INTERNATIONAL ENERGY AGENCY
AGENCE INTERNATIONALE DE L'ENERGIE

ENERGY EFFICIENCY REQUIREMENTS IN BUILDING CODES, ENERGY EFFICIENCY POLICIES FOR NEW BUILDINGS

IEA INFORMATION PAPER

In Support of the G8 Plan of Action

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INTERNATIONAL ENERGY AGENCY

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It carries out a comprehensive programme of energy co-operation among twenty-seven of the OECD thirty member countries. The basic aims of the IEA are:

- To maintain and improve systems for coping with oil supply disruptions.
- To promote rational energy policies in a global context through co-operative relations with non-member countries, industry and international organisations.
- To operate a permanent information system on the international oil market.
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- To promote international collaboration on energy technology.
- To assist in the integration of environmental and energy policies.

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The OECD is a unique forum where the governments of thirty democracies work together to address the economic, social and environmental challenges of globalisation. The OECD is also at the forefront of efforts to understand and to help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population. The Organisation provides a setting where governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies.

The OECD member countries are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States.
The European Commission takes part in the work of the OECD.

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ABSTRACT

The aim of this paper is to describe and analyse current approaches to encourage energy efficiency in building codes for new buildings. Based on this analysis the paper enumerates policy recommendations for enhancing how energy efficiency is addressed in building codes and other policies for new buildings. This paper forms part of the IEA work for the G8 Gleneagles Plan of Action.

These recommendations reflect the study of different policy options for increasing energy efficiency in new buildings and examination of other energy efficiency requirements in standards or building codes, such as energy efficiency requirements by major renovation or refurbishment.

In many countries, energy efficiency of buildings falls under the jurisdiction of the federal states. Different standards cover different regions or climatic conditions and different types of buildings, such as residential or simple buildings, commercial buildings and more complicated high-rise buildings.

There are many different building codes in the world and the intention of this paper is not to cover all codes on each level in all countries. Instead, the paper details different regions of the world and different ways of standards. In this paper we also evaluate good practices based on local traditions. This project does not seek to identify one best practice amongst the building codes and standards. Instead, different types of codes and different parts of the regulation have been illustrated together with examples on how they have been successfully addressed.

To complement this discussion of efficiency standards, this study illustrates how energy efficiency can be improved through such initiatives as efficiency labelling or certification, very best practice buildings with extremely low- or no-energy consumption and other policies to raise buildings' energy efficiency beyond minimum requirements.

When referring to the energy saving potentials for buildings, this study uses the analysis of recent IEA publications, including the World Energy Outlook 2006 (WEO) and Energy Technology Perspective (ETP). Here, we based the estimates of potentials on the scenarios presented, in particular on the predictions of consumption in the residential and commercial sectors in the WEO 2006.

Finally, this paper recommends policies which could be used to realise these large and feasible energy saving potentials in new buildings, and the use of building codes by renovation or refurbishment.

The paper addresses as well experts as policy makers and interest groups with particular interest in energy efficiency in new buildings. Some parts might hence seem simplified and known for some experts, such as the discussions on barriers or the climatic impact on efficiency. Other parts might on the other hand seem a little technical for the policy oriented reader or for some interest groups. But there are large and compelling opportunities, this is recognised by many experts as well as there is a will to act by many policymakers and governments. But still too little happen because there are barriers and low understanding also in the institutional parts or little communications between different layers of the implementation process.

The paper hence aims to bridge these gabs by addressing several different groups at the same time. So hopefully the reader will accept these inconveniences.

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1 Introduction

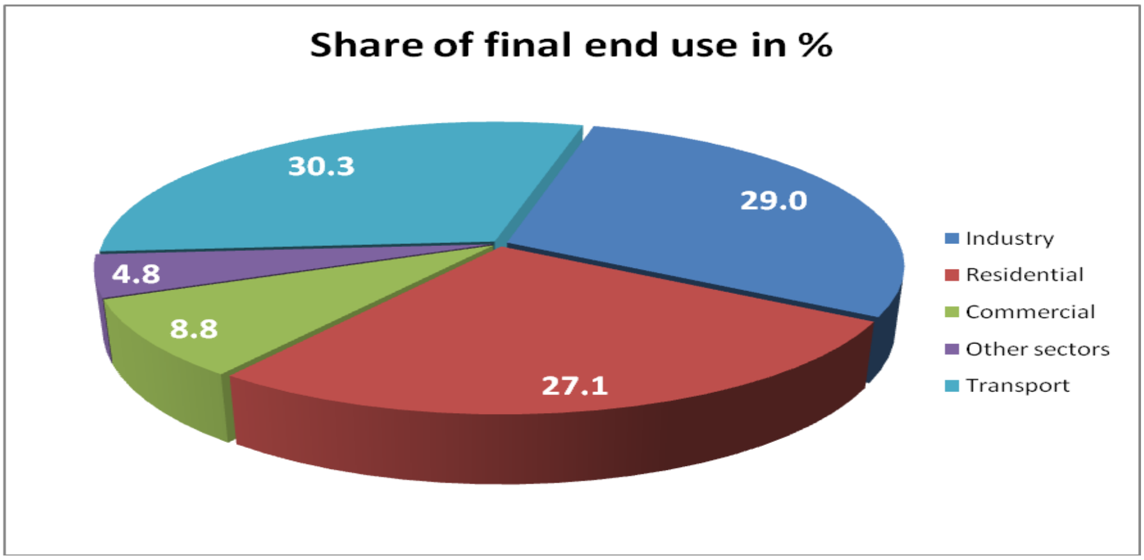
1.1 The rationale for energy efficiency in building codes

The use of energy in buildings accounts for a large share of the total end use of energy.

In sectors such as residential and the commercial sector the major part of the energy consumption takes place buildings. This includes energy used for controlling the climate in buildings and for the buildings themselves, but also energy used for appliances, lighting and other installed equipment.

In other sectors a small part of the energy consumption is similar used for similar purposes in relation to the buildings. This is for instance the case for some buildings in the industry used for administration or some buildings agriculture or forestry.

Figure 1. Energy consumption in different sectors.



According to the IEA statistics for energy balance for 2004-2005,(2007 edition), the total final energy use globally accounts for 7209 Mtoe (Mega Tonnes Oil Equivalents).The residential and commercial sectors account for respectively 1951 Mtoe and 638 Mtoe, which is almost 40 % of the final energy use in the World[1]. The major part of this consumption is in buildings.

The energy efficiency of new buildings determines the building sector's energy consumption for far longer than other end-use sectors components determine their sector's efficiency. Buildings will typically be constructed to be used for many decades and, in some cases, for more than a hundred years. In other energy end uses, the capital lifetime for efficiency improvement will be, at most, a few decades.

Improvement of buildings' efficiency at planning stage is relatively simple while improvements after their initial construction are much more difficult: decisions made during a building's project phase will hence determine consumption over much, if not all, of a building's lifetime. Some measures to improve efficiency are possible only during construction or by major refurbishment, likely to happen only after several decades. Other

[1] The end use of energy alone in the residential and the commercial sector is equivalent to 108.4 Ej (exajoules). 1 single exajoule equals 1000 Pj (petajoules) or 10^{18} joules.

improvements will be very cost effective or maybe even free or at negative costs when implemented at project stage, but can be expensive at a later stage.

Energy efficiency requirements in building codes or energy standards for new buildings are therefore among of the most important single measures for buildings' energy efficiency. This is in particular the case in times of high construction activity or in fast developing countries.

The importance of energy efficiency requirements in building codes or standards extends beyond their role in new buildings. Building codes and efficiency standards often serve as the efficiency target for refurbishment or other improvements of existing buildings. Buyers and renters of buildings or units will often compare new and existing buildings. With increased interest for efficiency will high requirements in building codes therefore spur the demand for refurbishment or general improvements of existing buildings.

As buildings have a relatively long life major refurbishments will necessarily take place during their lifespan – which can be around every 30 – 40 years for residential buildings. This will take place because major parts of the buildings and installations will be worn-out and have to be replaced, and because lifestyle and demands for comfort are constantly changing in a modern society. Replacements and smaller refurbishments might even occur more often. These refurbishments or change of equipment provide a compelling opportunity to improve a building's efficiency. Energy saving can often be obtained at lower costs when other construction take place; in some cases, additional improvements require only small or no additional funding if the basic construction requires work or equipment is replaced, in other cases it can save construction costs, scaffolding etc. Requirements for energy efficiency by refurbishment are therefore an important issue which should be included in building codes.

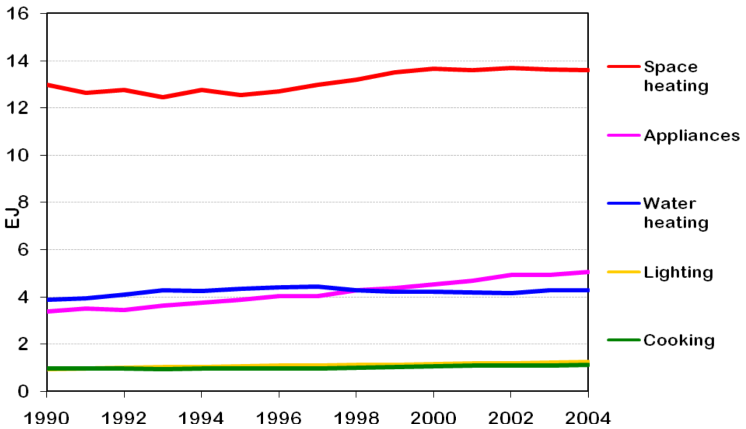
1.2 Energy use in buildings

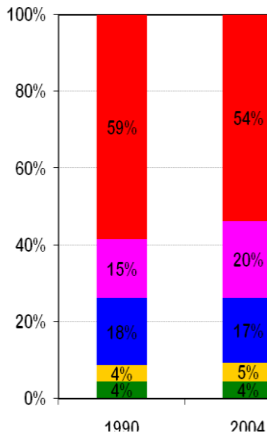
Energy is used in buildings for various purposes: heating and cooling, ventilation, lighting and the preparation of hot sanitary water among them. In residences and commercial buildings, installed equipment and appliances require energy, as do removable devices like mobile phone chargers and portable computers. However, identification of fixed and fluctuating demand for energy rarely appears in a building's consumption metric, as most measurement consider only the total amount consumed by the whole building.

Subdivision of energy consumption can be particularly difficult in the cases of electricity, where air-conditioners, appliances, lights, pumps and heating installations all draw electricity and often from the same metering. Natural gas, too, can serve several end uses at once, including heating, cooking, and the provision of sanitary hot water.

Given the difficulty in subdividing buildings' energy requirements and the use of different fuel types, most analysis examines energy use in building as defined by end-use: space heating, cooling, cooking, etc. The split in use of energy will be due to uncertainties and it will vary with different types of building and also with the age and use of the buildings.

Figure 2. Energy use in residential buildings.

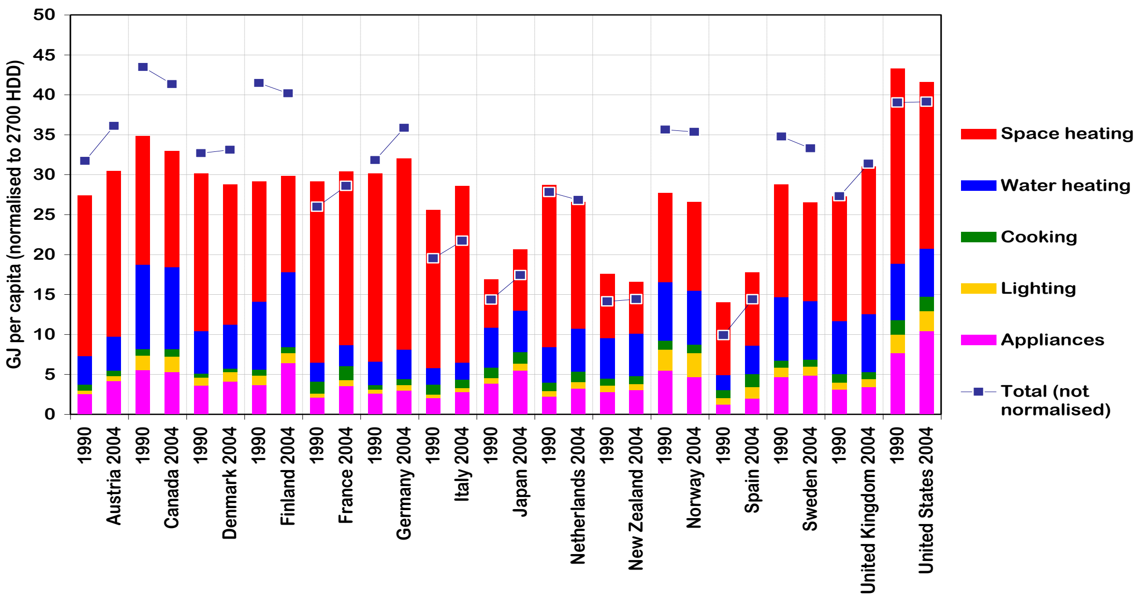




Source: 30 Years of Energy Use in IEA countries. A large part of the energy consumption in residential buildings are used for direct building related use such as space heating, which accounts for more than 50 % in selected IEA Countries.

These differences in the use of energy in different countries can best be illustrated by a subdivision of energy consumption in residential buildings, which is the most homogenous type of buildings.

Figure 3. Subdivision of energy consumption in residential buildings in select IEA countries.



Source: 30 Years of Energy Use in IEA countries[2]. As illustrated, the use of energy is different in individual countries both in concern of level as in the subdivision. The graph also shows issues on comparison and normalisation, which will be targeted later in this paper.

[2] The different indicators set by the Energy Use in the new Millennium in IEA Countries are currently being re-examined in the context of an ongoing IEA indicator study. The consumption in buildings is highly dependent on price levels and local traditions and some of these are further discussed in the study.

Building-related end-uses - heating, cooling, ventilation and the preparation of hot sanitary water - require approximately 75% of a residential building's energy demand. Building codes generally address these drivers of building-related consumption. Only more occasionally, codes cover other end-uses like lighting in service buildings, though this varies by country, as discussed later in this paper. For service buildings, the share of energy use for other purposes will often be larger and for some types of service buildings it can be more than 50%.

1.3 Energy efficient buildings benefits society

Energy consumption in buildings is a large share of the world's total end use of energy. In member states of the OECD, residential and commercial buildings require approximately 35 % of the end use of energy in addition to this energy is used for buildings also in the industry. Globally, buildings account for close to 40% of total end use of energy. Given the many possibilities to substantially reduce buildings' energy requirements, the potential savings of energy efficiency in the building sector would greatly contribute to a society-wide reduction of energy consumption. The implications of such potential reduction should not be underestimated, as the scale of energy efficiency in buildings is large enough to influence security policy, climate preservation and public health on a national and global scale.

By reducing buildings' energy consumption, a nation can reduce dependency on imported energy and strengthen its strategic position. In the 2000 Green Paper setting forth a strategy to secure energy supply[3], the European Union named energy efficiency as the best way to establish energy security over a longer term. Different IEA scenarios show similar trends.

Moderation of energy-end use in buildings will also reduce greenhouse gas emissions and pollution produced by the combustion of fossil fuels. This environmental benefit appears on two scales, local and global. Because much of buildings' demand for energy requires local energy combustion in individual heating systems or district heating, reduced energy demand improves air quality at the local level. In particular in developing countries a reduced demand for energy requires fewer power plants, thereby delaying or obviating the construction of new generation and grid capacity and enabling communities to devote public funds elsewhere.

Given the potential scale of energy savings across the building sector, reduced demand for energy and fossil fuels can substantially contribute to a nation's compliance with domestic or supranational targets for the reduction of greenhouse gas emissions.

When adequately ventilated, energy efficient buildings are generally healthier than traditional buildings. Relative to traditional buildings, energy efficient buildings offer a more stable indoor climate, with less draught from windows, walls, floors, and ceiling constructions. Because residents of energy efficient buildings must spend relatively less to heat and cool their homes to within the margins of acceptable comfort, energy efficient construction reduces fuel poverty[4] across society. As households demanding less energy for building-related uses, they burn less fuel locally, thus doubling the potential to improve public health and otherwise benefit local communities.

Among these potential public benefits of energy efficiency in buildings, employment in the construction sector should not be dismissed. As extensively documented on the European

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[3] European Union, Green Paper of 29 November 2000, "Towards a European strategy for the security of energy supply".

[4] Fuel Poverty describes the dynamic in which the high cost of creating a standard level of indoor comfort requires an unsustainable portion of a household's budget. Rather than pay the energy costs, households choose to instead reduce indoor comfort to below normally-accepted limits.

level for instance by EURIMA/Ecofys studies, energy efficiency in buildings creates jobs – an estimated half-million new positions in the European construction sector, were higher efficiency to be regulated.[5]

1.4 Energy efficiency in new buildings

Many means to save energy in new buildings also offer the potential to save money. Individual homeowners and building users investing in energy efficiency will often recover costs in a short period through lower energy expenses. This "payback time" on energy efficiency investment can be as short as a few years. These energy savings are similarly profitable from the macro-economic perspective of national policy. Increased efficiency in new buildings is hence profitable for individual building owners and society as a whole.

Though the construction activity in OECD countries is relatively low, the energy saving potential of new buildings remains large. This potential accumulates year by year because of the long lifetime of buildings: most buildings constructed today will remain in use until after 2050. Logically, new buildings present a good opportunity to save energy over the long term.

In many developing countries, new constructions accounts for a larger share of the buildings. In these countries, such as China and India, the energy savings by energy efficiency in new buildings will have a larger and faster impact on the economy and result in larger savings than in OECD nations. In developing countries a high consumption in new buildings will increase the demand for new supply and grid capacity. In these nations, the general benefit of improved efficiency in new buildings can be seen more quickly and will be felt more profoundly.

1.5 Energy efficiency is not just a choice for the individual owner

Because the efficiency of a new building will influence its energy consumption until renovation or even the whole lifetime, the decisions taken during design and construction will influence decades of building use. Lost opportunities in the construction phase will lead to increased costs if done at a later stage and can wildly inflate the running costs for future users. While individuals continue to determine much about a building's fate, the energy efficiency of a new building should not be viewed only as a matter for individual choice but as a more collective issue, influencing society at large and a future generation of building users.

Some improvements of energy efficiency in new buildings might require a need for development of new solutions or for training of builders or installers, which it is too complicated or costly for the individual owner or constructor to carry in connection to one or a few projects. These solutions might still be cost efficient when first developed and training has taken place. There is therefore a need for overall actors to take the responsibility to drive the development of efficient technologies and buildings, which will reduce costs in the long term and increase the potentials when improved solutions or products penetrate the market.

1.6 Efficient new buildings make efficient existing buildings

New buildings become existing buildings and all existing buildings were once new, hence will the efficiency of new buildings determine the efficiency of existing buildings over time. Exactly when a new building enters into the stock of existing buildings varies by legislation. In some jurisdictions, the "new" designation applies to a building only until the first day of

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[5] Several EURIMA reports on Cost-Effective Climate Protection in the EU Building Stock, WWW.EURIMA.org.

its use; in other areas, certification of a "new" building is valid for up to 10 years.[6] A change in legislation, such as increased energy efficiency requirements, will typically force the conclusion that buildings constructed before the date of promulgation must be considered to be existing buildings.

New buildings are rarely improved or renovated in the first years. The efficiency of new buildings will therefore directly influence the consumption for many years and they will be the standard for improvement of existing buildings, since renovation projects often aim to bring buildings up to the present standard. Efficiency demands for new buildings then becomes the driver also for existing buildings. This dynamic is in particular visible in countries with a long tradition of energy efficiency requirements for new buildings, where there is a substantial supply of more efficient existing buildings on the market. This process can be supported by energy labelling or certification schemes where new and existing buildings are compared as required in most members states of the European Union[7].

The presence of efficient new buildings also influences the decisions made for. Occurring at 30-40 year intervals during a building's lifespan, major renovations or refurbishment aim to repair and replace parts of a building, such as windows and installed equipment following decades of use and in the context of new technology and demands for functionality. In general, these renovations aim to meet the energy efficiency requirements currently in force and applied to new constructions. Thus, strong regulations for highly efficient constructions influence the efficiency of both new and existing buildings. In recognition of this, building codes sometimes include energy efficiency requirements specific to renovations or major refurbishment and enlargements of the buildings[8].

Requirements for highly-efficient new constructions also influence the market for products typically installed in buildings, promoting energy efficient models of windows, boilers, pumps and air-conditioners. Once on the market, these products may become standard in both new and renovated buildings. The way in which energy efficiency regulations for new buildings can open the product market to efficient equipment and catalyse the eradication of inefficient products can be observed in the disappearance of single-glazed windows and non-condensing gas boilers from German, Dutch and Danish markets.

1.7 Conclusion - The need for energy efficiency requirements for new buildings

Given the long lifespan of most buildings, the relative energy efficiency of new buildings will influence energy consumption for many years. Construction of buildings offers compelling opportunities for energy efficiency, as decisions made during a building's design phase entail smaller costs with greater potential energy savings relative to later intervention.

If decided upon in the early design phase, energy efficiency is often considerable less expensive since increased insulation will have only marginal costs for the increased layers of insulation, increased thickness of construction or increased efficiency in appliances. Some efficiency improvements may even reduce construction costs because the efficient solutions are more cost effective or because the need for heating or cooling systems might be reduced.

Decisions which entail no or very low cost at the early project stage include the form of the building, its orientation, the orientation of its windows, and its structural materials. When

[6] Certification for new buildings is valid for 10 years according to the European Directive on Energy Performance in Buildings.

[7] It is a demand in the directive on Energy Performance of buildings that all new buildings have to be certified.

[8] California building codes and the EU Directive on the Energy Performance of Buildings both specify efficiency requirements for building refurbishment. The International Model Building Codes, used in the US and Canada, also include requirements for renovation.

included during the design phase, energy efficiency improvements can reduce the demand for and costs of cooling and heating systems. These same decisions, when made after construction, can be prohibitively costly to enact. In other cases, improvement of energy efficiency late in a building's construction would involve irreparable damage to its structure. Examples of this are rebuilding massive concrete floors placed directly on the ground, hidden pipes or foundations with heat losses. Even when energy improvements are suggested at the late planning phase of a building, it is still preferable compared to introducing them after construction.

2 Building codes and standards

Energy efficiency requirements in building codes can ensure that concern is taken for energy efficiency at the design phase and can help to realise the large potentials for energy efficiency in new buildings. Energy efficiency requirements for new buildings are set in different ways. Based on national or local traditions they can either be integrated in the general building codes or standards for new buildings, or they can be set as separate standards for energy efficiency.

This paper addresses both energy requirements set in building codes and in separate energy standards for buildings. It is generally not the intention to differentiate between requirements in building codes and requirements set in legislation specifically concerning the energy efficiency of buildings. The terms "building codes" or "energy standards" for new buildings generally refer to energy efficiency requirements for new buildings whether they are set in building codes, specific standards or other ways, unless otherwise stated.

This analysis does not support the superiority of either method. Instead, this paper indicates the implications of each type of code for its enforcement. When energy efficiency requirements are set as part of the general rules, it is natural to include their enforcement in the general system for building approval, while separate energy standards impose a separate system for energy efficiency enforcement.

2.1 National or regional levels

In some countries, building codes and standards for energy efficiency are set at a national level. In countries with large climatic differences the national building codes might includes values which are adjusted to the local conditions. These are referred to as national building codes. In other countries, local states or regions establish energy efficiency requirements in buildings. This applies in particular to large countries with a federal government. In this case, a model building code is often developed to cover the whole country, either on a public or as a private initiative[9]. Individual states or regions then modify the national model standard to local conditions; and must adopt this legislation, before it becomes mandatory.

Finally, some countries delegate the establishment of energy efficiency requirements for buildings to local authorities. In this case, the city council, regional government or federal state may autonomously set and enforce standards. This independent governance is now quite rare, particularly in OECD countries, where energy efficiency is seen to be far too important from a national perspective. Countries where codes are set on a local level will usually have a standard set on national level and the recommendation to adopt or adjust the standard locally.

[9] In US the ASHRAE and IECC codes are developed by private organisations but with a large participation from the national authorities. See later in the paper for a further description of these model codes.

3 Energy efficiency requirements in building codes

Building codes are not a new invention and building codes or standards for new buildings address several concerns, such as construction safety, fire safety and occupants' health. One of the earliest examples of regulations for buildings is Hammurabi's law from Mesopotamia, established around 1790 BC. Among the 282 rules or contracts, which regulated every part of society, six concern the construction of houses and the penalties for builders.

Many countries or cities have hence a long tradition of setting rules for constructing of new buildings, often initiated in response to disasters such as a large urban fire, an epidemic or a natural catastrophe such as an earthquake. Requirements for constructing buildings were then set in order to avoid or minimise future disasters. Compared to this energy efficiency regulation for new buildings is relatively new in most countries.

Early energy efficiency requirements for buildings responded to poor insulation levels which could lead to health problems because of moisture or air-infiltration. Most regulations for energy efficiency in buildings before the oil crises in 1973/74 are from northern regions with cold winters, where the climate can considerably influence public health. Requirements on specific constructions with some thermal characteristics in these regions first appeared during the period between the two World Wars, when some countries regulated the introduction of simple insulation in the form of air layers in cavity walls or double layer floors of timber beam.

The first real insulation requirements for U-values[10], R-values[11] and specific insulation materials or multi-glazing, date back to the late 1950s and the early 1960s in Scandinavian countries. These national requirements were intended to improve energy efficiency and comfort in buildings. Comfort was the prime motivation for raising the requirements – in a reflection of increasing standard of living, people wanted better and improved living conditions.

In many countries, the oil supply crisis of the early 1970s catalysed the development of energy efficiency requirements for buildings. Those countries already enforcing efficiency regulations generally raised their requirements during the early 1970s to further reduce energy consumption and decrease dependency on oil. During the 1980s and 1990s, energy efficiency requirements were set or increased in most OECD countries. In part, this new legislation responded to the Kyoto Protocol, or other targets to reduce or stabilise CO_2 emissions.

Today, mandatory minimum energy efficiency requirements in the form of building codes or standards exist in nearly all OECD countries. However, substantial differences persist between legislation of the states, regions and cities.

Regulations for energy efficiency in buildings in developing countries, and especially in rapidly developing countries such as India and China, seeks to improve comfort and to reduce the dramatic increase in energy consumption in this sector with the economic capacity to install cooling or heating systems.

3.1 Setting energy efficiency requirements

When requirement for energy efficiency are set in a separate standard they are less bound by other building rules and can contain more samples and specific documentation of

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[10] U-value: *thermal transmittance* is a technical value describing how much energy passes through one m² of a construction by a difference of one degree in temperature, measured in W per K per m².

[11] R-value: *thermal resistance* describes how well a construction or insulation material resists the penetration of heat, measured in K * m² per W. The (U value) = 1 / (R value).

potential use for contractors or building designers. However, as separate standards, they require their own enforcement system.

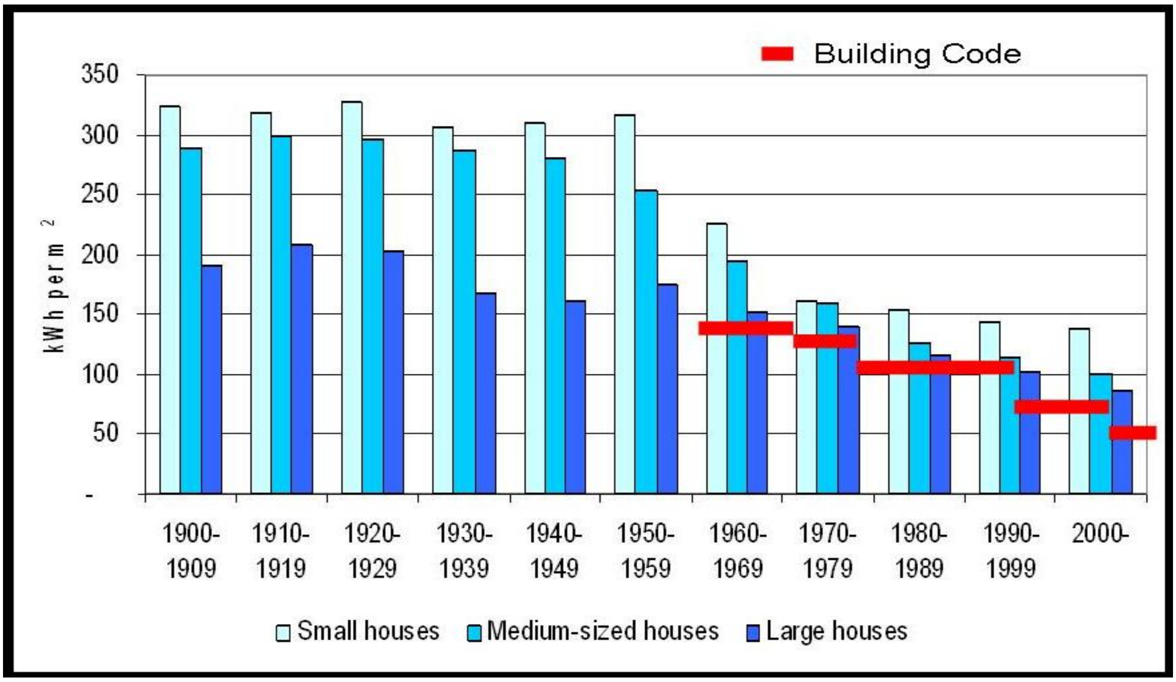
Energy efficiency requirements included in buildings codes are usually set in a specific chapter and enforced along with the general rules of the building codes. If the building industry is familiar with general requirements in the building codes, integrating efficiency requirements can efficiently inform industry actors of energy conservation measures. Energy efficiency requirements included in building codes are often brief, while specific standards are typically longer and more comprehensive.

Some countries mix both approaches by referring to standards. For example, in Germany, general building regulations refer to many specific DIN[12] standards. In many other countries specific guidelines to describe calculation rules and possible use accompany building codes such that the general rules appear in the building code, while standards contain specific details. Many jurisdictions refer to national, CEN[13] or ISO standards.

Impact of minimum energy efficiency standards

Most OECD countries regulate energy consumption in new buildings by setting minimum energy efficiency requirements in buildings codes or in a separate regulation. Several examples illustrate these regulations' impact on energy efficiency in new buildings.

Figure 4. Actual energy consumption in single family houses in Denmark, relative to energy efficiency requirements in building codes.



The results of energy certification of more than 200.000 buildings the average consumption over each decade are compared with energy efficiency requirements in the building codes. [14]

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[12] DIN is "Deutche Institut für Normung": German institute for norms and standards.

[13] CEN, European Committee for Standardisation, is currently developing 31 international standards for calculation of energy performance in buildings to be used in connection with directives from the European Union.

[14] SBI rapport om Varme Besparelser i Boliger, 2003 – heat savings in residential buildings. Information energy consumption in new buildings is also calculated by SBI, The National Building Research Institute in Denmark.

In 1961 Denmark established one of the first building codes which systematically regulated energy consumption. Since then, building codes have been updated several times, including major changes in 1972, 1979, 1997, and in 2006. As illustrated in Figure 4, studies of existing buildings track the trend of declining energy consumption in the context of rising efficiency requirements. The results of early regulations to improve thermal comfort, policies taken in the 1930s and 1940s to ensure construction of cavity walls and double layer beam floors in large residential buildings can be seen too. The lapse between lapse between promulgation of new requirements and their full implementation in the building sector can be seen too, evidence of insufficient enforcement and information.

A similar trend is shown in other countries: buildings' improved energy performance follows the introduction and strengthening of building codes with lapse between promulgation and improvement corresponding to the strength of local law enforcement.

3.2 International trends in energy efficiency requirements for new buildings

Though most energy efficiency requirements in building codes followed local, state or national tradition, the past decade has shown a trend in supranational collaboration to develop international energy efficiency requirements or standards. Examples are the US based Energy Efficiency standards (IECC 2004[15] and ASHRAE 2004[16]) which are used in US and Canada, and the European Energy Performance in Buildings Directive (EPBD) that required member states of the European Union to establish requirements for energy efficiency in new buildings, effective January 2006. To supplement the EPBD, the European Union aims to establish a model building code for energy efficiency for the European region (2006 EU Action Plan for End-use Efficiency) and to develop CEN standards for energy performance calculation. These CEN standards are on the way to be amended and adopted as ISO standards too.

Most countries have started with one common standard for energy efficiency, but have over time developed separate standards for small and simple residential buildings and for large, complex or non residential buildings, in consideration of the dissimilar energy performance.

4 Barriers to energy efficiency in new buildings

4.1 If it is feasible, why is it not done?

Many barriers impede energy efficiency in buildings, and perfect function of the building sector market in economic terms. Insufficient information, insufficient finance for efficiency improvement, split incentives, users' lifestyle choices and multiple decision makers all hamper buildings' efficient performance. Among the building sector's barriers to efficiency, some are specific to new buildings.

When buildings are designed and constructed, energy efficiency is but one concern amid many, some considered more urgent by decision-makers. These can be structural or fire safety, room size, and even the view from the windows. Energy efficiency in buildings may hence be low on the list of requirements.

Focus on incremental costs

Those involved in building projects tend to emphasize investment and construction costs without due consideration of buildings' future running costs. Often these involved parties only have a direct interest in the construction budget and not the total budget, and may be

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Each of the 200.000 buildings was inspected by energy consultants and energy consumption calculated based on similar conditions as are used in building codes.

[15] IECC 2004, International Energy Conservation Code for residential buildings.

[16] ASHRAE 2004, American Society of Heating Refrigerating and Air Conditioning Engineering.

unwilling or unable to evaluate future costs, including those for energy and other resources. Few actors involved in a building's construction have the training required to analyse a building's lifecycle costs and guide construction practices to improve future efficiency. The known costs of construction are thus considered more carefully than unknown future costs.

Construction decision makers not interested in future costs

Many large buildings are constructed by professional developers and most single family houses by construction companies. After construction, developers sell the buildings to future occupants or users. Those who make decisions regarding energy performance will most commonly not pay the energy bills. Building occupants, who pay energy bills, are rarely involved in the building design.

Insufficient efficiency awareness among consumers, designers and banks

Many different decision makers takes decisions, which can influence the energy efficiency of new buildings such as designers, financers, builders, installers and buyers, but most of these know very little about energy efficiency of buildings. Lack of knowledge in just one of these chains can block for energy efficiency in new buildings.

Most buyers of buildings only buy a few times during their lives. Unpractised buyers may not be mindful of the implications and costs of low energy efficiency and, even if aware, may intervene too late during building construction to promote energy efficiency in new buildings. Energy efficiency might therefore be left up to other actors in the construction of buildings. However, most designers, builders and installers know or care little about energy efficiency.

Because designers and contractors make the initial decisions that influence energy performance, both groups can craft an efficient structure. Too often, however, neither engineers nor efficiency advisors are extensively involved in the early design process.

When evaluating a potential construction project a lending financial institution generally focuses on construction costs without attention to implied future costs for energy. Banks may hence be reluctant to fund investments in measures to improve efficiency, even if these investments are feasible and profitable. Insufficient awareness among financiers of efficiency's benefits may prove prohibitive to the construction and operation of efficient buildings and the limited scope of this valuation can frame a budget unresponsive to potential reductions in future costs. Consumers and builders that seek energy efficient construction may not be able to obtain the loans to finance efficiency investment.[17]

Cost structures and lack of capacity

Some energy efficiency measures involve special equipment or expertise not readily available on all markets. Lack of capacity, possible delays due to delivery time or extra fees paid to an expert can deter contractors' interest in efficient construction and further reduce market interest in efficient products or techniques. In addition, some builders are unwilling to invest in training.

Split incentives, brief occupancy and efficiency's marketing difficulties

Decisions regarding the energy performance of many buildings are often split between building owners or constructors, who would be required to pay for efficiency investments, and building occupants, who would reap the rewards of lower running costs for energy. Total costs might be reduced by efficiency, but because it is split on different persons it might be rejected.

[17] Financing Energy Efficient Homes: Existing Policy Responses to Financial Barriers, Philippine de T'Serclaes, IEA 2007.

In buildings such as shops or flats, occupancy time can be short: some buildings are seen as short term investments. Since investments in energy efficiency in buildings are often only profitable over a longer term, few of these conservation options are explored when buildings or units are rented or even bought for a short period.

Transaction of new and existing buildings too rarely considers the avoided costs of energy efficiency. In part, this reticence is due to the fact that the complex calculation of future savings includes several uncertainties, such as future energy prices and real estate market fluctuations. Owners who invest in higher energy efficiency cannot be sure of making a profit or even just recovering initial investments when re-selling the building.

4.2 Inertia against efficient buildings

In addition to these classic economic barriers there is also inertia in the building sector, in which economically-irrational attachment to aspects of a consumer's lifestyle biases a consumer against energy efficient choice in buildings. For reasons of status, marketing and social ritual, individuals and companies use more energy than basic comfort might require. Relative to these conditions, economic optimisation may have a far lower rank in the mind of the energy consumer or building owner.[18]

Energy is invisible

The use of energy is often physically invisible to consumers. Only the status and comfort of using energy will be visible to the energy buyers themselves and to others. A building that does not require air-conditioning might be comfortable and cheap to run, but only by installing air-conditioning can owners or developers demonstrate that indoor comfort is a high priority. Some installations or ineffective energy use signal that the users and owners of the building can afford to make a comfortable indoor comfort and care about the well-being of building occupants. Even the noise from air-conditioning units can be seen as an added value because this makes comfort visible for owners and guests in hotels or in workplaces.

Some might consider a reduction of energy consumption and increase in efficiency as a decrease in comfort or status. For energy users with a good economic foundation ineffective energy use will not usually influence the lives substantially since energy costs will only be a small part of the overall budget. Increasing energy prices might help to reduce this barrier.

Mistaken beliefs in energy efficiency

Owners of buildings or buyers of new buildings may mistakenly believe that the efficiency of a certain building is very good even if it is not. In particular, buyers may mistakenly believe that new constructions automatically are so much more efficient that there is no need to take any further action. Increased energy efficiency in new buildings will hence not be of concern even despite of feasible and compelling opportunities. This might hamper increased efficiency in new buildings, because more efficient buildings and products will not penetrate the market since consumers believe that the existing products and building are already efficient enough.

Slogans such as "energy efficient buildings" or "low energy buildings" have been misused in application to new buildings that only just fulfil the energy minimum standards. However, when buyers feel satisfied with their putatively-efficient building, they are less likely to take further action to improve efficiency.

[18] Danish Building Research Institute, SBI, Ole Michael Jensen, "Barrierer for realisering af energibesparelser i bygninger" (Barriers to the realisation of energy savings in buildings).

Building codes set the minimum standard and the maximum

Many building buyers interpret the mere existence of building codes to be sufficient warranty for the efficiency of new buildings, but the efficiency standards appearing in building codes rarely represent the optimum for efficiency. Building codes often tend to be the exact level as those for new buildings and not the minimum - which was the original intention of the authority - because builders and designers rarely find an incentive to exceed these efficiency standards which might increase initial costs.

Instead building codes should serve as a common and sure baseline from which to gauge progress and initiatives should be taken to ensure that better energy efficiency would be considered in new buildings.

Barriers work together

Most barriers to energy efficiency in new buildings interact and strengthen each other. Many initiatives for improved energy efficiency in buildings have returned small or limited results because some barriers have been overlooked or insufficiently addressed. For example, a change in legislation and subsequent information campaigns will fail if building constructors and installers do not have access to sufficient funds for efficiency investment. A successful policy, or package of initiatives, will simultaneously have to address all major barriers to buildings' energy efficiency.

Conclusion: Barriers

Many barriers hamper energy efficiency in new and existing buildings. When new buildings are designed and constructed, energy efficiency is but one concern among many factors in construction. Energy efficiency in buildings may be low on the list of requirements for the building. The development of most buildings focuses on construction costs with very little concern for running costs. Different people and budgets may govern the operation of a building, often entailing split incentives for energy conservation. Very rarely will any single decision maker participate in all aspects of a buildings construction, operation and financing. Most decision makers will not have the data or capability to calculate a building's lifetime costs and estimate the consequences of early design decisions. Consumer inertia regarding buildings' energy performance stems from the fact that energy is invisible, that the energy costs of new buildings seem imaginary and that improved efficiency can decrease prestige.[19]

There is hence need to increase awareness of energy efficiency and possibilities for further improvements in new buildings at all levels and to address all barriers simultaneously. Comprehensive policies are best suited to overcoming these self-compounding barriers.

5 Regulation of energy efficiency in new buildings

Since many barriers hamper energy efficiency in new buildings, there is a strong request for policies which address energy efficiency in new buildings. Energy efficiency requirements for new buildings effectively reduce energy consumption in buildings. Building codes or standards for energy efficiency regulate on the efficiency of the building envelope, including the structures around heated or cooled parts of the building, but often they also regulate the efficiency of different part of the heating, cooling and ventilation system and maybe even other energy using equipment,.

The energy efficiency requirements of the building shell or envelope have historically been the first to be regulated and they are today an essential part of nearly all regulations for energy efficiency in new buildings. The other segments of constructions and installations

[19] Further work under the Gleneagles Plan of Action will examine barriers and inertia relative to energy efficiency in buildings. A specific paper will address these barriers in the context of existing buildings.

that influence a building's energy performance[20] can be addressed in the regulation of energy efficiency, but these parts are more rarely included in the requirements.

5.1 Building envelope

The building envelope is a term for the parts of the building which surround the heated and cooled parts of the building. This includes external walls, floors or ground deck, roofs or constructions towards unheated ceilings, windows and doors. If a cellar is heated then the cellar walls and the cellar floor are part of the building envelope. If it is unheated, the building shell includes the floor between the ground floor and the cellar. The building envelope may also address heat loss through foundations or other thermal bridges.[21]

Requirements for energy efficiency in external parts of the building, the building envelope, are generally set based on resistance to heat transparency through a unit of the construction, R-values, or a value for the heat transparency through a unit by a specific temperature, a U-factor or a U-value.[22] In cold climates, low U-values or high R-values prevent heat from escaping from buildings, and in hot climates they prevent heat from entering buildings. U-values or U-factors will typically be given in w/m^2 per °C or as Btu / ft^2 per °F.[23]

Windows

Windows, doors and other parts of buildings that include glass areas require special attention: beyond its role in insulation, glass provides buildings with daylight and heat from sunlight. In cold climates, solar heat gains can reduce a building's need for active heating. In hot climates, however, the heat from sunlight needs to be removed by cooling. The orientation of windows and glass areas should suit the different amounts of light approaching the building from the north, south, each and west and complement a building's needs for heating and cooling.

Special glass constants (G-values) for windows indicate the amount of sunlight that can penetrate each pane of glass. Calculations for windows can be rather complex and in US and Canada standards for windows include a range of solar heat gain coefficients (SHGC), visible light transmission (VLT) and shading constants (SC).[24]

There are several methods to improve the efficiency of windows or other glass areas. These include increasing the layers of glazing to double- or triple-glazing, coating the glass, or filling the space between glass plates with an inert gas or a vacuum to reduce heat transfer. Window frames that position the glass and separate panes also offer the potential for thermal efficiency improvement. The thermal dynamics and lighting potential of windows and glass areas should be considered in specific rules or in calculation procedures.

Shading

Shading, shutters and reflection can greatly reduce sun penetration of windows and other glass areas. Shading is a rather complicated issue which often requires complicated models

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[20] The energy performance of a building describes the overall energy efficiency of the building in terms of energy consumption by a standardised use.

[21] A Thermal Bridge is a construction or a part of a construction that conducts heat more efficiently than the surrounding construction. Cold bridges can be foundations or massive parts of a construction that normally include insulation materials.

[22] U-value and R-values are inversely proportional $U = 1/R$.

[23] SI units watt per square meter per degree Kelvin (or degree Celsius) - W/m^2 per °C - and IP units in Btu per square foot per degree Fahrenheit – Btu/ft^2 per °F - can be compared because values in SI equals values in IP multiplied by a factor $k = 5.6783$

[24] For further description of window calculations and values such as SHGC, VLT, and SC see the US National Fenestration Council (NFCR). Homepage http://www.nfre.org/.

which simulate three dimensions. For simple building these models can be complicated to use since they will require many information on the building for and shading parts which have to be calculated with concern of the movement of the sun on the sky in the actual building sight.

Some countries have developed simplified guidelines to be used in connection with more simple buildings and by builders. Figure 5 shows such an example from California.

Figure 5. Solar protection in California

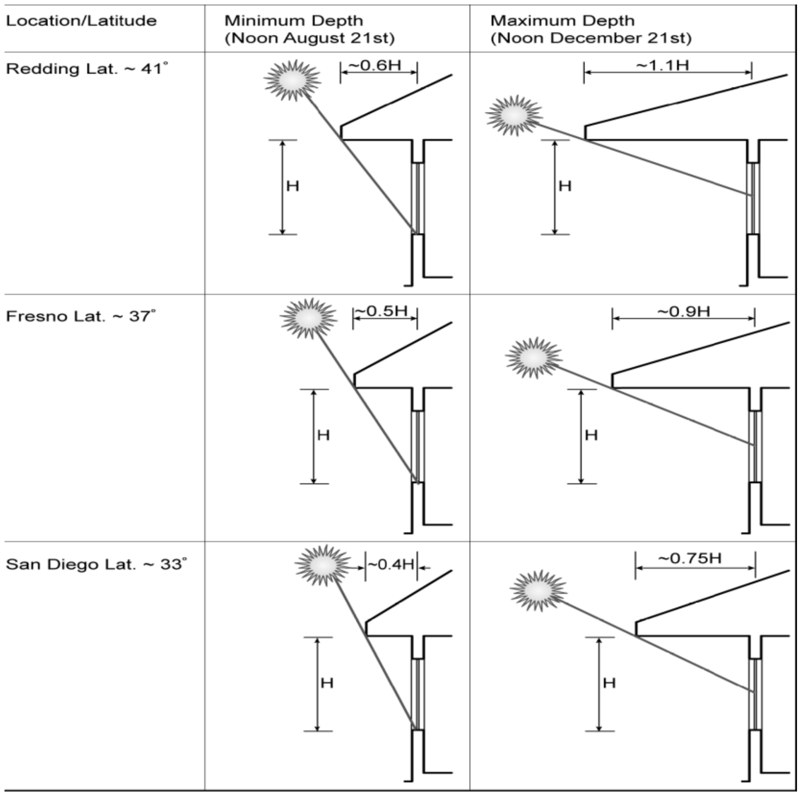

Illustration of solar penetration and shading from the California Energy efficiency standards for low-rise residential buildings.

Air Filtration

Air filtering around windows and glass areas[25] creates an indoors draught. When considered thermally, the undesired air filtration is a loss of energy as it requires redundant heating or cooling. Similar filtrations come from the connection of building parts in general and for some constructions such as boards, which have contracted allowing small openings to appear.

Natural air filtration can provide some – in the past maybe even all - required ventilation. However, ventilation with natural air currents can entail large heat losses from constant air exchange and inconvenient timing and intensity. Natural air filtration is difficult to control and evaluate. Air tightness is often treated separately in building codes and can be assessed in a "blower door test".[26] As buildings become more efficient, air filtration can be one of the major conduits for heat loss in an otherwise highly-insulated building.

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[25] Filtration of air is used as term for the uncontrolled infiltration of air from outside. This air comes in around windows, in connection between building parts, connection between plates or boards. In old buildings this exchange of air can be substantial.

[26] In such a test, a door is replaced with a special device which can put pressure inside the building. It is the metered how to keep the pressure as a value for the filtration.

5.2 HVAC systems

HVAC systems maintain a building's comfortable indoor climate through Heating, Ventilation and Air Conditioning (Cooling). These systems profoundly influence energy consumption in buildings. Without heating, cooling and ventilation systems there would be no energy consumption in the building, since it would be totally dependent on outdoor conditions. There is an inverse correlation between the efficiency of the building and the need for HVAC systems: highly efficient building envelopes reduce the need for heating and cooling systems. Good and intelligent designed buildings can reduce or even avoid the need for heating and cooling and reduce the need for ventilation.

Efficiency improvements in HVAC systems can lead to substantial savings, but these savings will also depend on the efficiency of the building in general. If, for instance, energy efficiency is improved in a heating boiler or an air-conditioner, total savings will depend on the total need for heating or cooling in the building. Higher requirements for the building envelope might reduce the potential for savings in HVAC systems. Finally the HVAC systems need to be in a good balance with the buildings in general and they need to be of a proper size which fits with the actual heating, cooling and ventilation needs.

Ventilation

Well-insulated, airtight buildings often require active ventilation to remove used air and introduce fresh air for occupants. Natural ventilation, like the flow of air through open windows, and mechanical ventilation both circulate air. Ventilation can also be included in air-conditioners which combine simultaneous heating and cooling. There are many technologies to improve the efficiency of ventilation systems, including heat exchangers and heat pumps.

For ventilation systems there is a need to be aware of both the energy use in ventilation system it self for fans and preheating of the air etc. but there is also a need to take concern for the heat losses which comes with the exchange of the air. Ventilation systems should hence effectively ensure the necessary air exchange, not more and not less.

Heating systems

Many possible systems can heat a building. Collective heating can include a combined system based on a heating supply in the building such as a boiler or on an external supply in the form of district heating or heating from combined heat and power production. Buildings can also draw heat from individual systems such as electric heaters, heat pumps or individual ovens. Finally, heating can be integrated in the ventilation and air-conditioning systems.

Centralised heating systems include a distribution system in the building such as pipes[27], ducts[28], tanks, pumps, fans, or exchangers. The efficiency of the overall system depends on the efficiency of all its components, and an efficient boiler can become an inefficient heating system if parts are poorly connected and badly calibrated. In individual systems, the efficiency often depends alone on the efficiency in the heating source only.

Building Codes will often address the efficiency in the system in general and in the components of the system. Some buildings might have multiple systems with a mix of functions, which should all be addressed.

Cooling

To maintain a comfortable and healthy indoor climate, the heat must be removed from overheated buildings. Cooling systems can be centralised or decentralised into small units

[27] All pipes for transportation of heated water for the heating of the building and for heating of hot sanitary water.

[28] Ducts, all canals to transport air in a cooling, ventilation or air conditioning system.

installed in every room for instance with small split units which are installed in each room. For split units, it is mostly the efficiency of the cooling device and the control system which are of importance for the overall efficiency. Within centralised systems, the dimensions and control of the system itself and the distribution ducts both determine energy efficiency. Air tightness is especially important for building cooling, as air leakage can substantially reduce the efficiency of mechanical cooling. Some buildings work with natural cooling or with night cooling, both of which reduce the need for active cooling.

Air Conditioning

Air conditioning systems generally combine the capacity to ventilate, cool, and heat. In a basic definition, an air conditioning system will supply the building with heated air if outdoor temperatures are cold, with cooled air during hot days and with plain air if the building requires only ventilation. For air condition systems, it is primary the efficiency of the overall system and / or components which are regulated, including the heating, cooling and ventilation components.

Dehumidification

In humid climates and in buildings producing much humidity, like swimming halls or other indoor bathing facilities, moisture may need to be removed from inside buildings. Itself an often energy-intensive process, dehumidification can be integrated into air conditioning systems. Building regulations in humid climates, should account for the energy involved in humidity control.

Hot sanitary water

Many buildings' occupants require hot sanitary water for hygiene, food preparation, cleaning and commercial purposes. The central heating system can provide this water, as can a separate system using electricity, oil, gas, solar thermal energy, heat pumps or district heating. Efficiency regulations often address hot sanitary water.

Ducts and pipes

Because ducts and pipes determine much of the energy efficiency of heating and cooling system, ducts and pipes should be carefully dimensioned, assembled, insulated and placed in the most efficient manner inside or outside the building shell.

Automatic controls

Automatic controls of systems can largely determine or influence the efficiency of these systems. Individual systems as heating, cooling, ventilation or lighting systems can have individual automatics or the overall system can be controlled by one overall central system, which controls all the functions. If the systems are controlled by individual systems this can in some cases lead to conflicts between for instance the heating and the cooling systems. Good and efficient automatics can ensure the optimal use of the HVAC systems can be addressed.

5.3 Renewable Energy

The use of local sources of renewable energy can be either passive or active. In passive systems the renewable energy is used to avoid the need for heating or cooling while the active systems will transform the energy from for instance the sun or the wind into electricity, heat or cooled energy carriers from which energy is used, as if it came from a non renewable HVAC system.

With a decreasing energy demand in buildings these sources become an important part of the energy performance of the buildings and the more advanced standards include these sources.

Requirements for energy efficiency in buildings and the calculation of energy performance can both address integrated renewable energy systems. These requirements can either be set for the renewable energy sources themselves – for example, in a demand for solar heating of sanitary water, as in the case for Spain - or as part of an overall energy performance (see below), where the demands are set for the maximum delivered energy.

Passive Solar

In a building heated by passive solar energy, glass areas are oriented and arranged so as to optimise the capture of solar light and heat. When buildings are highly insulated and energy efficient, passive solar energy can meet a substantial share of the heating demand, even in cold climates.

Because a building's exposure to solar energy varies over the year and during the day, constructions must be able to store and balance solar energy. Buildings capturing too much heat may require cooling, offsetting the efficiency gains of passive heating. Passive solar heating of buildings requires good models for balancing heating in multiple zones[29] to provide even temperatures throughout the building.

Passive cooling and ventilation

In passive cooling systems natural cool resources for instance in water or in the ground can be used to reduce the need to cool the buildings. Passive cooling systems can also use the fact that the temperature might be colder at night or use different phenomena's which will cool air or building parts.

In natural or passive ventilation different options are used to avoid active ventilation systems. Natural ventilation is often used in small residential buildings and often these buildings are constructed with out or with very limited use of active or mechanical ventilation. In larger buildings and in particular in service buildings the use of natural ventilation requires a high emphasis in the design phase.

When natural ventilation or passive ventilation is used in large buildings natural sources of wind or airstreams because of difference in temperatures are used to drive the ventilation. This is typically achieved through an intensive design phase where the shape of the building is adjusted or where specific elements such as special designed windows are introduced.

Passive cooling and ventilation can reduce energy consumption substantially but is difficult and complicated to address in building codes or standards for new buildings.

Active renewable energy systems

In active renewable energy systems the energy from the renewable energy sources are actively transformed into heating, cooling or electricity and the used as energy supply which comes from non renewable HVAC systems. Some of these systems can often be integrated in the buildings or in the building shell.

Solar water heaters are one of the most commonly used renewable energy supplies in buildings and in these systems water is heated by the sun and the heat is stored until used. Similar systems can be used to heat the building but this increase the need for storage and sometimes even from one season to another.

Photo voltaic (PV) is another example on active use of solar energy in buildings, where solar energy is transformed into electricity and used for the buildings supply of electricity. Solar energy can also be transformed directly into cooling and used as a cooling source. These systems will often require little storage, because they produce when needs for cooling are high.

Other renewable energy sources in building can be small building integrated windmills or systems that use biomass or waste products from the buildings and heat pumps can be used

[29] By multiple zones the building is shared in parts, which are treated individually in the calculations.

to increase the use of renewable energy supplies for instance in the ground, in air or in water.

5.4 Installed equipment

Installed systems other than HVAC systems can influence a building's energy performance in two different ways: through their own energy demand and through their production of waste heat which can result in increased cooling loads or decreased heating loads. Given their connection with buildings, some appliances fall under the auspice of building energy efficiency requirements in building codes and appear in the calculation of energy efficiency performance of buildings[30].

Some equipment and electrical appliances have more loose connection to the building and can more or less simply be removed or exchanged without interfering actively with the building itself. Other IEA studies examine the efficiency of these appliances.

Lighting

Lighting requirements respond to a building's design. The need for lighting, especially during daytime, will depend on the size and placement of a building's windows, and the building's situation. The need for lighting can be reduced by the use of automatic controls which depends on the orientation of buildings windows, the supply of daylight, use of the room etc.

Indoor lighting systems produce heat, in form of waste energy depending on the actual type of installations, that can reduce energy demand for indoor heating in cold climates or during winter and raise demand for indoor cooling in hot climates or by summer. Building regulations can govern lighting systems general or more commonly only the built-in lighting systems. Assessment of highly energy efficient buildings should also consider lighting. [31]

Appliances

Many electrical appliances such as white goods device or televisions and computers will have an interaction with the building in which they are installed, since they will contribute to waste energy for the building. This will influence the need for heating and cooling. In particular in cooled building waste energy from inefficient appliances can lead to double energy loss, first because they use more energy themselves and second because they create waste energy, which has to be cooled away by the cooling or ventilation system.

In highly efficient buildings, heat from installed appliances can substantially influence the need for heating and cooling. Around the world, programmes such as FEMP and Energy Star in North America, EU appliance labelling schemes and Japan's Top Runner promote energy efficient appliances[32].

Efficient appliances are treated in a special study as a part of the Gleneagles Plan of Action and in IEA publications such as Saving Electricity in a Hurry and Cool Appliances.[33]

5.5 Zoning of buildings

Zoning of a building means that the building is divided up into separate areas, each with the potential for uniquely-calculated requirements for energy efficiency and indoor climate.

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[30] As specified in the European Directive on Energy Performance in Buildings, lighting for non-residential buildings and the heat gains from other appliances must be calculated in general energy performance.

[31] Lighting is treated in depth in the IEA study: Light Labour's Lost: Policies for Energy Efficient Lighting. 2006

[32] Top Runner is a Japanese system where producers are encouraged to develop and implement energy efficient systems. Further description of Top Runner later in this paper under building codes in Japan.

[33] Cool Appliances, Policy Strategies for Energy Efficient Homes, 2003. An update of this publication is under preparation.

There might be transfers of energy from one zone to another, if there are differences in the indoor temperatures. Zoning can be needed for passive solar conditions, for building ultra low energy consumption and for complex buildings that have multiple functions, to ensure that suitable indoor climatic conditions are obtained in different parts of the building.

5.6 Integrated design

Integrated design is a term used for a process where all the elements described above are used to reduce the energy consumption in a building.[34] In this process actions are taken to reduce the energy consumption as well through insulation or efficiency as through the design of the buildings and the HVAC systems. Passive use of renewable energy and other natural sources is an integrated part of the design and development process and there is an interactive process between the design of building and systems.

Integrated design requires more emphasis on energy efficiency and systems in the early planning phase than traditional design and it is difficult to regulate through building codes and energy efficiency standards, but the most advanced standards or energy performance calculation includes options for integrated design. Some examples where the integrated design process is used are described later.[35]

5.7 Conclusion

Many elements influence the energy performance of a building; building codes often address the most integrated of these elements: the building envelope and HVAC systems. Other appliances and Renewable Energy are more rarely included.

Many building energy efficiency regulations started with requirements for the building shell, and nearly all efficiency regulations for new buildings include requirements for the building envelope. As the building's envelope improves, regulations focus on the energy efficiency of HVAC systems. Finally, when all parts of building and HVAC systems are covered, regulations address other installations and renewable energy.

For some regulations, energy efficiency requirements are primarily set for buildings and the building shell. While some building codes include the energy consumption of installed equipment and appliances, some include lighting and others do not. The treatment of renewable energy systems in building codes also varies.

The most advanced building codes or standards for energy efficiency in buildings today include all of these aspects. It should be the aim to include most of these elements in building codes or the calculation of energy performance, especially when requirements are high, since this will increase the saving potentials and will prevent sub-optimisation of the demands for some parts of a building.

6 Types of regulation

Energy efficiency requirements can be set in different ways and the basic types are:

- **Prescriptive.** This method sets separate energy efficiency requirements for each building part and for each part of the equipment. Individual components must achieve compliance with their specific targets.

[34] In the integrated design other use of resources will also be evaluated and the process will also include the consideration of costs by different options.

[35] Examples where an integrated process is used can be Passive Houses, Zero Energy or Carbon Buildings and Green Buildings.

- **Trade-off.** Values are set for each part of the building, but a trade-off can be made so some values are better and some are worse than the requirements.
- **Model building.** Values are set as in the trade-off, and a model building with the same shape is calculated with those values. A calculation has to demonstrate that the actual building will be as good as the model building.
- **Energy frame.** An overall framework establishes the standard for a building's maximum energy loss. A calculation of the building has to show that this maximum is respected.
- **Performance.** Energy performance requirements are based on a building's overall consumption of energy or fossil fuel or the building's implied emissions of greenhouse gas.

6.1 Prescriptive

When using the prescriptive method, energy efficiency requirements are set for each component of the building. This could be a thermal value (U-value) for windows, roofs or walls. The prescriptive method can include efficiency values for technical installation, ventilation, orientation of buildings, solar gains, the number and size of windows. To comply with a prescriptive standard, each part of a building must meet its specific value.

A simple version of a prescriptive building code set thermal values for the essential 5–10 building parts. In the most complicated systems, energy efficiency requirements are set for all parts of building and installations, including heating installation, cooling units, pumps, fans, and lighting. In some cases, these requirements are even adjusted according to size of the equipment or the size of or percentage of windows based on floor area or the outer wall.

In general, instructions for the prescriptive method are easy to implement. U-values can be followed by descriptions of typical constructions which fulfil the requirements and requirements for equipment can be combined with the labelling of products. A prescriptive method could require an appliance to be labelled A or B, or rated with energy stars.

6.2 Trade-off

The trade-off method sets values for individual building parts and / or for parts of the installations, akin to the prescriptive method. However, in meeting a general standard for efficiency, a trade-off can be made between the efficiency of some parts and installations such that some values are exceeded while others are not met.

The trade-off is generally made in simple terms. Trade-off can be made between U-values for the building shell[36] or between building shell and the energy efficiency requirements for heating and cooling installations. The trade-off model provides more freedom and flexibility than the prescriptive method. The calculations are normally simple and possible to do by hand or in a simple spreadsheet.[37]

6.3 Model Building

In the model building method, values are set for each building part and / or for the parts of the technical installations. Based on the values and the characteristics of the actual building a model building is calculated with all the set values for losses and efficiency. This calculation follows a clearly defined method. The actual building is then calculated by the same method using the actual values for the individual building parts, heating, cooling, and

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[36] For instance U-values are balanced according to the area, so 10 m² with + 0.2 in one value can be exchanged to 20 m² with – 0.1 in another value.

[37] By trade off models a special attention should be taken for systems with a long lifetime such as insulation and building structures and systems with short or medium lifetime, such as most HVAC systems.

ventilation systems. The total result of the calculation is compared with the model building and the actual building must perform as well as or better than the model building.

The most complicated models include all parts of the technical systems in these calculations, including all parts of heating systems, ventilation, cooling, lighting, built in equipment etc. Renewable energy can be included in the calculations, to make a solar collector, for instance, reduce the general efficiency requirements for the heating system or even the insulation level.

The model building gives more freedom and flexibility for building designers and constructors than a prescriptive model. Expensive systems can be changed with improved efficiency in parts of the building or installations where efficiency will be more cost effective.

6.4 Energy Frame

The Energy Frame for a building sets a maximum of energy loss from the building. This is usually set as a total frame for the building, a value pr. m^2 building area or as a combination. The energy frame will then be followed by a procedure on how to calculate the energy losses from simple values such as the u-values, temperature, surface and heat gains from sunlight etc. Values for the individual parts are not set in this model but only for total loss or use of energy.

This method enables the constructor to build parts of the buildings that are less energy efficient when other parts are made better than typical constructions. This method can as example also avoid limiting the size window area, as improved windows or increased insulation can adjust for the additional heat losses or larger sun gains by having a larger surface of windows. As long as the overall value is met, the building is approved.

The energy frame can also be defined as an overall thermal value (adjusted u-value), pr. square meter of building floor area or similar. Again it will be the constructor's decision to document that the building is built up to the standard of the model building given by the overall values.

Similar to the model building this gives more flexibility in the fulfilment of the requirements and this can easily be adapted to the most economic solution. On the other hand it increases the need for calculation.

6.5 Energy Performance

With the energy performance method, a total requirement for the building is set based on the supply of energy or the resulting environmental impact, for instance in form of CO_2 emissions. This method requires a comprehensive method for calculating the energy performance of a building, with standard values for climate and use of the different types of buildings. Constructors are required to use an advanced computer based model for the calculations, which integrate all the different parts and installations of the building.

Values for energy performance are set on the basis of an overall value, consumption pr. m^2 or a mixture, for different types of use or different types of buildings etc. Installations as renewable energy in the building will usually be calculated as improvement in performance, meaning that a solar collector or solar cells can substitute insulation, efficiency in boilers or air conditioners. The performance model requires handling multiple factors as solar gains, recovery of energy losses, shading and efficiency in installations.

In the energy performance, comparing the use of different energy forms such as heating (gas, oil or district) with the use of electricity is necessary. Depending on local energy conditions, there may be adjustments, where some kWh's or Gj are valued higher than other or the comparison can be based on energy costs.

In performance calculations, the maximum value is often set for the use of fossil fuels, primary energy use or as a maximum CO_2 emission. Free trade-offs can be made between insulation and installation of efficient equipment, but also based on the selection of fuels, the use of renewable energy, the primary design (form) of the building, use of daylight, and intelligent installations or automatics. Windows with better thermal values can be used to increase the window area or negative losses can be out balanced with positive gains as passive heating.

Energy performance standards give optimal freedom for constructors or designers to reduce energy consumption within the frame. If efficient boilers or air conditioners are more cost effective than improved insulation, the constructors can choose this alternative to improve performance. Similarly, it will be possible to substitute more expensive solutions in the building envelope with efficient renewable energy systems or heat recovery. The model adapts to a change in prices, technical development and allows new solutions and products. There is a need to develop and maintain sophisticated calculation methods and computer tools that take all these important factors into account.

6.6 Mixed models, hybrids

Some countries use a mix of the above models. For example, an energy frame for the building might be combined with prescriptive values for installed products. Another typical mixture is when building codes allow a choice between the simple approach with prescriptive values, an energy performance or an energy frame. The designers can therefore use a model which is simple to calculate, or choose a more complicated model, which offers more freedom and flexibility. Sometimes both performance values and prescriptive values are set, where the prescriptive values are tighter than the value for the overall calculation, which ensures that buildings constructed after the prescriptive values, automatically fulfil the energy frame or energy performance requirements.

Some countries or states have two or more models which have to be fulfilled at the same time; in this case, energy efficiency requirements will grow from the prescriptive models over the energy frame to energy performance. The target is to ensure that no building part or component of the heating or cooling system is too poor, but rather to base the overall calculation on a model that gives more flexibility. The aim may also be to avoid moisture problems if building parts without insulation result in condensation, or to compensate for different lifetimes of components.

6.7 Development

Most countries have started with prescriptive values. When energy efficiency requirements increased and more elements included, trade-offs or an overall frame allowing adjustments of the individual values was required. Today, energy performance models and computer tools are being developed in many regions. International standardisation has been introduced with the aim of developing and harmonising models to calculate energy performance.[38]

At the same time, countries have decided to have several methods for compliance with norms which allow builders and constructors to choose. This is especially the case for small residential buildings where there is a general effort to make simple and comprehensive rules.

6.8 How to compare

In order to compare building codes, the different types can be simplified into two basic forms. Building codes which are set based on energy efficiency requirements for individual

[38] Standards have been developed under CEN and are now under adoption and development in the ISO.

building parts - "U-value based building codes" - and the codes for which these requirements set the overall frames in order to calculate energy consumption - "Performance based building codes".

U-value based building codes

The Prescriptive Method, the Trade-off Method and the Model Building Method are all based on standard maximum values for transmission (U-values)[39], coefficients, energy efficiency values and similar values which can easily be compared. Whether trade-offs are possible will accordingly influence the level of the values.

Calculation or performance based building codes

The Model Building, Energy Frame and Energy Performance methods are all based on calculated energy consumption and all require calculation models and computer tools.

The calculation procedures are normally set national, regional or local. However, CEN[40] / ISO[41] are developing international standards which will ease future comparisons. These types of regulations have to be compared based on total performance or the total frame, but again climate conditions must be taken into account.

6.9 Conclusion

Energy efficiency requirements can be set in different ways, prescriptive, trade off, model building, energy frame or energy performance. Requirements are basically set either on a building part or component level or as an over all maximum for a calculated value.

The different methods have different advantages and disadvantages. U-value and efficiency based codes, in particular for the prescriptive model, is generally the easiest to understand for constructors, since the values are given on a disaggregated level. Standard constructions and installations can be given which fulfil the energy efficiency requirements, and buildings can be constructed without calculations or the use of computer models.

The prescriptive method develops standard solutions that can help to reduce costs on sight, but may lead to over optimisation of particular parts of the buildings or installations, which can lead to increased costs for energy efficiency. However, the trade-off allows some flexibility and freedom in selecting methods and solutions or in optimising energy efficiency without requiring too many calculations. With the energy frame, and finally with energy performance, these possibilities for flexibility and optimisation of costs for efficient solutions will increase. Using the performance model requires computer-based models and a deeper understanding of some of the principles.

It is not easy to determine which type of code is best as it often depends on the actual experience in the country and the development of the construction industry. Often several types of energy efficiency requirements exist side by side as alternatives.

Comparison of building codes are difficult between the different types of codes and can only be justified for codes based either on individual values or performance and frame based values.

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[39] Or minimum values for resistance (R-values).

[40] CEN European Organisation for Standardisation, which have developed standards for the implementation of the European Energy Performance in Buildings directive. Homepage www.cen.eu.

[41] ISO is the International Organization for Standardization, which is currently working on the development of further international standards for energy performance calculations for buildings, Homepage www.iso.org.

7 Conditions for Building Codes, Comparison

Local conditions greatly influence the energy performance of buildings. When comparing building codes, the most significant considerations are climatic conditions, including local temperature, humidity and ambient natural light.[42]

Heating

In cold climates or in the heating season heating is the most important energy issue, and there is a direct link in the difference in temperatures and the loss of energy from buildings. Energy losses through a wall, floor, ceiling, and window or by ventilation are directly proportional to the difference in indoor and outdoor temperature. Similarly will the savings obtained by insulation or improved efficiency.

A simple value to define the need for heating in cold climates is Heating Degree Days[43] (HDD). Heating will be reduced through the positive use of energy from the sun that comes into the building through windows, from body heat, or waste energy in appliances. This is adjusted by using the heating degree days based on a temperature lower than 20 °C, for example 18°C or 17°C[44].

Cooling

In hot climates cooling is the most important energy use in buildings and outdoor temperatures will have a large impact on cooling needs. Cooling needs also depends on the hours of sunlight, the intensity and how much the sunlight penetrates the building. A simple value to show the need for cooling is Cooling Degree Days.[45] Solar radiation based on the penetration of sunlight in the building will increase the need for cooling. Heat gains from people and appliances in buildings increase the need for cooling too. This is addressed by using a colder temperature than the designated indoor temperature for the calculation of Cooling Degree Days.[46]

Higher cooling needs will lead to higher consumption in the same building, and at the same time larger saving can be obtained from a particular measure such as insulation, better glazing or improved efficiency in the air-conditioning or ventilation systems.

Humidity

Humidity is another climatic condition that influences buildings' energy consumption. In areas with a high rate of humidity, especially when both hot and humid, air-conditioning must reduce indoor humidity both for comfort and to prevent moisture damage in buildings and installed equipment.

There are other parts of energy consumption that are influenced by climatic conditions, such as lighting, which depends on the hours of light and the intensity of the sunlight etc. Less daylight in polar areas during winter will require more energy for lighting. For a

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[42] For further explanation, see the IEA Working paper Comparing Building Codes and Selecting Best Practices (September 2006.)

[43] One Heating Degree Day is a day during which the average difference between inside and outside temperature is one degree Celsius. A day during which the indoor temperature is 5 degrees higher than the average outdoor temperature is counted as 5 Heating Degree Days. Heating Degree Days are commonly used in OECD countries.

[44] Heating Degree Days are named by the indoor temperature used as the baseline for calculation: for instance, HDD20 if the baseline temperature is 20 °C or HDD18 for 18 °C. HDD 18 or HDD 17 are most commonly used.

[45] Cooling Degree Days, CDD, are calculated like Heating Degree Days, though using only days where outdoor temperature exceeds a certain temperature. The CDD metric is not as commonly used as HDD figures; CDD data are available for all countries.

[46] Some countries use a temperature much below 20 °C to adjust for solar radiation and other heat gains. For example, the ASHRAE codes use as low a temperature as (10 °C) for the calculation of CDD.

general comparison of codes and standards and a selection of best practices, heating and cooling and to some extend humidity are important parameters to be considered.

Different influences of appliances

Heat losses from inefficient lighting systems and installed appliances will have a different impact on energy performance in cold and hot climates. In cold climates, waste energy from heating appliances or light installations can, to some extent, be used to substitute heating – at least during the cold part of the year – while in hot climates this waste energy leads to increased cooling. Savings in efficient appliances and lighting in hot climates will therefore count twice in the energy performance, while they count less in cold climates. In hot climates, it is hence even more important to be careful with the wasted energy from such systems.

7.1 Climatic classifications

There is a clear need to take climatic conditions into consideration when Building Codes or other measures for buildings are evaluated, compared or when Best Practices are selected. Buildings act different in cold and hot climates. It is therefore not possible directly to compare the heating requirements, for instance in north European countries with the cooling requirements in Australia or in Southern India[47].

Some countries with more climate zones use a system of classification for different areas and set different energy efficiency requirements for insulation and energy efficiency based on the climatic conditions in these areas. This is, for example, the case for the USA and China where a climatic correction is built into the energy efficiency codes based on degree-days.

Köppen Climate Classification

Climate classifications are often based on the Köppen Climate Classification system, which proposes six general climate types: A) tropical, B) dry, C) mild latitude, D) serves latitude, E) polar and H) for highland. Each of these classes is divided into sub categories according to the type of winter or summer. The 6 basic climates is subdivided at least 23 different sub-climates. The Köppen climate classification has been the basis for different systems of building energy efficiency regulations setting up different requirements for different climatic zones.

The 6 basic climates in the Köppen Classification are not sufficiently homogeneous to evaluate and compare building codes since some climates include a large variety of conditions in which buildings will perform differently in term of heating and cooling. The sub-climates are more homogeneous, but it seems on the other hand too complicated to work with 23 different classes when comparing energy efficiency in buildings.

The standard building codes

The ASHRAE standard for commercial and large complex buildings uses 8 zones and 17 sub zones (A, B, C) alone for the US. They follow calculations of Heating Degree-Days, Cooling Degree-Days and moisture (Marine, Dry, and Moist zones) and are adopted according to state borders[48].

The latest version of the International Energy Conservation Code, IECC – a model code for low rise residential and simple commercial buildings - has been simplified, and in this code the US is shared in 10-12 zones (8 general zones 1-8 and some sub zones A, B and C for

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[47] Climatic classifications and the need for simplification are discussed in further details in the IEA Working Paper on Comparing Building Codes and Selecting Best Practices.

[48] These climatic zones for US were developed by DOE's Building Energy Code Program specifically for use in the US codes and standards. Both ASHRAE and IECC use heating degree-days 65°F (18°C) and cooling degree-days 50°F (10°C).

some of the general zones). The zones in IECC are based on the number of Heating degree-days and cooling degree-days. The major part of the zones is based either on heating or degree-days, but 2 zones are based on both heating and cooling degree-days[49].

7.2 Simplifications of climatic conditions

The systems mentioned above seem too complicated for a general evaluation and comparison of building codes. For a valuation and comparison of building codes around the world, it is preferable to work with more simplified conditions. In this model the different climatic conditions are split 6 different basic climatic zones based on heating and cooling requirements. There might be a need to add one further zone based on extreme humidity, which results in a need to reduce humidity[50]. In general, the climates could be described as follows:

- **Cold climate -** a climate where winter is cold and summer temperatures never or only rarely reach a level above comfort level (22 - 25 °C). In this climate, there will hardly ever be a need for cooling. This is the case for large parts of Russia, Scandinavia and Canada.
- **Heating based climate -** where the need for heating in winter is large, but where summer temperatures can reach a level where cooling becomes an option at least for comfort reasons. This is the case for Central and North of Europe, most of Canada and central US.
- **Combined climate -** where winter is cold and summer is hot. Heating is necessary in winter as well as cooling in summer. This applies to Moscow and central parts of Russia, Shanghai region and other parts of in China.
- **Moderate climate -** where both summer and winter are mild and the need for heating and cooling is quite limited. Portugal and central parts of California, as examples.
- **Cooling based climate -** where summer is hot with a need for cooling in the summer but where there can be a need for heating in the winter. Greece, Italy, southern California, Australia.
- **Hot climate -** a climate where summer is hot and winter warm where winter temperatures never get below comfort level (16 - 18 °C). Florida, northern Australia, Central Africa.

Table 1. Simplified climate zones, heating and cooling degree days

	Heating	Cooling
Cold Climate	2000 ≤ HDD 18 °C	CDD 18 °C < 500
Heating based	2000 ≤ HDD 18 °C	500 ≤ CDD 18 °C < 1000
Combined Climate	2000 ≤ HDD 18 °C	1000 ≤ CDD 18 °C
Moderate Climate	HDD 18 °C < 2000	CDD 18 °C < 1000
Cooling Based	1000 ≤ HDD 18 °C < 2000	1000 ≤ CDD 18 °C
Hot climate	HDD 18 °C < 1000	1000 ≤ CDD 18 °C

Proposal for simplified climatic zones based on heating degree days and cooling degree days.

[49] Both ASHRAE and IECC standards will be further describe in paragraph on building codes in North America.

[50] A further discussion and description on these zones can be found in the working paper on Comparing Building Codes and Selecting Best Practices from September 2006.

The allocation of climate into these 6 basic zones could be based on Heating Degree Days and Cooling Degree Days as proposed in Table 1.

7.3 Valuation of building codes

For a comparison of thermal regulations for new buildings and installations this can be further simplified into 3 different main areas:

Cold climate and heating based climates

In both Cold Climates and Heating Based Climates, the comparison can be based mainly on heating needs and efficiency in heating and ventilation installations. In both types of climates, heat gains from the sun and internal sources will reduce the need for heating and benefit energy efficiency, although concerns should be taken primarily in heating based climate to avoid over heating in the summer. Windows and other openings should be constructed mainly to benefit from the sun's free energy. Efficiency of heating systems should also be addressed. In a simplified comparison, regulation can be compared based on heating degree days.

Hot climates, cooling based climates

In Hot Climates and Cooling Based Climates the comparison can be based mainly on cooling needs and on efficiency of cooling installations. In both types of climates, energy from the sun the internal heat gains will increase the need for cooling. Solar radiation in the building and the internal loads should be reduced and controlled as much as possible as this will have energy savings in appliances and installation as well as in cooling. Windows and other openings should be protected for heat gain from the sun through shading etc. Efficiency of cooling systems should be addressed too. In a simplified comparison, regulation can be compared based on cooling degree days.

Mixed climates

In a Combined Climate or a Moderate Climate it is impossible to make a simplified comparison based only on heating degree days and cooling degree days as it is necessary to balance heat gains from the sun and internal resources with cooling and heating demands over the year. The best solutions will be highly dependent on actual local conditions. Shading, clever and integrated solutions are essential in these regions to allow solar penetration in winter and reduce heat gains in summer are needed in order to balance heat and cooling needs.

Shading, orientation of windows and openings are of major importance for the total energy balance of the buildings. Comparison of building codes and valuation or selection of best practices is rather complicated.

8 Least Lifetime Costs

Since climatic conditions have such a large impact on the building codes and there are different ways to set buildings codes, it is difficult to compare these energy regulations for new buildings in different countries or regions. At the same time it can be interesting to compare the code with general optimum for the energy efficiency level for the requirements.

One possible comparison of building codes is to look at the least total costs seen over time (LCA). In this comparison the costs for the investments will be compared with the economic benefits for the owner or user of the building in terms of savings.

For buildings, most savings have a long life time and for some savings it might even be the whole lifetime of the building. For buildings in general, it is reasonable to look at a 30-year timeframe as this is a typical interval before a new building requires the first major renovation and which also fits with maximal mortgage or loan periods in many countries.

8.1 Methodology

Energy efficiency improvement often have an initial cost – seen as an investment – which is carried by the owner or constructor of the buildings. This increases the total investment and this will lead to a need for larger loans for the construction of the building. In new buildings investments costs can either be additional costs if building parts are improved or technical equipment replaced with more efficient equipment or it can be full costs for new systems.

Many decisions are taken mostly based on the initial costs. Instead of looking only at incremental costs, the total costs should be addressed including the energy use. For new buildings should be valued over 30 years seems rational. Interest rates should be estimated and the annual payment for the improvement should be calculated. In some cases, this timeframe is longer than a first occupier or owner might stay in or use a building, but in the event the property is sold the improved efficiency should lead to a higher resale price, which will enable the first owner to recover the investment.

At the same time investment in energy efficiency will lead to reduced energy consumption in the building and maybe changed costs for maintenance. Based on estimated savings, energy prices and prognoses for development over the next 30 years, the savings for the first year and in the following 30 years can be calculate.

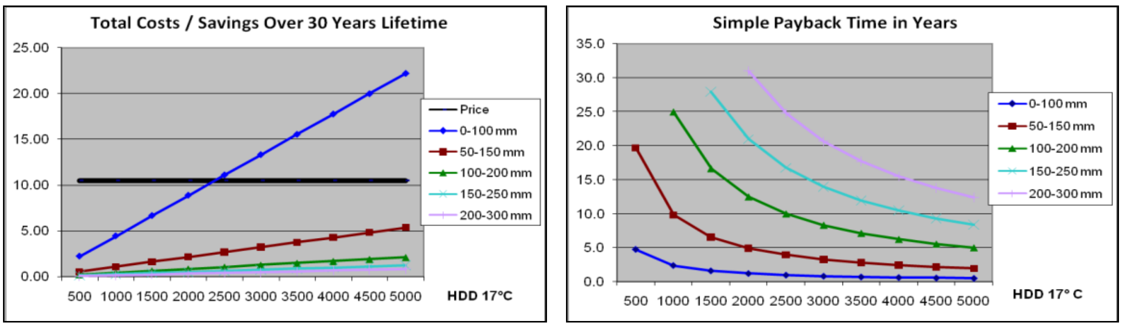
If savings over 30 years are larger than investment costs and costs for financing the improvement is said to be feasible, since it reduces the total cost for the use of in the building over 30 years. This should in general reduce costs for owners and users of these buildings.

Costs for investments, maintenance and savings can either be calculated summarised over 30 years or it can be calculated as a yearly average value for the costs and savings per year.

8.2 Energy efficiency optimum

Energy savings depend on climatic conditions. In cold and heating based climates this will mainly depend on heating needs given by the Heating Degree Days, in hot and cooling based climate this will mainly depend on cooling needs given by Cooling Degree Days.

Figure 6. Saving potentials and investments depending on the heating degree-days



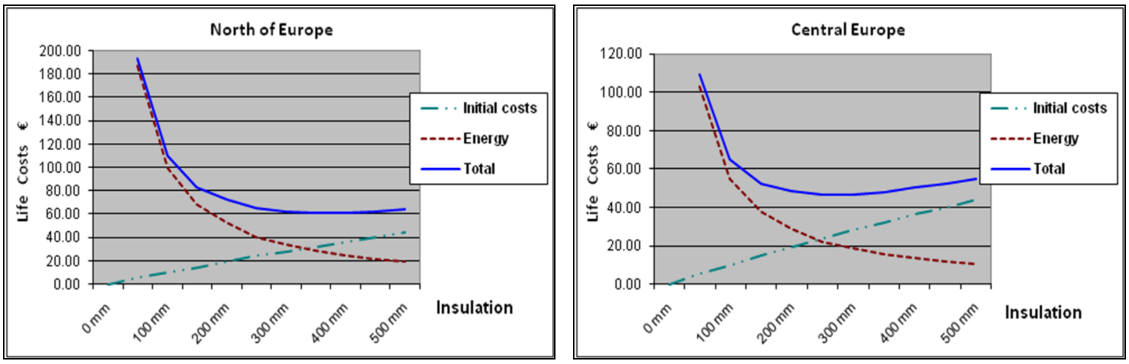
Example of a simple insulation of a ceiling construction shows that the saving potential for improvement of the building envelope is proportional with the increase in heating degree-days, but the savings for additional insulation will also decrease with increased insulation. First part shows the costs while part two shows the simple payback time for additional insulation.

For different climatic conditions, the optimum for part of the building or heating, cooling and ventilation system can be assessed for the optimal size of insulation or energy efficiency that would be the cheapest over a longer term (30 years).

Increased insulation will have the same costs independent of the climatic conditions. The savings will on the other hand depend highly on the climate and the amount of heating degree days, but will also be different for the first part and for the following insulation. A simple example on costs and saving is illustrated in figure 6.

Since savings from insulation is highly dependent of the climatic conditions, while costs for additional insulation is nearly independent of the climate, this will give a different feasibility of insulation in different climates similar will the optimal level of insulation is seen over lifetime[51]. A simple calculation for two different parts of in Europe is illustrated in figure 7.

Figure 7. Lifetime Costs for insulation in North of Europe and for Central Europe.



Life Cost Analysis for simple roof insulation in a climate with 4500 HDD 17°C [52] and for a climate with 2200 HDD 17 °C.[53] Cooling need is expected to be very low in these regions and savings on cooling are not included in the calculation.

Based on this example a least cost curve for insulation thickness depending on Heating Degree Day can be drawn for Europe. As shown in this graph, quite substantial levels of insulation in North Europe show the lowest costs over 30 years.

Such curves can be drawn for different parts of the building and for the heating, cooling and ventilation systems. However, the different types of insulation (glazing, heating, cooling or ventilation systems) will to some extent interfere and improved insulation might reduce the improvement benefits of a boiler and vice-versa. Reductions in total costs can also occur as energy savings will be greatly reduced that a smaller or no heating system will be required.

In a curve for insulation or efficiency there may also be points where additional costs appear because of increased thickness of constructions or changed solutions. Similar might the curves be influenced by local price levels and traditions[54].

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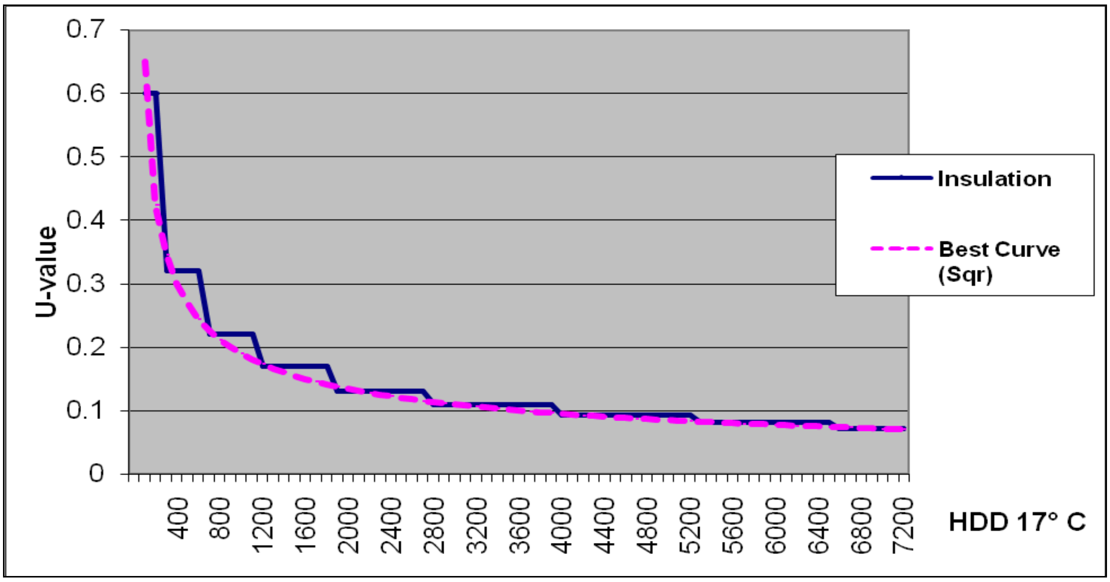
[51] The lifetime costs are calculated over 30 years and the savings in energy costs and maintenance costs are compared with the incremental investment. Interest rates are taken into account and so are expectations for future energy costs and so is inflation in general and for maintenance in particular.

[52] 4500 HDD 17 °C is climatic conditions similar to Scandinavia or central Canada.

[53] 2200 HDD 17°C is climatic conditions similar to Central Europe or Seattle or similar northern regions in US.

[54] An example on a curve based on local traditions is given in the following chapter on building codes in the European Union.

Figure 8. ***Curves for the optimum of life costs for simple insulation***



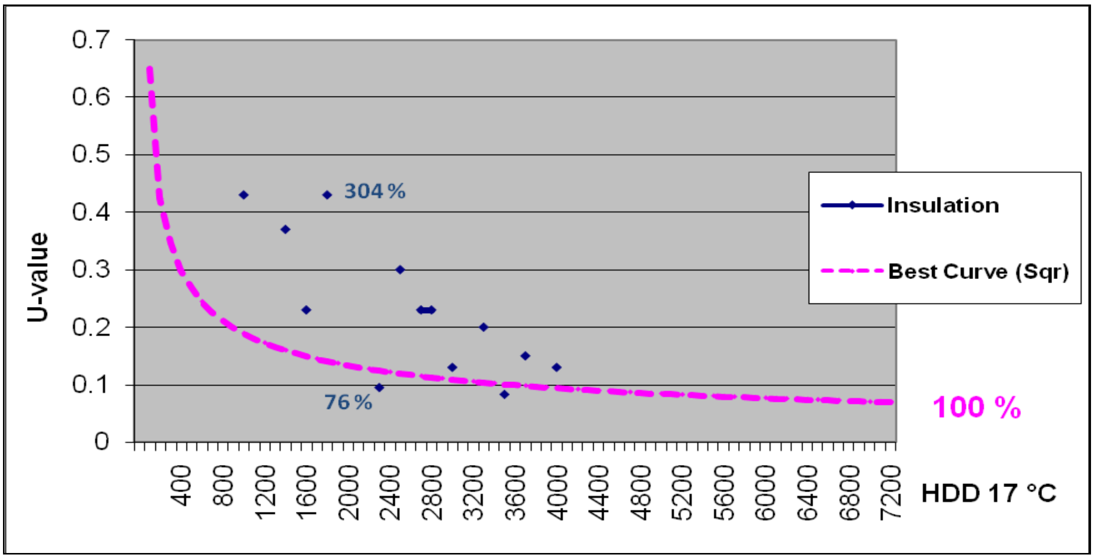
Least Cost Optimum for simple roof insulation based on additional layers of 50 mm each and a continuous best line. Curve estimates depending on the Heating Degree Days. This curve doesn't include savings from reduces heating or cooling systems[55].

An overall solution to this problem would be to estimate the least cost optimum for the overall energy performance of the building, although this is complicated.

8.3 Indicators for efficiency in new buildings

Based on the least cost curve above, an indicator can be developed. This indicator can show how far the demands in building code are from the least costs optimum for different parts of the building and the installations. A theoretical graph with this indicator is shown in Figure 9.

Figure 9. ***Graph on the indicator according to HDD***



U-values for roof insulation compared to life cost optimum.

[55] Reduced need for heating and cooling can reduce total costs (principle of Passive Houses); this will reduce the optimum u-values even further, see paragraphs on passive houses.

Based on this least cost curve and indicator will also show how much of the optimum is achieved in individual countries. The optimum achievement could be set to 100 %. A value above 100 % would then show that the u-value is over the optimum. Values below 100 would indicate that the level for the building code is stricter than the optimum.

There could be good reasons to go beyond the least cost optimum for instance by setting a value for reduced CO_2 (in certificates or by subsidy), or because these requirements could be used to reduce the costs for energy efficient solutions in general or could be a part of a national policy to obtain greenhouse gas emissions. Similar will improved U-values be able to reduce the need for heating or cooling installations and this might reduce the total costs of the building[56].

9 General status in regions

9.1 Europe

In the European Union, the regulation for energy efficiency in buildings is based on directives, which have to be implemented in all the member states. The most important directive for energy efficiency in buildings is that on Energy Performance in Buildings.[57]

Energy Performance in Buildings Directive

According to this directive, all member states have to set standards for energy efficiency in new buildings based on the energy performance of the building. The performance has to take into account the building shell including air-tightness, heating and cooling installations, ventilation, the orientation and position of the building, passive solar systems and solar protection and the indoor climate according to the annex to the directive. For non residential buildings built-in lighting systems has also to be included. The positive influence of Active solar systems and other renewable energy systems, CHP[58], district heating or cooling and natural light also have to be taken into account.

Table 2. Annex with calculation elements required in the EPBD

Annex 1 1. The methodology of calculation of energy performances of buildings shall include at least the following aspects: (a) Thermal characteristics of the building (shell and internal partitions, etc.). These characteristics may also include air-tightness; (b) Heating installation and hot water supply, including their insulation characteristics; (c) Air-conditioning installation; (d) Ventilation; (e) Built-in lighting installation (mainly the non-residential sector); (f) Position and orientation of buildings, including outdoor climate; (g) Passive solar systems and solar protection; (h) Natural ventilation; (i) Indoor climatic conditions, including the designed indoor climate.

The requirements for the calculation are set in the annex of the directive. It is left up to the subsidiarity of the member states to set and develop models for energy performance.

It is up to member states to decide the level of energy efficiency requirements, but these levels have to be revised at least every 5 years and updated, based on technological development. In general, it is left up to the member states to set up the calculation

[56] See under passive houses later in this paper.

[57] Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on Energy Performance in Buildings

[58] Electricity produced by combined heat and power.

method based on these conditions, but the European Commission has initiated an initiative where the European Standardisation Organisation[59] develops standards to calculate the different parts of the energy performance. 31 standards are under preparation for the calculation of heat loses, heat gains, efficiency in heating, ventilation, air-condition systems, lighting and automatics, etc.[60]

The European Directive on Energy Performance sets standards for major refurbishments or renovations of large buildings with more than 1000 m².[61]

The directive on energy performance further claims that buildings must have a certificate when constructed, sold, rented out. Large public buildings must be certified regularly. All new buildings have, therefore, to be certified. There have been discussions between member states during the implementation as to whether the best time for this certification is during design or after construction. During design certification can influence decisions and ensure that energy efficiency concerns are taken into consideration at an early design stage. Certification after construction can control the actual state of the building and guarantee that the energy efficiency requirements have been fulfilled. A few countries go for both types of certification[62].

Finally the directive on energy performance in buildings sets demands for inspection of heating and cooling systems.

A special homepage “Buildings Platform”[63] is supported by the European Commission giving information on the progress of implementation in member states and the directive in general.

Other directives

There are other directives that have a large impact on energy performance or energy efficiency of buildings. This includes the Eco-Design Directive[64] indicates the top set demands or demands for labelling of different appliances and products and the directive on Energy end-use and Energy Services[65] setting targets and demands for energy services and energy efficiency activities, and different labelling or energy minimum standard directives etc.

The Eco-design directive is aimed at the energy efficiency of products and appliances including many products installed in buildings such as household electrical appliances. This directive will, therefore, have an impact on the energy performance of buildings.

The Eco-design directive is a framework directive, defining the principles, conditions and criteria for setting environmental requirements for energy-using appliances (Eco-design). It therefore makes no direct provision for mandatory requirements for specific products; this will have to be done at a later stage for given products. The framework directive applies to all energy-using products that are placed on the market. It also covers parts that are intended to be incorporated into products, if the environmental performance can be

[59] CEN, European Committee for Standardization.

[60] An overview of the standards can be found on the homepage www.builidngsplatform.org

[61] Larger renovations are defined as renovation, which costs more than 25 % of the buildings value or which concern more than 25 % of the building shell.

[62] Information from the project Concerted Action EBPD can be found on www.buildingsplatform.org.

[63] The buildings platform, http://www.buildingsplatform.org, is a project supported by the European commission to inform on the energy performance directive and the implementation in the European Countries.

[64] Directive 2005/32/EC of the European Parliament and the Council on the eco-design of Energy-using Product.

[65] Directive 2006/32/EC of the European Parliament and the Council on energy end-use efficiency and energy services.

assessed independently. All energy sources are covered, in particular electricity and solid, liquid and gaseous fuels.

General status

The European Union has set up a directive outlining basic requirements for energy efficiency standards for new buildings and by refurbishment, but many details are left up to the individual member state. In particular, the individual member state has to define the level of the minimum requirements for new buildings.

The European Commission has set up different facilities to work for harmonisations of the rules in the countries and among these are: The Concerted Actions EPBD[66], which is a cooperation project aimed at converging regulations in the countries. The Buildings Platform[67], which aims to share information on the implementation. Different frame programmes support projects providing input to develop rules in individual countries. These activities will include a project to develop a common building code standard for Europe based on different climates.

Most countries in the European Union have updated their energy efficiency requirements for buildings within the last 2 years or are in the process of setting up new requirements based on energy performance of buildings. The levels for these standards vary substantially.

Sweden

Sweden has very long tradition of energy efficiency requirements for new buildings. Already in the late 1970s stringent requirements was introduced in Sweden. Although they have only been slightly changed over time they are still today among the highest energy efficiency requirements in the world.

Table 3. Main values for the building envelope for new buildings in Sweden.

Building Code in Sweden	U-value W/K per m2	
	South	North
External Walls	0.13-0.14	0.12-0,13
Ceilings / roofs	0.15	0.13
Grown deck	0.16	0.13
Floors with heating	0.12	0.10
Floor over open air	0.10	0.08

The Swedish building regulation requires that individual values depend on the type of construction, and where the building is situated. All of the values for efficiency are high and comparable with the values for passive houses in central Europe.

Rules are set for ventilation and other thermal comfort and for efficiency in installed products, such as boilers and air conditioners. At the same time, values are set for the overall energy performance and consumption for the building. Values depend on whether the building is in the north or south of Sweden with different values for commercial and residential buildings.

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[66] Concerted Actions EPBD was a project formed in 2005 and ending in June 2007, but expected to continue in 2007 – 2010 with 29 states as members. Concerted Action conducts workshops and information share among the member states. Homepage www.EPBD.org.

[67] An information activity supported by the European Commission to inform on the implementation of the EPBD directive in general and in the individual member states on the homepage http://www.buildingsplatform.org/cms/

Table 4. Maximum overall performance values for new buildings in Sweden.

Building Code in Sweden	Overall performance values kW / m² per year	
	South	North
Residential buildings	110	130
Commercial buildings	100	120
Electrically heated Buildings	75	95

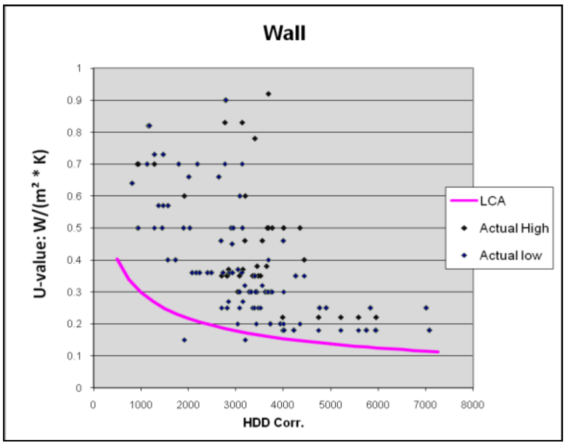
Energy performance values are set as maximum per m² floor area per year for the different types of buildings.

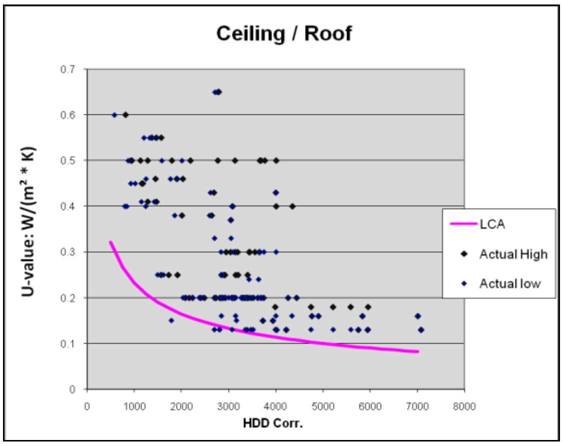
As well the values for maximal energy performance and the requirements for insulation of the building envelope are close to those for the Passive House standard[68]. The compliance with these values has to be documented with the actual consumption after construction.

Comparison U-values

If the values set by the member states of the European Union are compared with the least cost optimum over 30 years for the different types of energy efficiency requirements in the building regulation, then these requirements are shown to be quite far from this optimum.[69]

Figure 10. Comparison of energy efficiency requirements in the building codes and LCA





Wall and ceiling insulation is compared here with the Least Costs optimum (LCA).[70] The values for LCA values are estimated based on the actual climatic conditions in major cities in all the countries and with actual costs in this region.[71]

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[68] Passive house standard sets vales for buildings with ultra low energy consumption and they are treated more deeply in a separate chapter later in this document.

[69] The costs for energy efficiency improvements in many cases are highly depend on weather there are only additional costs or if the whole costs have to be covered by the improvement. By construction of new buildings there will typically only be additional costs for efficiency requirements in building codes, since improvements can be planed before the actual products are purchased or installed.

[70] Values are calculated as annual costs based on a formula: $A + (1+j)^n * i / (1+n)^{n-i}$, where a = annuity factor, I = interest rate, n = lifetime. Lifetime for insulation is set to maximum 30 years even if savings by some types of insulation might last longer, because a new refurbishment of change of use might occur over time.

[71] The values for the LCA are based on the EURIMA and Ecofys study on building codes: U-values for better Energy Performance of Buildings.

There is a big difference in how close the values in the building codes are to the least cost optimum. Only a few countries have values, which are close to these values. Additional savings from reduction of heating and cooling installations not are included in the calculation. If these savings were taken into account the result would show lower values for the optimum and a larger distance between actual values and the LCA optimum[72].

The graphs also show that some countries have regions where some larger cities might be close to the line while other cities in the country are far from the LCA optimum. This would infer different energy efficiency requirements for different regions[73].

9.2 North America

Setting standards for energy efficiency in buildings in the US and Canada is the responsibility of individual states, but there is substantial difference between the systems in the two countries.

In the US state codes are generally based on model codes which are developed by private organisations in collaboration with US Department of Energy (DOE); International Energy Conservation Code (IECC)[74] by the International Code Council (IECC) and the ASHRAE standard[75] by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), Inc. The DOE participate in upgrading the model codes and on publication the DOE is required to make on published a determination as to whether these new codes or revisions would save energy in buildings relative to the previous edition. By a positive determination for a new or revised IECC codes states are required to report and certify to DOE whether it is appropriate to update their residential codes to meet the new requirements, or they have to explain why it is inappropriate to do so. By a positive determination regarding the ASHRAE standard, states are required to update their commercial energy codes to meet the standard and demonstrate that they have done so.

The DOE is required to provide financial and technical assistance to assist states to upgrade, implement, and enforce their energy codes[76] and DOE provides information on the implementation of building codes in the individual states[77].

In Canada there is a similar situation where requirements for energy efficiency are set by the states based on model codes, National Building Code for Canada 2005[78]. Rules for energy efficiency for heating, ventilation and air conditioning are set in Part 6 of this code including calculation procedures for energy performance. The code is developed by the National Research Council, Canada and the Canadian Commission on Building and Fire Codes.

Two different standards

The ASHRAE and the IECC standard codes are both built on prescriptive efficiency requirements for each part of the building and installations or trade off models where

[72] Least cost optimum is calculated with an oil price on 70 USD per barrel. After the calculations were done the price increased substantially. If this price level is used the least cost optimum would be lower and the distance between the actual level and the LCA even larger.

[73] The IEA seek to involve in a project wit EURIMA and ECOFYS in order to develop and test a model to estimate least cost options for energy performance in buildings.

[74] International Energy Conservation Code (IECC) 2004 supplement set by the ICC.

[75] ASHRAE/IESNA Standard 90.1-2004, Energy Standard for Buildings except Low-Rise Residential Buildings, set by the American Society of Heating Refrigerating and Air-Conditioning Engineers.

[76] 42 USC 6833

[77] Homepage http://www.energycodes.gov/implement/state_codes/

[78] Further information on the Canadian National Building Code and requirements and calculation procedures on http://www.nationalcodes.ca/nbc/index_e.shtml

buildings are compared to a model building. The ASHRAE's residential high-rise[79] and non-residential energy standards as well as the IECC, use four different methods for specifying climate dependent energy efficiency requirements.

Both standards are based on US traditions but in the last few years there has been a work to merge and complement the codes and a declaration to prepare the codes for use in other parts of the world. Both ASHRAE and IECC are model codes, which are intended to be adjusted to local conditions. Most states use the IECC for low-rise residential and simple buildings while the ASHRAE is used for large and complex buildings and for trade and service buildings.

Both the ASHRAE and the IECC includes requirements for existing buildings by refurbishment. The ICC has also developed a specific standard for energy efficiency in existing buildings IEBC, International Existing Building Code and the model code for residential buildings IRC, International Residential Code. The IEBC basically references the provisions of the IECC and the IRC. The IRC has a specific energy chapter which is substantially the same as select residential low rise portions of the IECC. However, the IECC and IRC are developed separately and there are some differences.

International Energy Conservation Code

The International Energy Conservation Code 2004 (IECC 2004) is a model building code or standard for energy efficiency of new buildings. It was devised by the International Code Council (ICC), and is based on US conditions and traditions for energy efficiency regulation. This code IECC 2004 sets rules for residential (with less than 4 floors) and for small and less complicated commercial buildings while it contains a reference for the ASHRAE for large and complex buildings[80]. There is an emphasis on new buildings.

Rules are based on climatic zones, which are set based on cooling degree days CDD and heating degree days HDD and some humidity conditions. In general, the US is split into 8 different zones, based on the level of cooling and heating. Some humidity conditions divide the zones into dry, humid and marine areas.

Rules are set as prescriptive values for building parts, heating and cooling systems, ventilation and lightning. Insulation requirements are set as R-values or U-factor where $U = 1/R$ for each climatic zone separately. These values have to be fulfilled for each building part in the prescriptive model. Some specific regulations are given for pipe and duct insulation, air tightness, sealing, hot water systems, mechanical ventilation and circulation of hot water. Rules for heating and cooling equipment are only given as sizing requirements.

IEEC also includes a trade-off model where some parts can be made with less energy efficiency as long as the total building still fulfils the same overall requirements which would be the result of fulfilling each single demand. In this model the same values are used for the trade off model as reference values for the model building. The trade-off model is based on energy costs which take into account the different energy costs for gas, oil or electricity. Specific and more detailed values are set for some steel solutions. Finally it contains a frame with an overall assessment where total values have to be obtained.

The energy efficiency requirements for residential buildings and those for new commercial buildings are indicated in two separate chapters.

The prescriptive model is described as Mandatory Requirements, while the trade-off model is referred to as Performance Based requirements. Finally there are some requirements for the use of software for the Performance based model. Some basic assumptions are set for

[79] ASHRAE only address residential buildings with 4 floors or more above grade.

[80] According to the IECC small commercial buildings or parts shall either fulfil the requirements in the specific chapter for non residential buildings or the requirements in the ASHRAE.

the reference buildings used in the trade off model such as amount of windows (18 % of floor area) and calculation values.

Table 5. IECC 2004, Climatic zones

Zone number	Thermal Criteria IP Units	SI units
1	9000 < CDD50°F	5000 < CDD10°C
2	6300 < CDD50°F ≤ 9000	3500 < CDD10°C ≤ 5000
3A and 3B	4500 < CDD50°F ≤ 6300 and HDD65°F ≤ 5400	2500 < CDD10°C ≤ 3500 and HDD18°C ≤ 5400
4A and 4B	CDD50°F ≤ 4500 and HDD65°F ≤ 5400	CDD10°C ≤ 4500 and HDD18°C ≤ 5400
3C	HDD65°F ≤ 3600	HDD18°C ≤ 3600
4C	3600 < HDD65°F ≤ 5400	3600 < HDD18°C ≤ 5400
5	5400 < HDD65°F ≤ 7200	5400 < HDD18°C ≤ 7200
6	7200 < HDD65°F ≤ 9000	7200 < HDD18°C ≤ 9000
7	9000 < HDD65°F ≤ 12600	9000 < HDD18°C ≤ 12600
8	12600 < HDD65°F	12600 < HDD18°C

Climatic zones in the IECC 2004 are basically based on Heating and Cooling Degree Days although some also take into account the humidity. The zones are adjusted to the state limits to simplify the administration[81].

The IECC apply for major renovation and refurbishment projects too. The values R-values and U-factors (prescriptive) in the regulation have to be fulfilled in some renovation projects, for example a full exchange of windows must comply with the energy efficiency requirements for windows. A special standard is developed for refurbishment of existing buildings, International Existing Building Code (IEBC). [82]

Table 6. IECC 2004, U-factors in SI units

Climatic Zone	Fenestration U-factor	Skylight U-factor	Ceiling U-factor	Wood Frame Wall U-factor	Massive Wall U-factor	Floor U-factor	Basement Wall U-factor	Crawl Space Wall U-factor
1	6.81	4.26	0.20	0.47	1.12	0.36	2.04	2.71
2	4.26	4.26	0.20	0.47	0.94	0.36	2.04	2.71
3	3.69	3.69	0.20	0.47	0.80	0.27	2.04	0.77
4 Except Marine	2.27	3.41	0.17	0.47	0.80	0.27	0.34	0.37
5 and Marine 4	1.99	3.41	0.17	0.34	0.47	0.19	0.34	0.37
6	1.99	3.41	0.15	0.34	0.34	0.19	0.34	0.37
7 and 8	1.99	3.41	0.15	0.32	0.32	0.19	0.34	0.37

IECC 2004 U-factors for different climatic zones in SI units. [83]

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[81] These zones were developed in a special project financed by DOE.

[82] Conversion factor Btu / (h * ft^2 * °F) => W / (m^2 * °K) for the U-factor = 5.678263337

[83] Implementation depends on legislation in the individual state.

ASHRAE

The ASHRAE 90.1 Standard 2004 is developed by the American Society of Heating, Refrigeration and Air-conditioning Engineers, Inc. This standard applies particularly to large and complex buildings, mainly in the commercial sector, but minimum efficiency requirements are set for all building types exempt for low-rise residential buildings. There is a small overlap between buildings covered by the IECC code and the ASHRAE standard as large residential, small or less complicated commercial buildings are covered by both.

In order to check the compliance with the standard, there is a requirement for labelling of installed equipment or components and also for building parts such as windows, walls and roof. The labelling of built constructions has to be made by the installer or constructor.

The requirements can be fulfilled either by prescriptive values or by calculation of energy consumption. As part of the ASHRAE standard there are normative appendices with values and calculation rules. Some parts are partly mandatory while others are only informative. There are links to different reference standards that have to be applied to the calculations.

Compliance

Compliance with the ASHRAE standard can be achieved in three different ways:

1. The Prescriptive Approach where all individual requirements for Building Envelope, HVAC systems, Service Water Heating, Power, Lightning and Other Equipment are achieved.
2. The Energy Cost Budget, where the energy consumption must be below a value calculated based on a calculation for the building and fixed values for efficiency.
3. The Design Energy Cost where all parts of the building and the installations have the same energy or better energy efficiency than the figures used for the calculation of the Energy Cost Budget.

The Prescriptive Method

Rules are set in ASHRAE section 5, 6, 7, 8, 9 and 10 and each part of this must be fulfilled individually. If compliance with one part is fails, the whole project is rejected.

Building envelope

The values for insulation and fenestration are given for the similar climatic zones as the International Energy Conservation Code IECC 2004, with 8 general zones of which some which are shared into A, B and C. All in all the code has 17 different conditions for the US while only the general 8 zones are used for Canada.

Values are set for the different parts of the building as U-factors or as R-values (U = 1/R).[84] Values are set for separation from conditioned space, heated and/or cooled, to outdoor, to semi-conditioned or unconditioned space and between semi-conditioned spaces and outdoor or unconditioned spaces.[85] Values are set for fenestration too, giving R-values or U-factors, solar heat gain coefficients (SHGC), visible light and transmittance (VT), shading coefficients (SC) for windows and glass areas. Finally values are given for air leakage.

The energy efficiency requirements for the zones are further shared in values for Non-residential, Residential and for Semi-heated areas. Some values for walls, floors and roof etc. depend on the type of construction – steel, massive, wood construction etc. Values for windows depend on the share of windows.

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[84] Values are set in IP units, Btu / (h * ft^2 * °F).

[85] Also called the building envelope.

For the building shell it is possible to make a trade off, where some parts can be improved to a better standard thus allowing other parts to be of a lower standard as long as the total value is still fulfilled.

Heating, ventilation, and air-conditioning

Requirements for HVAC systems[86] are set for air-conditioners, Condensing Units (De-humiliation), Heat Pumps, Water Chilling Package, Package Terminals, Room Air Conditioners, Heat Pumps, Furnaces, Duct Furnaces, Unit Heaters, Boilers and Heat Reinjection Equipment in individual tables.

Values for insulation of ducts and pipes depend on the type of room in which they are located as the expected temperature inside the pipes and ducts. Requirements and instructions are set for automatics to control HVAC systems as well as for Freeze Protection, Humidification, Dehumidification, Leakage and Sealing. Compliance for HVAC systems are set based on the calculation method.

Service water heating

Requirements are set for commercial water heaters, sizing, efficiency, insulation of pipes and tanks, automatics, circulation pumps, pool heaters, heat traps etc. These are based on the size of the system in kW for electric systems and the Btu/h for gas or oil fired equipment. Compliance can be in the prescriptive method or in conjunction with the calculation method.

Lighting Other Equipment

Commercial lighting efficiency requirements are set as prescriptive values, including controls for the lighting system, such as automatic shutoff and space control and tracking. Values are set for efficiency in Luminary Wattage and for sizing. A special method is described for the calculation of lightning power density based on the type of functions used in the building (in W/ft^2). Values for electric motors are set depending on the horse power for the output.

General

The ASHRAE standard covers new buildings and their systems, new portions of buildings and new systems or equipment in existing buildings. Special rules apply to refurbishment of buildings if this includes extension or increase of the building outside the original building shell. Alterations of the building envelope shall then fulfil the prescriptive requirements.

In an annex to the ASHRAE, standard values for Heating Degree Days and Cooling Degree Days and other climatic information are given for the US and Canadian states, as for major cities. The ASHRAE standard is a very comprehensive standard for energy efficiency in buildings and values are set for different parts of the building, HCAC systems and other installed equipment at a very detailed level and for multiple climatic zones.

General status US and Canada

As it is up to the federal states in both US and Canada to set and enforce minimum standards for energy efficiency in buildings the energy efficiency requirements for buildings vary substantially over the North American continent. Most states have implemented regulations based on the ASHRAE standards for commercial and larger residential buildings and the IECC codes for small residential buildings.

Many states have chosen levels based on the recent levels in ASHRAE and IECC while other states have based the regulations on older versions of these standards or set standards at a lower level. Some states have chosen to take the energy standards further that the ASHRAE and IECC codes, this is in particular the case for California and Florida where substantial

[86] HVAC systems are Heating, Ventilation and Air-Conditioning systems.

resources have been used to develop individual energy efficiency standards. Both the US and Canada provide web homepages with information on the standards in individual states.[87]

***California*,**

California has probably the most comprehensive minimum energy efficiency standards for buildings in the world. The standards are very detailed, and they regulate nearly every part of energy consumption in buildings including valuable explanations and examples. The Californian codes are shared in a relative simple[88] but comprehensive code for small residential buildings[89] similar to the IECC code and for non commercial and high-rise buildings[90] based on the ASHRAE standard.

The California energy efficiency standards for buildings set efficiency requirements which in many ways are higher than those of IECC and ASHRAE. The standards have specific values for efficiency for all parts of the building and for most energy consuming appliances and installations included in the energy performance in buildings are set in the standards and on a very detailed level.

The energy efficiency requirements can either be fulfilled in part (prescriptive rules) or by a calculation based on a comparison with fixed values and the fulfilment of the prescriptive rules (energy model building or a trade of model). The codes include some instructions for installers or constructors on how to fulfil the requirements. Energy efficiency requirements are set for different regions from very hot areas to cold areas in the mountains in the north. Values are set for different climatic zones.

In particular, minimum energy efficiency requirements compliance manual for non-residential and high-rise buildings are voluminous (more than 1000 pages), but it contains values which can be useful for many regions in the world.

Ontario

The energy efficiency requirements in Ontario were increased from 1st January 2007, leading to a reduction of an estimated 21.5 % of consumption in new small residential buildings and 16 – 18 % in large residential and non-residential buildings. This is achieved through an increase in the requirements for insulation, windows and efficiency in gas boilers. At the same time it was announced that these requirements for houses would be further strengthened with insulation levels increased in 2010, and that buildings from 2012 would have to meet a national guide line for energy efficient buildings. For non-residential buildings a further increase in energy efficiency will be implemented in 2012. Actual costs and the pay back times for building owners were calculated for these new demands.

Estimates over the costs and feasibility of increased requirements for new buildings shows that the first increase in 2007 were paid back in only 3-4 years, while the large reductions of 35 % for small residential and 25 % for non residential and buildings from 2012 would be paid back in only 5 – 8 years for typical new buildings.[91]

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[87] For US especially the http://www.energycodes.gov/implement/state_codes/ DOE homepage is giving an overview of the implementation in the individual state and it includes links to most of these standards. Additional proposals for energy efficiency are given by the Insulation industry, NAIMA, on WWW.NAIMA.org

[88] The Californian Code for small residential are more complicated than the IECC and most other codes for small residential buildings in other states in US and in Europe.

[89] California's energy efficiency standards for low-rise residential buildings.

[90] California's Energy efficiency Standards for Non-residential Buildings, High-Rise Residential Buildings and Hotels/Motels.

[91] More information can be found in The Power of Building Better, Increasing the Energy Efficiency Requirements of the Ontario Building Code to Create a Culture of Conservation.

Table 7. Estimated increased capital costs, savings and payback periods for houses, Ontario.

	Estimated energy savings	Estimated Increased Capital Costs	Simple Payback Periods
December 31, 2006	21.5 %	$ 1.600	3.0 years
December 31, 2008	28 %	$ 2.700	4.4 years
December 31, 2011	35 %	$ 5.900 – 6.600	6.9 – 7.9 years

Compared to the 1997 Building Codes and calculated for a typical 2000 square feet gas-heated house in Centre Toronto Area.[92]

This example shows that increase of energy efficiency requirements in new buildings can be very cost effective because seen over a 30 years period these savings will be a very profitable investment for the building owner[93]. It is planned that the new regulation will be followed by a labelling scheme which should make the improvements visible in the market.

Table 8. Estimated increased capital costs, savings and payback periods for non-residential and large residential buildings, Ontario.

	Estimated energy savings	Estimated Increased Capital Costs	Simple Payback Periods
December 31, 2006	16 - 18 %	$ 0.98 – 1.11 / ft^2	3.3 – 4.7 years
December 31, 2011	25 %	$ 1.40 – 3.46 / ft^2	5.0 – 7.7 years

Compared to the 1997 Building Codes and calculated for a typical high-rise residential and office buildings. The range depends on size, type, location and method of construction.

9.3 Japan

Energy efficiency in buildings in Japan is set by two different standards; Criteria for Clients on the Rationalization of Energy Use for Buildings for non residential buildings, and Design and Construction Guidelines on the Rationalisation of Energy Use for Homes for residential buildings. Both standards are part of the national Energy Conservation Law that was first adopted in 1979.

Mandatory schemes are set for the reporting on energy efficiency measures and for labelling of buildings. This includes that buildings with more than 2000 m^2 building have to report on the efficiency and compliance with these standards. Information on buildings that do not fulfil the requirements can be published by the relevant ministry. For small and medium sized buildings the energy efficiency requirements are not set as mandatory standards and there are no penalties for non compliance, but the Design and Construction Guidelines on energy efficiency, request the owners of small and medium sized buildings to make attempts to comply with these measures. [94] The jurisdiction of both the standards is

[92] Background information from the Ministry of Municipal Affaires and Housing, Ontario. Source for estimates of Costs, Savings and Payback Periods http://www.mah.gov.on.ca/scripts/index_.asp

[93] Background information from the Ministry of Municipal Affaires and Housing, Ontario Source for estimates of Costs, Savings and Payback Periods http://www.mah.gov.on.ca/scripts/index_.asp

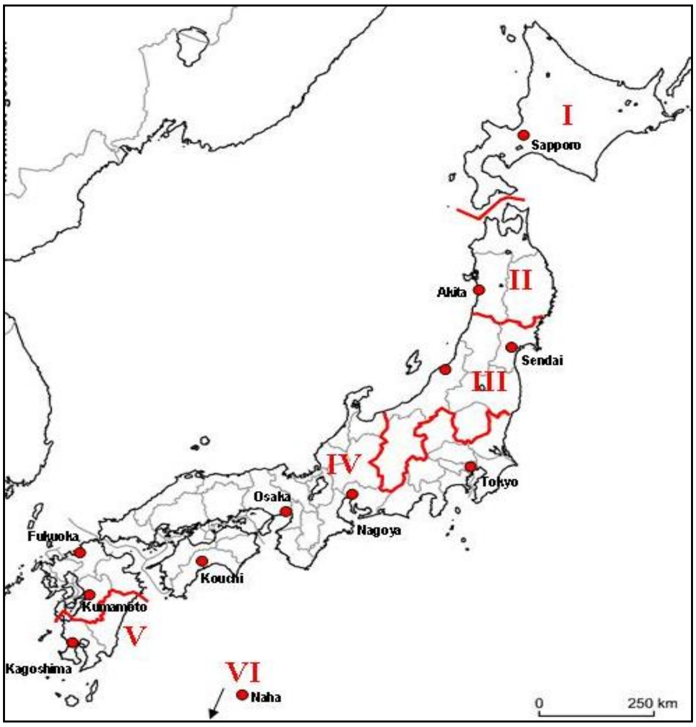
[94] Even though that the guidelines and the request to make attempts to fulfil these guidelines to some extend equals obligatory in nature in Japan's legal system it is the impression that the compliance rate is very low compared with other OECD countries.

in the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and the Japanese government are preparing a change of the regulation which will make the standards mandatory for a larger part of the buildings and which will increase the enforcement of the standards.[95]

Residential buildings

The energy efficiency requirements for residential buildings are set in Design and Construction Guidelines on the Rationalisation of Energy Use for Homes. These requirements are in two parts of which one is prescriptive and the other is a performance model. The requirements for residential buildings are set for 6 different climatic regions.

Figure 11. The climatic regions in Japan



Values for buildings in Japan are set for 6 different climatic zones.

Energy efficiency in buildings can be based on a performance model as an option to the prescriptive model, where the values for the building are set based on the volume of the building.

Table 9. Maximum allowable space conditioning loads for houses by climatic areas

Area classification	I	II	III	IV	V	VI
Standard annual heating and cooling load (unit: MJ/m^3/year)	390	390	460	460	350	290

Values for the maximal energy use indifferent areas set per cubic meter or space in a residential building.

There is a specific calculation procedure, which has to be followed.

[95] The MLIT informed IEA in February 2008, that the revision will include mandatory requirements for all new buildings with more than 300 m² and that a further lowering of the threshold is still being discussed.

Values can also be based on a prescriptive model maximum where maximum values are set for energy loss through construction, U-values, for individual building parts depending on the type of construction and whether insulation is inside or outside the construction. These values vary for different parts of Japan.

Table 10. Energy efficiency requirements for heat transfer coefficients in residential buildings

Type of house	Insulation material & construction	Building component		Standard heat transfer coefficient					
				Area classification					
				I	II	III	IV	V	VI
Houses of reinforced concrete structure, etc.	Constructions using interior insulation	Roof or ceiling		0.27	0.35	0.37	0.37	0.37	0.37
		Wall		0.39	0.49	0.75	0.75	0.75	1.59
		Floor	Portions exposed to open air	0.27	0.32	0.37	0.37	0.37	-
			Other portions	0.38	0.46	0.53	0.53	0.53	-
		Floor edge in contact with earth	Portions exposed to open air	0.47	0.51	0.58	0.58	0.58	-
			Other portions	0.67	0.73	0.83	0.83	0.83	-
	Constructions using exterior insulation	Roof or ceiling		0.32	0.41	0.43	0.43	0.43	0.43
		Wall		0.49	0.58	0.86	0.86	0.86	1.76
		Floor	Portions exposed to open air	0.38	0.46	0.54	0.54	0.54	-
			Other portions	-	-	-	-	-	-
		Floor edge in contact with earth	Portions exposed to open air	0.47	0.51	0.58	0.58	0.58	-
			Other portions	0.67	0.73	0.83	0.83	0.83	-
Other houses		Roof or ceiling		0.17	0.24	0.24	0.24	0.24	0.24
		Wall		0.35	0.53	0.53	0.53	0.53	0.53
		Floor	Portions exposed to open air	0.24	0.24	0.34	0.34	0.34	-
			Other portions	0.34	0.34	0.48	0.48	0.48	-
		Floor edge in contact with earth	Portions exposed to open air	0.37	0.37	0.53	0.53	0.53	-
			Other portions	0.53	0.53	0.76	0.76	0.76	

Values for the different parts are set in W per °C pr sec. Different values are set for different types of constructions and for reinforced concrete structures, and other types of buildings.

Commercial buildings

The Criteria for Clients on the Rationalisation of Energy for Buildings sets rules for energy efficiency in commercial buildings and high-rise residential buildings. This standard is based on energy performance or energy frame values. These values are mainly set for two types of values PAL, Perimeter Annual Load for the performance of the building envelope and values CEC, for the Coefficient or Energy Consumption for the Equipment.

The two values are calculated by the following formulas:

$$\text{PAL} = \frac{\text{Annual space conditioning load in the perimeter zone (MJ/year)}}{\text{Area of perimeter zone } (\text{m}^2)}$$

$$\text{CEC} = \frac{\text{Actual Energy Consumption (MJ/year)}}{\text{Standard Energy Consumption (MJ/year)}}$$

PAL values are set in general for the whole building using the Perimeter Zone, which is set as perimeter spaces, that is 5m within the exterior wall, plus the top story just under the roof. There are also some correction factors to account for differing surface to volume ratios.

The CEC values are set for different parts of the HVAC systems. The values for PAL and CEC are set for different types of buildings and for different climatic regions of Japan. CEC values are set for the HVAC system in general, and specific for ventilation (V), lighting (L), hot water (HW) and the elevator (EV).

Table 11. PAL and CEC requirements by commercial building types

Building type	Hotel	Hospital or clinic	Retail	Office	School	Restaurant	Hall
PAL	420	340	380	300	320	550	550
CEC/AC**	2.5	2.5	1.7	1.5	1.5	2.2	-
CEC/V**	1.0	1.0	0.9	1.0	0.8	1.5	1.0
CEC/L**	1.0	1.0	1.0	1.0	1.0	1.0	1.0
CEC/HW**	1.5 – 1.9 (depending on Ix)						
CEC/EV**	1.0	-	-	1.0	-	-	-

*The PAL values are set in MJ/m² per year, while the CEC values are factors for efficiency of specific appliances. Ix means sum of circulation pipeline length and primary pipeline length (m) over averaged daily water consumption rate (m^3). ** AC: Air-Conditioning, V: Ventilation, L: Lightning, HW: Hot Water, EV: Elevator.*

For V, L, HW and EV, equations are set by MLIT for the calculation of the actual and the standards of energy consumption.

Supporting measures

The voluntary standards for energy efficiency of residential and commercial buildings are supported by different measures including the Housing Qualification Assurance Law of 2000, setting rules for a voluntary housing performance labelling system for new buildings for the protection of consumers. This is based on many different aspects including safety, stability, and indoor air quality and energy efficiency. Building efficiency is rated in this system.

A voluntary system is set up for Green Building Rating; this system is called the CASBEE system, Comprehensive Assessment System for Building Environmental Efficiency.

The building efficiency standards for new buildings in Japan are also supported by the top runner program for energy efficiency in appliances including air conditioners and by energy efficiency standards for many appliances. The Top Runner Programme sets a high energy efficiency target for different products. Companies – who want to be a Top Runner – have to show that the average efficiency of their products is better than the minimum efficiency value. This helps to ensure that products of high energy efficiency standards are available on the market, including HVAC products such as heaters, coolers, water heaters and fans.

Conclusion

The Japanese regulations have lead to very high energy efficiency in appliances and other equipment installed in buildings. As well the building codes, the supporting initiatives promote the development of very efficient installations. In the building regulations the CEC values are set for the HVAC system in general and for the individual parts.

Energy efficiency in installed products is also highly promoted through the labelling standards and the top runner schemes, which has lead to highly efficient appliances in general.

9.4 Australia, New Zealand

In Australia the regulations for energy efficiency in new buildings are set by the national government, but to be enforced have to be adopted by the federal states. In the present building regulations there is a 5 star system for rating energy efficiency in both residential and commercial buildings. These stars have been quite successful and have been used to drive the market towards higher efficiency than minimum requirements. The fifth star was introduced in order to include a rating for buildings beyond the old 4 star system.

In the state Victoria the local government has decided to use 5 stars as the mandatory minimum requirement, and this way promotes and ensures highly efficient buildings. For the construction industry the energy stars function as a warning for future building regulations and gives the industry time to test new standards and develop appropriate solutions.

10 Developing Countries

10.1 China

Energy efficiency standards in China have been adopted in separate standards over time:

- Energy efficiency standard for residential buildings in the Heating Zone in north China, from 1986 and revised in 1995. (Heating Based Climate)
- Standard for the residential buildings in the Hot-Summer and Cold-Winter region in central China, from 2001. (Mixed Climate)
- Standard for the hot summer- Warm Winter in South of China, from 2003. (Cooling Based Climate)
- Standard for tourist hotels, from 1993.
- Standards for public buildings, from 2003.

Some of the major cities such as Beijing and Shanghai have special standards.

In the past, compliance with the existing regulations was a large problem. Although today this situation has improved, there is still need for further improvement.

Energy efficiency requirements are set based on U-values for constructions and these vary in different codes. The codes also set different rules for the HVAC systems for energy efficiency requirements for boilers, air-conditioners, insulation of pipes etc.

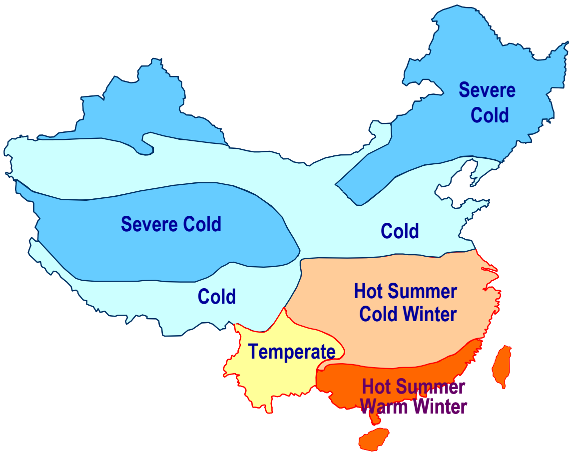
A new building code for all of China is under development and expected to be issued in 2008. Values will be set for 5 different climatic regions and are set separately for residential and for public (commercial) buildings. In some regions the energy efficiency requirements are further split in 2 – 3 different sets of requirements based on the Heating and Cooling Degree Days[96].

[96] Heating Degree Days 18 °C are used for heating and Cooling Degree Days 26 °C are used for the cooling.

The energy efficiency standard is developed by the Central Ministry of Construction, MOC, but the implementation and enforcement are to the responsibility of the regional governments.

China already has a green Building Rating System but is interested in establishing a certification or labelling system for buildings to help ensure the efficiency of new buildings and the visibility of energy efficiency in the market place.

Figure 12. China climate regions as defined by the Ministry of Construction.



Climatic zones in China as indicated by the Ministry of Construction. Severe Cold and Cold zones are the heating based regions, Hot Summer and Warm Winter and the Cooling based zones. Hot Summer Cold Winter and Temperate are the mixed zones where both cooling and heating is used.

Energy efficiency in new buildings in China is important as a substantial part of the world's new construction is in China. According to the Ministry of Construction in China, more than 2 billion m^2 are constructed in China every year, which accounts for more than 40% of all new constructions in the world.

10.2 India

Until 2007 there were no energy efficiency requirements for new buildings in India, but a new regulation for large commercial buildings were adopted June 2007. The building code target large commercial buildings, defined as buildings with a connected load of 500 kW or greater or a contract demand of more than 600 kVA or with a conditional area of more than 1.000 m^2.

The energy efficiency building code includes both a prescriptive and an energy performance method. The values for efficiency in the prescriptive part are very detailed and include many options. The building code is inspired by the ASHRAE code and the building code in California.

The building code was issued in 2007, but will be voluntary at first as it has to be adopted by each of the individual federal states to become mandatory. It may take further time before the code is enforced and controlled as this is the first time such a system is introduced in India. The Ministry of Power has estimated that it will take 1 year for the code to become mandatory and further 1 – 2 years before sufficient control and sanction systems are in place.[97]

[97] In the final communiqué from the joined India and IEA workshop on Buildings Codes and Energy Efficiency in Buildings held in Delhi the 4 and 5 November 2006.

The introduction and enforcement of a building code for large commercial buildings in India is very important as it is projected that India will build more commercial buildings in the next 5 – 7 years than exist at present.[98] Some of India's recent buildings have extremely high energy consumption for cooling owing to large glass surfaces with very little sun protection. Shading is an important part of the proposal for the energy efficiency building code.

11 Comparison of U-values in OECD countries

Comparison of energy efficiency demands in Building Codes, or standards for energy efficiency in new buildings, are as discussed earlier in the paper complicated, because the demands will dependent on local traditions and on the climatic conditions in the individual country or state. Sometimes the conditions even vary substantial within one country or state.

Since it is impossible to compare regulations between climates which are fundamentally different, comparison will only be made alone in heating-based climates or alone in cooling-based climates. In combined climates with extensive needs for both heating and cooling the comparison is difficult and different elements for cooling and heating have to be added or compared.

Much experience with setting requirements for energy efficiency exists in cold and heating based climates, as the lack of insulation or efficiency can lead to substantial health problems for residents. Energy efficiency regulations to reduce the need for heating are well-known in these parts of the OECD. This comparison will, therefore, concentrate on cold and heating based climates, where there little or no need for cooling or where cooling is only used to a minor extent and is of less concern. This climatic situation exists for the majority of Europe and a large part of the US and Canada, but also for a significant area of Japan, a part of southern Australia and for New Zealand.

As discussed in the chapter on different types of codes, the demands in energy requirements (Building Codes) can be set in fundamentally different ways; some codes set demands for the whole buildings energy performance while other codes have requirements on the individual parts of the building and the heating and cooling systems etc.

This comparison will therefore focus on values set on the individual building parts – prescriptive values – and will only include the building itself. The aim will be to compare u-values for different building parts and building regulations with the major aim of reducing heating.

11.1 Methodology

By this comparison, u-values for the individual building parts are compared separately. This includes values for ceilings, external walls, floors and windows. Different values are set in different states or regions. In North America, the values are set as R-values for building some parts as ceilings, walls and floors, while values are set in u-values for windows. All values are recalculated into u-values and the comparison is made in SI units.[99]

Some building codes sets values for different constructions such as timber frame walls, heavy massive walls or cavity walls. In this case both the lowest and the highest values are used and compared

[98] Information given at the joined India and IEA workshop on Buildings Codes and Energy Efficiency in Buildings held in Delhi the 4 and 5 November 2006

[99] Other values for windows, such as light transmission and shading, are not taken into account.

In the US, u-values for windows are often set as different values, depending on the amount and size of windows. Larger areas of window imply lower u-values for the windows and often these values are dependent on the ratio of windows to floor area – in this case both lowest and highest maximal values for windows are used for the comparison[100]. This can give multiple points for the same location in the same state and will hence spread the values further.

In Europe, u-values are in some cases only set as absolute minimum values, because the real values are determined by the total energy performance of the buildings. This gives to some extent a difference in the representation of the values. Hence, stricter values could have been used for the comparison, since the u-values in actual typical houses will need to be lower to fulfil the energy performance demands.

Values in the comparison mainly focus on those for residential buildings – where these values are mostly common - and in some cases only small residential buildings such as one and two family houses. For many countries these values are similar to those for non-residential buildings. However, in some countries these values for non-residential buildings are different or compliance demands are set different for these buildings.

The u-values are illustrated based on the climate in the countries, states or the cities. This is based on heating degree days. Values are calculated on base 18 °C and US values for 65 °F which are quite similar.

The comparison is made only for countries, regions or areas with major heating needs the so called cold climates and the heating based climates. This includes some states the US and some parts of other states,[101] Canada, most of Europe although only parts of some southern European countries, parts of Japan[102], southern parts of Australia and for New Zealand.

Cooling is taken into account for the areas within the heating based climates and 50 % of the cooling degree days base 18 °C or 65 °F are added to the heating degree days used for the comparison. This gives a modified number of heating degree days for the comparison, which is a little different from the values which can be obtained from the national weather databases.[103] All modified heating degree days are recalculated into HDD 18 °C.[104]

The calculation of corrected heating degree days can be illustrated as:

$$\mathbf{HDD_{corr} = HHD_{18^\circ C} + 0.5 * CDD_{18^\circ C}}$$

By the selection of u-values and climatic data major cities or a representative range of values are chosen for the individual countries and states. In the US, Japan and some European federal states, values are set for different zones in the states or the country. In this case some cities are chosen to illustrate different zones in the individual states or countries. Therefore, not all cities and all parts of states and countries are illustrated in

[100] Values can for instance indicate the level if the windows account for 12 % of the floor area and the graduated until they account for 25 %. Stricter levels are typically set by large are of windows. In this case minimum and maximum values are used in the comparison.

[101] Only countries, states or cities where the cooling needs in term of CDD 18° are less than 60 percent of the HDD 18 °C are included in the comparison

[102] The requirements for Japan are only set as guidance. These values are not mandatory, but are still included in the comparison.

[103] For the model building code – International Energy Conservation Code – the values for cooling degree days were only given for base 50 °F and these values are substantial higher than the values for 65 °F. The modified heating degree days for this code are hence only modified with 25 % of the cooling degree days to be comparable with the other values.

[104] Heating degree days in HDD 65°F are 1.8 times higher than values set in 18°C.

the graphs, only the representative areas and those parts representing cold or heating based climates.

Values for the individual building parts are set in many countries. These graphs only illustrates part of these – around 60 states and nations are represented in the graphs with more than 200 sets of u-values and modified heating degree days,

11.2 Possible misinterpretation of the values

Even when limited to u-values for building parts there is a big difference in the way these values are set in the different regions. Some countries set different values for different types of walls or floors and maybe there are even some types of constructions, which are not regulated. Other countries set one common fixed value, which cover all types of walls. This is also the case for ceilings and roofs or different types of floors, depending on whether these floors are placed on grown or over air.

Some countries only use u-values to support an overall demand for the energy performance, where the real requirements for insulation and efficiency are set. Hence, u-values only represent the absolute minimum for the constructions – maybe only for health reasons or to prevent moisture or lack of comfort - while the real values normally will have to be higher to ensure compliance with the overall performance requirement. In this case the u-values represent a kind of “a lower minimum requirement”. This is often the case in Europe, where the Energy Performance in Buildings Directive requires that building codes are set based on the energy performance of buildings. In other states or countries values are set either on prescriptive u-values or as an overall frame for the building. This means that values can often be lower than the maximum u-values given in the building code, and that these values represent “a minimum requirement”. This will in general underestimate the demands in some European countries, since the actual u-values have to be lower.

For some countries or states there is a possible trade off between the values, but this only influences the actual levels to a very limited extent. This is the case for most North American values. In the US, values for windows are often set depending on windows area in the building and different values are set based on the percentage of windows in relation to floor area. In some cases increased area of windows even increase the requirements for other building parts too. In this case multiple values are presented in the graphs.

In other states and countries the values are the absolute minimum, while the stricter demands by increased area of windows are regulated trough the demands for the overall performance of the buildings, which automatically will increase the demands for the windows or for other parts of the buildings with increasing area of windows.[105] This gives a difference in the values and the best US values should hence be lower than the European values.

In some regulations u-values are set to take into account losses in thermal bridges, in other regulations specific values are set for thermal bridges while the u-values for the construction only covers the general value. This can influence the values to a minor extend. Similar, separate values for transmission constants, thermal bridges, light transmission etc. can be set in building codes, while other codes only include only one single value.

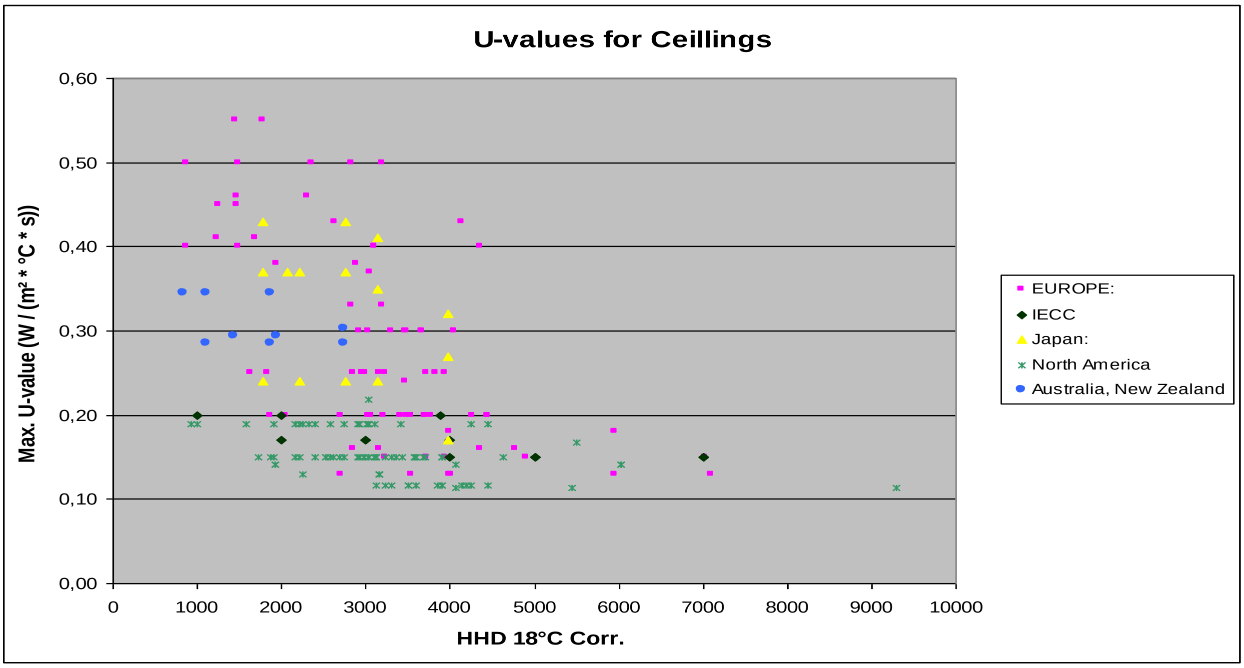
These differences have to be taken into consideration when values are compared and the results are analysed.

[105] When windows are included in overall energy performance requirement, larger surface of windows increase the heat loss and this will automatically raise the demands for windows or for other parts of the building. In countries with energy performance requirements there will hence typically be no differentiated demand for windows.

11.3 Comparison ceilings

Figure 13 illustrates the u-values for ceilings, roofs or used attics. Values are shown as a function of modified heating degree days.

Figure 13. U-values for ceilings for selected OECD countries with cold or heating based climates.



Heating degree days for heating based countries are modified for cooling. Values for ceilings also include values for insulation around heated attics or in roofs. One location can be represented by if more different values are set for different types of constructions.

There are large differences in the level of requirements for u-values for ceilings in the OECD countries. The requirements for ceilings are rather high in North America compared to other regions meaning that the u-values are substantially lower than Europe, Japan and Australia. In general, U-values in the US and Canada are close to or slightly better than the IECC 2004 standard and u-values are typically under 0.20 W per m² per second and per °C.

In Europe the values are quite spread and there is a substantial difference between south and north. Values for northern Europe are close to the US values, while level for the values for southern Europe varies substantially and generally is higher than values from similar climates in the US.

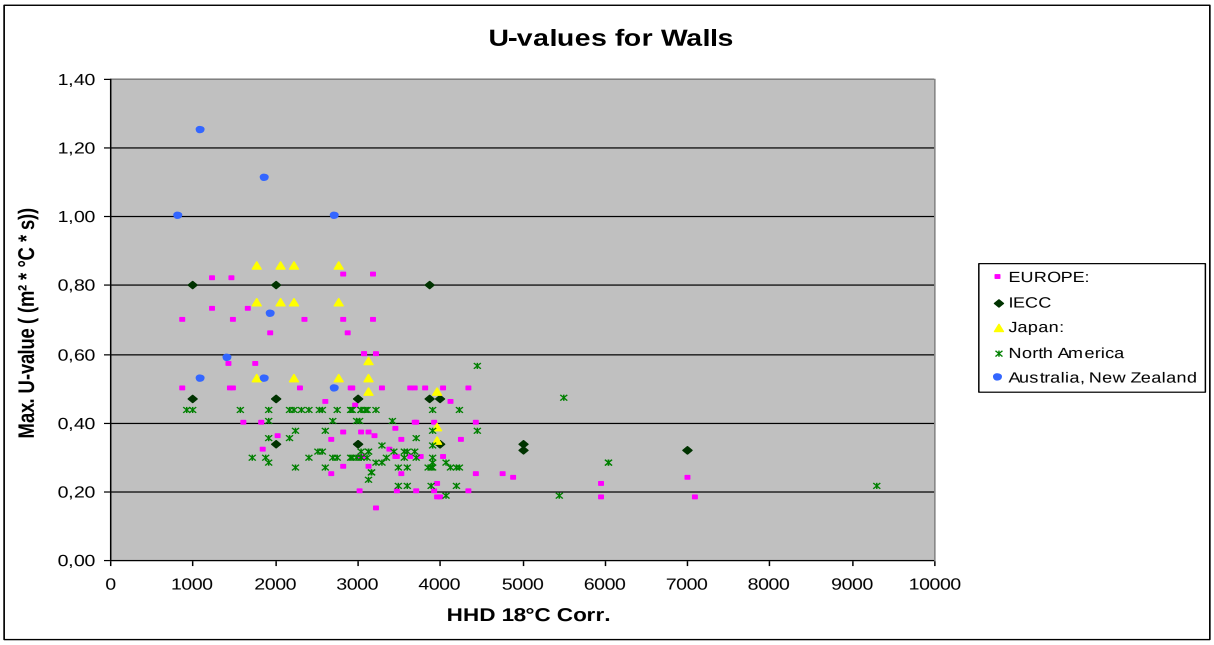
11.4 Comparison walls

U-values for walls for three construction types: timber frame, massive or cavity walls are shown in Figure 14. Values are shown as a function of modified heating degree days.

U-values for walls are rather diverse in all regions and there are large regional differences. These values vary, especially in Europe, and there is a large difference between the north and south of Europe. Values from north of Europe seem to be slightly stricter than for similar climates in North America. Values from the south of Europe are often substantially higher than for similar climates in North America. Japanese values are in general higher both for concrete enforced buildings and for wooden constructions.

Most states in the US and Canada have implemented higher demands for external walls than the values in the mode building code IECC. For some codes only certain types of walls are included or there are different values for timber frame and heavy constructions. Many states in North America are represented by more values for different types of walls.

Figure 14. U-values for external walls for selected OECD countries with cold or heating based climates.



Heating degree days for heating based countries are modified for cooling. Values include values for timber frame constructions, massive walls and cavity walls. One location can be represented by multiple dots.

11.5 Comparison floors

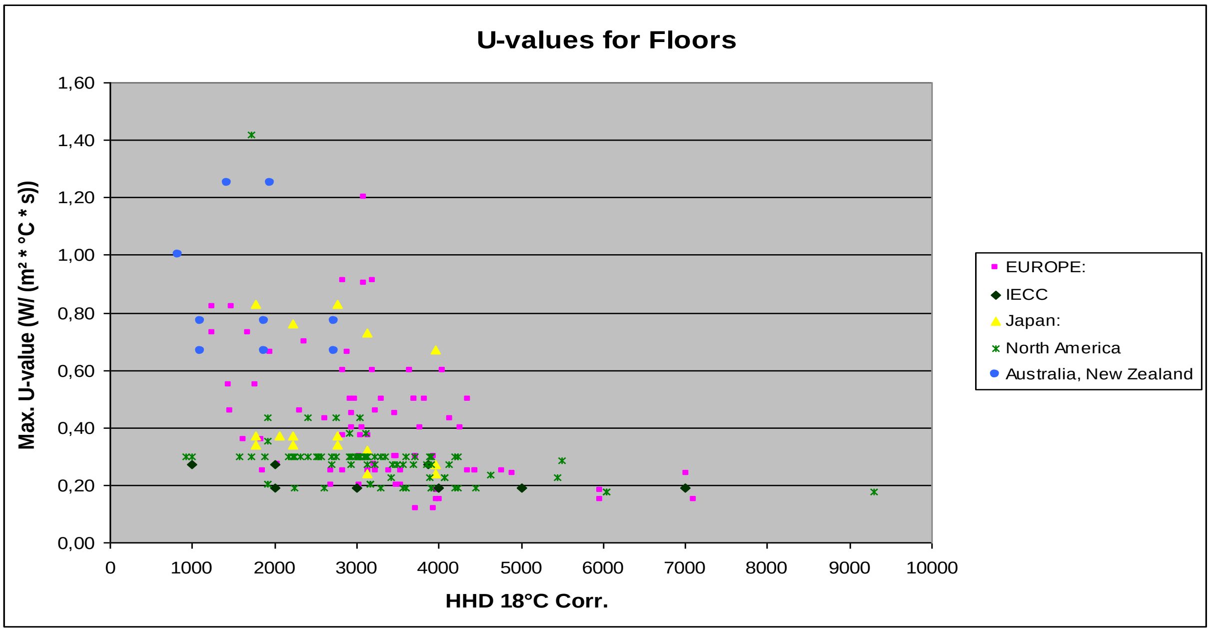
Figure 15 illustrates the u-values for floors on slab ground, over unheated cellars or over open air. Values are shown as a function of modified heating degree days.

U-values for floors in heating based regions of North America are in general lower than the similar values in Europe. In particular, this is the case when values from southern Europe are compared with similar climates in the US. In some northern countries in Europe the values are, however, stricter than the similar climates in the US and Canada. Japanese values are rather consistent with the European values. The Japanese values for timber frame constructions are even close to American values. U-values in North American states tend to be at level or higher than the model standards IECC.

11.6 Comparison windows

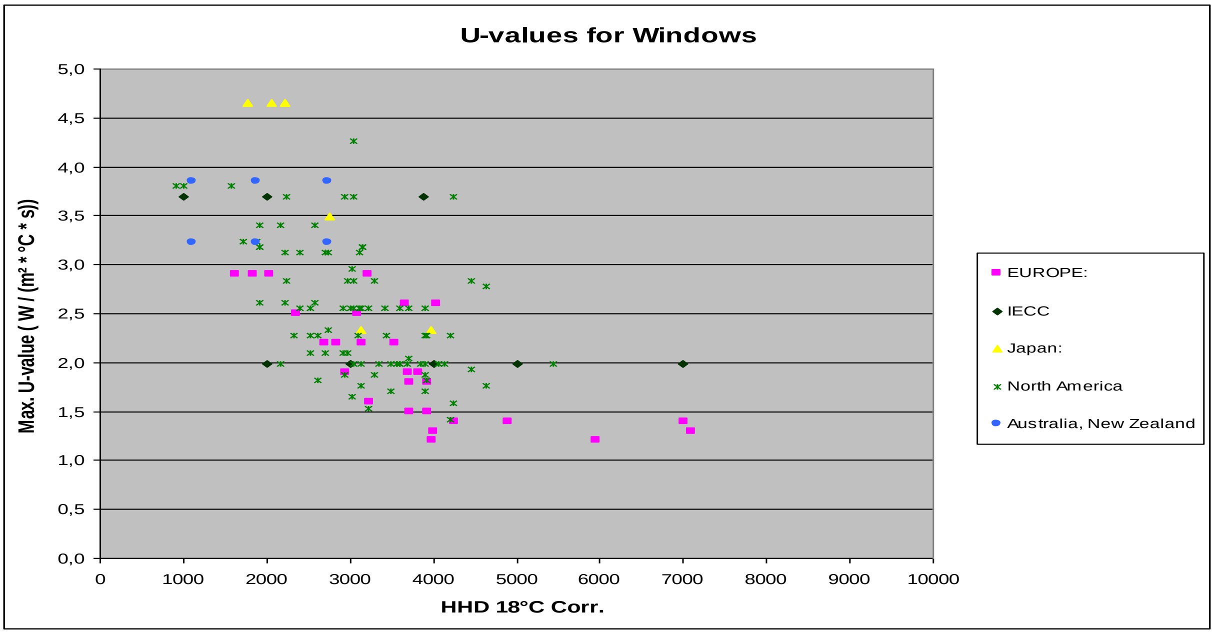
U-values for windows are illustrated in Figure 14. Values are shown as a function of modified heating degree days.

Figure 15. *U-values for floors for selected OECD countries with cold or heating based climates.*



Heating degree days for heating based countries are modified for cooling. Values include values for floors on the ground, over air or over unheated heated cellars. One location can be represented by multiple dots.

Figure 16. *U-values for windows for selected OECD countries with cold and heating based climates.*



Heating degree days for heating based countries are modified for cooling. One location can be represented by multiple dots if different values are set depending on the area of windows.

The u-values for windows vary substantially and there is up to a factor 3 between the most efficient and the less efficient windows in similar climates. Requirements for windows are stricter in Europe than in the US and Canada, and some states in North America do not have requirements for u-values in windows. Some states set requirements for types of windows, for instance double glass or for energy efficient glassing.[106]

Values for North America are rather diverse and several states have implemented values, which are stricter than the requirements in the model building codes. For some US states, there are different values dependent on the surface of windows meaning that a larger surface of windows will lead to a higher demand for the windows.[107] Several values can be shown for these states and this adds to the diversity.

11.7 Overall comparison of prescriptive values

As can be seen from the comparison of the individual parts of the buildings there are substantial differences between the different regions of the OECD. These results do not point in favour of one single region, but show that lessons can be learned in all regions and that there is still room for improvements of the requirements.

To valuated the total efficiency of the building envelopes of these prescriptive regulations a common over all u-value could be developed. This overall value would take into account the values for ceilings, walls, floors and windows. A simple overall u-value adds the u-values for ceilings, walls and floors with a modified value for windows. Windows are in this value only calculated with 20% since the area of windows for small residential buildings normally will be less than 20 percent of the floor, ceiling and wall areas, and because the values for windows would otherwise totally dominate the overall u-value.

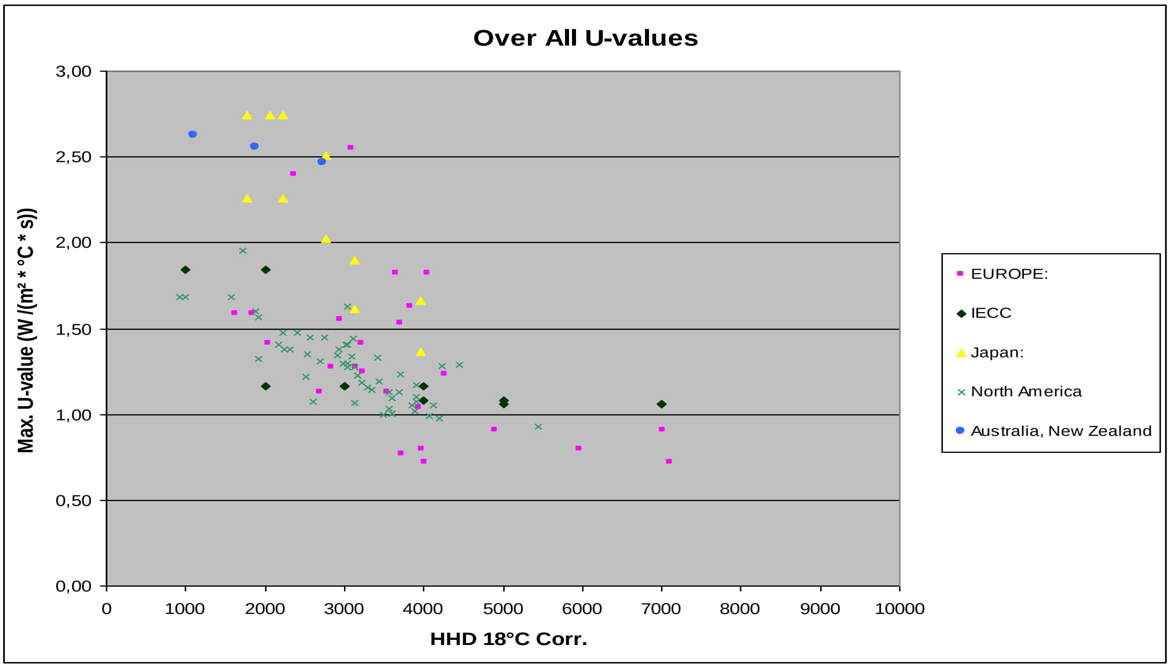
$$U_{overall} = U_{ceiling} + U_{wall} + U_{floor} + 0.2 * U_{window}$$

The overall U-values for requirements, which include all these u-values, are shown in Figure 17. In case there are different u-values for the same construction part the value is calculated as a mean between the maximal and the minimal value for these parts giving only one value for each city, state or country.

[106] Energy efficient glazing could be low energy glassing with double or triple layers of glass windows, and / or where the room between the windows is filled with gasses with thermal reduction and where the glass is covered with foil to reduce the transmission of heat or sunlight.

[107] These values can be set a window area on 12 % of the floor area, with additional and gradually stricter values for 15 %, 18 %, 21 % and up to 28 %. In case of several values highest and lowest value are plotted on the graph.

Figure 17. Overall u-values for selected OECD countries with cold or heating based climates shown as function of heating degree days.



Heating degree days for heating based countries are modified for cooling. Values include values for ceilings, walls, floors and windows. One location, state or country is only represented by one dot.

There is a big difference in how the prescriptive requirements are implemented in the different regions. In Europe there are substantial differences between the northern and the southern parts. In the north of Europe the requirements are quite strict, while the picture is more mixed in the South.

In North America the requirements seems to be more homogenous, probably because of the model codes for energy efficiency of buildings the IECC and the ASHRAE. Values for the states are in quite good compliance with especially the International Energy Conservation Code, IECC.

The most strict code in terms of overall u-value was found in Sweden with an overall value close to 0.7, followed by Denmark (0.77) for renovation or extensions, while u-values are not set for totally new constructions[108], and Norway (0.84) and then followed by Finland (0.94) and Ontario for the coldest part of the climate with more than 5.000 HDD 18°C (0.93).

The Swedish building code is in fact based on energy performance and the values for individual building parts are only set to support these values. Buildings will, therefore, typically have to be built to even stricter requirements than these u-values in order to fulfil the over all values.[109]

The main level for prescriptive values in the building codes in Central Europe and North America are approximately at the same level.

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[108] Values for new constructions in Denmark are only set as an overall performance. U-values will typically need to be lower than the above values for extensions and refurbishment. Some u-values for new buildings are set to avoid condensation and loss of comfort and some standardisation.

[109] The actual level of u-values in Sweden based on the energy performance demand is shown earlier in this paper.

Passive houses[110] would be substantial lower than these values and would have a value close to or less than 0.5 compared to the Swedish values on 0.7 and other values, which with few exceptions are larger than 1.0. Using passive house standards as building codes would, therefore, typically more than halve the energy losses in new buildings alone by better requirements for the building envelope.[111] For some countries this is even a reduction by up to 75 – 80 %.[112]

11.8 Comparisons Cooling Based Climates and Energy Performance

There are less data available to compare for hot and cooling based climates and a different valuation needs to be made concerning the different building parts, since the ceiling insulation is highly efficient and needed, while there would be less concern on insulation of floors, because floors can have a cooling effect in the hot seasons.[113] Windows would also need a special treatment and this should include shading as well as light transmission, which needs to be taken in account in the overall evaluation.

Comparison of energy performance will require more details on the calculation methods including which consumptions are included and how the calculation is performed. When requirements are set as energy performance or an overall frame this is calculated in different ways in different countries and regions since only regional or national calculation methods exists so far. A complicated model or method needs to be established to compare performance values. This will require many decisions and an agreement on the right model on how to compare and treat different elements, which will influence the comparison substantial.

11.9 Conclusion

When prescriptive values in building codes are compared based on heating degree days there are some differences between the regions. Requirements for ceilings and floors are relatively high in North America, and values for ceilings are higher than comparable climates especially in Southern Europe and Japan.

Requirements for walls are higher in Northern Europe than in North America and Japan, while the values for walls are higher in the US than in similar climates in Southern Europe. Requirements for windows are higher in Europe than in North America.

In the US and Canada most values are close to or slightly better than the model building codes for energy efficiency and they seem to be quite homogenous. Values in Europe vary substantial and especially there is a large difference between high demands in the North and more differentiated and lower demands in the South of Europe.

The highest requirements for u-values are found in the Nordic countries and in Ontario in Canada. Sweden has the highest requirements found in this comparison of u-values closely followed by Denmark and Norway.

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[110] See the information paper on Energy Efficiency Requirements in Building Codes and Energy Efficiency Policies for New Buildings.

[111] In passive houses the supply of energy from sun as from persons and appliances will take a much larger share than in traditional buildings. This will mean that such standards – based on passive houses - would dramatically reduce consumption in cold and heating based climates, where these buildings are well tested and often feasible.

[112] In passive houses the energy demand would be further reduced through efficient heating and ventilation systems, from heat recovery and other energy efficiency measures.

[113] Different studies indicate that floors can have a cooling effect in the hot seasons. This indicates that floors should be less insulated in cooling based climates. See for instance the ECOFY studies on energy potentials in Europe. Roof will on the other hand have a larger impact since the roof is both heated by outdoor temperature and direct sun radiation. In cooling based climates there is hence an increased need to balance the values and to use energy performance in the regulation

Lessons can be learned in all regions of the OECD and there is a substantial room for convergence especially in Europe. Compared to passive houses, there is still quite some room for improvement of building standards.

12 Enforcement, encouragement

12.1 Why are carrots and sticks needed?

High requirements for energy efficiency in new buildings will only have an impact if new buildings are actually constructed in accordance with the requirements.[114] Since there are so many barriers and as the construction of new buildings is complicated, there is a need for enforcement of efficiency regulations for new buildings.

Often there is a high interest in the incremental costs of a new building, and during design and construction to keep down the costs even if this increases the final cost for the users of the building. This will as mentioned under barriers for energy efficiency normally work against energy efficiency because the gain of low energy consumption will only show with time while the increased costs are immediately evident.

The building process in general is complicated and complex for the ordinary builder and difficult for buyers of new buildings to ensure that the rules for energy efficiency are fulfilled. Good building codes should therefore be combined with strong enforcement systems.

12.2 Enforcement systems

Enforcement systems will depend on the type of building regulation that is used. If building efficiency is a part of the general building codes and rules for buildings it will often be enforced in the same system as other requirements in the building codes. If the code is set in a specific standard it may be decided to leave the control up to a specific system for energy efficiency or to combine this with other types of control. In many cases, it is up to the local authority to control the compliance on building regulations.

Both systems have advantages; if the control is combined with that of other building regulations this will typically imply systems to deny buildings to be taken into use or other sanctions which also apply for safety reasons etc. But, on the other hand, if compliance is controlled by energy efficiency specialists this may ensure that these controllers have the necessary knowledge.

In some countries control of efficiency is based on accreditation systems where responsible experts can loose the right to construct or to apply for permits if the rules are violated.

Examples on enforcement

One example of an initiative to support building codes is an energy inspection of buildings. According to the European Directive on Energy Performance all new buildings must be certified by an independent expert. Some countries use this to ensure that energy efficiency requirements are fulfilled, for example both Portugal and Denmark have introduced new regulations. In both countries the buildings energy efficiency must be declared before the building is constructed. This can be done by the architect or the company responsible for the construction. After construction, a certificate has to be issued by independent consultants including review of the self declaration. If the building fails to

[114] The compliance of building codes is a major problem in many countries both in the OECD and in the developing countries. IEA will conduct further studies on compliance with energy efficiency requirements in 2008 and this will include building codes.

comply with the regulations, the use of the building can be denied until an adequate efficiency level has been obtained[115].

In Denmark these requirements are based on investigations which showed that as many as 67 % of all new buildings failed on the energy efficiency requirements for insulation of pipes and tanks, and that up to a 1/6 of general construction costs was used to repair constructions and installations, which were incorrectly carried out in the first place.

Several countries use certificates of compliance of energy efficiency requirements for new buildings, including many European countries, Japan and Australia.

12.3 Encouragement systems

Another incentive to fulfil building codes or efficiency standards can be given through encouragement systems, which support compliance with requirements. This can be a subsidy, which will only be obtained if certain energy efficiency requirements are fulfilled. These can either be based on the pure compliance with requirements in the codes or it can be requirements, which are stricter than the energy efficiency requirements in these codes.

Examples on encouragement

In different regions of Austria there are subsidies combined with energy efficiency requirements, which are stricter than the minimum requirements in the building codes. This can be additional insulation, improved windows or installation of renewable energy sources such as solar collectors, photo voltage or biomass ovens or boilers. In some Austrian provinces this has lead to nearly all buildings being constructed with an energy efficiency which is better than the requirements in the codes, but as a minimum the requirements are fulfilled.

In US tax incentives have been given in the last years to increase the level of insulation and to encourage the constructer and building owners to go further than the minimum requirements. These incentives have probably also helped to increase the compliance with the codes.

13 Beyond the Building Codes

Building codes and energy standards for minimum energy efficiency set minimum requirements for energy efficiency for all new buildings. In many cases it is as shown above possible and feasible to build with a much higher efficiency thereby improving the economy over the long term. No building codes or energy standards found in this study limit constructors or future owners to go for higher energy efficiency. But still the vast majority of new buildings are constructed exactly with minimum requirements of energy efficiency.

However, some buildings aim for much higher efficiency standards and among these are:

- Low Energy Buildings
- Passive Houses
- Zero Energy Buildings and Zero Carbon Buildings
- Plus Energy Buildings

Other types of buildings also aim at higher standards beyond the requirements in energy efficiency standards and buildings codes, for example, Green Buildings, Intelligent Buildings, Integrated Design, Sustainable Buildings or Ecological Foot Print.

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[115] The requirement to deliver a certificate is a part of the building code and the control of the certificate is a part of the general compliance check done by the local authorities. The consultants responsible for the certificates are certified and controlled through the national certification scheme.

13.1 Low Energy Buildings

This term is generally used to indicate that buildings have a better energy performance than the typical new building or the energy efficiency requirements in building regulations, and that the building hence will have a low energy consumption compared to a standard building.

In some countries or regions, low energy buildings are defined by the building codes or in relation to the energy standard. The low energy buildings can be defined as having half the energy consumption or a specific percentage of those constructed according to the standards. Unfortunately there is a large variety in how efficient this will be. First of all it will depend on how this percentage is set and on the actual energy efficiency requirements for buildings or the general standards for new buildings. A building which can be classified as low energy in one country may use more energy than a standard building from another neighbouring country. In some countries the definition of low energy buildings is vague and may be used for all buildings that are better than the minimum standard.

Over time standards have improved and what was low energy standards some years ago may be standard today. If there is no protected definition for low energy buildings this may lead to all new buildings being called low energy, and that consumers will be presented with a low energy building even if it hardly fulfils the actual energy efficiency requirements.

In some countries, therefore, the term low energy buildings can be a little confusing since it has no clear definition. In other countries it is clearly defined and a useful guide for those who want a buildings with efficiency above the standard.

Energy Star*, *positive labelling

For many countries in the European Union a level beyond the building code is defined as a part of the certification of new buildings, which has to be implemented as part of the Energy Performance in Buildings Directive. Typical specific classes such as A or B on a scale from A-G or A+ and A++ are used to indicate that these buildings are built better than standard. Some countries have used a large part of the scale or even the whole scale to show the difference in new buildings using all the letters from A-G to classify new buildings.

In Germany, Austria, Denmark and Switzerland special standards exists for low energy buildings. Niedrigenergihäuser (G, Au) 30 W/m² per year, Minergie® (Sw) 42 W/m² per year[116] of heat demand for space heating and sanitary hot water and Low Energy Class 1 on 50 % and 2 on 25 % reduction of the energy needs in the building code (Denmark).

In Australia different stars are used to show the efficiency of buildings. As many as 5 stars are awarded for maximum energy efficiency. With the increase in energy efficiency requirements over time, the minimum requirements in the state of Victoria are equivalent to 5 stars.

In the US a label called ENERGY STAR is used for buildings which use 15 % less energy than the requirements in efficiency standards for new buildings as defined in ASHRAE and IECC 2004.

[116] The 1.1.2009 the maximal transmission value for Minergie is reduced from 42 W/m² to 38 W per m².

13.2 Passive Houses

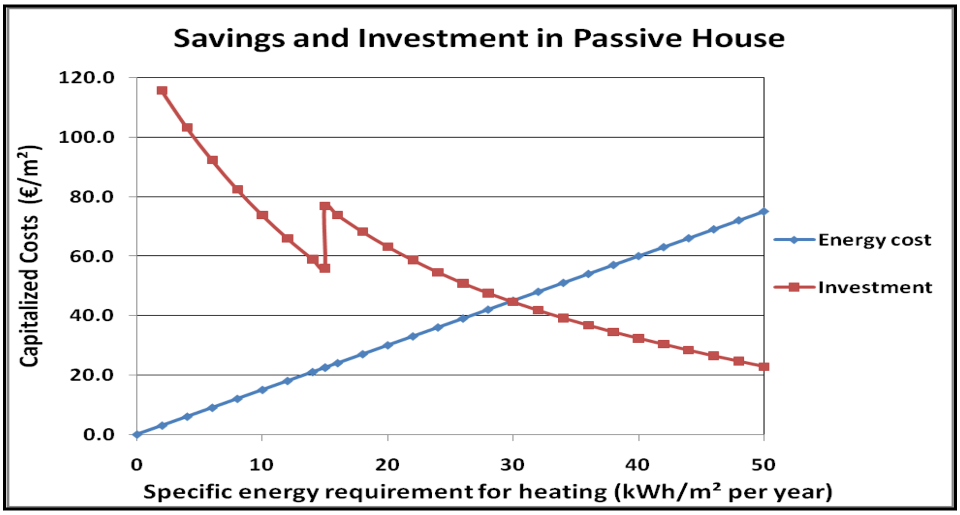
A passive house is a building in which a comfortable indoor climate can be obtained without a traditional heating or cooling system. Compared to traditional building they use far less energy. For most countries these demands are 70–90 % reduced compared to the actual energy efficiency requirements for heating and cooling, but this depends on the actual energy standards. For countries with high energy efficiency requirements it is less.

The principle of a passive house

With increasing efficiency the additional costs for energy efficiency measures will increase. In general the most cost effective measures will be used first. The closer the building comes to zero energy consumption the more costly measures are hence needed to increase energy efficiency and reduce the consumption. At the same time there will be different options where savings will occur, because some installations or equipment is no longer needed.

One of the most interesting reductions in costs is when the energy consumption is getting so low that a traditional heating system is no longer needed and building relationally can be heated alone with the passive solar gains and the ventilation systems.

Figure 18. The additional costs and savings in a Passive House.



Passive house, with increasing efficiency the consumption decrease, but the costs for construction goes up. At a certain point the heating system can be saved and this gives a substantial reduction in costs – this point is close to 15 kWh/m² per year.[117]

When increased investment costs and capitalised costs for energy over lifetime are added, the final costs for the improved energy efficiency can be found. These total costs are shown in figure 19 together with the capitalised costs for energy.

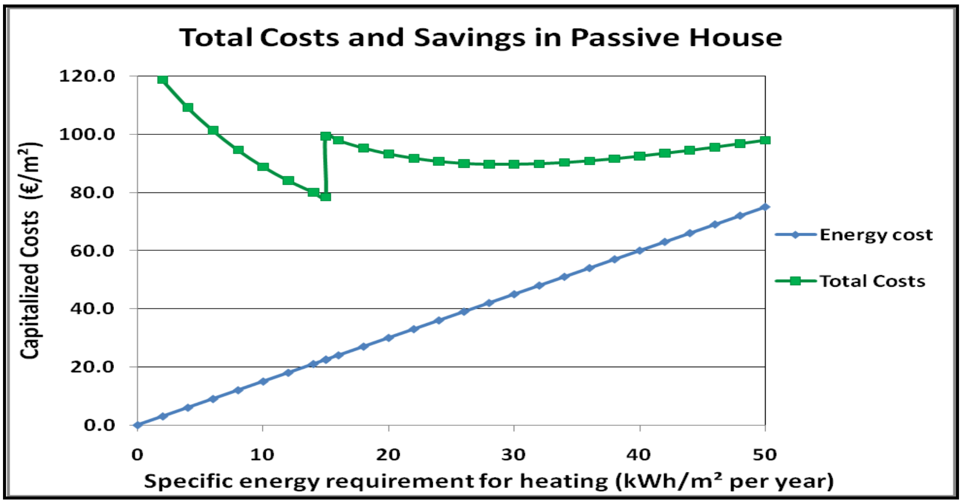
It can be seen from the graph that the total costs for a building, with 15 kWh/m² per year is lower than the total costs for buildings, which are built to a standard, which require 50 kWh/m². With higher consumption the savings are even higher and at no point the costs are lower than the passive house.

In the example shown in the graph in Figure 19 the costs for a house, which requires only 7 kWh/m² per year, would be same costs as a house build with the demands in the building

[117] Based on costs and estimates from the Passive House institute in Darmstadt. Costs are for central Europe (Germany).

regulation with 50 kWh/m², when the costs are seen over lifetime (30 years). Over time there are no additional costs for the owners or users of passive houses.

Figure 19. The total for improved efficiency in a Passive House.



When additional costs and savings in by improved efficiency in buildings are added, the costs will show a drop by 15 kWh/m² per year. The total costs for a building over lifetime for a passive house will hence be cheaper in a passive house (15 kWh/m² per year) compared to a house build according to a building regulation which require 50 kWh/m² per year.[118]

Similar principles can be used in hot and heating based climates. In this case shading and orientation of building and windows and passive cooling techniques are essential. The points for reduction of costs in passive cooling buildings are different and more dependent on the local conditions and there is no similar specific standard as for the passive heating buildings (Passive Houses).

Definition

To be a passive house a building must fulfil different conditions:[119]

- The building must not use 15 kWh/m²/a or less (≤) in heating energy[120].
- The specific heat load for heating source at design temperature must be less than 10 W/m².
- With the building pressurised to 50Pa by a blower door, the building must not leak more air than 0.6 times the house volume per hour (n50 ≤ 0.6/h).
- Total primary energy consumption (primary energy for heating, hot water and electricity) must not be more than 120 kWh/(m²a).[121]

The passive house standard was defined in 1988 [122] and the first passive house was built in Darmstadt in Germany in 1990.

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[118] Based on costs are based on an oil price around 60 USD per barrel. With higher oil price the savings are substantial higher and the benefits from the passive house is larger.

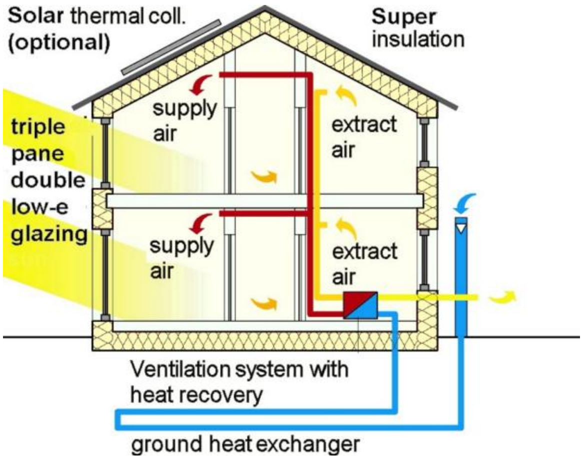
[119] These are set and controlled by the passive house institute in Darmstadt. The values are particular adopted for the central European countries.

[120] The maximum value for heating on 15 kWh/m² per is equivalent to 4.8 Btu/ft² per yr.

[121] The maximum energy consumption on 120 kWh/m² per is equivalent to 38.0 Btu/ft² per yr.

[122] The passive house standard was defined by Dr. Wolfgang Feist from Institute für Wohnen un Umwelt Darmstadt and Professor Bo Adamson from Lund University of Sweden.

Figure 20. Principles for a Passive House.



A passive house or a passive building uses the passive solar gains to an optimum and often this needs to be balanced between cooling and heating. The passive house has an extreme degree of insulation – which vary with the local climate conditions – very efficient windows and efficient HVAC systems with natural pre-cooling of air.

Passive houses in practice

Certain construction requirements are necessary for passive houses. They must be:

- **Highly insulated.** All the building parts for walls, roofs and floors are insulated with U-values within 0.10 – 0.15 W/m² per K.
- **Designed without thermal bridges.**[123] All thermal bridges in construction have to be avoided. A construction of a passive house is set to be “Thermal Bridge Free” if the maximum bridges are under 0.01 W/m per K.[124]
- **With comfort windows.** Windows in a passive house are especially efficient and have three layers of glass, coating on multiple sides and are filled with gas. They will also have warm edges and special energy efficient frames. Overall, U-values for these windows are 0.70 – 0.85 W/m² per K.
- **Very air tight.**[125] The building must be constructed so it is particularly air tight and special care for this must be taken.
- **Supplied with efficient mechanical ventilation.** To ensure sufficient ventilation passive houses are supplied with mechanical ventilation which will secure a controlled air exchange on 0.40 times per hour.
- **Using innovative heating technology.** The heating and cooling of these buildings are typically supplied by innovative systems which include a heat exchanger.[126] Typically this will be combined with a heat pump or a highly efficient small heating system.

[123] A *thermal bridge* is a part of the construction which leads energy better than the rest of the construction. This can be the connection between building parts or the foundation of the building.

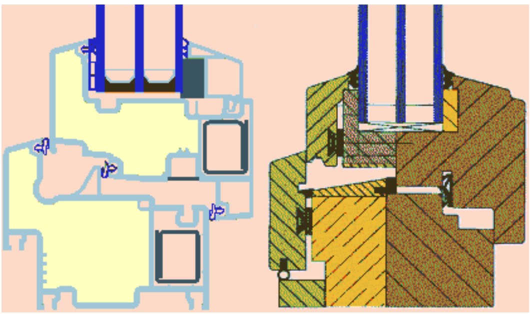
[124] Thermal bridges are typically measured by the amount of energy which will pass trough the thermal bridge per meter of length.

[125] That a building is air tight is meaning that no draft can pass trough constructions or between different construction parts.

[126] A heat exchanger takes the heat from the indoor air and heats the outdoor air before it is supplied in a heated building and takes the heat out of the out door air if the building is cooled.

All the details of the building envelope and the HVAC systems in a passive house are made with a high emphasis on energy efficiency. Building details are different from a traditional house, more insulation is added, special care taken with connections, steam tight components used systematically and some constructions changed substantially, such as windows.

Figure 21. Two different examples on comfort windows solutions



Constructions for passive houses are substantially different. Comfort windows were developed especially to the requirements in passive houses with u-values below 0.85. This requires 3 layer of glass, filling with gas, coating of the glass, hot separation of the glasses and special frames.

Passive houses are not bound to a specific type of constructions and examples have been designed based on different types of buildings, such as concrete, bricks, wooden frame houses and totally new construction types similar can comfort windows be of different types.

Even if the standard is called passive house it is also used for large residential buildings, commercial and public buildings such as schools, shops or office buildings.

Cooling – limitations

The passive house standard is basically defined for the central European climate, typically a heating based climate where there is only a limited cooling need for comfort reasons. It has moved north to the Cold Climates. A specific project – CEPHEUS[127] - supported by the European Commission has tried to take the passive houses out in different countries Germany, Austria, Switzerland, France and Sweden. 14 construction projects with 221 units were built as passive houses and monitored in this project. Some initiatives have been taken to extend the Passive House concept to cooled climates in southern Europe too.

Passive houses is mainly an European phenomena and there is a need to define a further standard, which define the standards and clever solutions for the cooling based and hot climates and which can be useful in all climates.

Benefits and costs comparison

Passive houses will have a comfortable indoor climate; because air is fresh and dry due to the mechanical ventilation and heat exchange of air. Due to thick insulation, there are no "outside walls", which are colder than other walls; floors and windows are not cold either.

Since there are no radiators, there is more room on the walls. The temperature are stable and change very slowly - with ventilation and heating systems switched off - a passive house might looses less than 0.5° centigrade per day (in winter).

In many countries passive houses use 70-80 % less energy for heating compared to other new buildings. Costs for new buildings are only slightly higher than those for traditional

[127] CEPHEUS – Cost Effective Passive Houses as European Standard, from 1998 – 2001.

buildings because the additional costs for insulation and ventilation systems are outbalanced with savings since it is unnecessary to install a traditional heating system.

The result from the CEPHEUS project showed that the additional incremental costs for houses on average was paid back in 20-21 years in simple payback time, and with interest they were paid back in 25 years.[128] Since 2001 energy prices have gone up and the costs for special units for passive houses are reduced, because these components become more mature building components. Seen over a 30 years lifetime, passive houses will therefore be a feasible alternative in central and northern Europe compared to houses with standard energy efficiency.

Example on policies to promote passive houses

In Austria and some parts of southern Germany passive houses are generally available on the market. Different programmes to promote these buildings have been very successful. In the Upper Austria province, the passive houses had a market share of 7 % of the market for one family houses in 2006.

The trend for passive house to penetrate the market have been going on in Upper Austria at the same time as low energy buildings have overtaken the major part of the market for one family houses and residential buildings in general. It is expected in Upper Austria that traditional houses will disappear from the market in a few years from now and that the voluntary standard will have moved to low energy. Upper Austria is in general favoured by a relative mild climate with mild winters and a modest need for cooling, but the development towards passive houses has been driven by a very active policy.

Table 12. Low energy buildings and passive house in Upper Austria

One Family Houses in Upper Austria	2003	2004	2005	2006
Traditional new Buildings	67 %	45 %	24 %	15 %
Low energy buildings	31 %	52 %	71 %	79
Passive houses	2 %	3 %	5 %	7 %

Passive houses have taken a major market share in upper Austria. At the same time low energy buildings, which use less than 30 kWh/m² per year for heating, have taken the major market for new buildings.

Parts of the policy to promote passive houses in Austria are subsidies, which can only be obtained by the owner, who constructs passive or low energy houses, certification schemes for buildings document the passive house or low energy class and different promotion initiatives and some very active energy agencies in these states. In Vorarlberg in Austria Passive Houses are now standard for all buildings with public subsidy. Passive houses in Austria are estimated to be around 4 % of all new one family houses.

The increased use of passive houses has made these technologies widely known by constructors and users in Austria. The passive houses standard is also used to an increasing extent, for other types of buildings such as schools, shops and office buildings.

In southern parts of Germany passive houses have taken approximately 2% share of the market for new one family houses, and the standards are becoming commonly known by constructors and installers. Also in Germany there are different programmes to promote passive houses and the passive house standard in general.

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[128] Average for the 14 projects with 221 residential units in 5 different countries, Austria, Germany, France, Switzerland and Sweden based on 2001 prices.

The passive house concept is spreading in Europe and passive houses are constructed in Germany, Austria, Switzerland, France, Belgium, Holland, Denmark and Sweden. Some experiments with passive houses are also taken in northern Italy and in Spain, where the cooling needs have to be addressed.

13.3 Zero Energy Buildings

Zero Energy Buildings are buildings that do not use fossil fuels but only get all their required energy from solar energy and other renewable energy sources.

Although this seems quite obvious, there is still need for further definition and agreement on clear international standards etc. In particular there is a difference in how the Zero Energy Buildings are used in Northern America and in other parts of the world.

Definitions

Zero energy buildings can be defined in various ways, including:

- **Zero Net Energy Buildings** are buildings that over a year are neutral, meaning that they deliver as much energy to the supply grids as they use from the grids. Seen in these terms they do not need any fossil fuel for heating, cooling, lighting or other energy uses although they sometimes draw energy from the grid.
- **Zero Stand Alone Buildings** are buildings that do not require connection to the grid or only as a backup. Stand alone buildings can autonomously supply themselves with energy, as they have the capacity to store energy for night-time or wintertime use.
- **Plus Energy Buildings** are buildings that deliver more energy to the supply systems than they use. Over a year, these buildings produce more energy than they consume.
- **Zero Carbon Buildings** are buildings that over a year do not use energy that entails carbon dioxide emission. Over the year, these buildings are carbon neutral or positive in the term that they produce enough CO_2 free energy to supply themselves with energy.[129]

Defining Zero Energy Buildings

Compared to the passive house standards there is no exact definition for the way to construct or obtain a zero energy building. In principle this can be a traditional building, which is supplied with very large solar collector and solar photo voltage systems. If these systems deliver more energy over a year than the use in the building it is a zero net energy building.

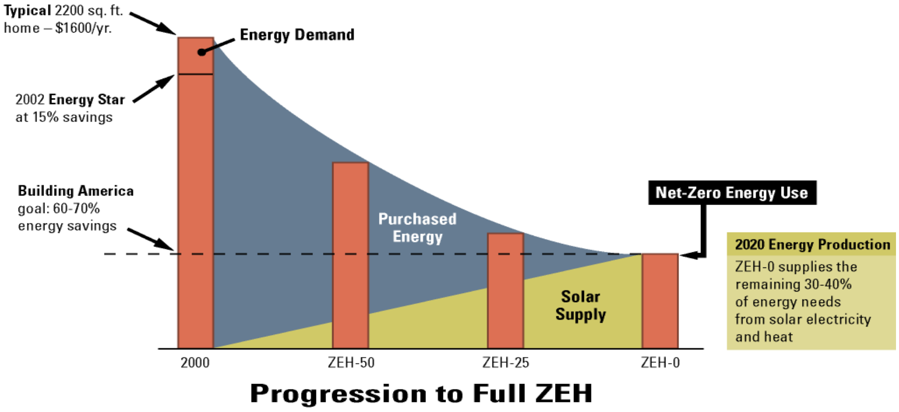
Traditionally it is normal to substantially reduce energy consumption use passive solar energy[130], install highly energy efficient equipment and lighting, mechanical ventilation with heat recovery and then use renewable energy to supply the buildings. In cooling based or hot climates intelligent shadowing will prevent the building from being overheated.

Most programmes for Zero Energy Buildings built on these principles; reduce energy demands, use energy gains and reduce need for cooling by shading etc, supply with highly efficient HVAC systems, install highly efficient equipment and lighting and supply the remaining need for energy by renewable sources such as solar collector for heating and PVH or small windmills for electricity. A Zero Energy Building can be a passive house where the remainder of energy is supplied from solar collectors, PVH and other renewable energy.

[129] Zero Carbon Buildings differ from Zero Energy Building in the way that they can use for instance electricity produced by CO2 free sources, such as large windmills, nuclear power and PV solar systems which are not integrated in the buildings or at the construction sight.

[130] Energy gained from the sun trough windows and glass areas without active solar systems.

Figure 22. US figure on zero energy buildings



The way to net zero energy buildings in US.[131] *Best practice for low energy or zero energy homes are expected to be real Net Zero Energy Buildings from 2020.*

Normally all energy use in the buildings will be included in the calculation of a zero energy building and this includes installed white goods, lighting, ventilation, air conditioning etc. In high rise buildings energy use for elevators will be included too.

In hot or cooling based climates in particular, there is a strong emphasis on energy efficient equipment because first these appliances have to be supplied by renewable energy but secondly the waste energy has to be removed by ventilation and cooling.

Examples on programmes for low energy buildings

Zero energy homes. The US program Zero Energy Homes defines the target for the program as the construction of zero energy buildings, but so far the buildings only have to be below 50 % of the energy consumption in the building regulations. In real terms the houses should be called "on the Way to Zero Energy Buildings". These buildings are in fact to be classified as low energy buildings.

An interesting aspect of the programme is that the defined goal is zero energy use. Special programmes are set up to promote and support these buildings. Help for Finance is provided through the tax credits. Experience from the programme is that buildings cost a little extra but that this can be compensated by the reduction of other installations, for instance in the type of kitchen or by reduced living space. Energy efficiency improvement in these buildings is paid back through traditional loans for new buildings and there will be a positive balance already the first year because the savings more than out balance the additional cost for loans.

When Zero Energy Homes are constructed they are normally sold faster that other similar buildings with traditional energy standard[132].

Examples of true net zero energy buildings as well as stand alone zero energy buildings have been built in the past. In Germany zero energy stand alone building was built by the Frauenhofer Institute in 1998 and it was occupied for 3 years by a small family without being connected to any energy grids nor having any energy supply except from the sun. In this example energy was stores in a hydrogen fuel cell.[133]

[131] Graph from Zero Energy Buildings and Zero Energy Homes presentations. David Goldsteen, DOE, on the workshop on Energy Efficient Buildings Meeting the Gleneagles Challenge, Paris 27-28 November 2006.

[132] Information from DOE Zero Energy Homes program.

[133] Zero energy Stand alone Building. The Solar House in Freiburg, from a self-sufficient solar house to a research platform. Frauenhofer Institute.

The WBCSD[134] has defined a project on Zero Energy Buildings. The aim of this project is to develop and construct Zero Energy High-rise Buildings and to promote zero energy buildings in general. Another aim is also to change the buildings industry and to make zero energy buildings and technologies commonly available.

13.4 Green Buildings and Sustainable Buildings

Green Buildings are those with increased energy efficiency, but at the same time reductions are made on water consumption, use of materials and assessment of the general impact on health and environment. Green buildings can include a long list of requirements including resources, indoor air quality and requirements that all products for the building must come from a local region.

Very often Green Buildings will be supported by Life Circle Assessment of the buildings in which there will be a high emphasis on all elements in the life circle, where all phases are assessed. This includes production and transport of materials used for the building, use of resources for the running of the building, but also the disposal or the demolition of buildings are included.

The standards for Green Buildings can vary from region to region and some countries have set up their own definitions for Green Buildings. Some of the more known standards are in U.S, Canada, Australia and U.K, but many other countries have standards.

LEED Buildings

In US and Canada a specific standard LEED[135], Leadership in Energy and Environmental Buildings is set up, setting the requirements for the buildings to fulfil. The LEED standard can be obtained on different levels; Certified, Silver, Gold and Platinum with increasing requirements for the different requirements for the building. The LEED standard is set and controlled by the US Green Building Council, USGBC.[136]

The LEED standard includes Sustainable Sites, Water Efficiency, Energy and Atmosphere, Material Resources, Indoor Climate, Innovation and design. Energy and Atmosphere is the most important criteria for the buildings, but far from the only one and major other areas give the possibility of points too. In connection to the LEED buildings ASHRAE is developing a special standard for the Design of High-Performance Buildings – ASHRAE standard 189P, this work is supported by the DOE.[137] This will lead to further stringency of the LEED requirements in US.

Canada has established its own LEED standards which is set and controlled by the Canadian Green Building Council (CaGBC). There are other Green Building Rating Systems, including the Japanese CASBEE system.[138] Coordination and share of information between the different Green Buildings organisations are done by the World Green Building Council, WorldGBC.[139]

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[134] WBCSD – the World Business Council of Sustainable Development is an organisation of more than 180 multinational companies. See www.wbcsd.org

[135] LEED standard Leadership in Energy and Environment Design sets demands for all the different parts of the life circle of the building. A certain number of these demands must be fulfilled and the building must obtain a certain amount of points to be classified.

[136] USGBC – US Green Building Council, see homepage www.USGVC.org. Similar organisations exist in other countries.

[137] The ASHREA 189P standard is a codified version of the USGBC standard for LEED V2.2 and is in public review.

[138] The CASBEE system is also mentioned under Japan.

[139] World Green Building Council, WorldGBC,[139] is an international umbrella organisation, with the homepage www.worldBGC.org, with connection to Green Buildings Organisations in different parts of the world.

Sustainable Buildings are similar to the Green Buildings, but there are often small differences in the definitions. Often buildings will fall under both the Green Building and the Sustainable Buildings category

14 Dynamic Building Codes

14.1 Building codes have to be changed over time

The construction market is under constant change. New products come into the market and existing products become improved and/or more cost effective. Examples of products, which have come into the market and have gained a market share over the last decades, are low energy windows, condensing gas boilers and highly efficient heat pumps. Today new energy products come in to the market such as Photo Voltaic components, passive solar house heating system units, and comfort windows[140].

The energy prices and solutions for heating and cooling change; this will change the limits for what is feasible and rational to set as minimum requirements in building codes. Similarly will families and companies have new requirements for comfort in buildings and new appliances come in the buildings and will use energy and increase losses from all these appliances.

The energy efficiency requirements for new buildings are one of the drivers for these changes in the markets. With the changed possibilities and the changed conditions for the products and prices will change the feasibility for different solutions. New and more efficient products will lead to the possibility of increasing the requirements for energy efficiency over time.

Examples on dynamic building codes

The increased requirements for energy efficiency in building codes will similarly lead to the development of intelligent solutions and improvements of products. Buildings codes and energy efficiency requirements can be a driver for further development, in particular if they are announced in advance, giving the construction industry time to prepare and develop the right solutions to make the new requirements as cost effective as possible.

The European Directive on Energy Performance in Buildings requirements from all the member states that building standards are set and regularly reviewed and updated. These requirements shall be reviewed at regular intervals, which should not be longer than five years and, if necessary, updated in order to reflect technical progress in the building sector.

The ASHRAE standards and the International Energy Conservation Code, IECC, are also updated regularly and the borders for these standards meet regularly to ensure that the standards are kept up to date, and that new improvements are prepared. New versions are constantly under preparation.

Some buildings codes are set way in advance or some of the energy efficiency requirements in the building codes are phased in slowly to ensure that the industry is prepared for the new solution. One example is the building code for Ontario in Canada, where the new buildings codes, which were introduced in 2006 includes that requirements will be strengthened in 2009 and again in 2012.

Setting energy demands and announcing these years before the change in the demands gives the industry time to adjust and prepare for the new regulation. This reduces the costs by the change and also reduces the criticism from industry or from constructors.[141]

[140] Comfort Windows see under paragraph for Passive Houses.

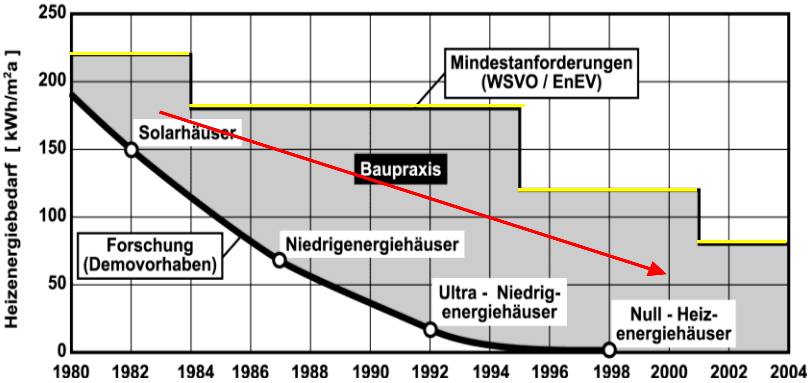
[141] Was the experience by the introduction of "Mindestanforderungen" (WSVO/EnEV) in Germany in the 1980s where this was announced years before and the same did the major changes.

14.2 Toward Zero energy as building code

Zero Energy Buildings, Passive Houses, LEED buildings and other low energy buildings are driving the best part of the market and help to demonstrate new technology as to develop new energy efficiency solutions and products. Building Codes on the other hand will remove the least efficient part of the new buildings and force these to be more efficient. A strong policy on both building codes and ultra low energy buildings can play together and be a common driver for highly energy efficient buildings.

In Germany such a double sided policy has been working since the 1980s, where research has developed more and more efficient buildings, which have been used to develop, test and demonstrate new solutions. At the same time Passive Houses and other low energy buildings have been used, and subsidised, to move the most efficient buildings towards ultra low energy consumption. This has created a small market for the most efficient products, which has helped the products to mature and be ready for the building market.

Figure 23. Development of ultra low buildings and building codes in Germany.



From Frauenhofer Institute 2006, H.E.

Demonstration projects in Germany have been used to move the limits for the possible energy efficiency and this has opened the way to strengthen the general energy requirements for new buildings. Hans Erhorn from Frauenhofer Institute at the workshop on Energy Efficient Buildings Meeting the Gleneagles Challenge, Paris 27-28 November 2006.

Today passive houses are taking up a small share of the market and this helps new products to be developed for efficient heating with small heat load, ultra efficient windows, building construction without cold bridges and all of this also helps to train constructors and installers to produce these efficient solutions. Then these solutions can then slowly move into the traditional buildings, where for instance thermal bridges today is a major problem for both efficiency and comfort.

In some areas of Austria such as Upper Austria and Vorarlberg[142] a similar development towards Passive Houses and other very low energy consuming buildings takes place and passive houses uptake increasingly parts of the new constructions.

Examples on building codes on the way to Zero Energy Buildings

In the long term, buildings need to have an energy consumption which is ultra low (Passive House level) or even Zero Energy Building level to be sustainable. Some countries have taken initiatives and have defined this as the target for building codes already in 10 years from now.

In the beginning of 2006 new demands for energy efficiency in building codes was introduced in Denmark for new buildings both for small residential buildings and for large

[142] In Voralberg the passive house standard is mandatory for all public subsidized buildings.

and complex buildings. These building codes are based on energy performance of the buildings but special demands are set for the building envelope too. With these demands new buildings have an energy demand for heating and hot water, which are around 55 kWh / m^2 per year.

In the new building code 2 new low energy classes are defined at less than 75 % (class 2) and less than 50 % (class 1) of the building code. Parliament have agreed on an action plan where building codes shall be strengthened to low energy class 2 level in 2010 and to low energy class 1 in 2015. This will bring the demands in the building codes in 2015 on the level of the demands in Passive House both for the over all consumption as for heating load in the building.

In UK the government decided an action plan in December 2006 setting a target that all new buildings should be Zero Carbon Buildings in 2016. This includes and action with movement in steps; in 2010, a 25% improvement in the energy/carbon performance set in building regulations; then in 2013, a 44% improvement; then, finally, in 2016, to zero carbon buildings.[143] The UK action plan includes steps to be taken to tighten building regulations over the next decade to improve energy efficiency of new homes and to publish a Code for Sustainable Homes, which includes a green star rating for properties.[144]

15 Potentials for energy efficiency in new buildings

For new buildings most regulations are far from the least cost optimum if costs are calculated for 30 years based on investment, interest rates, mortgage costs, and accumulated energy costs.

Experience in the US shows that energy consumption in new one family houses can be halved (Zero Energy Homes) and that this will lead to reduced overall costs for the owners already from the first year. This reduction in costs will increase over time.

Comprehensive studies in the US[145] show that energy consumption can be reduced by 75 % without additional total costs for the owners. They also show that Zero Net Energy Buildings can be built today with only relative small additional total costs for the owners in terms of higher total annual costs.

In Europe estimates are highly dependent on the building regulations at the present state, but studies show that in many countries the efficiency can be improved by a 70-75% reduction in energy consumption without additional costs or with very limited additional costs for owners.[146] A reduction of 70-75 % will in often correspond to a Passive House.

IEA studies on scenarios in 2006 [147] show the possibility of a 70 % reduction in most OECD countries over longer time. These results are also supported by the Findings in this study. However in some countries such as Sweden, Denmark and the Netherlands the demands for new buildings are closer to the least cost optimum and the possible reduction is smaller.

In developing countries the possibilities for savings in new buildings are even larger than in OECD since the present standards for energy efficiency – if they exist – are lower.

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[143] Zero carbon means that, over a year, the net carbon emissions from all energy use in the home would be zero.

[144] Building A Greener Future: Towards Zero Carbon Development, December 2006.

[145] Studies described by ICF International consultants and documented in Building a Path Towards Zero Energy Homes with Energy Efficiency Upgrade. Dean Camble, Brian Dean and David Meiesegeier. ACEEE 2006.

[146] These savings are documented for instance in the CEPHEUS project on Cost Effective Passive Houses as European Standard.

[147] In the scenarios in Energy Technology Policy Perspective, Scenarios & Strategies to 2050.

If passive houses became more commonly adopted on the market these technologies would become less expensive[148] and this could increase the cost effectiveness of these houses and increase the saving potentials even further.

A targeted policy to increase the development of more efficient solutions through demonstration projects, research and development could accelerate this development[149]. Such a policy could help Zero Energy Buildings to become a feasible solution.

The conclusion is that passive houses are already a feasible alternative in many cases, and while zero net energy buildings will increase costs, they are not dramatic and it must be expected that these building can become feasible in the within the next 1-2 decades.

15.1 Conclusion on potentials in new buildings

The possibilities for savings in new buildings are calculated based on the figures and forecast from WEO[150] and from the forecasts of new constructions and estimates of the efficiency of new buildings and the feasibility. The efficiency forecasts for China and India are of particular importance since approximately half of all the worlds new constructions are in China and India[151].

If energy consumption in new buildings is halved compared to the base scenario in WEO this would lead to savings in the size of 10-15 EJ[152] (10000-15000 PJ) in 2030 or 230 - 350 Mtoe. These savings would be feasible both for the owners and for society as a whole.

By a strong policy for ultra low or even net Zero Energy Buildings such as building standards demanding these efficiencies could increase these potentials even further. Saving potentials by Zero Energy Buildings and Passive Houses will therefore increase in the long term.

16 Refurbishment and renovation

Since buildings have a long lifetime of 50 – 100 years or more there will be need for major renovation and improvement in the lifetime of buildings. Refurbishments or improvements are necessary, because some parts of the buildings will need replacing, such as roofs, boilers, windows, variation systems, air condition etc. Change or refurbishment is also necessary because constructions, equipment or the organisation of the building becomes inadequate.

Typically these major refurbishment projects will take place at least 2 or 3 times over the life time of the building. For residential buildings this will typically occur every 30 – 40 years because of change in lifestyle and reduced functionality of the building parts and of heating and cooling systems. For commercial buildings these renovations may happen more often because the functions of commercial buildings change faster. By these major renovations or refurbishment of buildings, energy efficiency is in particular feasible and higher energy efficiency can be obtained.

Improvement of energy efficiency becomes more cost effective by refurbishment, because there is only need to pay for the additional efficiency costs, for instance if windows are replaced it is only necessary to pay the extra costs for efficient windows while the whole price of the windows, the installation, and the removal of the old windows have to be paid

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[148] CEPHEUS project on Cost Effective Passive Houses as European Standard.

[149] Energy Technology Policy Perspective, Scenarios & Strategies to 2050.

[150] WEO, World Energy Outlook 2006, IEA 2007.

[151] The development of efficiency in buildings in India and China will be studied further in the coming issue of the WEO.

[152] EJ is Exa Joule equivalent to 10^{18} Joule or 277 billion KWh.

by exchange alone for energy efficiency. Some building parts might be open and it is easy to fit extra insulation for instance in roofs constructions. Costs for scaffolding or establishment of a building site may be paid by the general renovation but might also be used for energy efficiency improvement projects.

Some works can only be done by renovation because the constructions are renewed or opened. This could for instance be floors, which are exchanged and therefore can be insulated or efficiency improved in other ways.

All in all efficiency projects by refurbishment will often lead to better feasibility of the projects, and will also lead to enlarged potentials because of lower better costs for efficiency. Timing for these projects is essential as it is necessary that they are carried out while these works go on. The day after the renovation or the refurbishment project is ended is too late and the next refurbishment or renovation maybe in 30 – 40 years.

The major barriers mentioned for new buildings above will to a large extent also influence projects by refurbishment. Major renovations and refurbishment projects are therefore often carried out without concern for energy consumption and possible efficiency projects.

Efficiency policies and initiatives are required to increase energy efficiency by renovation or refurbishment. Demands for efficiency should therefore be included in the building regulations in the form of building codes or special energy efficiency standards.

16.1 Potentials for efficiency by refurbishment

Different IEA scenarios show substantial potentials for improvement of energy efficiency in existing buildings. In these scenarios costs effective energy efficiency improvements in buildings play a major role in the reduction of the energy consumption. Many regional studies support these findings since the all identify major energy saving potentials in buildings.

A study made by ECOFYS on Mitigation of CO_2 Emission from the Buildings Stock[153] supported by EURIMA and EUROACE shows that 55 % of the energy reduction and CO_2 emissions from buildings in the 15 old European Union members can on average be saved alone through increased efficiency in the building shell.

A specific study was made for the additional member states from the last extensions of the union. The study carried out by ECOFYS[154] for new member states show larger savings giving potential savings for residential buildings of 67 - 80 per cent for the new regions on average for single family houses and 55 - 69 per cent for multifamily houses.

These two studies for the European Union calculated the economic least cost optimum for a 30 years lifetime and only measures, which are feasible for the owners are included in the estimates. Only savings which can be obtained through improvements of the buildings envelope are included.[155]. Further savings can be obtained through improvements of heating, cooling and ventilation systems, through energy supplies such as heat pumps and renewable energy sources such as solar collectors or photo voltage, which are integrated in the buildings.

[153] ECOFYS supported by EURIMA and EUROACE, Mitigation of CO2, Emissions from the Building Stock, Beyond the EU Directive on the Energy Performance of Buildings and Cost-Effective Climate Protection in the EU Building Stock.

[154] ECOFYS supported by EURIMA. Cost-Effective Climate Protection in the Building Stock of the New EU member States. All report can be found on www.eurima.org

[155] Measures are highly feasible for the building owners and money will be retuned up to 7 times over lifetime. EURIMA Energy savings in a nutshell, 2004 and Ecofys study on Sensitive Analysis of Cost Effective Climate Protection of the EU Building Stock., June 2006, to estimate the impact of high oil prices for energy efficiency.

Further studies have been carried out in individual member states in the EU[156]. They show similar potentials for savings, which exceed 50 % for the individual country.

Similar studies from US show that the energy consumption in the existing building stock can be reduced with up to 50 % alone through improved insulation.

16.2 Conclusion on potentials in refurbishment of existing buildings

The potentials for energy efficiency in existing buildings are calculated with the figures from WEO and combined with the findings in this study.

It is estimated that the total feasible potential for energy savings by renovation and refurbishment in most OECD countries will be around 50 % of the actual consumption. In transition economies this potential will be even larger, because of lower energy standard of the existing buildings. In fast developing countries outside OECD the feasible potentials is estimated to be larger too, but the savings in these countries will be reduced by an increase in the comfort levels both for cooling and heating.

Not all buildings will be renovated before 2030 since a full renovation cycles will take around 30 – 40 years, and a policy to demand improvement of efficiency by refurbishment would not be fully effective. The possible saving potential for these measures should therefore be estimated to be around 15 – 25 % of the consumption in the existing buildings.[157]

Based on the WEO 2006 and the values for 2004 this will result in possible savings on 15 – 40 EJ (15000 – 40000 PJ) or 950 Mtoe in 2030 alone if strong measures are taken for improvement of energy efficiency by refurbishment and major renovation.

17 Conclusion potentials

The potential for energy efficiency in buildings is very large both in new and in existing buildings. Over time the energy efficiency in buildings can be reduced by more than 50 % alone with measures, which are feasible already today.

Buildings have a long lifetime and it is possible and feasible to halve the consumption over a long period, but there is a need for taking action today. There is a special need to reduce consumption in new buildings and by renovation, improvement or refurbishment existing buildings, as energy efficiency in buildings is especially feasible by these actions.

Because buildings are renovated after 30 – 40 years, some existing buildings will not yet have been refurbished in 2030 and the potential to cost-effectively raise buildings' efficiency before 2030 is smaller than the total potential. The potential for energy efficiency in 2030 is therefore estimated to 30-50 EJ (30000 – 50000 PJ) per year in 2030 or 700 – 1200 Mtoe by initiatives addressing new buildings and improvements by refurbishment and major renovation.[158]

These cost efficient potentials will continue increase also after 2030 because there will still be need for improvements by refurbishment and because new buildings will continue to be

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[156] For instance estimates Danish Energy Authority a saving potential on heating on 48 %. Technical report for action plan. EDF estimates that France could reduce heat consumption with 55 % trough feasible improvements by renovation and that a best possible technology would be able to reduce consumption by 70 %. D.Osso, H.Bouia, P.Mandrou, MH.Laurent, paper for ECEEE 2007 (European Council for Energy efficient Economy).

[157] Further work and studies for existing buildings will go on in the continuation of the work on Gleneagles Plan of Action. The results will be published in an end use assessment of buildings in 2008.

[158] The potentials named in this study are larger than the estimates used in the WEO 2006 alternative policy scenario, but smaller than the potentials documented in Energy Technology Perspectives.

constructed. Similar will the limits for feasible improvements continue to increase because of new technologies, improved solutions and cost reductions.

To obtain these large potentials there is a need to take actions right now and to set up a package of policies and initiatives to improve the efficiency in buildings. These policies have to address al major barriers and there is need to set emphasis on both highly efficient buildings as for increasing the efficiency in the least effective new buildings as to set up strategies for development and demonstration.[159]

A package of recommendation is set up for these policies.

18 Recommendations

To realise the large potential for energy conservation in new and existing buildings, governments must surmount the barriers to energy efficiency in the building sector. Policies and measures to improve buildings' efficiency include:

All governments, states or regions should set, enforce and regularly update requirements for energy efficiency in new buildings. These requirements can appear independently or within building codes. Requirements for efficiency should be based on least costs over 30 years.

Energy efficiency in new buildings is a very efficient way to obtain savings, but many barriers work against energy efficiency. Building codes is a way to ensure and increase the energy efficiency in the vast majority of new buildings and can ensure a certain minimum standard in the buildings. Standards can be set either in building codes or as a specific standard for efficiency and they can be set on a national or a federal state level.

Buildings codes should reflect the least cost over time and not just the incremental costs for the buildings. Since the technology and the economy changes fast there is a need for regularly update of the standards.

Best practice and demonstration buildings such as Passive Houses and Zero Energy Buildings should be encouraged and supported to help these buildings penetrate the market. National target should beset to ensure that these buildings will really present at the market for new buildings in 2020.

Passive Houses (buildings that use so little energy that no heating or cooling system is needed) are in many areas a feasible alternative to traditional buildings, but many barriers work against these buildings. They need support to penetrate the market and become a real option for the general market. Zero energy buildings (buildings that use no energy over a year) are becoming more and more economic cost effective, but are still a more expensive solution than traditional buildings also seen over time. Support, demonstration projects, research and development is needed to mature this option and to bring these buildings in the market.

Passive Houses and Zero Energy Buildings should be the target for future buildings codes. A path should be set up to reach this target no later than 2030.

On the longer term only passive houses and zero energy buildings will be a sustainable solution. Passive houses or even Zero Energy Buildings should be set as a target for future building codes or energy efficiency standards to send a message to the market and to ensure the development of good solutions.

Financial restrains for new buildings preventing energy efficiency should be removed to ensure that buildings can be cost optimized over 30 years.

[159] Future IEA analysis of energy efficiency in existing buildings will offer further recommendations.

Financial barriers and maximum loans can be a barrier for increased efficiency. Information activities should be targeted on the increase of the understanding of energy efficiency and the cost benefits by these institutions.

Energy demands should be set by major renovation and refurbishment of all buildings, no matter the size, type of use or ownership of these buildings.

Energy efficiency by major renovation and refurbishment is a feasible possibility to increase the energy efficiency of existing buildings substantially. Building codes or standards for energy efficiency in buildings should include demands for energy efficiency of the whole buildings by major renovation or refurbishment and the codes should include efficiency demands for the individual components on installations by replacement.

Energy efficiency for buildings should be made visible in the market place to give building owners a real choice. This could be by certification, labelling or other declaration of energy consumption.

There is too little emphasis on energy efficiency by the purchase of buildings although the energy costs can be a substantial part of the costs in the new building. Efficiency of buildings and life costs are difficult to understand for the ordinary buyer. Efficiency of new buildings and especially the efficiency of buildings, which are better than the minimum energy efficiency requirements in the building regulation should be increased for instance by stars, by labelling schemes or by certification of buildings. These schemes should be reliable and need to be controlled by governments or other public authorities.

Governments should lead by example and make new governmental buildings optimized for life costs over a 30 years time or for the whole life time of the building.

New public buildings and in particular buildings owned by the state should show a good example for the citizens and the companies. In particular public buildings should therefore be built based on a life time approach making these buildings a least as energy efficient and cost effective as possible over lifetime. Public building could even be used for demonstration to facilitate the development of even more efficient buildings. Governments should be the first to build to passive house standards or to construct zero energy or zero carbon buildings.

Governments should set up a package of initiative to address the barriers for energy efficiency in both new and existing buildings including the mentioned recommendations above.

Since there are many barriers that work against energy efficient buildings both for new and for existing buildings, there is a need for different initiatives to remove these barriers. Governments should study the efficiency in buildings and determine the most important barriers, which work against efficiency in buildings, and then set up a package of policies to remove the most important of these barriers as well for new buildings as for existing buildings.

Special outreach activities should be taken for the fast developing countries such as China and India where most of the world's new buildings are constructed.

Most of the new buildings are constructed in the fast developing countries and especially in China and India. The largest potentials for savings in new buildings are therefore in these regions. At the same time new supply systems are needed in these countries, which make energy savings in buildings even more feasible from a national economy. Special activities should be taken to ensure that buildings in the fast developing countries are as efficient as possible and that new technologies, Passive Houses and Zero Carbon Buildings are introduced.

Further R&D (Research and Development) should be undertaken in buildings including R&D in development and intelligent design of highly energy efficient buildings.

Although the energy potentials are huge in with measures which already exist and are feasible even today, then this potential could be increased further by research and development. If the potentials for zero energy or even plus energy houses can be unlocked, the total potential in the building sector will increase substantial over the longer term.

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