demand for it. Policy should also support advice to investors to find qualified architects, engineers, contractors, and certified surveyors for quality control including compliance with energy efficiency standards and requirements of financial incentive and financing programmes.
- **Energy audits and advice and assistance during retrofit**
  For existing buildings, individual advice is essential to help building owners identify concrete energy saving opportunities and to assess the related costs and benefits. Building owners need to understand these to be convinced to take action for improving energy efficiency at all, and for maximising benefits and avoiding mistakes when they invest. Policy should hence ensure there is free basic advice and consider providing grants for comprehensive energy audits and consultancy to stimulate demand for them. Policy should also support advice to investors to find qualified architects, engineers, contractors, and certified surveyors for ensuring quality control, including compliance with energy efficiency standards and requirements of financial incentive and financing programmes.
- **Provision of information**
  Informing investors and end-users about energy saving opportunities, both in new build and in retrofit, and the achievable cost savings and other benefits, as well as about assistance available through other policies and services, will enable decision-makers to make more informed choices and improve uptake of energy efficiency options.
  Important instruments for providing information are, for instance, information centres, demonstration buildings, information campaigns, websites, and calculation tools.
- **Feedback and measures on behaviour**
  Feedback measures will increase end users' awareness and transparency about their own levels of energy consumption. Combined with emphasis on the impact of user behaviour on the energy performance of a building, feedback measures can motivate users to change their behaviour, but also to invest in energy saving technologies. Feedback was shown to be more effective when social marketing techniques, normative messages and similar measures targeting behaviour change were applied.
  Important instruments for providing feedback on energy consumption levels are, for instance, individual metering, smart metering, and informative/comparative billing.
  Other measures targeting user behaviour include, e.g. prompts, motivation campaigns for behaviour change, energy saving competitions, and training of building users on energy-intelligent use of lighting, ventilation, heating, cooling, windows, and appliances.
  Experiences in many countries, including recent reviews on feedback programmes in the USA and Canada, show electricity and fuel savings in the range of 5% to 15%.

Feedback and other measures often need to be continued or repeated to secure such savings.

Incentives and financing

- **Financial incentives for ULEB and deep retrofits**

  Investors will evaluate costs and benefits of an investment in Low-Energy Buildings (LEBs), in Ultra-Low-Energy Buildings (ULEBs) or in very energy-efficient ('deep') retrofits to (U)LEB. Other investors may not even be aware of the possibility of improving energy efficiency. In order both to increase awareness of the benefits of energy efficiency and to improve the benefit-to- cost ratio and thus foster decisions in favour of constructing ULEBs or deep energy-efficient retrofits, financial incentives may be powerful instruments. They can make an important contribution to accelerating the market penetration of (U)LEBs and energy-efficient retrofitting as well as certain energy efficiency technologies or services with a better energy efficiency than required by Minimum Energy Performance Standards (MEPS). As a result, they help prepare markets for the next steps in strengthening MEPS towards higher energy efficiency levels for both new buildings and for retrofitting existing buildings.

  Examples of financial incentives include: direct grants, tax incentives, or indirect incentives (e.g. granting larger floor area, higher density, or expedited building permits). The choice will depend on national circumstances.

  Experience with many successful financial incentive programmes for improved energy efficiency in the building sector exists, but only a few examples have targeted ULEBs and deep retrofitting so far. Some Austrian provinces have already achieved more than 50% of ULEBs in new build through policy packages including financial incentives as an essential component. In Germany, the KfW programmes have been successful in promoting renovation of existing buildings to LEBs.

- **Financing**

  Financing instruments target the barrier of insufficient availability of, or access to, capital for financing the incremental up-front costs of energy-efficient buildings or retrofits. Scaling up investment in energy efficiency is crucial to achieve a sustainable energy future. Among the vast variety of different financing schemes, preferential loans, revolving energy efficiency funds or government-facilitated third party financing schemes (e.g. on-the-bill or property tax financing) are exemplary and suitable public policy responses to address the existing financing gap and to foster private investment.

Capacity building and networking

- **Education and training**

  Capacity building measures for workforce in the construction sector (architects, planners, developers, building contractors, installation contractors, facility managers, real estate agents and other intermediaries) aim to provide actors with the relevant knowledge and skills so they:

a) have knowledge on the status-quo of designing, building, retrofitting, operating, monitoring, and assessing Low-Energy Buildings, as well as the corresponding policy framework and market;

b) can correctly and convincingly inform investors, building owners and tenants about the cost-effectiveness and other benefits of such buildings or of energy-efficient retrofits.

Capacity building measures for public administrations responsible for urban development and construction on Low-Energy Buildings enhance their analytic capabilities required to develop effective policies on low energy building and to assess project feasibility.

There is also a need to educate the general public on energy efficiency and its benefits, and thus increase demand for energy-efficient solutions.

- **Certification of qualified actors**

  Certification of the qualification level of supply chain actors such as architects, energy or engineering consultants, energy service companies, and installation contractors, regarding energy-efficient design, building analysis, construction, or installation both increases their incentives to undergo training (because they will benefit from improved credibility among potential customers) and helps investors in their search for properly skilled and trustworthy service providers.

- **Energy efficiency clusters/networks**

  Networks such as local networks on Low-Energy Buildings and energy-efficient refurbishment or energy efficiency clusters of small and medium companies (SMEs) can link relevant actors and promote exchange of experiences and good practices. They are also instrumental for co-ordinating marketing, information and motivation, and professional training activities at the local or regional level.

- **Promotion of energy services for energy savings**

  Building owners or investors often lack the required capital and expertise and are afraid of technical and financial risks involved in improving energy efficiency. In such cases they can outsource the financing and implementation of energy efficiency investments to third parties, such as energy service companies (ESCOs) and private or public energy companies. This is more common for energy-efficient retrofits but could also be explored for new construction projects.

  Such an innovative service, however, faces its own barriers to market adoption. We therefore recommend that governments promote and support energy services such as energy performance contracting or third-party financing schemes and adopt for instance the following general measures for this purpose: providing targeted information and coaching to potential energy services customers, capacity building, standardised models and contracts, regulations such as the establishment of quality standards and certification schemes for energy service providers, facilitating energy service provider's access to financing and creating risk-mitigating measures, creating a favourable framework condition for energy service providers' involvement in public procurement, encouraging the establishment of an association of energy service providers and SuperESCOs.

RD&D and BAT promotion

- **Funding for research, development and demonstration (RD&D) projects**
  Through promotion of research and development activities as well as demonstration pro- jects (RD&D), innovations in terms of technologies and design concepts are fostered. RD&D is critical to drive the development of innovative building concepts, such as Low-Energy Buildings, Ultra-Low-Energy Buildings, and nearly Zero Energy or Plus-Energy Buildings, both in new build and retrofit, as well as the related technologies. This will contribute to mid-term and longer-term policy goals and help ensure that energy-efficient building concepts and technologies are ready for commercialisation in time. RD&D funding is a key driver for innovative ideas, assists the accelerated market introduction, and reduces the incremental costs of energy-efficient solutions. However, market breakthrough is often hindered by a plethora of market barriers and is thus likely to need further policy support. Through a coherent RD&D policy, governments can further capacity building of comprehensive national scientific and technological research institutions on energy efficiency (GTZ et al. 2006).
- **Public sector programmes**
  The public sector should lead by example. It can, thereby, also create first markets for energy- efficient building concepts and technologies.
  a) 'Lead by example' programmes in the public sector to 'deeply' retrofit existing buildings to very low energy consumption levels and to only build (ultra) low-energy buildings (as public buildings, in social housing, etc.):
  In addition to saving energy and reducing public expenditure, such programmes also raise awareness and investor confidence about the benefits of Low-Energy Buildings and retrofits and demonstrate cost-effectiveness. They also directly provide a market to suppliers of energy-efficient buildings and retrofits.
  b) Public procurement requiring very energy-efficient building technologies: The resulting demand volumes can increase market penetration and reduce market prices for these technologies. This, in turn, will lead to these technologies being used more often and eventually becoming the default technology in new construction and retrofit.
- **Bulk purchasing and co-operative procurement**
  Bulk purchasing and co-operative procurement works through gathering large buyers (private and public). It is useful for promoting very energy-efficient building technologies already avail- able on the market (BAT) or new, even more energy-efficient equipment ('technology procurement'). The resulting demand volumes can induce manufacturers to develop, produce and market these technologies and equipment, increase market penetration, and reduce market prices for these technologies. This in turn will lead to these technologies being used even more often.
- **Competitions and awards**
  Competitions and awards for exemplary ultra-low energy new buildings or retrofits can be an important means of rewarding frontrunners in energy-efficient design and construction techniques. The publicity gained by developers and architects as well as owners of award-winning buildings means value added in terms of profit and prestige

– this increases their motivation to strive for a very low-energy building to win an award.

The demonstration and the publicity will raise awareness and confidence on the demand side about the feasibility and cost-effectiveness of such new or refurbished buildings.

8.4.2.3 Guideline for designing energy efficiency policies for buildings

Successful policy requires careful planning and design, schemes to ensure compliance, and monitoring and evaluation to learn what works and what can be improved. This section provides some general tips for designing and implementing policies for energy efficiency in buildings and refers to what is good practice.

Based on existing research and empirical evidence bigEE recommends an evolutionary cycle approach to plan, design, implement and evaluate policies. As shown in Figure 22 there are two loops or cycles.

The external clock-wise cycle represents the initial policy-making process that involves:

- Setting up an aggregated energy saving target for the economy,
- Establishing sector-specific targets based on sectoral potential (e.g. quantitative targets for achieving the vision of new Ultra-Low-Energy Buildings),
- Designing a governance framework and providing funding to enable implementation of a comprehensive policy package to address actor-specific barriers and incentives,
- Evaluating policy costs and benefits prior to policy implementation,
- Implementing policy and monitoring how successful the policy is in achieving the saving potential,
- Revising the policy package and targets if needed.

The anti-clock-wise cycle represents two opportunities for reassessing the original policy design:

- The first feedback loop (on the right) facilitates revision of the targets if ex-ante evaluation (evaluation prior to the launch or implementation of policy or measure) projects over-achievement of the target. If underachievement is projected it should trigger further analysis and measures to achieve the desired target.
- The second loop (on the left) indicates the stages where the policy package can be revised, if ex-post evaluation (i.e. evaluation conducted after the policy is implemented and has completed its intended time duration) reveals lower energy savings than required by the policy target.

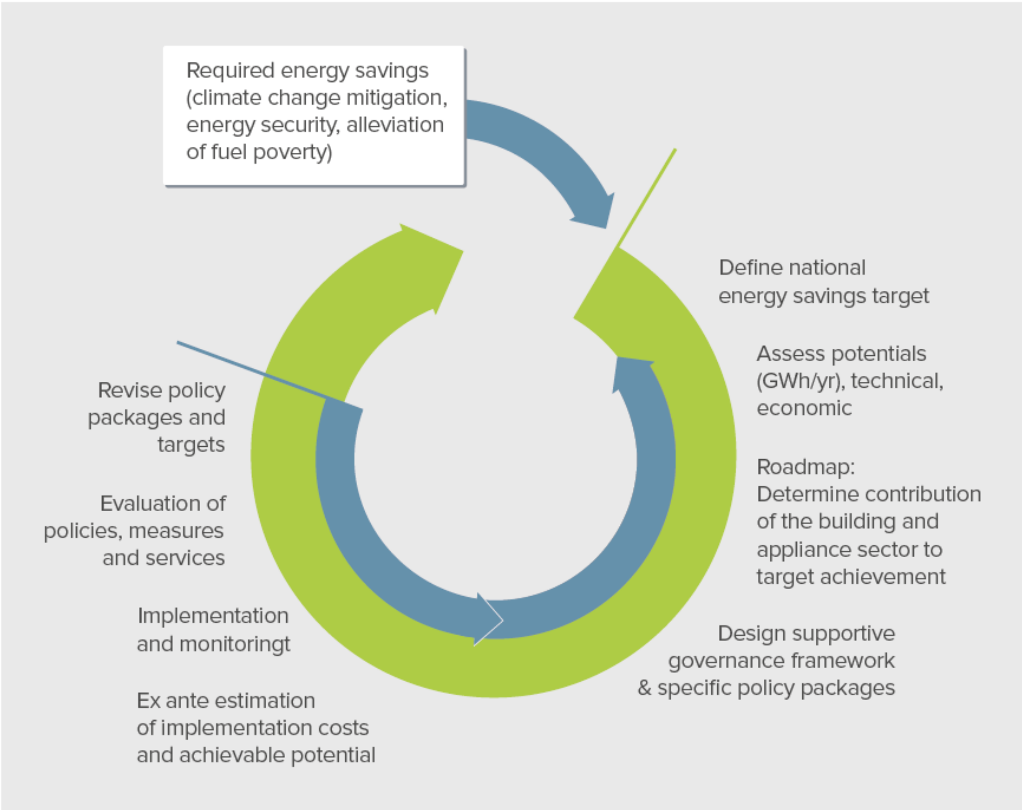


Figure 22 The policy planning, implementation, and learning cycle

(Source: Wuppertal Institute (2012a), adapted from Wuppertal Institute & Ecofys (2009))

8.4.2.4 Some guiding principles

Whatever the policy or measure to be designed or implemented, the following principles are useful to take into account. We recommend a thorough check of these guiding principles before designing and implementing a policy or measure:

- Build confidence in stable framework conditions
- Determine priorities based on status quo analysis
- Involve the market and assess the needs of market actors
- Make goals, instruments, and benefits transparent
- Increase uptake through highlighting co-benefits
- Design policies so as to create market dynamics towards highest levels of energy efficiency, while maximising benefits and minimising negative side effects
- Consider the social dimension
- Take national or local circumstances into account
- Monitor, evaluate and review policies

8.4.2.5 Need to monitor and evaluate policies

Policies and measures should be constantly monitored and thoroughly evaluated on a regular basis. The necessary mechanisms such as reporting requirements and well-defined methods for measuring and verifying results need to be established, and corresponding resources allocated already in the design phase, i.e. before a policy actually enters into force. Monitoring and evaluation (M&E) enables policy managers to demonstrate the programme's progress and its success or failure. M&E activities help to better understand the needs of target groups and to define intermediate objectives that are achievable and measurable.

The main differences between M&E are in the timing and frequency of observations or assessment and in the purpose and questions addressed. The following bullet points illustrate these differences between *ex-ante impact* evaluation, monitoring, *process* evaluation, and *ex-post impact* evaluation (Figure 23).

- **Ex-ante impact evaluation** starts with calculating the economic and technical potentials and assessing how much of the identified potential can be realised by what kind of policy or measure (or policy package).
- **Programme monitoring** will assist project managers in following and controlling the process, in quickly identifying problems and in solving them. The database generated in the monitoring process will be useful both for process and ex-post impact evaluations.
- **Process evaluations** serve to more systematically analyse programme performance at longer intervals than the more continuous monitoring. Unlike monitoring, process evaluations are more credible and often more useful, if done by external evaluators.
- **Ex-post impact evaluation** will show in detail whether a policy or measure has been effective in achieving its targets, e.g. as effective as anticipated in the ex-ante evaluation.

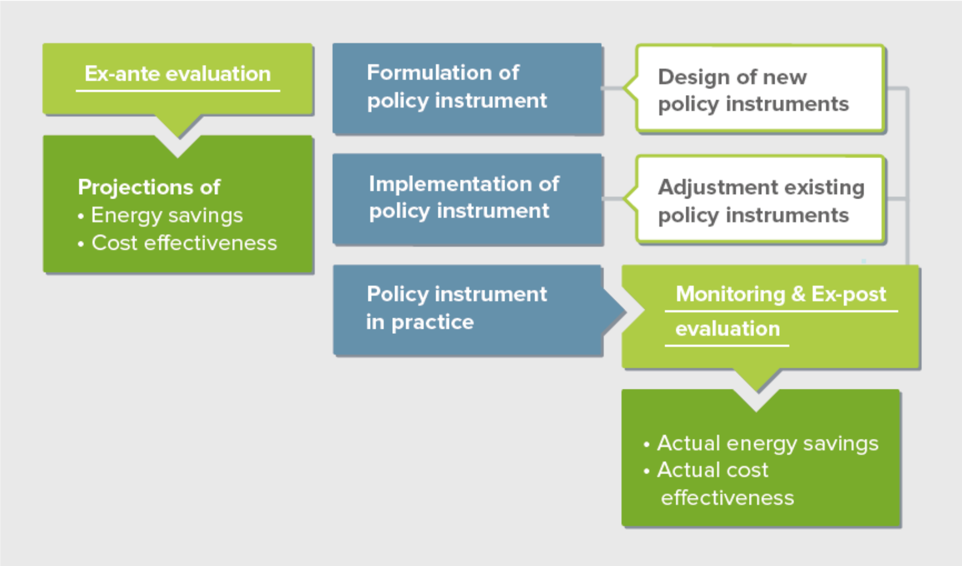


Figure 23 Why evaluation is important

(Source: Wuppertal Institute, 2012a, adapted from Ecofys, 2008)

8.4.2.6 Need to establish compliance and control and enforcement regimes

A missing or incomplete compliance system and sub-optimal monitoring procedures can have a major impact on the overall effectiveness of energy efficiency policies and measures. Badly planned and enforced compliance measures may lead to free-riding and related economic losses. Low rates of compliance will hinder market development and prevent the realisation of the full energy saving potential (IEA & OECD 2008).

8.4.3 Germany as a good practice example of policy packages

Germany's comprehensive policy package, to increase the energy efficiency in new build and the building stock, aims at a 20% reduction in building heat demand by 2020. It consists of fine-tuned single measures such as Minimum Energy Performance Standards (MEPS), a roadmap with near- and long-term goals, financial incentives and preferential loans (to exceed MEPS in new build and to trigger refurbishment), Energy Performance Certificates, individual advice and information platforms for home builders and -owners as well as for non-residential actors, professional training, the promotion of energy services, and various research and demonstration programmes.

Along with many state and local authorities and agencies, the German government-owned development bank KfW and the Germany's energy agency Dena facilitate financial resources and further expertise in order to achieve goals set in the roadmap. The Energy Efficient Refurbishment and Construction Programmes are probably the most well-known single measures, both implemented by the KfW. While the former successfully reduced annual energy consumption by 2,450 GWh (0.4 %) in 2010, the Energy Efficient Construction Programme (and its predecessor) reached annual energy savings of 1,341 GWh between 2006 and 2010.

While the KfW provides financial incentives and preferential loans in order to promote energy efficiency in Germany's building sector, the German Energy Agency Dena describes itself as a "centre of expertise for energy efficiency, renewable energy sources and intelligent energy systems" (Dena NA). Activities implemented by the consumer protection agencies as well as state and local governments and private initiatives complement these central government programmes.

Germany's energy efficiency efforts have been well orchestrated: Based on the EnEV, both the Energy Performance Certificates and an additional seal of quality have been developed, and Dena has developed a certification scheme, the Efficiency House (EH, Effizienzhaus), in order to calculate energy performance of buildings. In order to increase the German refurbishment rate and to make new buildings more efficient than demanded by regulation, the government offers financial incentives for all building sectors (e.g. residential, industrial) via KfW. The KfW makes use of the EH scheme and of the financial support provided by the government for energy audits, carried out by specially trained and certified energy advisors, to determine the EPC and possibly the EH. The better the EH standard, i.e. energy performance of a building after the refurbishment/ construction process, the higher the financial incentives. Information on funding possibilities and opportunities to save energy are most prominently provided through consumer information centres and the special trained energy advisors.
In the long run, by 2050, Germany attempts to reach a building stock that emits close to zero emissions, i.e. new and existing buildings will hardly have an impact on the climate as buildings will have become highly energy efficient, and the little energy still needed will be covered by renewable energies. Moreover, buildings' primary energy demand is to be reduced by 80%. As an intermediate step, the German government has proclaimed that it intends to reduce the heat demand by 20% by 2020 (BMWi & BMU 2010).

According to Power/Zulauf (2011), Germany's energy savings roadmap is based on three pillars: legislation, financial support for energy efficiency and renewable energy, and providing information and advice (Figure 24).

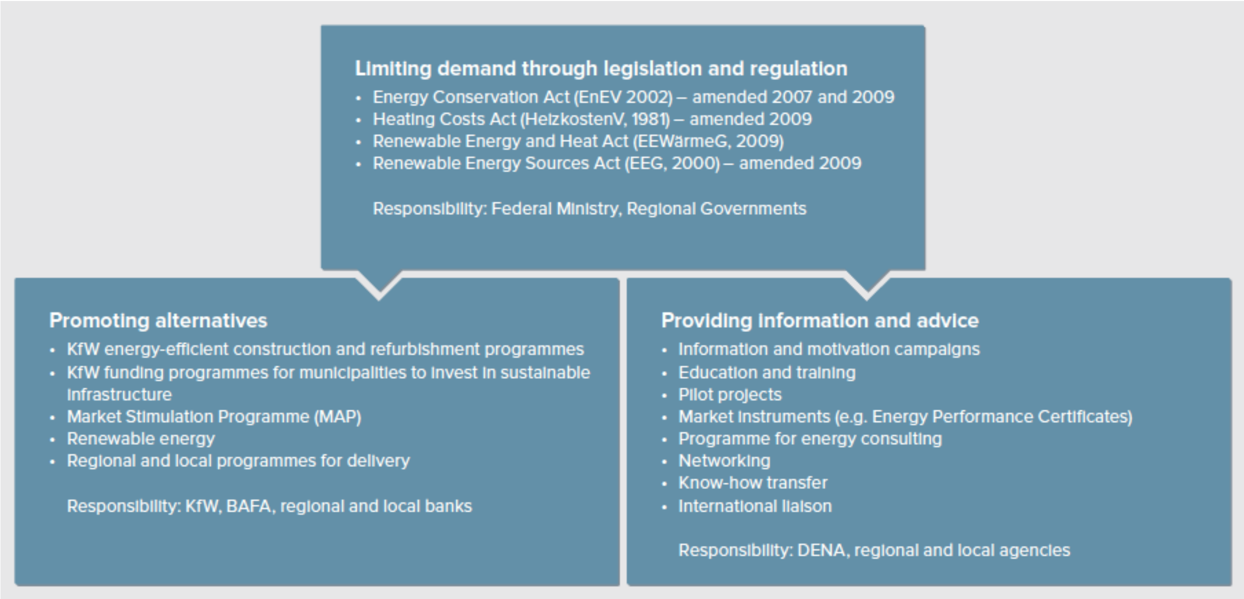


Figure 24 Three pillars of Germany's energy savings roadmap

(Source: Wuppertal Institute, 2012, adapted from Power& Zulauf 2011, p.6)

Germany has established a comprehensive package in order to increase the energy efficiency of its building stock, which consists of 17 million residential buildings with 3.37 billion m^2 (2004) of useful living area, and about 2.5 million non-residential buildings with about 2,213 million m2 of useful area (estimation by BMVBS 2011). The Energy Concept of 2010 clearly stipulates Germany's goal of a 20% reduction in building heat demand by 2020 and an 80% reduction in total building primary energy demand by 2050, while increasing the building refurbishment rate from 1% to 2% in the near term. The latter goal is of major importance in order to reduce building energy demand sustainably, especially because between 70% and 75% of Germany's buildings were built before 1979 when the first Thermal Insulation Ordinance for buildings became effective. Since then, Germany has tightened its minimum energy performance standards for new buildings several times with the Energy Savings Ordinance (EnEV)[6]. New residential buildings today may only use 75 % less energy than 35 years ago(Figure 25). By requirement of the EU Directive on the overall energy performance of buildings, the MEPS will need to be further strengthened so that all new buildings from January 2021 will be nearly zero energy buildings.

[6] The EnEV has been further tightened in 2012 and 2014. http://www.enev-2014.info/

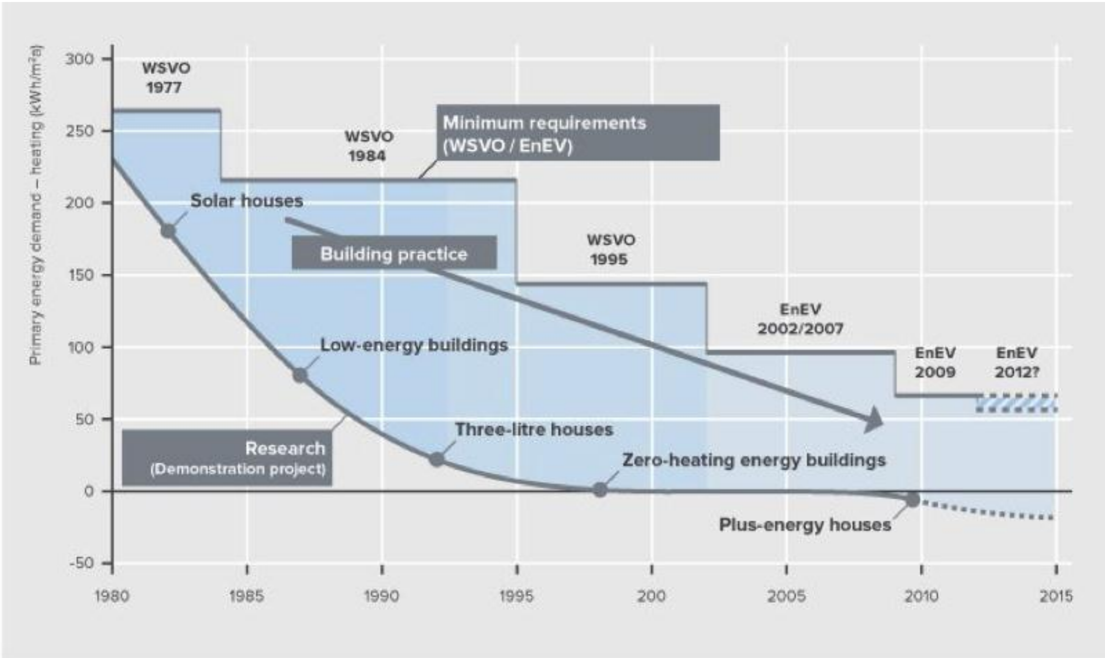


Figure 25 Evolution of Minimum Energy Performance Standards, demonstration projects, and building practice in Germany

(Source: Wuppertal Institute 2012)

Success factors of the German policy package:

- A long-term energy efficiency roadmap showing political commitment and creating confidence in the building sector
- The KfW as an experienced money lender providing various financial options to builders and building owners
- A highly trained workforce in the construction industry
- A large network of government-accredited energy advisors
- A link between MEPS, EPC, energy audits, and financial incentive/preferential loan programmes in energy-efficient renovation: the specially trained and certified energy advisors identify energy efficiency actions and determine EPC levels. They support investors with application and documentation required for the financial incentive/preferential loan programmes.
- The MEPS, the EPC and the financial incentive/preferential loan programmes take a holistic approach to energy-efficient building design and renovation. For example, the better the energy performance of a building after the refurbishment/ construction process, the higher the financial incentives.

8.4.4 Policy case study: KfW programme in Germany

In 2011, the energy-efficient refurbishment rate in Germany was at one percent, i.e. 200,000 building units per year, but the federal government has committed to increase it to two percent (BMWi & BMU 2010). Urgent action to decrease the energy consumption of these pre-1979 buildings is needed because they annually use 210 to 250 kWh/m_2 for heating and domestic water heating on average (space cooling is very rare in Germany). The BMVBS (2012) estimates that buildings can save up to 80% of their energy demand through energy efficient refurbishments. These would also decrease the building sector's share of about 38% to Germany's energy consumption in 2012 (DENA 2012).

In order to increase the refurbishment rate to two per-cent, Germany offers comprehensive financial assistance to residential building owners and builders through the government-owned economic development bank KfW Bankengruppe, especially because the lack of capital is one of the core challenges to owners in undertaking action. For making these programmes more effective, KfW has established its KfW-Efficiency House (EH; in German: Effizienzhaus) scheme. Within this scheme, buildings can be classified into different categories. The better the category, the stricter the standards for the building's primary energy demand and its heat losses due to transmission. Existing buildings that are to receive refurbishment must fit into one of the six EH classes after refurbishment: EH 115, EH 100, EH 85, EH 70, EH 55, Listed historic buildings (Denkmal) (from April 2012). New buildings are divided into EH 70, EH 55, EH 40. For both, new and existing buildings, the number indicates the building's maximum allowed primary energy demand in comparison to a new building built to meet Germany's minimum energy performance standard (MEPS) for buildings. For example, a refurbished EH 70-certified building demands only 70% of the primary energy of a comparable new building that just meets the requirements of the German MEPS. Moreover, there are maximum values for heat getting lost due to transmission for each category, as well. For instance, an EH 70 home may not lose more than 85% of transmission heat to that of a comparable new home. The minimum performance standards for new homes are stipulated in Germany's EnEV.

Building owners can apply for grants or soft-loans with a grant element that is deducted from the total credit amount. The loans are provided via the local commercial banks, not directly from KfW. The better the EH category achieved, the better the funding conditions.

The loan conditions for both, builders and owners, are highly preferential. The payback period can be up to 30 years with an initial grace period or moratorium. Interest rates can be as low as one percent, depending on market rates of loans that are then reduced using the government's budget support. The loan-application is processed via a local bank lowering the administrative burden for KfW and increasing the applicant's information about the programme with the help of a local bank official. The grant option is managed directly by KfW. Moreover, KfW recommends including an energy advisor to plan and supervise the refurbishment or construction process, in order to make sure that the envisaged EH classification is achieved. However, with respect to EH 40 and EH 55 certifications, an advisor is mandatory. After construction or refurbishment, applicants must hand in all relevant data to KfW, which reserves the right to conduct spot checks – a safeguarding or monitoring mechanism to prevent fraud.

According to a series of evaluation reports, the energy-efficiency refurbishment programme saved 2,679, 2,450 and 1,247 GWh/yr of final energy demand and reduced greenhouse gas (GHG) emissions by 955,000, 847,000 and 475,000 tonnes of CO2eq/yr in 2009, 2010, and 2011 respectively (BEI & IWU 2011; IWU & BEI 2011; 2012). It saved €215 million and €125 million in heating costs and set employment effects in motion to the tune of 92,500 and 52,000 person years in 2010 and 2011 respectively. The other programme, energy-efficient construction reduced energy demand by 300 GWh/yr resulting in heating cost savings of €36 million in 2011. Additionally, it reduced emissions by 85,000 CO2eq/yr and triggered employment effects of 199,000 person years for the same period. In 2011, both programmes only received €0.9 billion from the government budget while additional tax revenues through value-added and other taxes are estimated at about €6.3 million. However, this is related total investment, not just for energy efficiency improvements.

In addition to the programmes for residential buildings, there are also similar programmes to assist the public sector, mainly for energy-efficient refurbishment of local authority buildings.

Barriers addressed

- Knowledge and information barriers: The financial incentives and financing reduce the uncertainties about whether energy efficiency improvements are an attractive investment. KfW also recommends that investors use consultancy from energy advisors (for some investments this is even mandatory). KfW provides funding of up to 50% or a maximum of €2,000 for such a consultation (KfW 2011; CPI 2011).
- Lack of interest and motivation in energy efficiency-improvement: Consultations with an energy advisor also help to clarify uncertainties regarding hidden costs and future cost savings. Their advice can also reduce transaction costs. Moreover, investors who wish to apply for soft loans need to have their application processed by a local bank. This might also clarify some questions with respect to funding (CPI 2011). As KfW is a state-owned bank and in charge of the programmes, the trustworthiness of the programmes are increased.
- Economic and financial barriers: The core task of the programme is to provide investors with funding (preferential loans, grants) so that they become willing and able to carry out energy-efficient investments.
- The investor-user barrier: As the high number of soft loans provided to housing corporations shows, the KfW programme for energy-efficient refurbishment is able to effectively tackle this barrier by reducing capital cost to this group of investors. As stated above, in Germany the annual rent can be increased by 11% of the investment in energy efficiency improvement , so that landlords can profit from their investments directly.

Success factors

As KfW loans and grants are provided before construction or refurbishment, they increase a households' certainty about future financing options (CPI 2011).

Building on Schröder et al. (2011), the list below provides some more factors that have substantially supported the success of the programmes:

- Conditions of preferential loans improved energy performance and have incentivised energy-efficient building investments.
- A special feature compared to programmes in other countries is the promotion of an integrated optimisation of whole-building energy performance using the KfW's EH voluntary classification standard.
- Energy advice by an expert before and during construction or refurbishment is generally recommended and for some building measures it is mandatory. Expenses for these measures are eligible for funding, as well.
- The EH standards and the energy advice are also linked to the legally required Energy performance certificates. These can be easily created after the building or refurbishment.
- Over the course of time, Germany's building industry has gained major expertise in the field of energy-efficient refurbishment and construction. The KfW supports this through its KfW Academy.
- Hardly anybody is excluded from KfW's residential buildings programmes except those who are not credit-worthy.
- As both programmes are applicable all over Germany, KfW does not only give "weight" to the programmes, but also gives planning security to investors and the construction industry. The latter is further enhanced as the Energy Concept of the federal government as it declares mid- to long-term goals (e.g. increasing the refurbishment rate to 2% annually).

The high leverage creates a relatively low impact on Germany's overall budget (Schröder et al. 2011) and thus makes it easy for politicians to support the programme. There is even a positive overall effect on the government budget due to increased employment and the value-added tax on the incremental investments in energy efficiency.

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