From Single Buildings to Communities and Cities – Energy Efficiency in the Course of Time

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ABSTRACT

For quite a long time energy conservation and energy efficiency were concentrated on a single building approach. Until 2000 nearly all national building regulations were based on net energy balances (energy needs) comprising transmission losses, ventilation losses, solar gains, internal gains and heating gains. Due to that the development focused on reduced transmission and ventilation losses, and so-called low energy houses or passive houses were designed and demonstrated in pilot projects, at first for new constructions and later on also for refurbishment projects. The national energy performance requirements were based on U-values for building components and then on heating energy needs. With the beginning of the new century, the next step was to integrate the efficiency of the heating, ventilation and domestic hot water systems. Instead of low energy needs, low energy use is now the goal. In most countries the primary energy use (which is the energy use multiplied with primary energy factors dependent on the specific energy source) became the limiting factor in requirements for buildings. Other countries are using the CO_2 emissions as a limit. Nowadays, the efficiency of the building systems is equally important as the quality of the building components, and the more building systems are getting integrated (e.g. cooling systems), the more important is their efficiency.

On the other hand, strategies and technologies that are applied to many different buildings in the same area at the same time (like improving the efficiency of the district heating net connected to the settlement) can be just as efficient regarding the reduction of the energy use and the emissions. New national programmes, like the German EnEff:Stadt, concentrate on improving the energy efficiency of settlements or communities and are mirrored with European (Concerto) and IEA projects (IEA ECBCS Annex 51 “Energy efficient communities”). The paper gives an overview on the development of energy performance requirements by using Germany as example, national programmes for energy efficient buildings and communities and international (IEA and EU) projects. It presents examples of pilot projects and gives an insight in the work programme of the new IEA Annex 51 on energy efficient communities.

KEYWORDS

Communities, energy efficiency, energy performance, EnEff:Stadt, IEA ECBCS Annex 51

THE HISTORY OF ENERGY EFFICIENCY FOR SINGLE BUILDINGS

First steps to improve the energy performance of buildings were made after the energy crisis in 1973. Until then the existing requirements focused mostly on health and building safety. Minimum thermal resistances for building components were fixed in order to prevent moisture and mould on the internal surfaces of the building envelope. Figure 1 presents the history of energy performance requirements in Germany. As a first step to save energy, the German parliament adopted the first “Wärmeschutzverordnung” or heat protection decree for new buildings in 1977. It specified maximum component U-values and a mean U-value for the whole building envelope. In 1984 the mean U-value became the only requirement for buildings. The transition to maximum net heating energy demand requirements (heating energy needs) took place in 1995, and in 2002 the first requirements to the primary energy use for heating, domestic hot water and ventilation were made. Here, the final energy (energy use) is multiplied by fixed primary energy factors. In 2007 the covered energy uses were extended to cooling and lighting. Throughout this time, also minimum mean U-values were required. Concerning the renovation of buildings, requirements have been defined for a long time by stipulating maximum U-values for building components, earlier on by minimum insulation requirements.

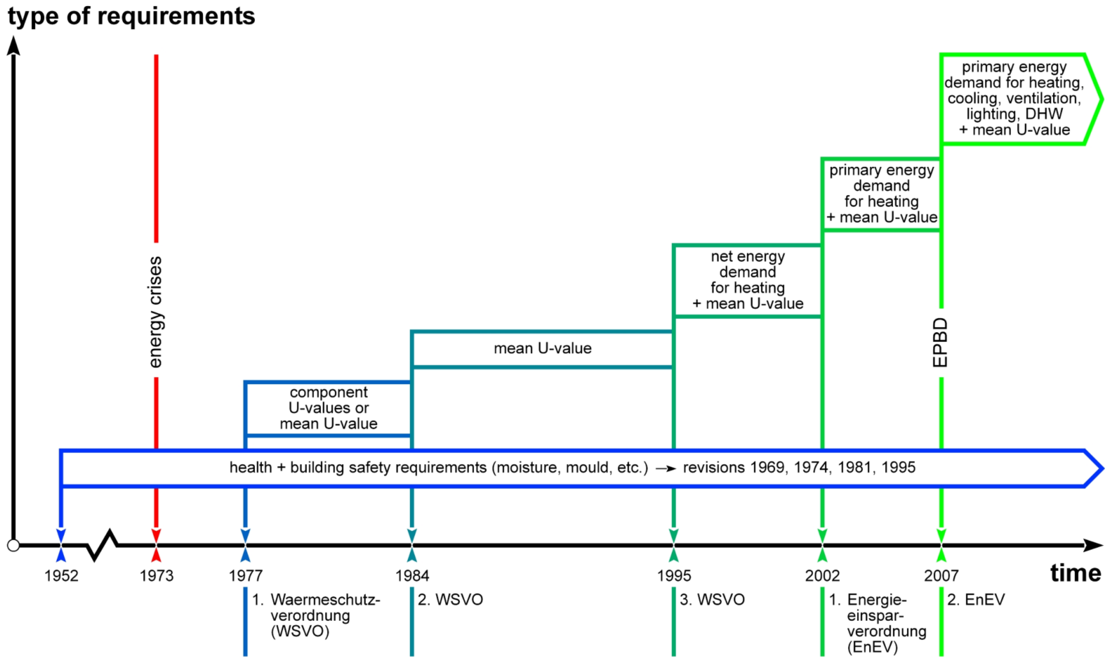

Figure 1: History of energy performance requirements for buildings in Germany.

The strengthening of national requirements has been made possible by industrial developments like high-performance windows, insulation with lower thermal conductivities or higher thicknesses, more efficient building service systems like condensing boilers or heat recovery systems, etc. These technologies had to be tested and their efficiency demonstrated in pilot or demonstration projects. Figure 2 visualises the relation between demonstration projects and national requirements in Germany. The demonstration buildings represent an energy efficiency level that is mostly about 15 to 20 years ahead of the requirements.

The first type of energy efficient buildings in Germany were the so-called solar houses of the 1980s. Similar to this kind of buildings in the US, it was attempted to design houses with large south-oriented windows - and therefore high passive solar gains - that should reduce the heating energy need. Mainly due to the rather bad window U-values of that time, the buildings produced high transmission losses and caused problems with overheating during sunny periods and in the summer. They were followed by a new type of houses, the low-energy houses. Here the design concentrated on minimum transmission and ventilation losses and therefore reduced heating energy needs. The energy performance of these buildings was much better than the solar houses, with about half as much primary energy demand. Passive houses and three-liter houses are further developed examples of low-energy buildings, featuring an increased insulation quality and a better building service system efficiency. While a passive house has a very low heating energy need, which is covered by an air-heating system mostly in combination with an electrical heat pump, a 3-liter-house offers a wide variety of building component and building service system sets but results in about the same primary energy demand. A 3-liter-house is defined as having a primary energy use equivalent to 3 liters of heating oil per square meter and year for heating and ventilation.

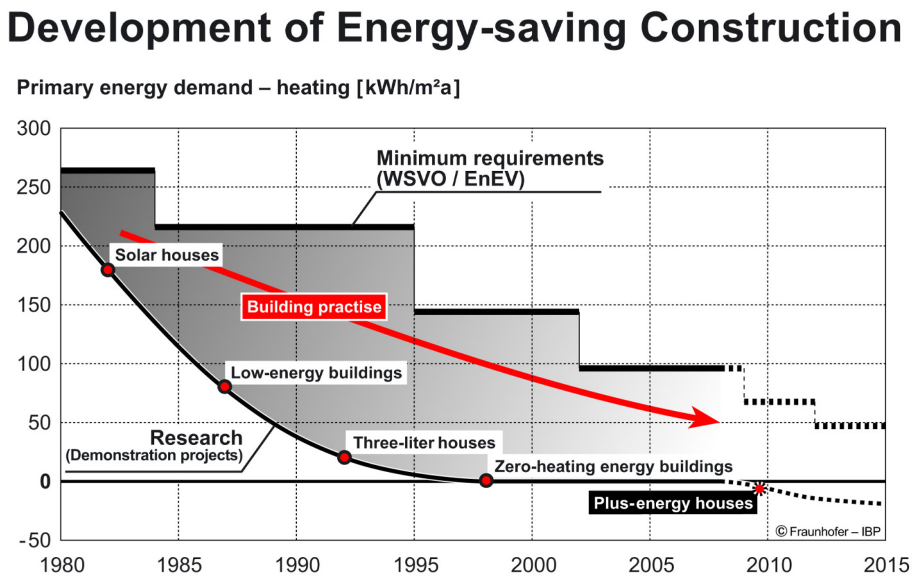

Figure 2: Developments of energy saving constructions in Germany comparing demonstration projects to the national minimum requirements.

In the late 1990s the first zero heating energy houses and even zero energy houses were built. These buildings worked with large storage systems such as water tanks and partly with batteries for buffering energy gained through solar thermal and photovoltaic panels during summer time. Newer developments, the so-called net zero energy houses use the grid as buffer and balance between heating energy and electrical energy uses. Thus the expensive storage systems can be omitted and the houses become more cost-efficient.

APPROACHES TO IMPROVE THE ENERGY EFFICIENCY OF COMMUNITIES AND CITIES

The first energy crisis also led to an increased awareness in communities that they have to optimise their energy supply. Local energy planning with the goal of energy efficiency and mainly with focus on district heating supply came up in the 1980s.

A first IEA ECBCS Annex (Annex 22) with 6 participating European countries collected the national experience with local energy planning. The four subtasks dealt with:
- software tools for energy planning
- models for the calculation of environmental aspects
- means to represent, demonstrate and advertise planning solutions
- implementation of the results of integrated planning procedures.

The work is documented in the technical synthesis report [1] and the final report [2] of Annex 22 to be downloaded from www.ecbcs.org/annexes/annex22.htm.

Annex 33 “Advanced Local Energy Planning” focused on the practical application possibilities of tools and models of modern system analysis for the description of complex municipal energy systems. The main result of the annex was the guidebook for advanced local energy planning [4] including application case studies.

The EU Initiative Concerto

In 2002 the European Union has started with the 6th research framework programme an activity focus for communities that combines innovative renewable energy concepts with measures for energy efficiency in the building sector. The projects are realised in geographically defined areas and integrate a multitude of technologies. The integrated approach shall ensure on the one hand efficiency and on the other hand the economical success of the reduction of CO_2 emissions. A Concerto project combines different actors like building owners and occupants, architects, construction companies, researchers, energy suppliers, energy agencies and investors. The defined energy strategy in each project is realised, monitored and evaluated. The gained experiences and results are summarised in a data base [4]. Currently 45 communities from 18 European countries are taking part in 18 different ongoing projects. Additional 9 communities are participating as observers in several projects. An overview of the strategies applied for improving the energy efficiency and the integrated renewable energies is given in tables 1 and 2.

Table 1: Applied energy efficiency strategies in the 45 communities that participate in the EU Concerto initiative.

Type of efficiency strategy	New built low-energy buildings (ecobuildings)	Refurbishment of the building envelope	Refurbishment of the building service systems	Addition of innovative building service systems	Combined heat and power units / district heating systems without integration of renewable energy	Energy management systems	Consultancy and incentive programmes
Number of communities that apply the strategy	27	29	13	7	5	16	14

Table 2: Applied renewable energy strategies in the 45 communities that participate in the EU Concerto initiative.

Type of renewable energy strategy	Solar heating or cooling	Photovoltaics	Wind power	Hydro power	Biomass boilers	Heat pumps	Combined heat and power units / district heating systems with integration of renewable energy
Number of communities that apply the strategy	29	31	14	3	10	13	33

The German EnEff:Stadt Programme

In 2007 the German Ministry for Economy and Technology (BMWi) started the research initiative EnEff:Stadt (energy efficient city) [5]. It demonstrates ways to increase energy efficiency through optimised concepts for efficient energy supply and use. The initiative considers typical city quarters or districts and focuses on important future urban tasks, ranging from the retrofit of historical quarters to the re-use of old industrial and business areas and innovative supply solutions including modern storage technologies. Pilot projects in communities and typical quarters shall afford exemplary and trend-setting knowledge that shall be transferred into a broader use. The projects comprise innovative design concepts, their realisation and associated scientific monitoring and evaluation. Innovative technologies and integrated concepts, a maximum of primary energy reduction as well as typical and transferable solutions with high signalling effect are the centre of the promotion programme.

An example for a demonstration project within EnEff:Stadt is the integrated energy concept for the city-quarter at Karlsruhe-Rintheim. The quarter includes about 40 multi-family buildings with about 1300 dwelling units and 3200 occupants. The buildings have been erected between 1958 and 1968. In parallel with the installation of a local district heating network supplied by a combined heat and power unit and waste heat, the buildings shall be refurbished in an energy and cost-efficient way. This shall also secure a certain independency from future high energy prices. The first two buildings will be remodeled into 3-liter-houses with the second building including additional measures for passive and active cooling. All buildings that are connected to the local district heating network will be monitored and optimised by an energy management system. The occupants will receive feedback concerning their user behaviour in order to further reduce the energy use. Experience formerly made by the building owners shows that this can decrease the energy consumption by 20 %. The whole concept shall be ready in autumn 2009. The characteristic energy values before and after the project are summarised in table 3. Figure 3 shows the site plan of the quarter and a photo of the building that shall be converted into a 3-liter-house. The primary energy use of the quarter shall be reduced by 17 % for electricity and by 86 % for heating energy. In total this will be a reduction from 19000 MWh primary energy to 4800 MWh.

Table 3: Characteristic energy values for the EnEff:Stadt project Karlsruhe-Rintheim before and after the project realisation (planned).

Characteristic value	Electrical energy use [kWh/m²a floor area]	Heating energy use [kWh/m²a floor area]	Total primary energy use [kWh/m²a floor area]	CO_2 emission [kg CO_2/m²a floor area]
Before	30	120	250	37
After	25	65	98	5

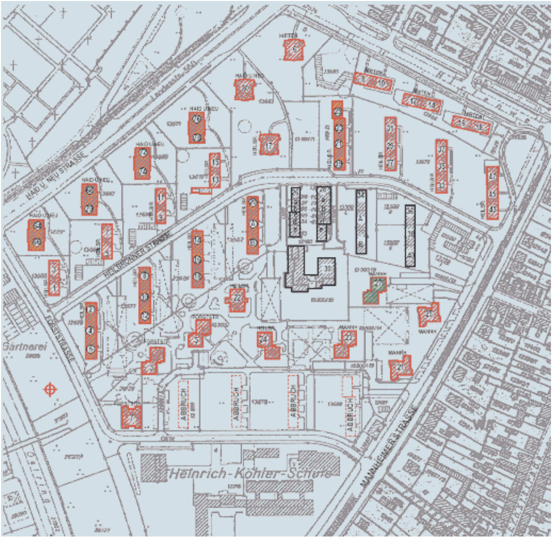

Figure 3: Site plan of the demonstration project Karlsruhe-Rintheim within the German EnEff:Stadt initiative (left) and photo of the multi-family house to be converted into a 3-liter-house (right).

THE NEW IEA ANNEX 51 – ENERGY EFFICIENT COMMUNITIES: CASE STUDIES AND STRATEGIC GUIDANCE FOR URBAN DECISION MAKERS

In 2009 a new IEA ECBCS Annex on energy efficient communities [6] was started which will work on 4 main tasks:

1. Existing organizational models, implementation instruments and planning tools for local administrations and developers – a state-of-the-art review
2. Case studies on energy planning and implementation strategies for neighbourhoods, quarters and municipal areas
3. Case studies on the preparation of integrated energy and CO_2 abatement concepts for towns or cities and implementation strategies
4. Instruments for a successful community energy policy

One of the major results will be a district energy concept adviser for municipal administrations, developers, housing associations and local policy makers. The tool shall enable them to assess the potential of various energy efficiency technologies applied at a specific quarter in the early planning phase.

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