Buildings Guide
Upgrade to ultra-low-energy buildings

bigEE

Strategic Approach

The Strategic Approach to improving energy efficiency in buildings

New residential buildings – Overview

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The residential building sector is responsible for 17–36% of individual countries' total final energy consumption, with the world average being 23% (GEA 2012). Conventional new buildings in OECD countries with a history of building codes already save about 50% of energy compared to the building stock. This improvement, however, is not enough to create a building standard with low lifetime costs nor to reach long-term climate protection targets. Much higher energy savings can already be achieved through proven high-efficiency building concepts. What's more, if implemented in a smart way, these concepts will even bring net economic benefits, in addition to other advantages.

Energy consumption, climate and conditioning concepts of buildings

The energy consumption of a building is highly dependant on various factors including climate and whether the buildings are passively or actively conditioned. In creating the standard for energy consumption in buildings, buildings within the bigEE project have been divided into four distinct types defined on whether they are passively or actively conditioned. These building types being:

Closed buildings

These buildings have a closed, i.e. air-tight building shell. They mainly use **active technologies** (e.g. heating or cooling plants and equipment) to condition the internal environment throughout the year. This allows for a greater control within stricter thermal comfort levels.

Hybrid buildings

Hybrid Buildings use both **passive and active technologies** to maintain thermal comfort. These buildings are designed so that for the greater part of the **year** the passive design options maintain the thermal comfort and only under extreme climatic conditions where this is not possible the active option is used.

Zoned buildings

Zoned Buildings are a **combination** of both **passive and active building models**. Here the building is divided into different zones, which are conditioned accordingly to their needs. Passive zones are usually found on the buildings perimeter and active zones in the buildings interior. This allows for the passive options such as natural light, solar insolation as well as natural ventilation to be used to the optimum.

Open buildings

These buildings are open and have no **active technologies.** These are also known as free running buildings. Temperatures can be to some extent controlled through passive options. Indoor temperatures follow the outside temperature. Internal temperatures ranging at best from the lowest temperature to the outside shade temperature in the tropics. In Hot
Climates and Temperate Summer Climates the internal loads e.g. persons or technologies can add a significant gain to the internal temperature.

The building conditioning concept determines the **energy consumption** of a building. In general it can be said that completely conditioned buildings or closed buildings consume the most energy. These buildings have thus been used as the basis for determining the limits in the energy consumption for each climate zone within the bigEE project.

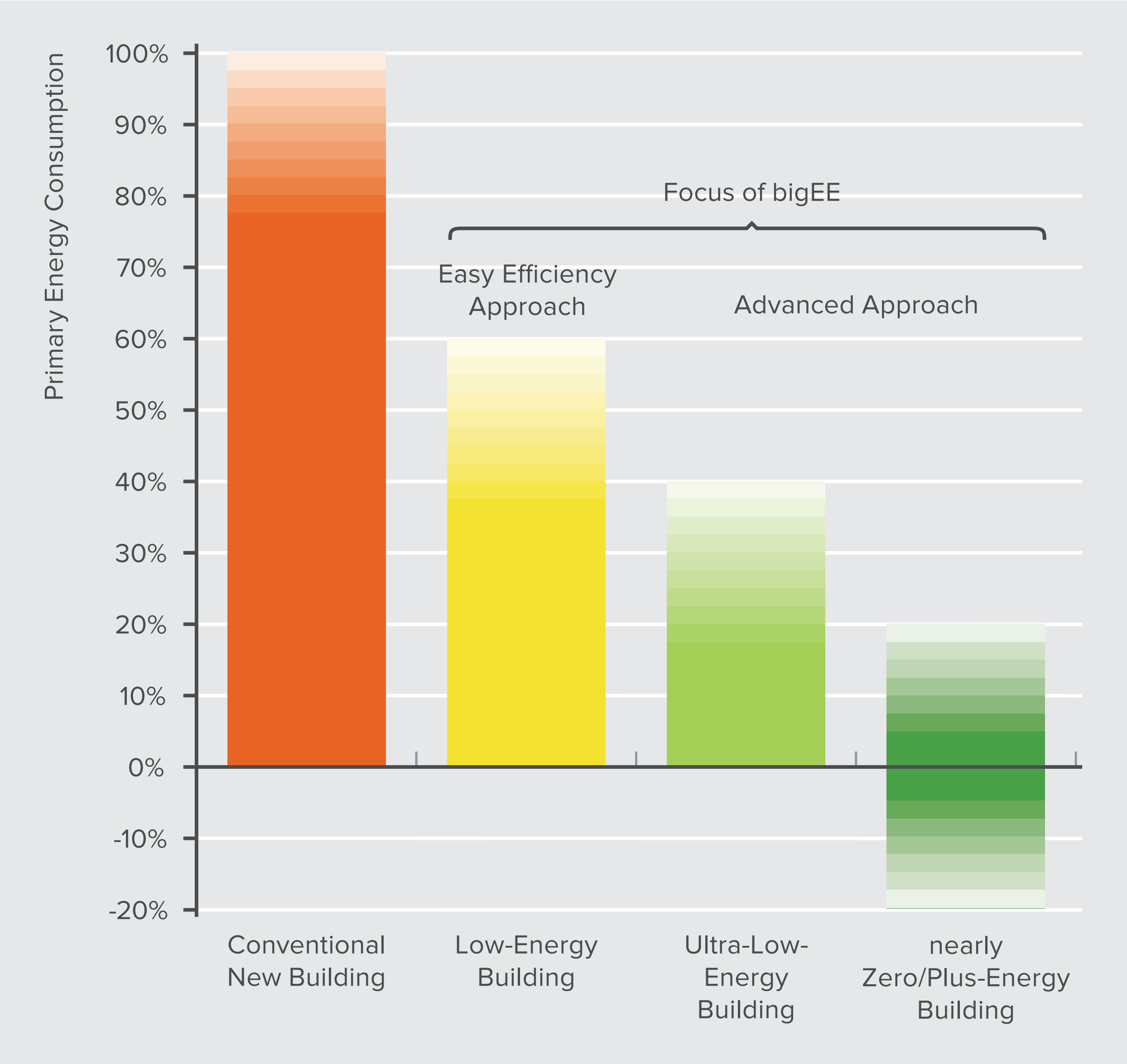

Figure 1: Specific primary energy consumption of new residential buildings for heating, cooling, ventilation and hot water: Comparison of three energy-efficient building concepts versus conventional buildings (in kilowatt-hours per square metre of treated floor area per year)[1]
Source: Developed by Wuppertal Institute for bigEE (2012)

Figure 1 illustrates possible energy savings of three energy efficiency concepts for new residential buildings with different levels of ambition in comparison to conventional new buildings.

[1] Electricity is weighted by a primary energy ratio (PER) of 2.5 according to the OECD average (own calculations based on (IEA 2010) for the year 2015), oil and gas by a PER of 1.1 (in accordance with VDI 2003). The energy consumption for lighting and for appliances is not included in this building specific graph, because - as a rule - both end uses are not building integrated but come as a procurement of the habitants. Nevertheless, it is important to implement energy-efficient lighting and appliances as well to achieve these low energy consumption levels (see the Options text Lighting and the bigEE Appliances Guide) and sometimes it is even a precondition to achieve a certain building efficiency performance (e.g. the Passive House standard). Also the energy consumption for vertical transportation is not included within the columns, because the graph is designed to be generally valid for all types of dwellings, but elevators are only relevant for multi-family houses, particularly high-rise buildings (see the corresponding Recommendations to Different types of dwellings).

Research as well as preliminary simulations done at the Wuppertal institute show that **conventional** fully conditioned new residential buildings in **temperate climates** consume on average about **120 to 260 kilowatthours** of primary energy[2] for cooling, heating, ventilation and domestic hot water per square metre of treated floor area (TFA) per year (kWhPE/m^2 TFA/year). In **cold climates** the average consumption of a conventional new residential building is about 70 to 170 kWhPE/m^2 TFA/year; it is lower than in temperate climates since due to the harsher climates, governments have started earlier to require and promote energy efficiency. In **hot and arid climates** this is about **140 to 160 kWhPE/m^2 TFA/year** and in **hot and humid climates** this rises to **260 to 400 kWhPE/m^2 TFA/year** due to the energy consumption for dehumidification.

Figure 1 shows that improving energy efficiency can reduce primary energy consumption for cooling, heating, ventilation and domestic hot water by **40 to 60% in a Low-Energy Building** (enabled by what we call 'Easy Efficiency Approach') and up to **90%** in an **Ultra-Low-Energy Building** (resulting from what we call Advanced Efficiency Approach). **(nearly) Zero or Plus-Energy Buildings** can realise 100% net reduction in energy consumption or even a positive energy balance (Advanced Efficiency Approach including building-integrated renewable energy). These energy savings are possible through a combination of options to reduce thermal loads to ensure optimum operation. Such measures include climate responsive building design and shading and thermal insulation, energy-efficient heating, cooling, ventilation and hot water equipment. Although lighting energy needs have not been included in this analysis for residential buildings, lighting loads should also be minimised. Indirectly, they also minimise cooling loads.

The three concepts are characterised as follows:

1. Low-Energy Building

Low-Energy Building (LEB) can be designed by what we call an **Easy Efficiency Approach**. This can achieve **primary energy savings** for cooling, heating, ventilation and domestic hot water in a range of about **40% to 60%** LEB is, however, not a clearly defined term in the literature and can therefore include various design and technology options. bigEE has defined LEB for new residential buildings through ranges for the overall thermal primary energy consumption for these end uses in each of our climatic zones. These ranges do not include energy consumption for lighting and appliances but assume energy-efficient lighting (using ca. 2 kWh/m^2/year) and household appliances (ca. 1650 kWh/year for a European household with a treated floor area of 120 m^2) because - as a rule - both end uses are not building integrated but come as a procurement of the habitants.. 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.

The Easy Efficiency Approach is characterised by an intelligent building design in combination with an appropriate choice of efficient technologies for heating, cooling, hot water production, lighting and so on. By fulfilling basic rules of energy-efficient design especially **'Passive Options'**, relatively high amounts of energy can be saved with relative low effort and costs. In the majority of cases, relatively moderate extra investment costs are more than compensated by energy cost savings within a few years and certainly over the lifetime of the buildings.

In the bigEE Buildings Guide section on residential buildings, you can find:

- A more detailed overview of LEB design in the Strategic Approach for Low-Energy Buildings
- Detailed recommendations for LEB design when selecting a type of building and climatic zone in the Recommendations section
- And corresponding real examples of LEB for these types of buildings and climatic zones, accessible both from the design recommendations and in the Building Examples section.

2. Ultra-Low-Energy Building

The Ultra-Low-Energy Building (ULEB) maximises a building's energy efficiency potential. In the context of the bigEE project, an Ultra-Low-Energy Building is defined by ranges of thermal primary energy consumption cooling, heating, ventilation and domestic hot water for each climatic zone, so as to achieve a **primary energy savings** of 60% to 90% for cooling, dehumidification, heating, ventilation and domestic hot water.

An **Advanced Efficiency Approach** is needed to attain these low levels of energy consumption. It can be cost-effective, depending on the relationship between extra building costs and saved energy costs, but this may not always be the case. Such an Advanced Efficiency Approach sets more ambitious energy efficiency standards, using the most energy-efficient components and systems (Active Options) available. Remaining energy consumption should preferably be met by renewable energy sources (solar radiation, ambient and geothermal energy, sustainable biomass)

Example for an Ultra-Low-Energy Building: The Passive House concept

The Passive House concept is the best-known and mature example of an Ultra-Low-Energy Building in the closed concept construction. Although it has been developed and proven for temperate and cold climate zones, it is in principle feasible all over the world with certain adaptations. Passive houses are generally described as "a building, for which thermal comfort (ISO 7730) can be achieved solely by post-heating or postcooling of the fresh air mass, which is required to achieve sufficient indoor air quality conditions – without the need for additional recirculation of air." (Passipedia 2012). In contrast to the general terms Low-Energy Building and Ultra-Low-Energy Building, Passive House (PH) is associated with a certified label with clear certification criteria requirements:

- The maximum **useful energy** consumption for each of space heating and cooling (i.e., the energy that is actually available to heat and cool the building) must not exceed **15 kWh**/m^2 TFA/year,

- The maximum **primary energy** consumption including domestic hot water and total household electricity (cooking, lighting and all appliances) must not exceed **120 kWh**/m^2 TFA/year. This latter requirement may not look so energy-efficient, being close to the energy consumed by conventional new residential buildings for cooling, dehumidification, heating, ventilation and domestic hot water. However, it should be noted that the **120** kWh/m^2 TFA/year requirement is valid for all types of buildings, while a level of approximately 80 kWh/m^2/year can easily be achieved in most climates for residential buildings, of which only 40 kWh/m^2 TFA/year is for cooling, dehumidification, heating, ventilation and domestic hot water.[2]

To meet these upper limits, certain building design parameters and/or technological options must be applied e.g. excellent insulation and airtightness as well as mechanical ventilation with heat or cold recovery. The most important advantages of the Passive House concept are the superior thermal comfort and air quality conditions and greater cost-effectiveness, since conventional heating or cooling systems can be downsized or completely omitted.

For hot climates, particularly hot and humid regions, open or hybrid concepts may be considered to achieve the Ultra-Low-Energy Building standard besides the hermetically sealed Passive House approach. These concepts rely on natural ventilation driven by thermal buoyancy or on zoning of rooms with different thermal comfort requirements.

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[2] For example, with highly efficient appliances and lighting for a household with a treated floor area of 120 m^2, yearly electricity consumption of 1900 kWh for household appliances (ca. 1650 kWh) and lighting (ca. 2 kWh/m^2/year) is achievable (Siemens 2009 / WICEE 2009). With the primary energy ratio of 2.5 that we assume, this results in ca. 40 kWhPE/m^2/year plus a maximum of 40 kWhPE/m2/year for heating, cooling, ventilation and hot water.

In the bigEE Buildings Guide section on residential buildings, you can find:

- A more detailed overview of ULEB design in the Strategic Approach for Low-Energy Buildings
- Detailed recommendations for ULEB design when selecting a type of building and climatic zone in the Recommendations section
- And corresponding real examples of ULEB for these types of buildings and climatic zones, accessible both from the design recommendations and in the Building Examples section.

3. (Nearly) Zero and Plus-Energy Building

(Nearly) Zero and Plus-Energy Buildings take the concept of Ultra-Low-Energy Buildings a step further. In addition to a highly energy-efficient building performance, the (nearly) Zero-Energy Building and the Plus-Energy Building concepts include **on-site renewable energy technologies** for generating power and also meeting cooling and heating requirements of the buildings. Supplemented with on-site or building integrated renewable energy systems and other technologies such as Combined Heating (or Cooling) and Power (CHP or CHCP), those buildings can be **transformed** from energy consumers to **(net or nearly) zero-energy and/or energy producers.**

As on-site generation is normally more expensive than reducing energy consumption, advanced levels of energy efficiency should be achieved first (Barthel et al 2006). If the amount of produced energy during a year is roughly equivalent to the annual primary energy consumption, the building can be described as a nearly Zero-Energy Building (nZEB). If the energy production exceeds the consumption, the term Plus-Energy Building (PEB) will be used.

In the bigEE Buildings Guide section on residential buildings, you can find:

- A more detailed overview of nZEB/PEB design in the Strategic Approach for Low-Energy Buildings
- Detailed recommendations for nZEB/PEB design when selecting a type of building and climatic zone in the Recommendations section
- And corresponding real examples of nZEB/PEB for these types of buildings and climatic zones, accessible both from the design recommendations and in the Building Examples section.

Strategy towards highly efficient building Performance

Figure 2 illustrates the strategic approach in the bigEE project idea: energy standards for buildings should transform from net high-energy consumption to the lowest energy consumption possible and ultimately to net energy production.

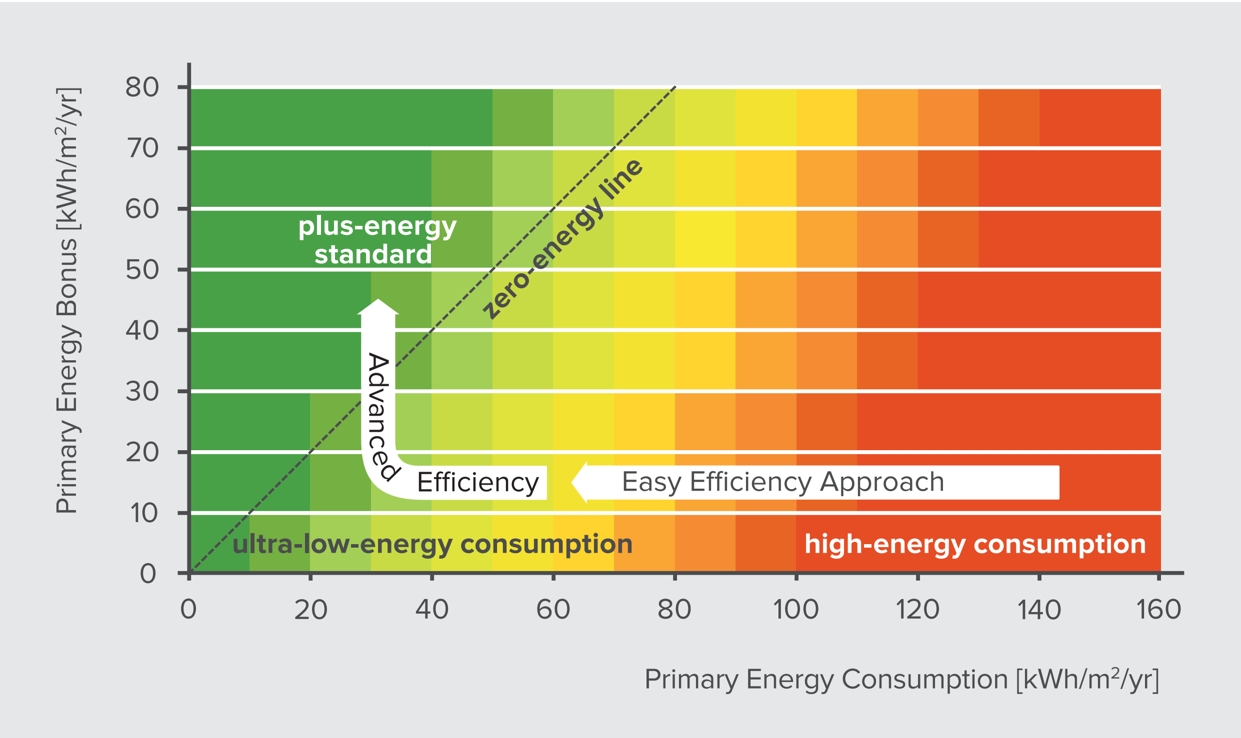

Figure 2: **Strategy towards highly-efficient building performance with net energy surplus.**
The strategic approach consists of two steps: firstly to reduce the final energy and thus the primary energy consumption from a high (red area) to a low level (yellow/green area) by designing a highly-efficient consumption and supply performance. Secondly by setting even more ambitious energy efficiency standards and implementing onsite power generation systems to deliver surplus energy within an annual energy balance.
Source: Developed by Wuppertal Institute for bigEE (2012)

In the short term, the Easy Efficiency Approach should be regarded as the minimum achievable target. Although it can significantly reduce energy consumption, this **first step** will not be **sufficient** to reach **long-term climate protection goals**. It is thus **necessary** to implement and support a long-term **Advanced Efficiency Approach** at the earliest to avoid lock-in effects, which result in new, inefficient houses to be continuing in use for decades because of long building lifetimes.

A timeline for standards

Highly energy efficient technologies are usually available first for new buildings and later dissemina-ted to existing buildings, because more effort is required for refurbishment than for new build. A pos-sible schedule for a step-by-step introduction of increasing building performance standards for new and existing buildings is illustrated in figure 3.

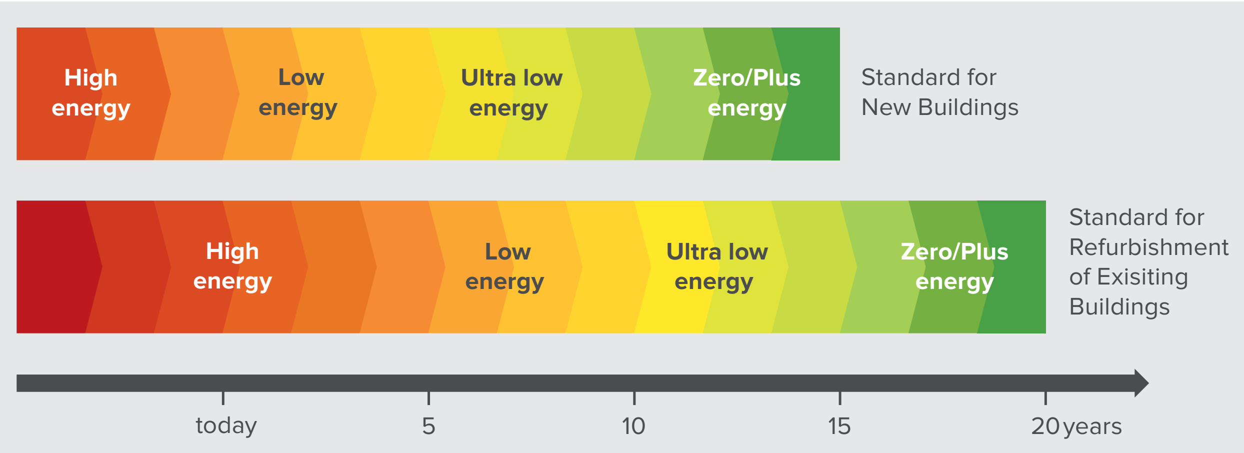

Figure 3: Exemplary schedule for the introduction of increasingly ambitious levels for energy-efficient buildings
Source: Developed by Wuppertal Institute for bigEE (2012)

Detailed design recommendations for Low-Energy, an Ultra-Low-Energy or even (Net or nearly) Zero- / Plus-Energy Buildings can be found in the Buildings Guide of the bigEE.net platform when selecting a type of building and climatic zone in the Recommendations section.

Further details on the design options for improving the energy efficiency in new residential buildings in a way that a Low-Energy, an Ultra-Low-Energy or a (Net or nearly) Zero- / Plus-Energy efficiency standard can be achieved, can be found under the section Options in the Buildings Guide of the bi-gEE.net platform.

The package of policies that can create a realistic time schedule for introducing increasingly ambiti-ous levels for energy-efficient buildings can also be found on the bigEE.net platform under the Policy Guide.

References

Barthel, C., Bunse, M., Irrek, W., Thomas, S. (2006):
Options and potentials for energy end-use efficiency and energy services. Wuppertal Institute. Wuppertal

EnEV-Online (2009):
Praxisdialog: Primaerenergiefaktoren_waermenetze.
http://www.bigee.net/s/mhp9nn

Global Energy Assessment (GEA) Council Writing Team (2012):
Global Energy Assessment: Towards a Sustainable Future. Cambridge University Press (see Table 10.1, data from IEA statistics online 2007)

IEA (2010):
International Energy Agency (IEA) World Energy Outlook 2011. Annex A Tables. International Energy Agency

Passipedia (2012):
The Passive House - definition. Passive House Institute. Darmstadt. Germany.
http://www.bigee.net/s/5ttjd1

Siemens (Publisher) (2009):
Sustainable Urban Infrastructure: Munich Edition – paths toward a carbon-free future.
Siemens AG. München.
http://www.bigee.net/s/ajycy3

VDI (publisher) (2003):
DIN V 4701 (August 2003): Energy efficiency of heating and ventilation systems in buildings - Part 10: Heating, domestic hot water supply, ventilation. Annex C, table C.4-1.
http://www.bigee.net/s/u94q41

VDI (publisher) (2010):
DIN SPEC 4701-10/A1 Amendment A1 (October 2009). Energy efficiency of heating and ventilation systems in buildings - Part 10: Heating, domestic hot water supply, ventilation. Annex C, table C.4-1
http://www.bigee.net/s/rjzvfm

WICEE (2009):
München 2058 - Wege in eine CO2-freie Zukunft (Background paper). Chapter 3.2.2. p. 76 et sq. Wuppertal Institute for Climate, Environment and Energy GmbH. Wuppertal

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Your guide to energy efficiency in buildings.

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bigEE is an international initiative of research institutes for technical and policy advice and public agencies in the field of energy and climate, co-ordinated by the Wuppertal Institute (Germany). Its aim is to develop the international web-based knowledge platform bigee.net for energy efficiency in buildings, building-related technologies, and appliances in the world's main climatic zones.

The bigee.net platform informs users about energy efficiency options and savings potentials, net benefits and how policy can support achieving those savings. Targeted information is paired with recommendations and examples of good practice.

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