Low-energy buildings in Europe - Standards, criteria and consequences

A study of nine European countries

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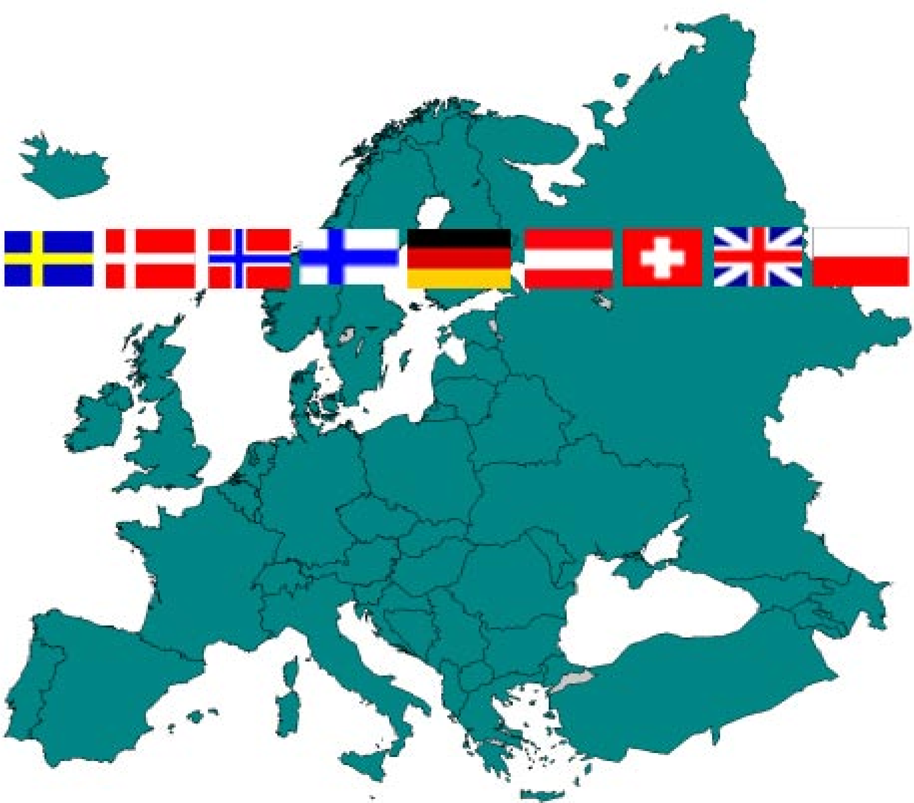

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Nuvarande forskning innefattar bl a utveckling av metoder för utveckling av beräkningsmetoder för godtyckliga flödessystem, konvertering av direktelvärmda hus till alternativa värmesystem, vädring och ventilation i skolor, system för brandsäkerhet, alternativa sätt att förhindra rökspridning vid brand, installationernas belastning på yttre miljön, att betrakta byggnad och installationer som ett byggnadstekniskt system, analysera och beräkna inneklimatet i olika typer av byggnader, effekter av brukarnas beteende för energianvändning, reglering av golvvärmesystem, bestämning av luftflöden i byggnader med hjälp av spårgasmetod. Vi utvecklar även användbara projekteringsverktyg för energi och inomhusklimat, system för individuell energimätning i flerbostadshus samt olika analysverktyg för optimering av ventilationsanläggningar hos industrin.

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Abstract

This thesis is a joint assignment by Lund Technical University LTH and Swegon AB.

Title Low-energy buildings in Europe – standards, criteria and consequences
- A study of nine European countries

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Problem description Low-energy buildings are nowadays often used in common speech, for selling or promotion – everything has to be *"low energy"*. But how do you know if your house is a low-energy building? And how do the manufacturers of the building components know? Is there an official definition, what technical criteria do these buildings have to fulfil? The growing of low-energy buildings causes a demand of compliant products that meet the requirements on performance and quality, but the jungle of definitions makes it hard for manufacturers, especially on an international level. Furthermore it is not always assured if the available regulation considers the consequences of the set criteria.

Energy savings should not cause a disadvantage of the indoor environment and people's comfort and health.

Purpose To list the currently defined low-energy building types and their regulations, compile the criteria concerning four subject areas with focus on ventilation and to analyse if possible consequences on the buildings indoor climate or on the design of the ventilation system are noticeable.

Method For a better understanding of low-energy buildings and its technical features, theory and definitions have been examined by literature studies. The available standards were collected through the responsible issuers, followed by a

compilation and comparison of criteria in the standards and a final analysis of possible consequences, based on the given facts of theory.

Conclusions Almost all nine countries have set standards where low-energy buildings are defined. But the level of specification varies severely, both between the countries as between different building types within a country. In many standards the building exclusively is defined by its energy performance – the most definitions considering additional criteria are available in Germany, Austria and Switzerland. The set criteria on the ventilation system are similar, which makes it possible to design components suiting many building types – Though, attention must be paid on sometimes differently defined efficiency rates for heat exchangers. Regarding indoor climate no remarkable consequences, but some differences e.g. regarding airflow rates, whose consequences require further research were found.

Keywords low-energy buildings, passive houses, standards and regulations, heat recovery, ventilation, indoor climate

Contents

1 Introduction

What exactly is a low-energy house, a passive house or a zero energy house and how well is it defined – by law, by a voluntary standard, or by a certification brand? What criteria do they have to meet?

Words as low-energy and passive house are used more frequently all over Europe, as environmental protection and resource conservation are hot topics in these days. Low-energy buildings involve the reduction of use of fossil fuel such as oil, gas and coal, which enhances sustainable building and development. There are many ways to make a building energy-efficient – By high insulation, using building components resulting in less thermal bridges, buildings with good air tightness or by technical installations such as mechanical heat recovery ventilation, which also benefits the indoor climate. Even if energy efficiency is important, the main reason for buildings is to give a good indoor climate, and a number of studies have indicated significant relationships between the ventilation and health and productivity in regard to offices, schools and dwellings (Andersson et al, 2006; Wargocki & Wyon, 2007). From an indoor environmental perspective it is also important to avoid possible moisture problems in the constructions.

As the concept of low-energy- and passive houses is not as spread and common in some European countries as in others, the level of standards and precise criteria vary. Other influences on the variety of standards are different outdoor climates and historical demands on indoor climate. In the jungle of definitions and standards it is hard for manufacturers to construct and develop systems and units that are low-energy house compliant on the European market.

What criteria do these different standards have in common? Are the limits reasonable and what consequences could they have? – On the indoor climate such as on the design of the ventilation system.

1.1 Background

Buildings are responsible for about 40% of the total primary energy use and for 36% of the CO_2 emissions in Europe (Europa, 2009). At the same time terms as *"reduction of Greenhouse gas emissions", "global warming"* and *"sustainable development"* are very present these days. Therefore the European Commission has published the European Energy Performance of Buildings Directive EPBD, a common legislation for European member states regarding the energy performance of buildings. The aim of the directive is to reach the EU climate and energy targets as defined in the Kyoto protocol (Europa, 2009).

The awareness of the necessity to save energy in the building sector by developing new building concepts has been present in many countries years before the EPBD.
In the seventies many experimental initiatives towards low-energy buildings were made in countries like Denmark, the United States, Sweden, Canada and Germany until the German Passivhaus Institut introduced the first passive house in 1990 (Elswijk & Kaan, 2008). Today the implementation of standardized low-energy building concepts has developed differently in each country. Concerning the passive house concept analyses of the social embedding progress[1] in several countries have been made. Figure 1 and 2 show the progress of some countries in 2005 respectively 2007, whereupon Austria and Germany have always been the leading countries.

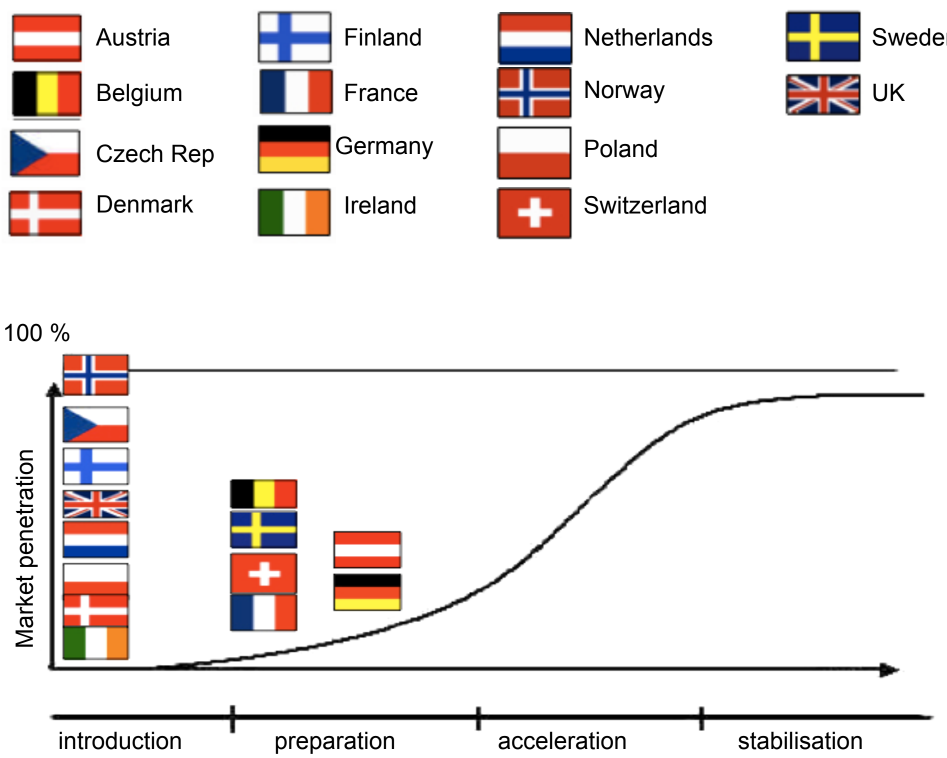

Figure 1: Market Penetration Passive Houses in 2005 (Elswijk & Kaan, 2008)

[1] A concept is socially embedded when it is accepted as *"business as usual"*, defined by four process phases: pre-development, introduction, acceleration and stabilisation (Elswijk & Kaan, 2008).

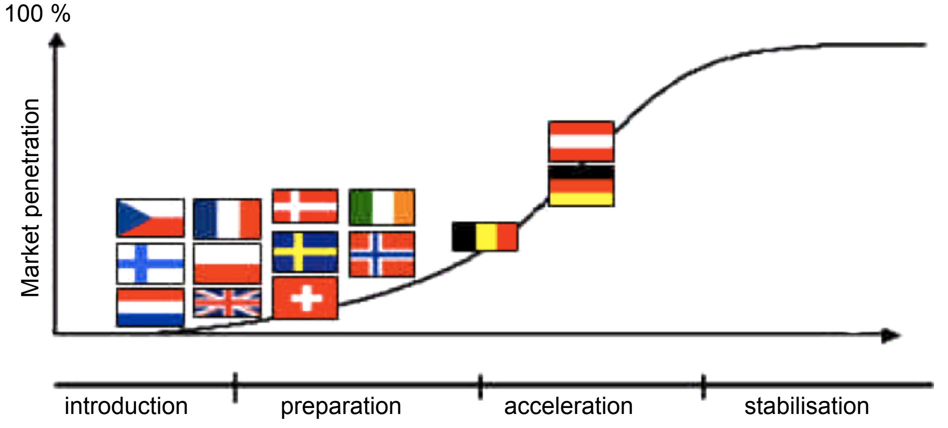

Figure 2: Market Penetration Passive Houses in 2007 (Elswijk & Kaan, 2008)

Research projects as CEPHEUS or PEP have shown that further information and knowledge about low-energy and passive houses in most European countries is still necessary, and accentuate the need of standardization by implementing certification schemes.

1.2 Aim and objectives

The aim of this diploma thesis is to explore the different types and definitions of low-energy buildings in Europe, to compare and compile existing standards and their criteria and find differences and similarities with focus on the ventilation of buildings and their indoor climate. Notable divergent limit values will be examined in an analysis of possible consequences on the indoor climate or construction of ventilation system components, to encourage considering if the set criteria are reasonable.

Besides, the result of this thesis shall be help for actors and manufacturers like Swegon AB to develop and construct compliant indoor climate and ventilation systems for low-energy houses on the European market.

Another objective is to eventually affect the standards – to attribute to a better understanding of the different standards between the countries and to refer to possible shortcomings.

1.3 Method

In an introducing theory-chapter fundamental definitions and explanations needed for understanding and analysing the concept of low-energy buildings will be given. Sources for the literature study are publications and articles, published by Universities, research groups, organisations, and brands of the building sector.
A research of which building types are existent will be made and the corresponding regulations collected through the responsible organisation of issue.

Following, a list of criteria relating to four subject areas (**Building envelope**, **Energy**, **Ventilation** and **Follow-up**) is looked through and compiled; in some parts consultation by the responsible issuer is needed, due to linguistic or understanding hinders. Based on the compilation of criteria a final analysis is made and conclusions will be drawn.

1.4 Limitations

The study is limited to nine European countries based on industrial interest and due to lack of interest on the topic in some countries. These are **Sweden**, **Norway**, **Denmark**, **Finland**, **Germany**, **Austria**, **Switzerland**, **Great Britain** and **Poland**.
Only building types that are defined or regulated by specific criteria will be examined, restricted to new build **residential** buildings. Criteria topics are chosen due to relevance for the aim of this thesis with focus on ventilation system and indoor climate. Criteria regarding building envelope and limit values for energy performance will be collected but not analysed in detail; consequences of discrepancies would be a matter of future work.

Limit values and requirements will only be listed as defined in the building-specific definition; overlying national regulations, if not specified in the definition or needed for analyzing, will not be contained.

1.5 Glossary

Active cooling	cooling by use of a mechanical system
Air diffuser	ventilation unit, distributing air into a room
Biomass	renewable energy; for heating often used in form of pellets
By-pass	function of bypassing the heat exchange under specified conditions as e.g. temperature or pressure
Centralized FTX	ventilation and heat recovery provided from a central, supplying more than one apartment in a multi-family building
Constant airflow system	CAV, airflow rates are constant and can not be varied
Decentralized FTX	every apartment is supplied by its own ventilation system with heat recovery in a multi-family building
Detached house	single-family house
District heating	heat generated in a centralized location, distributed to multiple buildings
EC-motor	electronically commutated motor, used for operating technical components as blowers and fans and preferred due to its high efficiency compared to other motor types
Efficiency	the ratio of work or energy output to total work or energy input
Electrical heat	heating by use of electrical energy, e.g. by heat pumps, direct-electrical heating, electrical floor heating, etc.
Energy carrier	energy supply form, e.g. district heat, electrical energy, biomass, wind or sun energy
Exhaust air	air leaving the building through an outtake
Extract air	air leaving a room, entering the buildings ventilation system
FT	mechanical ventilation system with supply and exhaust air

FTX	mechanical ventilation system with supply and exhaust air, equipped with heat recovery exchanger
Geothermal cooling	using lower ground temperatures for cooling, transferred to the building by a buried pipe system; renewable energy source
Gross area	a buildings gross area includes all areas, heated or non-heated; mostly including the thermal building envelope
Heat pump	device that extracts heat at low temperature from air, water or earth and supplies the heat to the building
Household energy	energy for electrical domestic appliances
Mixing effect	describes how well the air is being mixed in a room; connected to the technical performance of the air diffuser
Net area	differently defined between the countries; mostly the buildings gross area minus the thermal building envelope
Renewable energy	sun, wind, water, biomass, geothermal energy
Short-circuiting flow	when all supply air directly is removed with the extract air after introduction to the room; occurs if e.g. supply and extract units are installed near each other
Solar energy	energy gained from light and heat of sun, either passive or active; actively gained by a building by converting the energy with technical installations such as photovoltaic panels or solar collectors
Supply air	air supplied, entering a room by an air diffuser, air outtake
Variable airflow system	VAV, airflow rates can be varied, used for e.g. variable occupancy rates; in comparison to CAV systems pressure is regulated in the supply and exhaust air ducts
VOC, TVOC	volatile organic compounds; describing a number of different organic compounds, affecting the indoor climate; may have health consequences; TVOC is the abbreviation for total volatile organic compounds
Thermal building envelope	surrounding surfaces insulating an area from outdoors temperature

1.6 Abbreviations

Ach, arch	Air changes per hour
BRA	Bruksareal, engl.: *used area*
CAV	Constant Air Volume
CEI	cumulative primary energy input
CEN	European Committee for Standardization
CEPHEUS	Cost Efficient Passive Houses as European Standards
CO	Carbon monoxide
CO_2	Carbon dioxide
dB	decibel, measurement in acoustics
DIAG	Directive Implementation Advisory Group
DUT	Dimensionerande utetemperatur, engl.: *dimensioning outdoor temperature*
e.g.	for example
EnEV	Energiesparverordnung, engl.: *energy-saving directive*
Engl.	English language
EPBD	European Energy Performance of Buildings Directive
EU	European Union
FEBY	Forum för Energieffektiva Byggnader, engl.: *Forum for energy-efficient buildings*
Germ.	German language
HCHO	Formaldehyde

HVAC	Heating, Ventilating, Air Conditioning
H_g	Heizgrenzwert, engl.: *limit value for heating*, measured in kWh/m^2a
i.e.	that is, latin: *id est*
IEA	International Energy Agency
k:a	klima:aktiv
KfW	Kreditanstalt für Wiederaufbau, engl.: *Reconstruction Loan Corporation*
kWh	kilo-Watt-hours, 1 kilo-Watt / 1000 Watt
kWh/m^2a	annual kilo-Watt-hours per m^2 area
$l/s\ m^2$	litre per second and m^2 area, unit of e.g. air flow or leakage
m a.s.l.	meters above sea level
Nm	nanometre
NO_2	Nitrogen dioxide
O_3	Ozone
OIB	Österreichisches Institut für Bautechnik, engl.: *Austrian Institute of Construction*
Pa	Pascal, unit of pressure
PHPP	Project planning package for passive houses
PHI	Passivhaus Institut, Darmstadt
PPD	predicted percentage of dissatisfied people
ppm	parts per million
PVM	predicted mean vote
SFP	specific fan power

SIA	Schweizer Ingenieur- und Architektenverein, engl.: *Swiss association of Engineers and Architects*
TVOC	Total Volatile Organic Compounds
U-value	thermal heat loss coefficient, measured in W/m^2K
VAV	Variable Air Volume
VOC	volatile organic compound
W/m^2	Watt per m^2
$W/(m^2K)$	Watt per m^2 at a standard temperature difference of 1 degree Kelvin, unit of U-value and measurement for heat losses through building components

1.7 Swegon AB

Swegon AB is one of Scandinavia's important manufacturers for products and solutions for ventilation and indoor climate. The company offers a wide range from distribution products, waterborne indoor climate systems and air handling units to products for acoustics and flow control for most kinds of buildings. Besides the production Swegon AB has units for research and development, equipped with high-technology laboratories, allowing full-scale testing.

1.7.1 The company

Based and founded in Sweden, Swegon AB is today represented in 37 countries, 34 European and three on other continents (Dubai, Israel and USA). production is taking place in four factories – Arvika, Kvänum and Tomelilla in Sweden and St. Karins in Finland, where each factory is concentrated on different products (Swegon AB a).

Swegon AB belongs to the investment group of Latour[2] which owns about 60 companies and has annual sales of € 725 million. Swegon itself has annual sales of € 220 million and an export share of 70%. The total number of employees is about 1000 people (Swegon AB a). In 2007 the Finnish ventilation company ILTO Air Oy, a market-leading manufacturer in the field of home ventilation in Finland was bought by Swegon AB and is now named Swegon ILTO Oy. This acquisition shall expand Swegon's product range, now also including residential ventilation (Swegon AB c).

1.7.2 Energy-efficient ventilation

We show the way to the indoor climate of the future – is Swegon's slogan concerning ventilation. At Swegon the focus in research and development lies on creating energy-efficient systems – Building systems and units that create better indoor climate and are environmentally friendly at the same time.

Some significant innovations by Swegon providing good indoor climate combined with energy-efficiency are

- The *active chilled beam technology* – the in Europe widely spread technology using water provides powerful cooling to the building in an energy-efficient way
- *GOLD System* – world's leading compact air handling unit with integrated control functions, launched in 1994 as the first air handling unit to incorporate integrated control equipment and revolutionary technology

[2] Investment AB Latour - Swedish investment group with companies in many different industrial sectors and quoted on the OMX Nordic Exchange Stockholm Large Cap list. Swegon AB is fully owned by Latour since 1995 (Latour Investment AB).

- *WISE System* – Swegon's newest innovation on demand-controlled ventilation, saving energy by ventilating only when needed integrating intelligent systems and sensors.

1.7.3 Reference works

Swegon products are installed in a multitude of locations around Europe.
Some of the biggest works include the *European Parliament* in Strasbourg, *30 St Mary Axe*, also known as the *Gherkin* and the *Swiss Re Building* in London, England, *Turning Torso* in Malmö, Sweden, the *Copenhagen Opera House*, Copenhagen, Denmark or the *Volkswagen "Gläserne Manufaktur"* in Dresden, Germany.

1.7.4 Certification

Swegon AB's Quality Assurance and Environmental management systems are certified to the SS-EN ISO 9001 and ISO 14001 standards.
The GOLD air handling units and chilled beams are even Eurovent[3]-certified with zero tolerance[4] (Swegon AB a).

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[3] Eurovent Certification certifies the performance ratings of air-conditioning and refrigeration products according to European and international standards (Eurovent Certification).
[4] Zero tolerance means that all specified data is consistent with actual performance.

2 Theory and definitions

2.1 Energy

The *amount* of energy is measured in Joules (J) or kilowatt-hours (kWh) and originates from work with the unit (Nm). Power is the energy flow *per unit of time*, with the unit Watt (W) that is 1 Joule per second. The first law of thermodynamics states that energy cannot be created and not be disturbed, only transformed between different kinds. The second law of thermodynamics implies rules for which transformations are possible. Therefore the kind of energy is of interest as well as the source of energy. Energy sources are listed as *renewable* and *non-renewable resources*, *wind*- and *hydropower*, *geothermal* and *solar energy* (Bruckner, H., 2006). Depending on the state of transformation two kinds of energy are distinguished – *primary* and *secondary* energy. Primary energy is defined as

"*Energy that has not been converted into any other form such as hydropower, coal and crude oil"* (Bruckner, H., 2006, p.32).

Secondary energy is a product of the converted primary energy such as heating oil, fuel, gas or electricity. The product of using primary or secondary energy is called **end** energy (Bruckner, H., 2006), which can be delivered to a building in different forms; in form of electrical energy, district heating, energy from biomass or solar and wind energy – these are the energy carriers (Forum för Energieffektiva Byggnader, 2009).

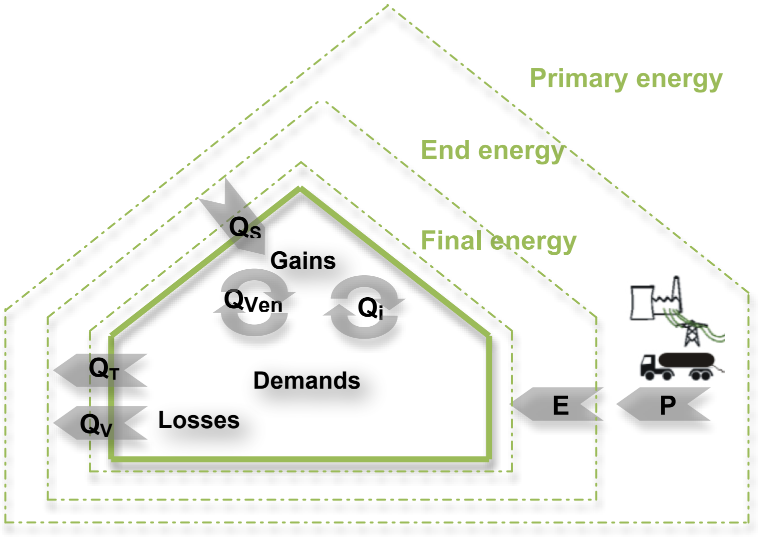
The different levels of energy use and demand of buildings can be rated relating to the different types of energy, which are

- **Primary energy** Includes energy costs for extraction, conversion and transportation of renewable or non-renewable resources
- **End energy** The to the user and building supplied amount of energy, not including the energy costs for extraction, conversion etc. as for primary energy. It is energy in form of e.g. electricity, district heat or biomass (Hoffmann, Hasting & Voss, 2005; Bruckner H., 2006)
- **Final energy** The result of the by the technical building system converted end energy – e.g. light or heat (Bruckner, H., 2006), influenced by the efficiency of the technical system components (Hoffmann, Hastings & Voss, 2005). The buildings calculated net energy demand is counted to the term final energy.

It is very relevant to be aware of what type of energy the limit value in a standard relates to when comparing limit values for e.g. energy use.

2.1.1 Energy balance of buildings

The ingoing and outgoing energy flows of a building are determine its energy balance, shown in figure 3. Based on the balance between supplied, generated and lost energy, the total energy demand of a building is calculated; losses and gains determine the final energy demand. Besides, the amount of used energy is dependent on the system boundary; on which level (**primary**, **end** or **final** energy) the demand is being considered.



P	*Energy for generation, conversion and transportation*	**Q_S**	*Gained solar energy*
E	*Supplied, delivered energy*	**Q_{Ven}**	*Gained energy by heat exchanger*
Q_T	*Heat losses by transmission*	**Q_i**	*Internal heat gains by persons, appliances, electronic devices and lighting*
Q_V	*Heat losses by ventilation and air leakage*		

*Figure 3: Buildings energy balance and energy levels (**primary**, **final**, **end**)*

Ways to lower the energy use of a building are *minimized heat losses* by a well-insulated building envelope with *low U-values* and *good air-tightness* and using energy-saving technical equipment as *heat recovery ventilation* and *heat pumps*.

2.1.2 Energy demand of buildings

A buildings energy demand is calculated by its need of energy in use, which is made up of the energy posts (Course Byggnadsteknik vid nybyggnad, 2007)

- **Space heating**
- **Space cooling** (optionally)

- **Ventilation air heating**
- **Ventilation air cooling** (optionally)
- **Domestic hot water**
- **Auxiliary energy**
- **Household energy**

Household energy is the electricity or other form of energy used for household appliances as e.g. dishwasher, washing machine, dryer, cooker, fridge, freezer, but also for lighting, computers, television and other electronic appliances (Boverket, 2009). **Auxiliary energy** is the required energy to operate mechanical systems for ventilation, control or security such as their components as pumps, valves et cetera (Kalz, Herkel & Wagner, 2009).

Which posts are included in the calculation of a buildings energy demand can be differently defined in the national regulations. An estimated breakdown of the energy posts percentage of a residential buildings energy use is: 71.3% space heating, 12% domestic hot water, 9.6% appliances, 5.3% auxiliary energy, 1.8% lights (BMWi, 2008).

Besides the greater energy demand for heating in colder climates, it should be annotated that the amount of household energy, as well as domestic hot water heating are dependent on the different user habits (Bagge, H., 2007).

2.1.3 Primary energy demand

Due to the energy use and CO_2 emission arising from transformation, transportation and distribution the rate of used energy often is related to the amount of used primary energy. The calculation methods for primary energy use vary between the countries, as well as the included energy posts do. Especially if household energy is included or not, can vary between different countries.

2.1.4 Heating demand

The heating demand in a building is defined as the annually needed energy for heating, measured in kWh/m^2a.

2.1.5 Peak load for space heating

The peak load for space heating is relating to power, often named P_{max} and measured in W/m^2. Depending on the standard the peak load can be differently defined but it mostly relates to the outgoing power of the heating system. The value includes heat losses by transmission and ventilation (Forum för Energieffektiva Byggnader, 2009), i.e. load for the ventilation system included.

2.1.6 Related areas

Energy values as primary energy demand, heating demand and peak load are referred to a specific related area, which can be differently defined in each country. A compilation and description of the different related areas are given in chapter 4.1.

2.2 Ventilation

To achieve a good indoor quality, prevent air pollution and moisture in buildings ventilation is needed. In many low-energy houses as e.g. passive houses, ventilation is also used for heating and cooling. There are different options to ventilate a building: by natural or different types of mechanical ventilation. Mechanical ventilation systems can have the quality of providing filtered supply air, clean from dust, pollen and spores, which is good for people with allergies or who suffer from asthma (Energieinstitut Vorarlberg, 2009). There are also studies showing relationships between prevalence of asthma and good ventilation in dwellings (Hägerhed & Engman, 2006).

The different types of ventilation systems can be listed as followed (Warfvinge, C., 2003), with abbreviations referring to the Swedish nomenclature

Type S	natural draught ventilation
Type FFS	natural draught ventilation supplied by fan
Type F	exhaust air ventilation
Type FVP	exhaust air with heat pump
Type FT	exhaust and supply air ventilation
Type FTX	exhaust and supply air ventilation with heat recovery

Today the FTX system is a frequently used ventilation system in low-energy buildings – primarily because of its quality to lower the energy use by recovering heat from the warm exhaust air and transferring it to the cold supply air, and the option to heat with the supply air. In the standards, mechanical ventilation with heat recovery is not always prescribed.

Mechanically heated and supplied air is sometimes feared as being polluted; this is prevented by built-in filters and the right placement of the air intake. An aspect, which should be taken into consideration is the supply air temperature – high temperatures have negative influences on the air diffusers ability to provide a good air exchange. Therefore, when having high supply air temperatures an air diffuser with high enough mixing effect should be chosen. To verify the effect, the air exchange efficiency in the room should lie between 40-60% (Sikander et al, 2009). More research seems to be needed regarding the air exchange efficiency and supply air diffusers in the case of heating with supply air, due to possible technical limitations of the different air diffuser types.

In Germany, Austria and Switzerland often the term *comfort ventilation* (germ.: Komfortlüftung) is used. Comfort ventilation includes specific requirements and quality criteria with focus on high comfort and energy efficiency. It is a mechanical ventilation system, equipped with exhaust and supply air with heat recovery, named *comfort* ventilation by providing a *comfortable* and hygienic indoor climate (Komfortlüftung.at); the technical system is corresponding to FTX systems.

2.2.1 Air leakage, air tightness

Air leakage, also known as air infiltration (introduction of outside air into the building) or exfiltration (leakage of indoor air out of the building) describes the volume of air passing through the building envelope, mostly presented in *l/s* or m^3/h.

The air leakage rate of a building is therefore a measurement of its tightness. Air leakage can cause many different problems as moisture or heat losses by warm room air with high vapour content penetrating the construction. For energy efficient buildings heat losses play an important roll; airtight buildings have a lower energy demand. Besides the advantage of saving energy, air tightness minimizes problems as draught and moisture risks and makes the ventilation more precise (Course Byggnadsteknik – komplexa byggnader, 2008).

Air leakage is usually detected by so-called Blower Door measurement at a pressure difference of 50 Pa between indoors and outdoors. The generated volume airflow is then defined either as the air change rate n_{50} – relating to the building volume with the unit h^{-1}, or the air permeability q_{50} – relating to the area with the unit $m^3/(m^2h)$ or $l/(s\ m^2)$ (Wirth, S., 2002).

2.2.2 Airflow rate, air exchange rate

To provide a good indoor climate (see definition in chapter 2.3) a certain rate of airflow is needed – the flow of supplied air into the building or exhausted out of the building, measured in m^3/h or *l/s* (Energieinstitut Vorarlberg, 2009). An additional variable for describing the exchange of air in a building is the air exchange rate, often named *n* and rated with the unit $1/h = h^{-1}$ or *ach* describing the air changes per hour (Energieinstitut Vorarlberg, 2009). It should be annotated that the rate of air exchange does not specify whether the air actually is mixed and exchanged everywhere in the room.

The interrelationship between the airflow rate and air exchange rate can be explained by the equation:

$$n = \frac{R}{V}$$ (Sandin, K., 1990. Equation L5:2, p.93)

n = air exchange rate, h^{-1}
R = airflow rate, m^3/h
V = building volume, m^3

When a mechanical ventilation system is used, the air exchange rate is made up of the mechanical air exchange rate n_{mech} provided by the system, and the air exchange rate by unintentional natural infiltration n_x:

$$n = n_{mech} + n_x \qquad \text{(Paul Wärmerückgewinnung, 2009 a)}$$

According to EN 382 the natural infiltration rate n_x is calculated by the equation:

$$n_x = \frac{n_{50} \cdot e}{1 + \frac{f}{e}\left(\frac{n_d}{n_{50}}\right)^2} \qquad \text{(Paul Wärmerückgewinnung, 2009 b)}$$

n_{50} *= air exchange rate at 50 Pa pressure difference, 1/h*
e = coefficient relating to wind deflector
f = coefficient relating to the number of wind exposed areas
n_d *= infiltration air exchange rate caused by imbalance, 1/h*

2.2.3 Imbalance

The concept of passive houses strives after balanced airflows. But studies have shown that there should always be an under pressure indoors compared to outdoors to avoid risk of condensation in the construction, especially in colder climates. This is made by imbalance, i.e. a difference between the supply airflow rate and extract airflow rate, causing a pressure difference. By increased imbalance (under-pressure), the natural leakage rate n_x is decreased (Johansson, D., 2005).

A so-called energy efficient air exchange rate n_v is defined as the ratio of ventilation energy that is lost after energy recovery by the heat exchanger, calculated according to the equation:

$$n_v = n\,(1 - \eta'_{WRG}) + n_x \qquad \text{(Paul Wärmerückgewinnung, 2009 b)}$$

n *= air exchange rate, h^{-1}*
η'_{WRG} *= temperature efficiency of heat exchanger, -*
n_x *= natural infiltration rate, h^{-1}*

I.e. a higher n_v rate includes higher energy demand. The interrelationship between imbalance and the energy efficient air exchange rate n_v, at different n_{50}-rates is shown in figure 4.

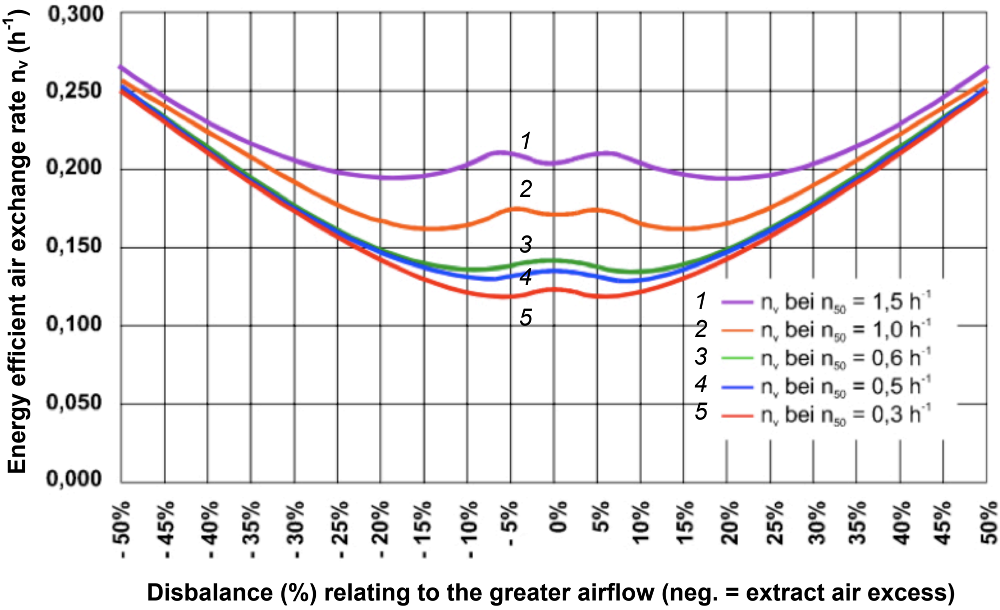


Figure 4. Interrelationship between imbalance and n_v at different n_{50}-rates (Paul Wärmerückgewinnung, 2009 b)

The figure shows the variation of n_v; being higher at 5% imbalance, lower at 10% (relating to the air tightness, n_{50}) and is from there on rising with increasing imbalance. The greater n_v involves higher energy demands; therefore the imbalance often is limited to a maximum of 10% (Paul Wärmerückgewinnung, 2009 b). Other studies have indicated an optimal imbalance of 15% relating to moisture safety and energy use (Johansson, D., 2005).

2.2.4 Ventilation efficiency ε_{rc}

The ventilation efficiency is described by the ratio between percentage of contamination in the exhaust air and percentage of contamination in the room and is therefore a measurement of how well the room is being ventilated and contaminants are removed (Swegon AB b).

Parameters that have influence on the ventilation efficiency are e.g.

- Supply air velocity
- Temperature difference between supply and exhaust air
- Positioning of supply and exhaust air terminals

2.2.5 Air exchange efficiency ε_{ra}

The air exchange efficiency describes how fast the air in a room is being exchanged, calculated by the ratio between the nominal time constant τ_n and the exchange time (two times the average age of the air, 2 τ_m) for the air in a room (Swegon AB b). Typically mixing ventilation should reach a rate of 50%, while short-circuits mean lower values which is a risk with heating by supply air, commonly used in passive houses.

2.2.6 Efficiency of components η

The performance of the technical equipment as boilers, fans and heat exchangers is described by their efficiency, which can have influence on the energy performance of the building. Therefore it is interesting whether standards have requirements regarding the efficiency of the technical building components or not. Regarding the efficiency of heat exchangers a number of different efficiencies are existent. A detailed description is given in chapter 2.2.8.

2.2.7 SFP-factor

The specific fan power is a measurement for the ventilation systems efficiency, calculated by the sum of electrical power needed for all fans of the ventilation system, divided by the highest supply or exhaust air flow rate. The SFP-factor is often measured in *kW/(m^3/s)* (Boverket, 2009). For constant airflow systems (CAV) this is a relevant way to describe the fan electricity, but for variable airflow systems (VAV) there is still a need of more research.

2.2.8 Heat recovery ventilation and relating efficiencies

Ventilation systems with heat recovery are equipped with heat exchangers, which are able to transmit the heat of the exhausted air to the incoming and supplied air. The most usual used types of heat exchangers are the rotary or plate heat exchanger, where the rotary exchanger works *regenerative* and the plate exchanger *recuperative*. The main difference between regenerative and recuperative heat exchanging is whether the two medias[5] (gas/gas, fluid/gas or fluid/fluid) get in contact or not. In a plate exchanger *(recuperative)* the medias are separated from each other, whereas in a rotary exchanger *(regenerative)* the medias stand in direct contact, which has the disadvantage of transmission of possible pollutions and moisture (Course Byggnadsteknik vid nybyggnad, 2007).

The performance of the heat exchanger is measured by its *efficiency*, whereas differently defined efficiency grades are existent – **temperature efficiency, heat**

---

[5] Gas and/or fluid – mostly used air and/or water. In case of heat recovery ventilation both medias mostly are air.

recovery efficiency and **heat providing efficiency,** all describing how much heat is gained by the heat exchanger but calculated with different initial parameters.
Besides, it is distinguished whether the efficiency is measured relating to the supply or exhaust side, which plays a great role (Paul, E., 2009).

The **temperature efficiency** η_t is calculated by the in- and outgoing air temperatures (Course Byggnadsteknik vid nybyggnad, 2007), according to the equation:

$$\eta_t = \frac{t_{\sup} - t_{out}}{t_{extr} - t_{out}} \quad (-) \qquad \text{(Johansson, D., 2005, p. 247)}$$

$t_{\sup}$ = *temperature of supply air after heat exchanger, °C*
t_{out} = *outdoor temperature, °C*
t_{extr} = *extract air temperature, °C*

The equation relates to the supply side, which is the most common used rate, as regulated in the European standard EN 308 (Paul, E., 2009).

The **heat recovery efficiency** η_{WRG} is calculated by the value of enthalpy $\dot{H}$ as initial parameter (Paul, E., 2009), i.e. besides the temperature, containing the air's humidity.

Measured from the supply side it is calculated by the equation, according to EN 308:

$$\eta_{WRG} = \frac{\dot{H}_{\sup} - \dot{H}_{out}}{\dot{H}_{extr} - \dot{H}_{out}} \quad (-) \qquad \text{(Paul, E., 2009)}$$

$\dot{H}_{\sup}$ = *enthalpy rate of supply air, kJ/kg*
$\dot{H}_{out}$ = *enthalpy rate of outside air, kJ/kg*
$\dot{H}_{extr}$ = *enthalpy rate of extract air, kJ/kg*

From the exhaust side, the heat recovery efficiency is calculated according to the equation:

$$\eta_{WRG} = \frac{\dot{H}_{extr} - \dot{H}_{exh}}{\dot{H}_{extr} - \dot{H}_{out}} \quad (-) \qquad \text{(Paul, E., 2009)}$$

$\dot{H}_{extr}$ = *enthalpy rate of extract air, kJ/kg*
$\dot{H}_{exh}$ = *enthalpy rate of exhaust air, kJ/kg*
$\dot{H}_{out}$ = *enthalpy rate of outside air, kJ/kg*

The heat recovery efficiency η_{WRG} is mostly resulting in a lower efficiency rate compared to the temperature efficiency η_t at equal conditions (Paul, E., 2009).

The **heat providing efficiency** η_{WBG} is calculated as the heat recovery efficiency, i.e. by enthalpy rate of airflows, but is additionally including the delivered heat from fan-motors. It is calculated by the equation:

$$\eta_{WBG} = \frac{\dot{H}_{extr} - \dot{H}_{exh} + \dot{Q}_{\sup,el}}{\dot{H}_{\sup} * - \dot{H}_{out}} \qquad (-) \qquad \text{(Paul, E., 2009)}$$

$\dot{H}_{extr}$ = *enthalpy rate of extract air, kJ/kg*
$\dot{H}_{exh}$ = *enthalpy rate of exhaust air, kJ/kg*
$\dot{H}_{out}$ = *enthalpy rate of outdoor air, kJ/kg*
$\dot{H}_{\sup} *$ = *enthalpy rate of extract air at humidity rate of outdoor air, kJ/kg*
$\dot{Q}_{\sup,el}$ = *heat rate from fan-motor, kJ/kg*

This calculation method results in a higher efficiency when using non-efficient motors having a greater energy demand – which may seem contradictory regarding energy efficiency.

The η_{WBG} is today often calculated according to another equation, named η'_W or $\eta'_{WRG,\ uncorrected}$:

$$\eta'_W = \eta'_{WRG,\ uncorrected} = \frac{\dot{H}_{\sup} - \dot{H}_{out}}{\dot{H}_{\sup} * - \dot{H}_{out}} \qquad (-) \qquad \text{(Paul, E., 2009)}$$

Due to the great variation of efficiency grades, an amendment of the European standard DIN EN 13 053 has been made, defining combined efficiency grades and including the rate of needed auxiliary energy. Even a possible calculation method including primary energy factors is given (Kaup, C., 2009).

A principle sketch of a heat exchangers function is shown in figure 5, three different types relating to the air flow (cross flow or counter flow), often used symbols and ranges of temperature efficiency are given in figure 6.

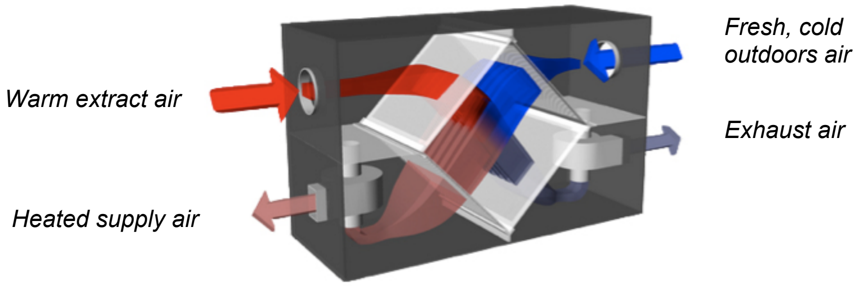


Figure 5: Principle sketch of ingoing and outgoing airflows of a heat exchanger (graphic from Tahan, N., 2009)

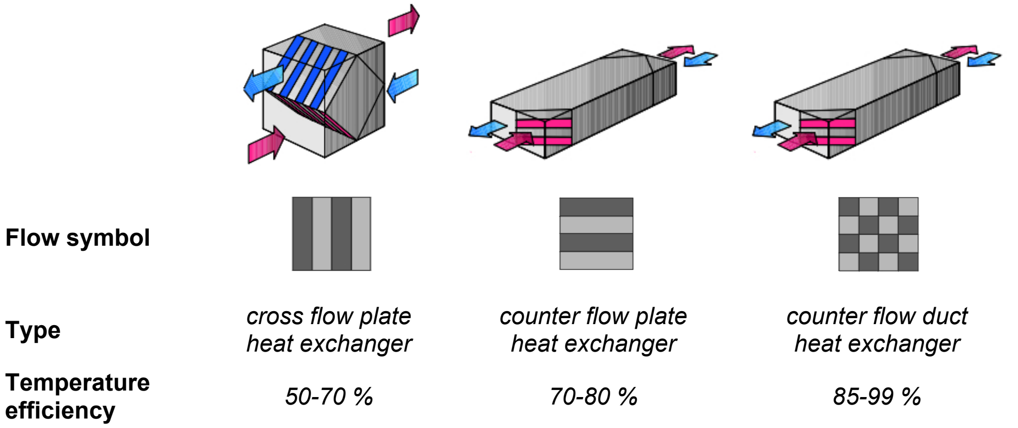


Figure 6: Cross flow plate, counter flow plate and counter flow duct heat exchanger (Paul Wärmerückgewinnung)

High efficiency is possible, but with increasing pressure drop and fan electricity as a result. It is a matter of optimisation, and a question of how optimal very high temperatures are in the end.

High efficiency is not always an advantage and might cause problems, for example at very low outside temperatures. At moderate outdoor temperatures, the temperature efficiency should be lowered, to avoid over-temperatures indoors. At cold outdoor conditions the humid exhausted air can cause condensation and freeze the heat exchanger. To prevent this, the temperature efficiency should be lowered, so that the exhausted air after passing the heat exchanger has a limited temperature, e.g. 0°C. The exchange of heat is therefore limited if freezing must be prevented (Jensen & Warfvinge, 2005). This limitation of the temperature efficiency should be automatic and continuous.

2.2.9 Heat pumps

A heat pump converts environmental heat (of air, ground water or soil) to thermal heat that can be used for space or domestic hot water heating in a building. A working fluid that vaporizes at low temperature and pressure circulates in the heat pump. In an evaporator the working fluid absorbs the supplied environmental heat and vaporizes. Under applied pressure the temperature rises, and in a condenser the working fluid relieves the heat into the waterborne heating system, condensates and continues circulating in the heat pump. The loop starts from the beginning. Relating to the heat source (air, water or geothermal energy) there are three types of heat pumps: air/water heat pumps, water/water heat pumps, and soil/water heat pumps (VdZ, 2005).

In passive houses often so-called *compact systems*, available in the combination of heat pumps and heat exchanger (named *heat pump compact unit*), are used. By connecting the two systems, the heat pump is using the air as heat-carrier for heating of domestic hot water. By this space heating, domestic hot water and ventilation are provided by one compact unit (Feist, W., 2006 c).

A measurement for the heat pump's efficiency and performance is the COP, coefficient of performance or seasonal performance factor (germ.: *Jahresarbeitszahl*), defined as the coefficient of annual delivered heating energy (kWh/a) and the ratio of supplied energy (kWh/a) (VdZ, 2005). Though, the second law of thermodynamics sets limitations on the possible COP rate.

2.2.10 Heating by the ventilation system

Usually the passive house concept includes the idea of space heating provided by the heated supply air of the ventilation system. Though, the realisation is limited due to different parameters.

At a peak load of 10 W/m^2 a building with an area of 150 m^2 and 2.5 m height, what gives a volume of 390 m^3, would need 1500 W (10 W/m^2·150 m^2) for heating. By using the equation

$$Q = V \cdot \rho \cdot c_p \cdot (T_{supply} - T_{indoor}) \qquad \text{(W)} \qquad \text{(Warfvinge, C., 2003, p.6:37)}$$

780 W would be provided at a supply air temperature of 35°C, an indoor temperature of 22°C and air flow rate of 180 m^3/h (50 l/s). 1080 W would be provided at a supply air temperature of 40°C, 1380 W at a supply air temperature of 45°C, and 1800 W at a supply air temperature of 52°C.

When using a heat exchanger for heat recovery, required supply air temperatures are calculated by the equation below.

$$T_{supply\ air} = \frac{Q}{V \cdot \rho \cdot c_p} + T_{indoor} - (1-\eta) \cdot (T_{indoor} - T_{outdoor}) \qquad \text{(Janson, U., 2008, p.161)}$$

Q = *Peak load for space heating, W*
V = *Ventilation rate, m^3/s*
ρ = *Density of air at 20°C = 1.2 kg/m^3*
c_p = *Thermal capacity of air = 1000 J/(kg K)*
η = *Temperature efficiency of heat exchanger, %*
T = *Temperatures, K (K=°C+273.15)*

Using the equation with heating exchanger, a supply air temperature of 42° C would be necessary for covering a heat load of 10 W/m^2 for the same building example as before (area of 150 m^2, height of 2.5 m), with an indoor temperature of 20°C, outdoor temperature 5°C, a heat exchanger with 80% efficiency and an airflow rate of 0.05 m^3/s (equals 0.5 ach). The example shows that the overall peak load for space heating only can be covered at quite high supply air temperatures even with heat exchanger.

Supply air temperatures higher than 52-57°C are not recommended due to the chemical reaction of dust particles at high surface temperatures that can cause emission of toxic gases and unpleasant smells (Kollmann, J., 2009). Usual lower limit values for supply air temperature are mostly between 15-18°C (Swegon AB b).

2.2.11 Demand-controlled ventilation

An option to minimize the energy demand for ventilation in a building is a demand-controlled system. The system is set up to lower the airflow rate when the building or room is unoccupied. Taking this option, some aspects should be considered, especially when the buildings is a low-energy or passive house. Lowering or shutting down the ventilation can cause higher humidity in the indoor air or higher concentration of pollutant emissions. As low-energy and passive houses are built more airtight, the natural ventilation by air leakage through the building envelope is not assured any more; therefore the effects of lowered ventilation should be taken into consideration when using this system (Sikander et al, 2009).

2.3 Indoor climate

Indoors climate is defined by parameters of *thermal climate, hygienic climate* (air quality)*, visual* (light) and *acoustic climate* (noise). The *thermal climate* includes temperatures (room air temperature, supply air temperature, operative temperature[6], surface temperatures) and air velocity; the hygienic climate includes parameters of ventilation (CO_2 content[7], air flows, supply air temperature, air velocity and throw) (Course Byggnadsteknik – komplexa byggnader, 2008).

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[6] Operative temperature – a value of ”sensed” temperature, calculated by including parameters as air temperature and surrounding surface temperatures. If air velocity is included, it is called *equivalent temperature*.
[7] CO_2 content – of air, measured in ppm (parts per million).

2.3.1 Thermal comfort

The term of thermal comfort is often used in accordance to good indoor climate and can be defined as *"a condition where people are satisfied with the thermal surrounding without feeling the need of warmer or colder conditions"* (Warfvinge, C., 2003, p.1:1). The indexes PMV or PPV are often used as measurements for thermal comfort, where PMV describes the predicted mean vote on a scale from -3 (cold) to +3 (hot) and PPV describes the predicted percentage of dissatisfied people (Course Byggnadsteknik vid nybyggnad, 2007). The scientific foundation for the requirements for reaching thermal comfort was provided by the Danish professor P. Ole Fanger and is today used in worldwide standards (DTU, 2001). To reach thermal comfort, parameters as air temperatures and velocities are defined by recommended limit values and should be considered when setting requirements on ventilation systems.

2.3.2 Guideline values

Guideline values for achieving thermal comfort and good hygienic and acoustic climate are listed in table 1. The values are listed for residential buildings (Ekberg, L., 2007).

	Higher comfort class	Lower comfort class
Thermal comfort		
Operative temperature, °C		
Winter	20-24 °C *recommended is < 23 °C*	
Summer	23-26 °C	
Floor temperature, °C		
General	22-26 °C	20-26 °C
Rooms not intended for children	-	16-27 °C
Vertical temperature difference, °C		
	< 2 °C	< 3 °C
Air velocity, m/s		
at 20° C	< 0.10 m/s	< 0.15 m/s
at 26° C	< 0.15 m/s	< 0.25 m/s
Hygienic climate – Air quality		
Concentrations		
Radon	100 Bq/m^3	
CO	2 mg/m^3	

NO_2		40 µg/m^3
O_3		50 µg/m^3
HCHO		50 µg/m^3
Filter classes		
		at least F7
Acoustic climate[8]		
LpA[9], dB (A)		
Residential rooms	22-26	30
LpC[10], dB (C)		
Residential rooms	42-46	50 (bedrooms)
LpAF[11], dB (A)		
Residential rooms	< 27 or < 31	< 35

Table 1. Recommended values for a good indoor climate (Ekberg, L., 2007)

2.3.3 Indoor climate in low-energy and passive houses

Research into low-energy and passive houses has shown that the thermal climate in the winter season is good, partly due to the well-insulated and airtight building envelope (Sikander et at, 2009). In warmer seasons, the opinion concerning the advantage of high insulation is split:

- In summer the indoor air temperature risks to become higher than in a conventional house. In this case the airtight building envelope makes it harder to get rid of the temperature surplus and more natural draught ventilation or even active cooling can be needed (Sikander et at, 2009).
- In summer habitants of passive houses are guaranteed a comfortable and chilled indoor climate without the need of active cooling. This is achieved by ventilating when the outdoor temperature is low, e.g. at night, and preventing incoming warm air at daytime. The well-insulated and airtight building envelope retains the low indoor temperature the whole day. This method implies the condition of great temperature differences between day and night (Krapmeier, H., 2006).

[8] Sound pressure levels Lp, relating to the weighting level A, C or AF; according to frequencies (Cirrus).
[9] LpA – sound level with A-weighting; i.e. frequencies audible for the human ear (Cirrus).
[10] LpC – sound level with C-weighting; i.e. frequencies used for the measurement of peak sound pressure level (Cirrus).
[11] LpAF – sound level with A-weighting and Fast time-weighting (Cirrus).

Out of this two statements the conclusion can be made, that if high indoor temperature by incoming warm air or heating by sun-faced glazed areas is hindered, a good indoor climate in low-energy and passive houses can be achieved even in summer. If the building is equipped with a FTX ventilation system, the system should be regulated so that it does not contribute to a too high indoor temperature and always be equipped with a by-pass function.

In the research project CEPHEUS measurements concerning indoor temperatures in passive houses in summer were made. The tests resulted in mean indoor temperatures between 21.9°-23.6°C in the period May-August. Temperature curves showed that comfortable summer-time temperatures could be attained by appropriate ventilation behaviour of the users and shading elements (Feist et al, 2001).

A consideration regarding the indoor climate in low-energy and passive houses, using airborne heating, are the limitations concerning temperature regulation in all building zones, e.g. in bathrooms, where discomfort has been investigated. Therefore is it important that the ventilation system is designed for a well-functioned correlation between heating and ventilation (Sikander et at, 2009).

As radiation of surrounding surface temperatures in correlation with the air temperature has great impact on the thermal comfort, the high insulation of low-energy and passive houses carries advantages. Herewith a larger temperature difference between indoor air and surface temperatures is prevented, and discomfort by cold surrounding surfaces at low outdoor temperatures, as in less insulated buildings can be hindered (Krapmeier, H., 2006).

2.4 Sustainable development – Sustainable building

"A development is sustainable if it meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 46) – is the definition of sustainable development by the World Commission on Environment and Development. The today very commonly used term of sustainability is a complex concept containing *environmental*, *economic* and *social* aspects and is used in many fields of the industry (Steger et al, 2005). Related to the building industry the term of sustainable construction is used. The reason why there is placed great importance on sustainability in this sector are facts as: (Bruckner, H., 2006)

- Building activities cause the greatest mass flows
- About 60% of the total generated waste is caused by the building sector (under construction)
- Products from the building sector have a long life expectancy

The *environmental* aspect of sustainability includes the usage of renewable and especially non-renewable resources as natural minerals, water, air and soil and the usage of energy for production, maintenance and removal of buildings. The environmental aspect also includes polluting emissions that harm the human health or ecosystem (Bruckner, H., 2006).

2.5 Types of low-energy houses

Low-energy houses have a very broad definition and are generally known as houses with a lower energy demand than common buildings regulated in the national building code. The term *low-energy house* is in some countries used for a specific type of building and therefore the overall term *buildings with lower heating demand* include the different types, such as (Wirth, S., 2002)

- Low-energy house
- Ultra house
- Passive house
- Zero-energy house

These are the most frequently used and commonly spread types; as described in chapter 3 there are further more types.

Low-energy House

A low-energy house is a building having a lower heating demand, with limit values differently defined in national standards. The buildings are distinguished by higher insulation of the building envelope, ventilation systems with heat recovery and windows and glass facades facing to the south to gain passive solar heat – where the climate so admits (Wirth, S., 2002).

Ultra House

Ultra houses are distinguished by the same characteristics as low-energy houses but with additional focus on using building materials and components with better thermo technical qualities as lower U-values (Wirth, S., 2002).

Passive House

"A passive house is a building, for which thermal comfort (ISO 7730) can be achieved solely by post heating or post cooling of the fresh air mass, which is required to fulfil sufficient indoor air quality conditions (DIN 1946)" (Feist, W., 2006a) … *"The house heats and cools itself, hence "passive""* (Passivhaus Institut).

The concept of passive houses is defined by no need of supplement heating systems except the ventilation system. Up to a load of 10 W/m^2 heating can be achieved by the ventilation system. Therefore houses classified as passive houses should not exceed a peak load of 10 W/m^2 to be able to heat without any supplement systems (Feist, W.). Thus, the value of heating load that can be achieved by the ventilation system is dependent on the ventilation air rate, which differs in many countries. Therefore the definition of at which level a house is working as a passive house can vary. The equation below shows the interrelation of *peak load for space heating* and the *ventilation air rate* at a maximum supply air temperature of 52°C (Janson, 2008).

$$Q = V \cdot \rho \cdot c_p \cdot (52 - T_{supply}) \qquad \text{(W)} \qquad \text{(Janson, 2008. Equation 1.2, p.25)}$$

Q = Peak load for space heating, W
V = Ventilation air rate, l/s, m^2
ρ = Density of air, kg/m^3
T_{supply} = Temperature of the supply air after the heat exchanger, °C

The limit value of 10 W/m^2 is based on a specific ventilation air rate. Therefore, in countries with higher required ventilation rates, the maximum peak load results in a higher limit value.

The ventilation-concept in passive houses is shown in figure 7, where fresh air is introduced to the buildings by an outside air intake, then heated by the heat of extract air in a heat exchanger and supplied to the rooms for heating. After heat exchanging the extract air is exhausted out of the building.

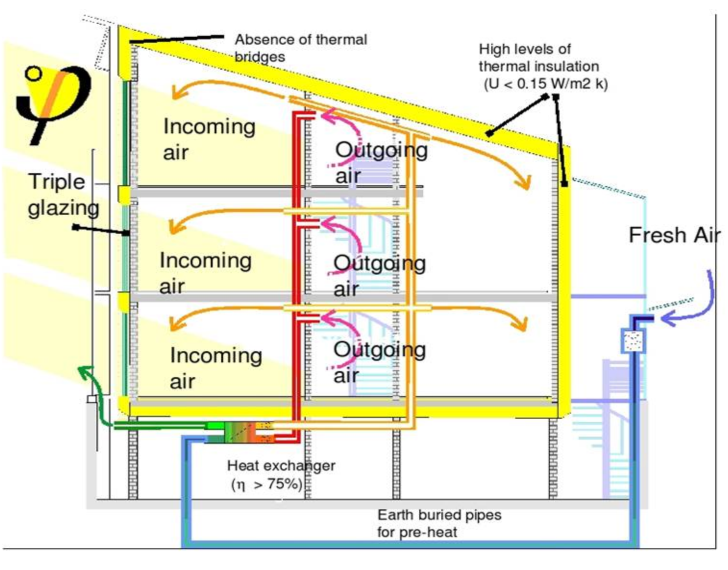


Figure 7: Ventilation concept of passive houses (Passivhaus Institut)

Zero Energy House

The term *zero-energy house* is a complex and currently very discussed term.
In general, zero-energy buildings are described as an energetically autonomous building, using solar energy and photovoltaic systems to generate energy, equipped with thermal storage systems. By producing as much energy as needed, the buildings are self-sufficient (Wirth, S., 2002). *"Zero"* stands for zero use of fossil fuels and the feasibility of this concept is being discussed heavily, followed by economically great costs for the technical equipment.

In the IEA[12] SHC Task 40 – ECBCS Annex 52, the term "*net zero energy building*" is being introduced, where focus lies on the economic balance of supplied and demanded energy by e.g. using community energy systems (Voss/Riley, 2009). In the newest amendment of the EPBD the term of *"nearly zero energy buildings"* is used as a goal for all new-built buildings in 2021. A unitary definition of the term is still missing (RICS).

Figure 8 shows a comparison of the final energy use of six different building types. Buildings complying with the "*German 1984 Ordinance*" are poorly insulated buildings, "*low energy houses + electric efficiency*" are defined by an efficient use of electricity and "*future passive houses*" are even better performing as the one's of the Passivhaus Institut (Feist, W., 1997).

[12] International Energy Agency – acting as an international energy policy advisor (IEA).

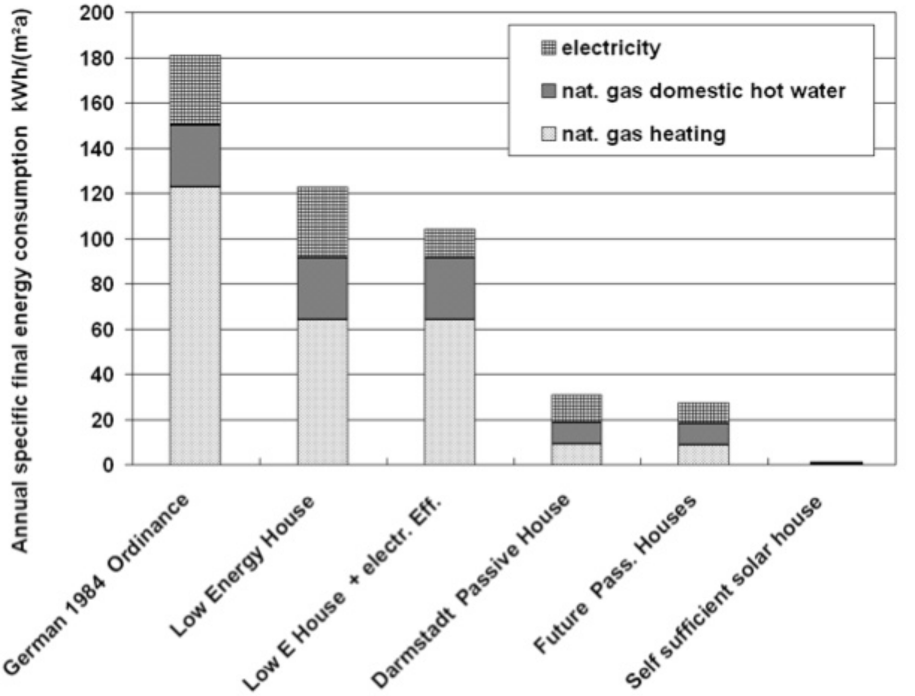
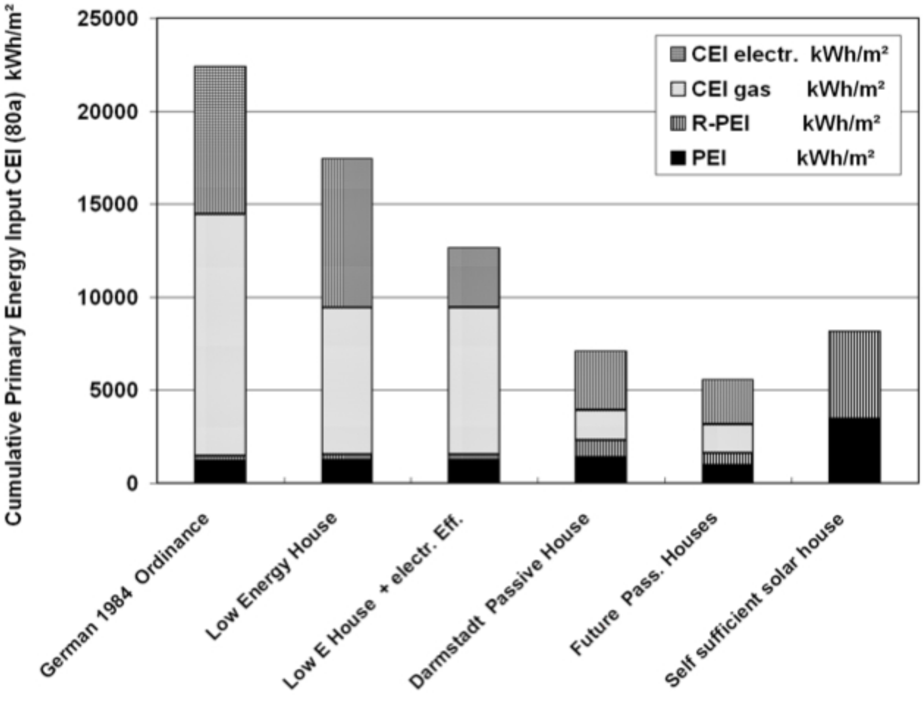


Figure 8: Annual end-use energy use (Feist, W., 1997, p.3)

Another comparison in figure 9 below shows the cumulative primary energy input CEI, a weighted rate of used primary energy for both production and replacement and building production. Here self-sufficient houses have a higher CEI than e.g. passive houses, which is referred to the higher energy input for production and replacement as for technical systems and are therefore – from the ecological point of view not better than passive houses.



CEI *cumulative primary energy input*
R-PEI *primary energy input for production and replacement*
PEI *primary energy input for building production*

Figure 9: Cumulative primary energy input compared (Feist, W., 1997, p.1)

2.6 Promotion and research projects

2.6.1 CEPHEUS

Standing for *cost efficient passive houses as European standards*, CEPHEUS was a research project running between 1998-2001, supported by the EU. The main purpose was to test the viability of passive houses in five European countries (Germany, Austria, Switzerland, Sweden and France) based on 14 passive house projects, and to demonstrate the feasibility of the passive house concept. Further animation was to promote the production and development of passive house compliant products as windows, heat recovery and heat pump units (Feist et al, 2001).

The project was carried out under these conditions (Feist et al, 2001)

- *PHPP* – all projects were calculated with the Passive house planning package
- *Dynamic simulation programs* – used in some projects for evaluation of thermal comfort and effects of different heat distribution systems
- *Air tightness testing* – tested in all buildings by the Blower door method

- *Site and manufacturer advice* – to solve problems such as thermal bridging and condensation water
- *Thermo graphic quality testing* – carried out at some projects
- *Initial adjustment of the ventilation system* – after the first trial run
- *Measurements* – the basic measurement programme contained space heat requirement, final and primary energy use, and occupant comfort. At some projects additional measurements such as electricity use of ventilation systems, indoor air moisture and CO_2 content, hot water circulation losses, air velocities, etc.
- *User manuals* – extensive constructions provided to the users
- *Social science evaluation* – carried out at some projects with focus on the satisfaction of users

The result of the CEPHEUS project was that all goals were reached; as goals regarding heating and primary energy defined in the passive house standard by the Passivhaus Institut as goals regarding indoor temperatures and user satisfaction. Expressly mentioned was the need of better knowledge among architects and consultants about the technical details and construction in passive and low-energy houses. A positive consequence of the project was the rising production of passive house compliant products (Feist et al, 2001).

2.6.2 PEP

Standing for *Promotion of European Passive Houses,* PEP was a project funded by the European Commission Energy & Transport DG[13] to promote the concept of passive houses in Europe (European Commission, 2010). The project was run between 2005 and 2008 in cooperation of nine countries: Ireland, UK, the Netherlands, Belgium, Norway, Denmark, Finland, Germany and Austria. The main goal was to spread information and knowledge about the in Germany developed concept and to encourage the social embedding of the passive house concept all over Europe by providing information in several languages on websites and in international conferences and workshops (Elswijk & Kaan, 2008).

The project resulted a successful development progress towards embedding the passive house concept in every participating country in comparison to the beginning of the project in 2005. Another result of the PEP was the definition of passive houses regarding to their geographical location (Elswijk & Kaan, 2008):

- *Nordic passive houses* > 60° northern latitudes
- *Central European passive houses* 40°-60° northern latitudes
- *Mediterranean passive houses* < 40° northern latitude

[13] Directorate-General for Energy and Transport

Topics in which further research and development is needed were identified as (Elswijk & Kaan, 2008):

- Implementation of the certification schemes for passive houses
- Research of the relation between hygienic requirements on ventilation systems and comfort and health
- Development of industrial prefabricated construction of passive house elements
- Synchronisation of national energy calculation methods, PHPP and the EPBD

2.6.3 North Pass

To promote the implementation of very low-energy buildings such as passive houses in northern climates the project *North Pass* was started in 2009. The cooperation consists of institutions from Norway, Denmark, Sweden, Finland, Estonia, Latvia, Lithuania and Poland under coordination of the Technical Research Centre of Finland VTT. Animations for starting the project were issues as adapting the German passive house concept to colder climates and the lack of awareness and of low-energy house compliant products (VTT, 2009).

The work plan of *North Pass* is reaching to 2012 with expected results as (VTT, 2009):

- Local criteria for very low-energy buildings
- Building concepts for meeting the criteria and guidelines for design
- Calculation and presentation of the benefits
- Country-specific market analyses and marketing approaches
- Business models for the very low-energy building market
- Dissemination of the results to designers, builders, decision-makers, etc.

The goals shall be aimed by a number of work steps, whereof one shall be implemented over the whole project period – information and dissemination by web sites, conferences and workshops, presentations, booklets and country-specified information packages in national languages (VTT, 2009).

2.6.4 Out-look – Austria as the European Passive house pioneer

In Vienna the construction of Europe's biggest passive house project, *Eurogate* has been initialized. Designed under the master plan of Architect Sir Norman Foster, a residential building areal consisting of 1700 apartment units in total, reaching over an area of 100 000 m^2 shall be built. The construction was started in October 2009; until the year 2011, 740 units shall be completed; the final completion is foreseen for the year 2016 (Build Up, 2009; Wohnfonds Wien, 2007).

Areal and building units, Eurogate Vienna (Wohnfonds Wien, 2007)

The construction of multi-storey passive houses is not new in Austria; the present state in Vienna is a number of 16, resulting in the highest density of multi-storeyed passive house buildings worldwide (IG Passivhaus, 2009).

Besides, Austria was the only country at the Olympic games of 2010 in Vancouver providing a Passive house for their athletes (IG Passivhaus).

3 Standards regarding low-energy buildings in Europe

All member states of the European Union have their own standards and laws concerning the energy performance of buildings – some of the building codes include the definition of low-energy buildings, and some don't. Besides the governmental standards there are non-governmental organisations, responsible for certification of different types of low-energy buildings having their own standards with criteria. A compilation of the different building types regarding their state of definition will be given divided into **official**, **semi-official** and **unofficial**. This will be more closely described in chapter 3.2.

A simple cross-country comparison of the limit values in the standards is often hindered by national differences in

- Calculation methods
- System boundaries between heat demand and heat supply
- Related areas for specific energy values
- Energy level (primary, end, final)
- Climate zones
- Using habits

A compilation of the national definitions of the related area and explanations of the referred energy values are given in chapter 4.

3.1 Europe

Standards for low-energy buildings in Europe have proceeded differently in each country and today there is no common certification or legislation for low-energy buildings valid for all European member states. As a movement towards reducing energy use and emissions, a common legislation concerning buildings' energy performance, the EPBD was published in 2002 and came into force January 2003. The intent of the directive was to promote environmental protection, meeting the goals of the Kyoto protocol[14] (CIBSE, 2003).

As the term of *nearly zero energy buildings* is being mentioned in the new directive, a short introduction of the EPBD will be given, but will not be counted among the standards for low-energy buildings.

[14] Kyoto protocol – an international agreement promoting climate protection, opened in 1997 and ratified by the EU member states in 2002. The main target is to reduce emissions of greenhouse gases, where the targets must be achieved by the period 2008-2012 (European Commission – Environment).

3.1.1 Energy Performance of Buildings Directive

The EPBD includes 15 articles containing definitions, calculation methodology, minimum requirements for new and existing buildings, requirements on inspection of technical systems etc. (CIBSE, 2003).

According to article *15(1)* of the EPBD directive 2002/91/EC all member states had to apply their laws and regulations to the EPBD at the latest in 2006. An additional period until January 2009 was allowed due to lack of qualified and/or accredited experts, according to article *15(2)* (European Parliament, 2008).

To support the implementation of the EPBD in the member states, the European Committee for Standardization CEN has published standards and guidelines containing calculation methods and definitions. The definitions have been developed in the report CEN/TR 15615, the so-called *"Umbrella document"*, a guideline for the application and interrelation of the individual CEN standards and have been mandatory regulated in the standard EN 15603 *Energy performance of buildings – Overall energy use and definition of energy ratings* (Hogeling & Van Dijk, 2007).

In November 2008 a recast of the EBPD 2002/91/EC was proposed by the European Commission; in November 2009 the EU institutions agreed on a revision of the EBPD. In article *9* of the new directive the target of "*nearly zero energy buildings"* is described:

> *"By 1 January 2021, all new buildings, including existing buildings undergoing major renovation, will have to meet 'very high energy performance' standards. The public sector should assume a leading role by ensuring that all new buildings they own or occupy meet the nearly zero energy standards as of 1 January 2019.*
> *… The current definition of 'nearly zero energy' buildings is left vague in the directive, allowing Member States to determine their own standards."* (RICS)

In the recast also the need for definitions of low- and zero-energy buildings was mentioned:

> *"The Commission also needs to lay down the principles for defining low or zero energy and carbon buildings."* (Commission of the European Communities, 2008)

The new directive is planning to be affirmed by the European Parliament in 2010. After publishing, the member states will have two years to adapt the new directive to their legislation (RICS). Concerning limit values and calculation methods, the EBPD requires that limit values on the energy performance shall be set at least at a level of end energy. Recommended are limit values on primary energy demand and CO_2-emissions (CIBSE, 2003).

3.2 Country-specific building types – State of definition

The today existing types of low-energy buildings in the nine European countries, regulated by either official, semi-official or unofficial definitions are listed below. Listed as **official** are building types defined in governmental and mandatory building regulations, **semi-official** are building types defined by an organisation or a certification brand regulated by specific documents, and **unofficial** are building types that are defined and labelled by a company or organisation but without certification, or building types that refer their definition to another country but not is available for certification. By certification not the national energy performance certificate but a specific low-energy-certificate is meant.

	State 1st January 2010	Certification
SWEDEN		
Low-energy "Minienergi"	Semi-official	✓
Passive house	Semi-official	✓
Zero-energy house	Semi-official	✓
NORWAY		
Low-energy	*Official* (not set yet)	-
Passive house	*Official* (not set yet)	-
Passive house current	Semi-official	✓
DENMARK		
Low-energy house class 1	Official	-
Low-energy house class 2	Official	-
Passive house	Semi-official	✓
FINLAND		
Low-energy house	Semi-official	-
Passive house – RIL	Semi-official	-
GERMANY		
RAL Low-energy house	Semi-official	✓
RAL Passive house	Semi-official	✓
Passive house	Semi-official	✓
Passive house suitable component	Semi-official	✓
3-litre-house	Unofficial	-
Effizienzhaus 70	Semi-official	-
Effizienzhaus 85	Semi-official	-

AUSTRIA		
Low-energy (state-aided)	Official	-
Passive house (state-aided)	Official	-
3-litre house	Semi-official	✓
Klima:aktiv Passive house	Semi-official	✓
Klima:aktiv house	Semi-official	✓
SWITZERLAND		
Minergie	Semi-official	✓
Minergie-P (Passive house)	Semi-official	✓
Minergie-ECO / P-ECO	Semi-official	✓
GREAT BRITAIN		
Passive house	Semi-official	✓
POLAND		
Passive house	Unofficial	-

3.3 Sweden

The current issue of the Swedish building regulation is BBR 16 / BFS 2008:20, valid since February 2009, where the most amendments were made in chapter 9 concerning the energy performance of buildings (Boverket). A definition of low-energy houses is not mentioned in the national standard BBR. Therefore FEBY, an organisation established in 2007 and funded by the Swedish Energy Agency, as a cooperation of

- IVL, Swedish environment institute AB
- ATON Technical consultation AB
- Lund University
- SP, Swedish institution for technical research AB

has published documents for certification of low-energy houses.

FEBY has published a voluntary standard for so-called Minienergi houses and Passive houses. A definition of zero-energy houses is included in the standard for passive houses. The definition of e.g. related areas and climate zones are referred to the national standard BBR. Both standards are based on the German definition of passive houses, with amendments made to the Swedish climate and taking experiences of in Sweden built projects into account. Buildings according to FEBY have two options for certification – either certificated as a building *planned and projected* as a passive house, or certificated as a *verified* building, where calculated values and listed criteria in planning have to be proven. Verification can only be achieved by examination by a third party.

3.3.1 Low-energy-house – Minienergihus

According to the definition in the FEBY-regulation, Minienergi houses are

> *"a definition of low-energy buildings that aim to perform better than new built buildings regulated in BBR 16 (BFS 2008:20)"* (Regulation FEBY Minienergihus, 2009, p.2).

To be defined as a *Minienergihus* FEBY has decided to use two definitions (Regulation FEBY Minienergihus, 2009)

- *According to FEBY projected Minienergihus* - Certification
- *According to FEBY verified Minienergihus* - Verification

Whereof the last-mentioned has to show documents and measurements that verify the building in use. A guideline for the verification is included in an additional FEBY-document; the guideline is not containing requirements but purposes for possible verification (Regulation FEBY Mätning och verifiering, 2009), which measurements have to be proven for verification are listed in the regulation Application form – Verification, 2009.

3.3.2 Passive house

According to the definition in the regulation FEBY Passivhus, passive houses are

> *"a definition of low-energy buildings that aim to perform better than new built buildings regulated in BBR 16 (BFS 2008:20)"* (Regulation FEBY Passivhus, 2009, p.2).

As for *Minienergi*-houses, FEBY is using two definitions for Passive houses (Regulation FEBY Passivhus, 2009)

- *According to FEBY projected passive house* - Certification
- *According to FEBY verified passive house* - Verification

3.3.3 Zero-energy house

FEBY *zero-energy* houses are defined by an additional requirement on the energy performance in the regulation for *FEBY passive houses*; other requirements are the same as for passive houses. Zero-energy houses have to supply as much energy as they annually use (Regulation FEBY Passivhus, 2009) and are only available for verification (Regulation FEBY Application form – Verification, 2009).

3.4 Norway

The national building regulation of Norway is TEK with the recent issue TEK07, valid since 2007. Concerning criteria on the energy performance of buildings the limit value of energy demand has been lowered by 25% in comparison to the former regulation TEK1997 (Statens Bygningstekniske Etat, 2007).

Low-energy or passive houses are not defined in the current national standard TEK07, but the Norwegian standardization agency is elaborating a standard for low-energy and passive houses, in that definitions and specific criteria shall be included, named NS 3700 (Enova Næring, 2009). The standard is based on the German definition and certification of passive houses with national adjustments due to differences in climate and construction standards; importance is laid on avoiding major variations to the Swedish and European standard. On a final meeting on November 26th 2009 the standard was supposed to be formally approved by the committee of Norwegian Standards and finally be set in January 2010 (Standard Norge, 2009).

3.4.1 Low-energy-house

In the draft of the upcoming official standard NS 3700 low-energy buildings are defined. Concerning the buildings energy performance two alternatives for rating the primary energy are being discussed (Regulation prNS 3700):

- Limit values for the buildings annual CO_2-emission; the emission shall be calculated by multiplying the annual supplied energy with CO_2-factors (different form factors for different supply forms)
- Required percentage of the heating demand must be covered by renewable energy.

3.4.2 Passive house

Parallel to low-energy buildings, passive houses are regulated in the draft of the coming Norwegian standard NS 3700. The regulation describes a passive house as

> *"a building with very low energy demand for heating and enables to simplify the buildings heating system"* (Regulation prNS 3700, p.4).

Regarding criteria on the buildings energy performance the same options for primary energy rating are being discussed; either annual CO_2-emission or prescribed percentage using renewable energies. Until the standard NS 3700 becomes mandatory, the current definition of passive houses in Norway is referred to the German PHI (Passiv.no).

3.5 Denmark

In Denmark low-energy houses are defined in the national building regulation BR08, divided into two classes; low-energy buildings class 1 and class 2 (Danish Enterprise and Construction Authority). The classification system and requirements on low-energy buildings were introduced in 2006 and are based on the EU-directive on EPBD (2002/91/EC) (Svendsen/Tommerup, 2006).

The passive house concept is known since 2000; concerning certification Denmark is referring to the German definition and criteria document *Criteria for passive houses,* Passivhaus Institut. The Danish passive house institute is part of the cooperation *Passivhus Norden* where adjustments of the definition to colder climates are being discussed; until then the criteria of the German Passivhaus Institut are valid (Passivhus.dk).

3.5.1 Low-energy-house

Low-energy buildings class 1 and class 2 are regulated in BR08, in chapter 7.2.4 *Low-energy* (Regulation BR08).

3.5.2 Passive house

The Danish passive house consulting company Passivhus.dk are responsible for certifying passive houses in Denmark. The certification method and criteria is referred to the German Passivhaus Institut (Passivhus.dk).

3.6 Finland

Since January 2010 the chapters C3, D2 and D3 (*Buildings thermal insulation*, *Buildings indoor climate and ventilation* and *Buildings energy performance*) of the Finnish building regulation have been renewed (Miljöministeriet). Low-energy buildings are mentioned but not specifically defined by limit values, only by a recommended guideline value for maximum heat loss (Regulation D3, 2010). Because the only criterion is a guideline value, this definition will not be accounted as a regulation for low-energy buildings.

Therefore the Finnish Association of Civil Engineers, RIL has developed a regulation for low-energy and passive houses, the guidebook RIL 249-2009 (RIL).
Besides, the VTT *Technical Research Centre of Finland* has a leading role concerning passive houses in Finland. They have published recommendations for passive houses in Finland, are building such and performing follow-up by energy measurements. The buildings are relating to the German passive house concept but with adjustments to the Finnish climate zone (Granbäck, A., 2009; Jari Rintamäki). Certification documents for Finnish passive houses are not available yet; therefore Danish certification is used, which again is referred to the German PHI (E-mail correspondence Jari Rintamäki).

3.6.1 Low-energy-house – RIL

In the regulation RIL 249-2009 the Finnish association RIL has defined low-energy buildings, classified into different types: M-30, M-35, M-40, M-45 and M-50, relating to the their annual delivered energy, e.g. M-40 has a demand of 40 kWh/(m^2a) (Regulation RIL 249-2009).

3.6.2 Passive house – RIL

Parallel to low-energy buildings, passive houses are defined in the RIL 249-2009; subdivided into different classes: P-15, P-20 and P-25, relating to their annual delivered energy, e.g. P-20 has a demand of 20 kWh/(m^2a) (Regulation RIL 249-2009).

3.7 Germany

In Germany buildings are regulated in the national building code EnEV *Energy Saving Standard*, the current amendment is the EnEV 2009. Many articles refer that by the former issue EnEV 2002 the low-energy building was standardized in Germany, e.g. that all new build houses are now built as low-energy houses (bau+energiekonzepte; Energie Wissen; Detail, 2006). Other articles controvert this statement and define low-energy buildings as buildings that fall below the limit values of the EnEV for e.g. primary energy demand by 30%. Here low-energy buildings are defined as buildings performing "better" than regular houses (Feist & Born, 2007).

In the current EnEV 2009 the term of low-energy buildings is not mentioned at all (EnEV 2009), what confirms that it is not a by law defined term. Therefore the *Gütegemeinschaft Niedrigenergiehäuser e.V.* has established a standard with criteria for low-energy and passive houses, certified by the quality label RAL-GZ 965 (Detail, 2006). The RAL-GZ provides even certification for "low-energy renovations" and "part renovations"[15], renovation of part of buildings (Regulation RAL-GZ 965).

For passive houses the German Passivhaus Institut in Darmstadt is responsible for the original certification of passive houses; introducing the concept in 1990 and using the planning package PHPP.

In Germany there are many further types of low-energy buildings that are defined by regulations:

- RAL low-energy houses
- RAL passive houses
- Passive houses
- 3-litre-houses
- Effizienzhaus 70, former KfW-40-houses
- Effizienzhaus 85, former KfW-60-houses

[15] RAL-GZ 965 certified part renovations – the certification includes a reference to renovated building components and its interaction to the non-renovated parts. The certification does not include an individual building-component-certification (Regulation RAL-GZ 965).

3.7.1 EnEV

The EnEV was first published in 2002 and replaced the pre-existing regulations *Wärmeschutzverordnung (WSVO 1995)* and *Heizungsanlagenverordnung (HeizAnlV 1998).* The present amendment of the EvEV is the EnEV 2009, valid since October 1st 2009. In 2012 another amendment is planned, with changes and tightened requirements by almost 30%. (EnEV-online, 1999-2009)

The prescribed calculation method refers to *EN 832,* as in the EBPD but with differences regarding related areas – the *EN 832* does not contain related areas, whereas the EnEV refers to a *net area* A_N*,* calculated by the buildings *heated air volume* (see chapter 4.1) (Hoffman/Hastings/Voss, 2005).
Hygienic requirements on mechanical ventilation systems are regulated in the standard VDI 6022.

3.7.2 RAL low-energy-house

Low-energy houses certified by RAL-GZ 965 are mainly regulated by having 30% lower heat losses by transmission than regulated in the EnEV. Besides there are other criteria on e.g. insulation, air tightness and ventilation (Gütegemeinschaft Niedrig-Energie-Häuser, 2009).
Low-energy buildings certified by the RAL-GZ 965 have two options

- *Certified building for "Planning"*
- *Certified building for "Construction"* (germ.: *Bauausführung)*

Whereof the last-mentioned includes certified planning and verification of the criteria after completion.

3.7.3 RAL passive house

In the same regulation as for RAL low-energy buildings, passive houses are available for certification of the quality label RAL-GZ; including the same options as RAL low-energy houses:

- *Certified building for "Planning"*
- *Certified building for "Construction"* (germ.: *Bauausführung)*

3.7.4 Passive house

The official concept of passive houses defined by specific criteria was first introduced by the *Passivhaus Institut* Darmstadt under the direction of Dr. Wolfgang Feist. All criteria have to be proven by the PHPP, *Passivhaus Projektierungspaket* (PHPP 2007), a project planning package published by the Passivhaus Institut containing e.g. calculation of the energy performance or planning tools for the ventilation system. The recent version PHPP 2007 has been updated with more features to adapt the simulation as much as possible to the planned building. The planning package also contains climate data for many European countries to enable the use of PHPP international (Passivhaus Institut).

The PHPP includes tools for (Passiv.de)
- Calculating the U-values of components with high thermal insulation
- Calculating energy balances
- Designing comfort ventilation
- Calculating the heat load (no heat load climate data contained yet for locations outside Germany)
- Summer comfort calculations

and many other tools for the design of passive houses.

Besides the certification of buildings as passive houses, the PHI offers certification of technical building components such as heat exchangers and heat pumps, certified as e.g. "*Passive House suitable component - heat recovery device*"; for a certificated example and a certification sample see appendix II respectively III.

3.7.5 3-litre-house

In Germany, x-litre-houses are concepts of low-energy houses introduced by the German institution *Fraunhofer IBP Institut für Bauphysik*, where the litre-value refers to the annual used amount of heating oil per m^2; corresponding to a value of primary energy demand.

The buildings are not available for certification. It is a building concept, defined and trademarked by the Fraunhofer Institut by the limit value of primary energy demand. No requirements on the technical system; the requirements are the same as for new built houses regulated in the national building code EnEV (3-Liter-Haus). By the Fraunhofer institute explained, 3-litre-houses are ultra-low-energy houses (E-mail correspondence Heike Erhorn-Kluttig).

3.7.6 Effizienzhaus 70

In Germany building or acquisition of buildings with low energy demands is sponsored by the KfW, a *Reconstruction Loan Corporation* by giving loans at reduced rates of interest. Buildings sponsored by the KfW are the former called KfW-40, KfW-60 and Passive Houses (Hoffmann, Hastings & Voss, 2005).

KfW-buildings are defined by limit values on their primary energy demand and heat losses by transmission. Other criteria are the same as on buildings in general, regulated in the EnEV (KfW Foerderbank). Buildings sponsored by the KfW must be by planned according to PHPP (KfW Foerderbank).

Since April 1st 2009 the term KfW-40-house is replaced by the definition *Effizienzhaus* – based on the EnEV 2007 called *Effizienzhaus 55* (valid until Dec 30th 2009), based on the EnEV 2009 now called *Effizienzhaus 70* (SPHaus, KfW Foerderbank). The former definition KfW-40 was based on an annual primary energy demand of 40 kWh/m^2a (relating area as defined in EnEV) (Hoffmann, Hastings & Voss, 2005); the newer terms Effizienzhaus 55 and 70 refer to the percentage of the maximum primary energy demand in the EnEV. – Effizienzhaus 70 has a primary energy demand of 70% of the limit value set in EnEV 2009 (KfW Foerderbank).

3.7.7 Effizienzhaus 85

Since April 1st 2009 the term KfW-60-house is replaced by the definition *Effizienzhaus* – based on the EnEV 2007 called *Effizienzhaus 70 55* (valid until Dec 30th 2009), based on the EnEV 2009 now called *Effizienzhaus 85* (SPHaus, KfW Foerderbank).

The former definition KfW-60 was based on an annual primary energy demand of 60 kWh/m^2a (relating area as defined in EnEV) (Hoffmann, Hastings & Voss, 2005); the newer terms Effizienzhaus 70 and 85 refer to the percentage of the maximum primary energy demand in the EnEV. – Effizienzhaus 85 has a primary energy demand of 85% of the limit value set in EnEV 2009 (KfW Foerderbank).

3.8 Austria

In Austria the nine federal states have individual building regulations, e.g. criteria on buildings energy performance may vary within the country. The calculation methods are prescribed according to the national institution OIB, which complies with the Austrian standard ÖNORM B 8110-1 and the European EN 832 (Hoffmann, Hastings & Voss, 2005). Besides, the OIB has the function to adjust the different regulations within the country to each other to make it easier for future amendments to the European standard. A common standard – today legally bound in all federal states, was established in 2007. Regarding energy performance of buildings the standard *Richtlinie 6 - Energieeinsparung und Wärmeschutz* has been published (OIB, 1999).

Since the introduction of Energy Performance Certificates for buildings in 2008 buildings are classified by their heating demand (germ.: *Heizwärmebedarf* HWB) and energy demand (germ.: *Heizenergiebedarf* HEB). As shown in figure 10, the classes range from A++, A+, A, B to G, where A++ is the building class with the lowest heating and energy demand (Energie Tirol, 2009).

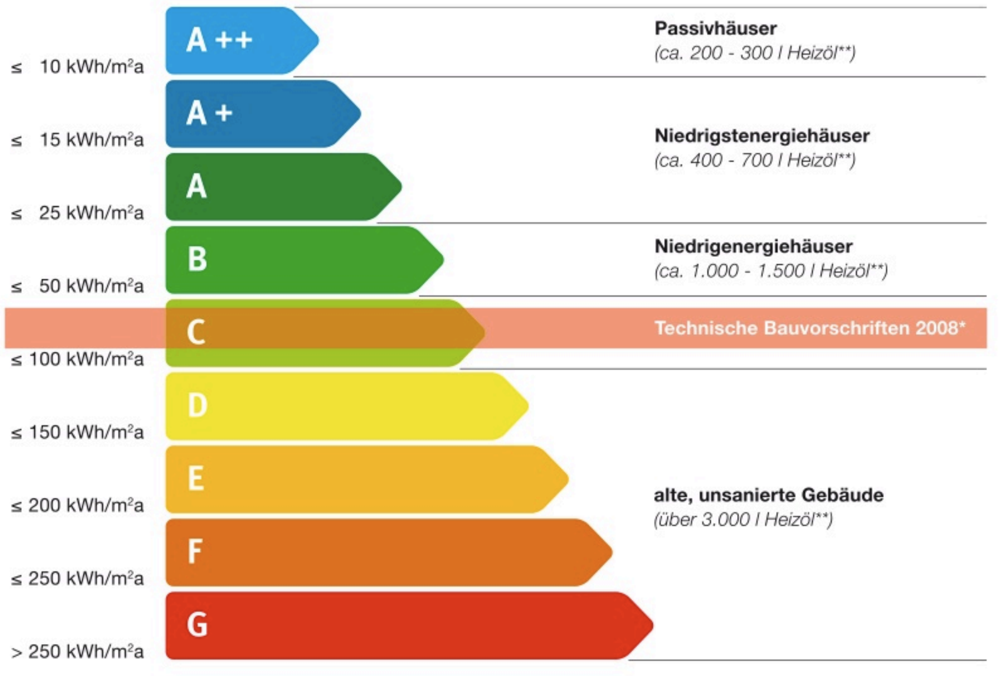


Figure 10: Energy classes Austria (Energie Tirol, 2009)

Regulated in the OIB the different classes are defined as (Regulation OIB 6, 2007):

A++	$HWB_{BGF,REF} \leq 10$ kWh/m^{2}a	D	$HWB_{BGF,REF} \leq 150$ kWh/m^{2}a
A+	$HWB_{BGF,REF} \leq 15$ kWh/m^{2}a	E	$HWB_{BGF,REF} \leq 200$ kWh/m^{2}a
A	$HWB_{BGF,REF} \leq 25$ kWh/m^{2}a	F	$HWB_{BGF,REF} \leq 250$ kWh/m^{2}a
B	$HWB_{BGF,REF} \leq 50$ kWh/m^{2}a	G	$HWB_{BGF,REF} > 250$ kWh/m^{2}a
C	$HWB_{BGF,REF} \leq 100$ kWh/m^{2}a		

$HWB_{BG,REF}$ is the annual heating demand per m^2 of the related area (see chapter 4.1).

The terms of low-energy houses often are ranged in the classes of the Energy Performance Certificate in articles, as in figure 10, but a statutory definition, e.g. in the OIB-regulation, is missing – Besides in regulations for state-aided building projects, where housing grants are given for building low-energy buildings. To be financially aided, low-energy and passive houses are defined in the regulation *Richtlinie der MA 2 über erhöhte Wärmeschutzanforderungen für geförderte Mehrwohnungshäuser* and the regulation *Landesgesetzblatt Wien – 27.Verordnung,* by law (Regulation RL MA 25; LGBl 27_2007).

Besides the definition of low-energy and passive houses in the governmental grant scheme, low-energy buildings can be certified within the Klima:aktiv house program, where for passive houses the PHPP is used. A difference between using PHPP or the Austrian calculation methodology of the OIB lies in the definition of the related area (see chapter 4.1).

Besides passive houses of the klima:aktiv program, passive houses relating to the German PHI definition are being certified by three institutions (IG Passivhaus)
- Energieinstitut Vorarlberg
- Herz & Lang
- Austrian Institute for Healthy and Ecological Building (IBO).

3.8.1 Low-energy-house

By criteria defined low-energy houses in Austria are only defined in the regulation for state-aided buildings; residential buildings including 3-1000 dwelling units. Requirements on the energy performance are divided for buildings with or without mechanical ventilation (Regulation RL MA 25; LGBl 27_2007).

3.8.2 3-liter House

The 3-liter House is a certificated type of low-energy house, defined as a house with a heating energy demand of 3 litre heating oil or the correspondent amount of gas or other supply sources as e.g. firewood per m^2 related area. Other criteria are set for heating demand in kWh/m^2a and the air change rate n_{50} (3-Liter-Haus).

3.8.3 Passive house

To be state-aided passive houses are regulated by criteria in the regulation *Richtlinie der MA 25 über erhöhte Wärmeschutzanforderungen für geförderte Mehrwohnungshäuser;* residential buildings including 3-1000 dwelling units (Regulation RL MA 25).

Besides passive houses of the governmental grant scheme, in Austria so-called Klima:aktiv passive houses are available for certification; a possibility to certify your building as a passive house within the Klima:aktiv Haus program (Klima:aktiv).

3.8.4 Klima:aktiv House

The Klima:aktiv project is an Austrian project promoting environmental protection in different sectors, with the common aim of reducing CO_2-emission and increasing the use of renewable energy sources. Since 2006 certification brands for different types of low-energy buildings are available (Klima:aktiv).

The buildings are evaluated by four evaluation-sections: **Planning and completion**, **Energy and supply**, **Building materials and construction** and **Air quality and**

comfort. In each section different criteria are listed, either as a prescribed must or selectable criteria. For fulfilling a selectable criterion a specific amount of points is achieved. After summing up the total amount of points through the four evaluation-sections the building either can be defined as a “klima:aktiv house” or as a “klima:aktiv passive house”. In total 1000 points can be achieved; to be certified as a klima:aktiv house all set up prescriptions and 700 points have to be reached, for klima:aktiv passive houses the set up prescriptions and 900 points are required (Klima:aktiv). The list of criteria and achievable points for klima:aktiv houses and passive houses is shown in appendix IV.

3.9 Switzerland

In Switzerland the national building regulation concerning energy performance of buildings is the SIA 380/1:2009 “Thermische Energie im Hochbau”. The term *low-energy building* is not defined in the national building code SIA and is no proprietary term with an official definition in Switzerland (E-mail correspondence Antje Heinrich). As a guideline to the so-called “2000-Watt-society”[16], the documentation SIA D 0216 *Effizienzpfad Energie* was issued in 2006, enhancing energy-efficient building for a sustainable development. In this documentation limit values for the primary energy use for *building material, indoor climate, domestic hot water, light and technical installations* and *mobility* to reach the “2000-Watt-society” are given for three building types – dwellings, office buildings and schools (SIA). As the documentation is a guideline and not containing any definitions of low-energy buildings it will not be further examined in this thesis.

For low-energy buildings a national certification brand, the MINERGIE-standard has become market leading in Switzerland (Minergie, 2009).

3.9.1 Minergie®-houses

Minergie is a since Feb 2003 published standard and certification brand, available for buildings in Switzerland and Liechtenstein. Buildings abroad shall be regulated in a separate regulation, which has not been set yet; until then the regulations for buildings in Switzerland and Liechtenstein are valid, with additional examination from the Minergie certification centre (E-mail correspondence Martin Pfirter). The certification of Minergie-houses is a charged service and valid for five years (Minergie, 2009). The different types of Minergie-houses are classified as

- Minergie®
- Minergie-P®

[16] 2000-Watt-society – A concept developed by the Technical University Zürich ETH describing the reduction of annual power demand of 6000 Watt per person to a third, 2000 Watt. The concept shall enhance the sustainable development and a reduction of CO_s emission to reach the goals of the Kyoto-protocol (Novatlantis, 2007).

- Minergie-ECO® / P-ECO®

The general criteria on Minergie-houses are (Minergie, 2009)

- Criteria on the building envelope
- Mechanical ventilation
- MINERGIE®-limit values (weighted energy values)
- Verification of thermal comfort in summer
- Additional regulations concerning lighting, cooling and heating supply, depending on the Minergie building type

Since the introduction of a new amendment of the Swiss building regulation SIA 380/1:2009 in January 2009, the criteria in the regulations for Minergie-buildings are split into verification either according to SIA 380/1:2009 or the older version SIA 380/1:2007. Verification according to the older version will be valid through 2010. In this thesis the verification according to SIA 380/1:2009 is being examined.

For verification of Minergie houses two different methods can be used:

- *System verification* criteria on energy performance, type of ventilation system and additional criteria as e.g. verification of thermal comfort in summer. The energy performance is rated by annual heating demand and the Minergie-limit value $E_{Minergie}$.
- *Verification by standard solutions* for residential buildings up to 500 m^2. 5 standard solutions are available, relating to the heating system: heat pump with geothermal heating; wood firing stove and solar energy; automatic firing furnace e.g. by pellets or waste heat; and heat pump using outdoor air as heat source.

Annotation: In the list of criteria concerning ventilation only the *system solution 5 - heat pump using outdoor air as heat source* is being examined. The system includes all-season energy supply for heating and domestic hot water and must be certified by the D-A-CH[17]. The system solution 5 is not allowed for buildings situated above 1000 m a.s.l. (Regulation Nutzungsreglement MINERGIE®, 2010).

The verification of Minergie-P and P-ECO is only realized by the method of *System verification.* This building type is comparable to the German definition and is often seen as the “Swiss version of passive houses”.

The building types Minergie-ECO and Minergie-P-ECO have to fulfil the same criteria as Minergie- respectively Minergie-P-houses regarding energy performance

[17] D-A-ACH – an evaluated quality mark in cooperation of Germany, Austria and Switzerland. Certificated heat pumps have to follow the regulation EHPA-DACH, 2009.

etc., but with additional criteria on health and environmental sustainability. For verification, Minergie-ECO and –P-ECO houses are evaluated by a computer-tool (available for free download on the Minergie homepage, Minergie 2009), including must-criteria and additional criteria that are evaluated by a point system (compared to the klima:aktiv house method).

The additional criteria regarding health are divided into **light, noise** and **indoor air**, regarding environmental sustainability there are criteria on **production**[18], **resources**[19] and **deconstruction**[20]. The must-criteria are mainly relating to building materials (Minergie, 2009).

All Minergie building types are followed-up by spot test; if the test does not satisfy the required criteria, penalties have to be paid (Minergie, 2009).

3.10 Great Britain

Buildings in Great Britain are regulated in the national Building Regulations, with the latest amendment in 2009 (Planning Portal UK). A governmental definition of low-energy or passive houses is not available yet. Therefore the national regulation *Code for sustainable homes* contains a rating system divided into six levels, where buildings are measured by their sustainability. Level 6 is the highest reachable. Thus the code provides a rating of how sustainable and energy-efficient the building is, it has no clear definition of low-energy buildings, or at which level a building is rated as a low-energy building; besides the definition of level 6 as "*being a zero carbon home*" (Regulation CSH). Since 2008 all new social housing must be built to a minimum of Code level 3, for private housing the Code is voluntary (Department for Communities and Local Government, 2008).

The Building Research Establishment BRE is certifying passive houses according to the German PHI in Great Britain (PassivHaus UK).

3.10.1 Low-energy buildings

Concerning low-energy buildings the *Code for Sustainable Homes*, CSH has been published in the United Kingdom. The code is the national standard for sustainable building of new homes and measures the sustainability of a building on six levels for energy and water efficiency, where level six is the highest sustainability rating. The buildings are evaluated in nine categories: **Energy and CO_2 Emissions**; **Water**;

[18] Production – use of building materials with low environmental impact for production and conversion (Minergie, 2009).
[19] Resources – preferred use of renewable resources and building materials available for recycling (Minergie, 2009).
[20] Deconstruction – use of constructions simple to deconstruct and building materials that can be recycled or environmentally friendly decontaminated (Minergie, 2009).

Materials; **Surface Water Run-off**; **Waste**; **Pollution**; **Health and Wellbeing**; **Management** and **Ecology** (Communities and Local Government; Department for Communities and Local Government, 2008).
As the Code is not including a clear definition of low-energy buildings, and is more a sustainability-rating system, the Code will not be included in the list of standards in this thesis.

3.10.2 Passive house

In the United Kingdom passive houses are certified by BRE, an organisation responsible for consulting, research and testing concerning the built environment (BRE Group). The certification is being performed in cooperation with the German Passivhaus Institut; referring to their criteria and using the PHPP 2007 (PassivHaus UK).

3.11 Poland

In Poland no governmental definition of low-energy buildings is existent. The non-governmental definition of passive houses is referred to the German Passivhaus Institut (Engelund Thomsen & Wittchen, 2008).

3.11.1 Passive house

In Wroclaw, Poland a passive house has been built according to the criteria of the German passive house; only the peak load for space heating exceeds the German requirement, what is referred to the colder climate. Certification of passive houses according to an official definition is not available yet (E-mail correspondence Szymon Firlag).

3.12 Regulations

The within this study used regulation documents for each building type, for examining the criteria in chapter 4, are listed below. The standards have the state of latest amendments made until **January 1st 2010**.

SWEDEN	**Regulation**
Low-energy "Minienergi"	FEBY Minienergihus, 2009
Passive house	FEBY Passivhus, 2009
Zero-energy house	FEBY Passivhus, 2009
Certification	FEBY Application form – Certification, 2009
Verification	FEBY Application form – Verification, 2009
Referred regulations	BBR 16, BFS 2008:20
	FEBY Mätning och verifiering, 2009
	FEBY Metodrapport, 2009
NORWAY	
Low-energy	prNS 3700
Passive house	prNS 3700
Passive house **current**	Passivhaus Institut – Passivhäuser mit Wohnnutzung, 2009
Referred regulations	Temaveiledning Energi, 2007
DENMARK	
Low-energy house class 1	BR08
Low-energy house class 2	BR08
Passive house	Passivhaus Institut – Passivhäuser mit Wohnnutzung, 2009
Referred regulations	BR08, Appendix 1
FINLAND	
Low-energy house - RIL	RIL 249-2009
Passive house - RIL	RIL 249-2009
Referred regulations	D5, 2007
GERMANY	
RAL low-energy house	RAL-GZ 965; NEH brochure
RAL passive house	RAL-GZ 965

Passive house	Passivhaus Institut - Passivhäuser mit Wohnnutzung, 2009
Passive house suitable component	Criteria – Certification of ventilation systems; Testing procedure ventilation central, 2009; Prüfreglement Lüftungsgeräte - Beiblatt Feuchterückgewinnung, 2009
3-litre-house	No regulation available – *Criteria received from E-mail correspondence Heike Erhorn-Kluttnig*
Effizienzhaus 70	KfW Energieeffizient Bauen 153/154, 2009
Effizienzhaus 85	KfW Energieeffizient Bauen 153/154, 2009
Referred regulations	EnEV, 2009 WoFIV, 2003
AUSTRIA	
Low-energy -state-aided	RL MA 25 LGBl 27_2007
Passive house -state-aided	RL MA 25
3-liter house	3-Liter-Haus [21]
Klima:aktiv House	Klima:aktiv Haus, Klima:aktiv summary
Klima:aktiv Passive house	Klima:aktiv Passivhaus; Klima:aktiv summary
Referred regulations	OIB 6, 2007 OIB Guideline, 2007 OIB Elaboration, 2007
SWITZERLAND	
Minergie	Nutzungsreglement MINERGIE®, 2010
Minergie-P -Passive house	Nutzungsreglement MINERGIE-P®, 2010
Minergie-ECO / P-ECO	Nutzungsreglement MINERGIE-ECO®, 2009
Referred regulations	EHPA-DACH, 2009 Minergie Standard Lüftungssysteme, 2009
GREAT BRITAIN	
Passive house	Passivhaus Institut - Passivhäuser mit Wohnnutzung, 2009
POLAND	
Passive house	Passivhaus Institut - Passivhäuser mit Wohnnutzung, 2009

[21] 3-Liter-Haus, no certification regulation available, only the information on the website.

4 Criteria

The different building types and their regulations are examined divided into four subject areas – **Building envelope**, **Energy**, **Ventilation** and **Follow-up**. Due to great differences in terms, definitions, calculation methods and related areas, a country-specific explanation of the used terms will be given in an introducing chapter.

The listed criteria and limit values are almost exclusively requirements – Recommended values are only charted if determined as relevant, written in *grey italic* font. Furthermore, only criteria that are included in the regulation for low-energy buildings are listed, amongst others to show how well the building type is defined and how many requirements are set beyond the requirements of the national building regulation. Only if a limit value is explicitly referred to another building regulation, the value is listed in *grey* font.

For the Norwegian official definition of low-energy and passive houses shall be annotated, that the standard is not mandatory yet. Therefore these criteria are written in *italic* font.

4.1 Related areas and country-specific definitions

Sweden

$A_{temp+garage}$ The area is composed of the in the building regulation BBR 16 (BFS 2008:20) defined area A_{temp} and the additional area of garages *inside* the thermal building envelope.

A_{temp} is defined as the surface area of temperature-controlled spaces intended to be heated to more than 10°C, enclosed by the *inside* of the thermal building envelope. On attics placed storage areas that are *inside* the thermal building envelope are only included in A_{temp} if they are actively temperature-controlled.

E_{viktad} weighted, to the building “bought” and supplied energy E_{viktad} (by the building produced energy is not included), weighted by energy form factors *e* according to the energy carrier: *electrical energy, district heating energy, energy out of bio fuel, solar and wind energy.* The form of energy supply is being evaluated by its resource efficiency. Limit values for E_{viktad} are only *recommendation* values.

The weighted supplied energy is calculated by the equation (Regulation FEBY Minienergihus, 2009, equation 1, p.4):

$$E_{viktad} = \sum (e_{el} \cdot E_{el} + e_{fv} \cdot E_{fv} + e_{bp} \cdot E_{bp} + e_{s,v} \cdot E_{s,v}) \leq E_{krav} \quad (\text{kWh/m}^2 A_{temp+garage})$$

E_{el}, e_{el}	Delivered electrical energy and respective energy form factor
E_{fv}, e_{fv}	Delivered district heating energy and respective energy form factor
E_{bp}, e_{bp}	Delivered energy out of bio fuel, and respective energy form factor
$E_{s,v}, e_{s,v}$	Delivered solar and wind energy, and respective energy form factor

and has always to be lower than the in the building regulation BBR 16 regulated E_{krav}.
Due to the ongoing discussion about climate zone related energy form factors, recommendation factors are given: e_{el}=2, e_{fv}=e_{bp}=1 and $e_{s,v}$=0. The recommended limit values for E_{viktad} are based on these form factors.

E_{krav} annual bought energy, defined in the regulation BBR 16, BFS 2008:20 and relating to the area A_{temp};
Includes energy for *heating, comfort cooling, domestic hot water and auxiliary energy*. Floor heating or towel dryers included; household electricity is not included.

The limit values in the national building regulation are (Regulation BRR 16, BFS 2008:20):

	Heated by electrical energy	Heated by other than electrical energy
Zone I	$E_{krav} \leq 95$ *kWh/m²a*	$E_{krav} \leq 150$ *kWh/m²a*
Zone II	$E_{krav} \leq 75$ *kWh/m²a*	$E_{krav} \leq 130$ *kWh/m²a*
Zone III	$E_{krav} \leq 55$ *kWh/m²a*	$E_{krav} \leq 110$ *kWh/m²a*

Annotation: E_{krav} relates to A_{temp} and E_{viktad} relates to $A_{temp+garage}$.

The different climate zones are defined as (Regulation BBR 16, BFS 2008:20):

Zone I	North-Sweden	*Norrbottens, Västerbottens* and *Jämtlands counties*
Zone II	Mid-Sweden	*Västernorrlands, Gävleborgs, Dalarnas* and *Värmlands counties*

Zone III	South-Sweden	*Västra Götalands, Jönköpings, Kronobergs, Kalmar, Östergötlands, Södermanlands, Örebro, Västmanlands, Stockholms, Uppsala, Skåne, Hallands, Blekinge* and *Gotlands counties*

Norway

Annotation: The proposal for the standard includes meanderings to the national building standard TEK 07 such as (Regulation prNS3700):

- For the calculation of the buildings energy demand other input values for internal heat gains from appliances shall be used; due to the precondition in low-energy and passive houses of using energy efficient equipment.
- In comparison to the national building standard, the prNS3700 proposes using climate data referring to the buildings situation.
- The standard prNS3700 proposes the use of CO_2 factors for evaluating the buildings energy use.

A_{fl} *heated area* of BRA; defined in the regulation NS 3940 the BRA is the building gross area minus the area of outer walls, i.e. the buildings area *inside* the thermal building envelope. The calculation of *heated* BRA shall be made according to NS 3031.

Annotation: An area is defined as *heated* if heat is supplied to the area by the buildings heating system (NS3031:2007).

E annual *net energy demand for heating*; relating to the yearly mean temperature θ_{ym} and the area A_{fl}.
The energy demand for heating includes *space heating* and *ventilation heating* (e.g. energy for the heating battery of the ventilation system). Domestic hot water is not included. Calculation according to NS 3031.

In comparison to the net energy demand for heating, the overall heating demand is including the *net energy demand for space heating, ventilation heating* and *domestic hot water* (prNS 3700).

Annotation: The regulation prNS 3700 annotates that the overall heating demand fully can be covered by thermal energy, which is defined as energy not coming from fossil resources, as e.g. solar energy, wind energy or hydropower in combination with heat pumps or other necessary equipment (E-mail correspondence Harald Vidnes).

θ_{ym} yearly mean temperature; defined in the regulation NS-EN ISO 15927-1.

Total supplied, delivered energy calculation according to NS 3031 and relating to the area A_{fl}; defined as the total amount of energy supplied to the building, expressed per energy supply form (district heat, electrical heat, fuel etc.) and weighted by energy form factors (or defined as the efficiency of the energy supply form), that is needed to cover the buildings *total net energy demand* (NS3031:2007).

Total net energy demand calculated according to NS 3031; includes the buildings total energy demand. The efficiency of the heating system is not included in the calculation of the *net energy demand* (Regulation Temaveiledning Energi, 2007).

The in the total net energy demand included energy posts are: *space heating, ventilation heating, domestic hot water, fans, pumps, lighting, technical systems* and *cooling*. Household electricity is not included (NS3031:2007).

Primary energy demand

Option A limit value for the buildings annual CO_2-emission in kg/m^{2}a, relating to the area A_{fl}, as the amount of total supplied energy is being multiplied by CO_2 factors. Relating to the energy supply form, given CO_2 factor values as listed in table 2 shall be used (Regulation prNS3700, p.11):

Energy supply form	CO_2 factor
Biomass	14 g/kWh
District heat	231 g/kWh
Gas	211 g/kWh
Oil	284 g/kWh
Electricity from power plant	395 g/kWh

Table 2: CO_2 factors according to energy supply form.

Option B a limit value, prescribing a certain percentage of the overall heating demand (net energy demand for *space heating, ventilation* and *domestic hot water*) that shall be covered by renewable energy. The percentage of the energy supply form that is accounted as renewable is given is table 3 (Regulation prNS3700, p. 11):

Energy supply form	Percentage of renewable energy
Biomass	100 %
District heat	45 %
Gas	0 %
Oil	0 %
Electricity from power plant	0 %

Table 3: Percentage of supply form accounted as renewable energy.

Denmark

A heated *"etageareal"* (engl.: floor area), defined in the additional regulation *Bilag 1 – Beregningsregler*, as the sum of all heated gross areas on each floor of the building, measured from the outside of the thermal building envelope (Regulation BR08, Appendix 1).
Heated areas are defined by being heated to at least 15°C (Regulation BR08).

E annual to the building supplied energy in form of electricity, district heating, oil and/or natural gas; like the in Sweden defined "weighted energy" E_{viktad}; where the buildings annual energy demand, supplied by different energy forms is weighted by energy form factors.

The buildings energy use is including energy for *heating, ventilation, active cooling* and *domestic hot water* and shall be calculated according to SBi 213. Household electricity is not included (Regulation BR08). SBi 213 is a guideline for the calculation program BE 06 regarding energy performance of buildings (E-mail correspondence Finn Nygaard Johansen).

Finland

In the RIL 249-2009 the energy performance of buildings is described in two categories; low-energy and passive houses. Their energy performance is defined by:

- Net energy demand for *space heating & cooling* and *ventilation heating & cooling*
- Delivered energy use for *space heating & cooling* and *ventilation heating & cooling*

Low-energy buildings (M) are defined by the criteria:

- Net energy demand must be between 26-50 kWh/m^{2}a
- Delivered energy use must be between 26-50 kWh/m^{2}a

Passive houses (P) are defined by the criteria:

- Net energy demand must not exceed 25 kWh/m^{2}a
- Delivered energy use must not exceed 25 kWh/m^{2}a

It is additionally specified (Regulation RIL 249-2009, p.29), that the net energy demand value is valid for a system efficiency of 1.0, and is being reduced or increased if the system efficiency is < 1.0 or respectively > 1.0 relating to the delivered energy form. This specification leads to the fact that the limit value for the delivered energy use is the required energy level.

$A_{br,h}$ *heated gross floor area*; i.e. the heated areas of A_{br}. Heated rooms have at least a temperature of 17°C (Regulation RIL 249-2009).

A_{br} total *gross floor area,* defined in the building regulation D5 as the sum of floor areas, heated or not heated, including the thermal building envelope, i.e. the outer walls (Regulation D5, 2007).

Annotation: In the Finnish building regulation the total gross floor area A_{br} is used as related area for buildings energy use. In RIL 249-2009 the *heated gross floor area* is used.

E annual *delivered energy* in kWh/m^2, relating to the gross area $A_{br,h}$.
It is calculated according to the used heating and cooling systems and the supplied energy (i.e. as district heating, electricity or fuel energy); primary energy factors are not used. *E* includes: energy use for *space heating, cooling and ventilation heating, cooling* and *auxiliary energy* of this systems (circulation pumps etc.). Domestic hot water and household electricity are not included, neither is the fan energy use of the ventilation system.

Calculation of the annual delivered energy is made according to the equation 3.1 in the Regulation D5. When different energy carriers are used, equation 3.1 shall be used individually for each energy carrier, to build the sum for the *total* delivered energy.

$$Q_{lämmitys,osto} = Q_{lämmitys} / \eta_{lämmitys} \quad \text{(kWh)} \qquad \text{(Reg D5, equation 3.1, p.13)}$$

$Q_{lämmitys,osto}$ = *heating energy delivered to the building, kWh*
$Q_{lämmitys}$ = *heating energy use (energy for the distribution system), kWh*
$\eta_{lämmitys}$ = *efficiency of the energy generation (boiler efficiency), -*

According to Regulation D5, $Q_{lämmitys}$ is calculated for space heating and for domestic hot water; according to RIL 249-2009 domestic hot water shall not be included.

The limit values for E apply to mid-Finland (*Jyväskylä*); for buildings situated in south- (*Etelä-Suomi*) and north-Finland (*Pohjois-Suomi*) the limit value for mid-Finland is being multiplied with degree-day correction factors for south- respectively north-Finland (RIL 249-2009).

The degree-day correction factors for low-energy buildings are (RIL 249-2009, p.29):

South-Finland	0.88
North-Finland	1.27

For passive houses (RIL 249-2009, p.29):

South-Finland	0.85
North-Finland	1.33

Annotation: Guideline values for primary energy use of low-energy and passive houses are given in RIL 249-2009 (p.33), but due to that official primary energy factors are not available yet and the calculation method is under preparation, the given values are only rough estimates. The annual primary energy demand for low-energy buildings should be lower than *180* kWh/m^{2}a; for passive houses it should lie between *135-140* kWh/m^{2}a.

Germany

A_{net} *net area* inside the thermal building envelope, defined as the *living area,* which is regulated in the WoFIV. Areas accounted to the living area are also conservatories, balconies, loggias, terraces and roof gardens; not included are basements, storage outside of the dwelling, laundries, boiler rooms and garages. To sum up the areas to the *net area*, areas of rooms with a height between 1-2 m are factorized by 0.5, unheated conservatories by 0.5, and balconies, loggias, terraces and roof gardens by 0.25 (usually 0.25 but maximal 0.5) (Regulation WoFIV, 2003).

A enclosing, heat transmitting area; calculated according to DIN EN ISO 13789 case *"Außenabmessung"*, including the *outer dimensions* of a heated area/zone.

A_N buildings net area (germ.: *Gebäudenutzfläche*), as regulated in EnEV, 2009. For residential buildings A_N is calculated as followed:

$$A_N = 0.32\, m^{-1} \cdot V_e \qquad (\mathrm{m}^2)$$

If the mean value of the *height between floors h_G*, measured from ground level of one floor to ground level of the upper floor, is more than 3 m or less than 2,5 m, the net area A_N shall be calculated by the equation (EnEV, 2009):

$$A_N = \left(\frac{1}{h_G} - 0.04\, m^{-1}\right) \cdot V_e \qquad (\mathrm{m}^2)$$

V_e Heated building volume in m³; the by the heat transmitting area *A* enclosed volume, i.e. enclosed by the thermal building envelope (Regulation EnEV, 2009).

V heated air volume in m³; the definition is dependent on the calculation method of primary energy demand (2 options): V is calculated as regulated in either DIN V 18599-1 or DIN EN 832. Simplified the equation below can be used (Regulation EnEV, 2009):

$V = 0.76 \cdot V_e \, (\mathrm{m}^3)$ for residential buildings up to three stories
$V = 0.80 \cdot V_e \, (\mathrm{m}^3)$ for other residential buildings

For limit values referring to the EnEV 2009 (Effizienzhaus 70, 85):

Q_P annual primary energy demand; including energy for *heating, cooling, ventilation* and *domestic hot water*, multiplied by primary energy form factors relating to the energy supply form (electrical energy, district energy, biomass etc.). Q_P of the EnEV2009 is relating to the area A_N.

For residential buildings Q_P can be calculated according to DIN V 18599 alternatively to EN 382.

In the EnEV the limit value for Q_P is set in form of: The primary energy demand must not exceed the primary energy demand of a given *reference building*, with the listed preconditions and inputs given in EnEV 2009 Appendix 1. Out of this reference building the limit value for Q_P must be calculated (Regulation EnEV, 2009).

For Passive houses certified by the Passivhaus Institut:

$Q_{P\ PHPP}$ annual primary energy demand, relating to the *net area* A_{net}; calculated in accordance to the PHPP Including energy for *heating, domestic hot water, auxiliary energy for heating and ventilation* and *household electricity.*

P_H peak load for space heating, calculated by PHPP and relating to the area A_{net}.

For all building types:

Q_H annual energy demand for heating, in kWh/m²a.
For RAL-houses as for Passive houses of the PHI the calculation method of the PHPP is prescribed. The limit value is relating to A_{net}.

H'$_T$ specific heat loss by transmission in *W/(m²K)*. Regulated in the EnEV 2009, it is calculated by the parameters V_B and A and relating to the heat transmitting building zone area *A*.

H'$_T$ is calculated by (Regulation EnEV, 2009):

$$H'_T = \frac{H_T}{A} \qquad \text{W/(m}^2\text{K)}$$

H_T = calculated heat losses by transmission in W/K; calculation method DIN EN 832

A = enclosing, heat transmitting area in m²

Limit values regulated in the EnEV, 2009:

Residential buildings		Limit value for H'$_T$
Detached	$A_N \leq 350$ m²	H'$_T$ = 0.40 W/(m²K)
	$A_N > 350$ m²	H'$_T$ = 0.50 W/(m²K)
One-side detached		H'$_T$ = 0.45 W/(m²K)
Other residential buildings		H'$_T$ = 0.65 W/(m²K)

$Q_{P\ 3L}$ annual primary energy demand for 3-litre-houses; in kWh/m² relating to the area A_N. Calculation shall be made according to the European methods in DIN 4108-6 und DIN 4701-10. The primary energy demand for 3-litre-houses includes energy for *heating* and its *auxiliary energy*, but not household energy or domestic hot water (E-mail correspondence Heike Erhorn-Kluttig).

Austria

$A_{BGF,\ cond}$ conditioned area of the *brut ground area* A_{BGF} (germ.: *Brutto-Grundfläche*). Regulated in ÖNORM B 1800 A_{BGF} is measured from the *outside* of the thermal building envelope.

An area is defined as *conditioned*, when there is a demand of conditioning (heating, cooling, ventilation or humidification) for keeping the required boundary conditions regarding temperature, ventilation and light (Regulation OIB Guideline, 2007).

A_{net} see related areas Germany.

l_c the characteristic length; form factor for a buildings compactness. The calculation of l_c is regulated in ÖNORM B8110 and H5055.

$l_c = V_B / A_B$ (m) (Energiesparhaus.at)

V_B = *heated brut volume,* m^3

A_B = *surface area of the thermal building envelope,* m^2

EEB Annual *end energy demand* including the energy need for heating (HWB), domestic hot water, ventilation, cooling, lighting and auxiliary energy (Regulation OIB Guideline, 2007). Household energy is not included.

The *EEB* (Q_{EEB}) is calculated as followed (OIB Guideline, 2007, p.7):

$$Q_{EEB} = Q_{HEB} + Q_{KEB} + Q_{BFEB} + Q_{LFEB} + Q_{LENI} \quad \text{(kWh/a)}$$

Q_{HEB} = *annual heating energy demand (HEB), kWh/a*

Q_{KEB} = *annual cooling energy demand, kWh/a (only for non-residential buildings)*

Q_{BFEB} = *annual energy demand for humidification, kWh/a (only for non-residential buildings)*

Q_{LFEB} = *annual energy demand for mechanical ventilation, kWh/a (only for non-residential buildings)*

Q_{LENI} = *annual energy demand for lighting, kWh/a (only for non-residential buildings)*

For residential buildings only the *HEB* shall be accounted, therefore the *EEB* is equivalent to the *HEB.*

EEB$_{BGF}$ specific *end energy demand*, relating to the buildings conditioned $A_{BGF,cond}$ (Regulation OIB Guideline, 2007).

HEB annual heating energy demand; calculated according to ÖNORM H 5056 (Regulation OIB Guideline, 2007); including energy for heating (HWB) and *domestic hot water*. (Regulation OIB Elaboration, 2007)

HWB annual heating demand; calculated according to ÖNORM B 8110-6; It is defined as the amount of heating energy that is needed to keep the ideal temperature of 20°C in temperature-regulated rooms (Regulation Klima:aktiv Summary).

Annotation: $HEB \neq HWB$ (Regulation OIB Elaboration, 2007)

HEB_{3L} limit value for the annual energy demand for heating for 3-Liter-houses. The calculation method is prescribed to using either

- VESH[22] of the Energy Institute Vorarlberg, related area $A_{BGF, cond}$
- GEQ[23], related area $A_{BGF, cond}$
- PHPP of the Passivhaus Institute, related area A_{net}

In case of doubt the result according to GEQ is valid.

$HWB_{BGF,WG}$ annual heating demand per m^2 related to the conditioned area $A_{BGF,cond}$; used at state-aided low-energy buildings.

The limit value for residential buildings $HWB_{BGF,WG}$ is calculated depending on the form factor l_c and whether the building is equipped with mechanical ventilation with or without heat recovery (germ.: *Wohnraumlüftung*) or not (Regulation RL MA 25):

$HWB_{BGF,WG} < 15 \cdot (1 + 2.5 / l_c)$ without *Wohnraumlüftung*
$HWB_{BGF,WG} < 11 \cdot (1 + 2.5 / l_c)$ with *Wohnraumlüftung*

For buildings with $l_c < 1.25$, $l_c = 1.25$ shall be used,
for buildings with $l_c > 5.00$, $l_c = 5.00$ shall be used.
The calculated limit value shall always be rounded to an integer.

Annotation: In the Regulation RL MA 25 the term "*Wohnraumlüftung*" is not defined. In consultation with the responsible organisation, the correct definition is mechanical ventilation with supply and exhaust air, equipped with heat recovery (E-mail correspondence Martin Groyß).

HWB_{PHPP} specific annual heating demand calculated according to PHPP and relating to the area A_{net}; used for state-aided passive houses and klima:aktiv passive houses.
In comparison to the limit value of $HWB_{BGF,WG}$, the limit value HWB_{PHPP} is not depending on the buildings compactness, i.e. the l_c factor.

$HWB_{BGF,WG,Ref}$ specific annual heating demand, relating to the area $A_{BGF,cond}$ and calculated in accordance to OIB 6; term used for k:a houses.

[22] VESH – Vorarlberger Energiespar-Haus
[23] GEQ – Gebäude Energie Qualität; software for calculation of energy demand and issuing energy certificates (Zehentmayer Software GmbH).

The limit value is depending on the buildings characteristic length l_c, shown in figure 11.

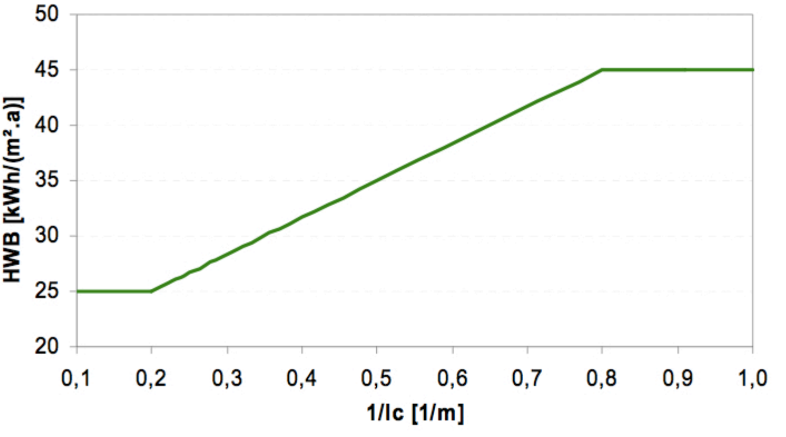


Figure 11: Limit values for $HWB_{BGF,WG,Ref}$ for klima:aktiv houses, depending on l_c (Regulation Klima:aktiv Haus, p. 29)

PEB_{PHPP} annual primary energy demand, calculated according to PHPP and therefore related to A_{net}. Including energy for *heating, domestic hot water, auxiliary energy for heating and ventilation* and *household energy*.

$PEB_{EBF,\ building\ services}$ annual primary energy demand for the building services (germ.: *Haustechnik*), i.e. PEB_{PHPP} without household energy; calculated according to PHPP and therefore related to the area A_{net}.

P_H Peak load for space heating (germ.: *Heizlast*) in W/m^2; calculated according to the PHPP, relating to the conditioned area A_{net}.

Switzerland

A_E according to SIA 416/1, the relating area A_E is defined as the sum of all *conditioned* floor areas inside the thermal building envelope. Conditioned areas are defined as areas in need of heating or cooling.

A_{th} area of the thermal building envelope in m^2. Calculated by the sum of all areas adjoining to outdoor temperatures, unheated areas, heated neighbouring areas and ground. Areas to unheated, neighbouring heated areas and ground are multiplied by reduction factors, whereof the reduction factor for heated areas is 0 and therefore these areas are not actually accounted (E-mail correspondence Antje Heinrich).

$Q_{h\ (Standard)}$ annual energy demand for heating relating to the area A_E; calculation method according to SIA 380:1/2009.

$Q_{h,li}$ limit value for annual heating demand, relating to the area A_E.
The limit value is dependent on the area of the thermal building envelope A_{th} and the area A_E. According to SIA 380:1/2009 the limit value of $Q_{h,li}$ for residential buildings is calculated by the equations (E-mail correspondence Antje Heinrich):

$$Q_{h,li} = Q_{h,li0} + \Delta Q_{h,li} \cdot (A_{th} / A_E) \qquad (\text{kWh/m}^2\text{a})$$

whereof:

	$Q_{h,li0}$, kWh/m²a	$\Delta Q_{h,li}$, kWh/m²a
Apartment building	55	65
Single family house	65	65

$E_{Minergie}$ Minergie-limit value; *weighted* limit value for annual energy for *heating, hot domestic water* and *ventilation*, relating to the area A_E and calculated by the equation (Regulation Nutzungsreglement MINERGIE®, 2010):

$$\frac{Q_{h,eff}}{3,6} \cdot \frac{g}{\eta} + \frac{Q_{WW}}{3,6} \cdot \frac{g}{\eta} + \frac{E_{LK}}{3,6} \cdot g \leq E_{Minergie} \qquad (\text{kWh/m}^2)$$

$Q_{h,eff}$ = *heating demand (including effective heat losses by ventilation through the thermal building envelop area A_{th}), kWh/m². Areas with greater height than 3m are can be corrected.*[24]

Q_{WW} = *heating demand for domestic hot water, kWh/m²*
E_{LK} = *electricity for ventilation, kWh/m²*
g = *weighting factor relating to form of energy supply*
η = *efficiency of heating system component*

The values of energy demand are calculated according to SIA 380/1:2009, the weighting factors *g* are given in the Minergie-Regulation.

[24] Since the introduction of the national standard SIA 380/1:2007, height-correction of rooms is not allowed anymore. Hence, Minergie has its own calculation method concerning this; the use is voluntary. For verifying the limit value for Q_h the correction must not be used; it is only valid in the calculation of the Minergie-limit value $E_{Minergie}$ (Minergie, 2008).

For buildings calculated by a climate reference above 800 m a.s.l. the Minergie-limit value $E_{Minergie}$ is raised by the additional values in figure 12 (Regulation Nutzungsreglement MINERGIE®, 2010):

Klimazuschlag

Bei Gebäuden, deren MINERGIE®-Nachweis mit einer Klimastation **höher als 800 m.ü.M** berechnet wird, gelten die folgenden Zuschläge zum MINERGIE®-Grenzwert.

Klimastation gemäss SIA 2028	Klimazuschlag in kWh/m²
Adelboden	0
Davos	4
Disentis	0
Engelberg	2
Grand-St-Bernard	8
La Chaux-de-Fonds	0

Klimastation SIA 2028	Klimazuschlag in kWh/m²
Montana	0
Robbia	0
Samedan	8
San Bernadino	2
Scuol	2
Zermatt	2

Figure 12: Climate reference stations above 800 m a.s.l.

$E_{Minergie-P}$ calculated as $E_{Minergie}$ but without additions regarding buildings situated above 800 m a.s.l. (Regulation Nutzungsreglement MINERGIE-P®, 2010).

$q_{h-MP\ max}$ specific peak load for space heating, relating to the area A_E. The limit value is only a criterion if the buildings mean heating is provided by the ventilation system.

$q_{h-MP\max}$ is calculated by a specific SIA-tool (SIA 380) by accounting only 50% of electrical heat gains. For the dimension of technical systems and its components this simplified calculation of $q_{h-MP\max}$ is not allowed; in these cases calculation according to the SIA 380/1:2009 shall be made.

4.2 Criteria and limit values in national standards

Annotation: Some criteria are listed in different fonts, such as

Grey font	– limit values regulated in the national building regulation
Grey *italic* font	– recommended limit values and advices regulated in the low-energy building standard
Black *italic* font	– limit values relating to the Norwegian standard prNS 3700, which has not been set yet.

Criteria referred to German PHI are relating to the German passive house definition of the Passivhaus Institut. Some limit values relating to the German PHI are marked with *"*"*; these are requirements not included in the regulation but announced on the homepage (Passiv.de).

4.2.1 Building envelope

Concerning the building envelope criteria such as U-values for windows and outer walls, and limit values for air leakage have been examined.
For windows, those facing outdoor temperatures are listed. If specified, it is noted if the U-value includes frame and glass. Concerning air leakage, the limit value for n_{50} at a pressure difference of 50 Pa is listed.

	U-values		Air tightness
	windows	outer walls	n_{50}
SWEDEN			
	including frame+glass		
Low-energy / Minienergi	Mean[25] ≤ 1.00 W/m²K	-	≤ 0.3 l/s m²
Passive house	Mean[25] ≤ 0.90 W/m²K	-	≤ 0.3 l/s m²
Zero-energy house	Mean[25] ≤ 0.90 W/m²K	-	≤ 0.3 l/s m²
NORWAY			
	including frame+glass		
Low-energy	*≤ 1.2 W/m²K*	*≤ 0.18 W/m²K*	*≤ 1.0 h⁻¹*
Passive house	*≤ 0.8 W/m²K*	*≤ 0.15 W/m²K*	*≤ 0.6 h⁻¹*

[25] Mean – buildings mean U-value of windows and glazed areas (Regulation FEBY Minienergihus, 2009)

Passive house *current*	German PHI	German PHI	German PHI	
DENMARK				
Low-energy class 1	-	-	≤ 1.5 h^{-1} (BR08)	
Low-energy class 2	-	-	≤ 1.5 h^{-1} (BR08)	
Passive house	German PHI	German PHI	German PHI	
FINLAND				
Low-energy	-	-	-	
	0.8-0.9 W/m²K	*0.12-0.14 W/m²K*	*≤ 0.8 h^{-1}*	
Passive house RIL	-	-	-	
	0.7-0.8 W/m²K	*0.08-0.12 W/m²K*	*≤ 0.6 h^{-1}*	
GERMANY				
RAL Low-energy	-	-	≤ 1.0 h^{-1}	
RAL Passive house	-	-	≤ 0.6 h^{-1}	
Passive house	≤ 0.8 W/m²K *	≤ 0.15 W/m²K *	≤ 0.6 h^{-1}	
3-litre house	-	-	-	
Effizienzhaus 70	-	-	-	
Effizienzhaus 85	-	-	-	
AUSTRIA				
Low-energy (state-aided)	(OIB 6)	(OIB 6)	Type S	Type FT
	Windows and glazed doors: ≤ 1.4 W/m²K Other vertically glazed areas: ≤ 1.7 W/m²K	≤ 0.35 W/m²K [26]	≤ 3 h^{-1}	≤ 1.5 h^{-1}

[26] This limit value is for outer walls in general; additional U-values are given for outer walls with small areas or walls adjoining other buildings (Regulation OIB 6, 2007)

	Rooftop windows: ≤ 1.7 W/m^2K Other horizontally glazed areas: ≤ 2.0 W/m^2K			
Passive house (state-aided)	-	-	≤ 0,6 h^{-1}	
	< 0.8 W/m^2K	*< 0.15 W/m^2K*		
3-litre house	-	-	≤ 1,0 h^{-1}	
k:a passive house	(OIB 6)	(OIB 6)	≤ 0.6 h^{-1}	
k:a house	(OIB 6)	(OIB 6)	Type FT ≤ 1.5 h^{-1}	Type FTX ≤ 1.0 h^{-1}
SWITZERLAND				
Minergie / Minergie-ECO				
System verification	-	-	-	
Standard solutions	ME-Modul 1.00	ME-Modul 0.15	-	
Minergie-P / Minergie P-ECO	-	-	≤ 0.6 h^{-1}	
GREAT BRITAIN				
Passive house	German PHI	German PHI	German PHI	
POLAND				
Passive house	German PHI	German PHI	German PHI	

Additional definitions: Switzerland

ME-Modul	certificated modules for windows and walls. Window-modules are regulated by the Swiss association for windows and facades (FFF); Wall-modules are regulated by Minergie itself (Minergie, 2009).	
Windows	ME-Modul 1.00	U_W-value of 1.00 W/m^2K, including frame and glass
Walls	ME-Modul 0.15	U-value of 0.15 W/m^2K

4.2.2 Energy

In the list of criteria concerning energy, peak load for space heating *P* and the annual energy demand/use *E* have been examined, whereof the energy use is listed relating to the type of energy level (primary, end or final energy).

SWEDEN

	P_{max}	E: primary energy	E: end energy	E: final energy
Low-energy, Minienergi				
Zone I	20 W/m²a $A_{temp+garage}$	-	E_{viktad} ≤ 88 kWh/m²a $A_{temp+garage}$	-
Zone II	18 W/m²a $A_{temp+garage}$	-	E_{viktad} ≤ 84 kWh/m²a $A_{temp+garage}$	-
Zone III	16 W/m²a $A_{temp+garage}$	-	E_{viktad} ≤ 80 kWh/m²a $A_{temp+garage}$	-
< 200 m²:				
Zone I	24 W/m²a $A_{temp+garage}$	-	-	-
Zone II	22 W/m²a $A_{temp+garage}$	-	-	-
Zone III	20 W/m²a $A_{temp+garage}$	-	-	-
Passive house				
Zone I	12 W/m²a $A_{temp+garage}$	-	E_{viktad} ≤ 68 kWh/m²a $A_{temp+garage}$	-
Zone II	11 W/m²a $A_{temp+garage}$	-	E_{viktad} ≤ 64 kWh/m²a $A_{temp+garage}$	-
Zone III	10 W/m²a $A_{temp+garage}$	-	E_{viktad} ≤ 60 kWh/m²a $A_{temp+garage}$	-
< 200 m²:				
Zone I	14 W/m²a $A_{temp+garage}$	-	-	-
Zone II	13 W/m²a $A_{temp+garage}$	-	-	-
Zone III	12 W/m²a $A_{temp+garage}$	-	-	-
Zero-energy house	see Passive house	-	E ≤ produced energy	

NORWAY

	P_{max}	E: primary energy	E: end energy	E: final energy
Low-energy				*net energy demand for **heating***
O_{ym} ≥ 5°C	-	***Option A**: CO_2: 35 kg/m²a* ***Option B**: 15 %*	-	A_{fl}<200m²: *E ≤ 30+5((200-A_{fl})/100) A_{fl}* A_{fl}≥200m²: *E ≤ 30 kWh/m²a A_{fl}*
O_{ym} < 5°C	-	***Option A**: CO_2: 35 kg/m²a* ***Option B**: 15 %*	-	A_{fl}<200m²: *E ≤ 30+ 5((200-A_{fl})/100) + 5(5-O_{ym}) kWh/m²a A_{fl}* A_{fl}≥200m²: *E ≤ 30 + 5(5-O_{ym}) kWh/m²a A_{fl}*
Passive house				
O_{ym} ≥ 5°C	-	***Option A**: CO_2: 25 kg/m²a* ***Option B**: 30 %*	-	A_{fl}<200m²: *E ≤ 15 + 3((200-A_{fl})/100) A_{fl}* A_{fl}≥200m²: *E ≤ 15 kWh/m²a A_{fl}*
O_{ym} < 5°C	-	***Option A**: CO_2: 25 kg/m²a* ***Option B**: 30 %*	-	A_{fl}<200m²: *E ≤ 15 + 3((200-A_{fl})/100) + 3(5-O_{ym}) kWh/m²a A_{fl}* A_{fl}≥200m²: *E ≤ 15 + 3(5-O_{ym}) kWh/m²a A_{fl}*
Passive house *current*	German PHI	German PHI	German PHI	German PHI

DENMARK

	P_{max}	primary energy	E end energy		final energy
Low-energy class 1	-	-	E ≤ (35 + 1100/A) kWh/m²a	A	-
Low-energy class 2	-	-	E ≤ (50 + 1600/A) kWh/m²a	A	-
Passive house	German PHI	German PHI	German PHI		German PHI

FINLAND

		P_{max}	primary energy	E end energy		final energy
Low-energy						
			180 kWh/m²a $A_{br.h}$			
M-30	mid-Finland	-	-	E ≤ 30 kWh/m²a	$A_{br,h}$	-
	south-Finland	-	-	E ≤ 26,4 kWh/m²a	$A_{br,h}$	-
	north-Finland	-	-	E ≤ 38,1 kWh/m²a	$A_{br,h}$	-
M-35	mid-Finland	-	-	E ≤ 35 kWh/m²a	$A_{br,h}$	-
	south-Finland	-	-	E ≤ 30,8 kWh/m²a	$A_{br,h}$	-
	north-Finland	-	-	E ≤ 44,45 kWh/m²a	$A_{br,h}$	-
M-40	mid-Finland	-	-	E ≤ 40 kWh/m²a	$A_{br,h}$	-
	south-Finland	-	-	E ≤ 35,2 kWh/m²a	$A_{br,h}$	-
	north-Finland	-	-	E ≤ 50,8 kWh/m²a	$A_{br,h}$	-
M-45	mid-Finland	-	-	E ≤ 45 kWh/m²a	$A_{br,h}$	-
	south-Finland	-	-	E ≤ 39,6 kWh/m²a	$A_{br,h}$	-
	north-Finland	-	-	E ≤ 57,15 kWh/m²a	$A_{br,h}$	-
M-50	mid-Finland	-	-	E ≤ 50 kWh/m²a	$A_{br,h}$	-
	south-Finland	-	-	E ≤ 44 kWh/m²a	$A_{br,h}$	-
	north-Finland	-	-	E ≤ 63,5 kWh/m²a	$A_{br,h}$	-
Passive house RIL						
			135-140 kWh/m²a $A_{br.h}$			
P-15	mid-Finland	-	-	E ≤ 15 kWh/m²a	$A_{br,h}$	-
	south-Finland	-	-	E ≤ 12,75 kWh/m²a	$A_{br,h}$	-
	north-Finland	-	-	E ≤ 19,95 kWh/m²a	$A_{br,h}$	-
P-20	mid-Finland	-	-	E ≤ 20 kWh/m²a	$A_{br,h}$	-
	south-Finland	-	-	E ≤ 17 kWh/m²a	$A_{br,h}$	-
	north-Finland	-	-	E ≤ 26,6 kWh/m²a	$A_{br,h}$	-
P-25	mid-Finland	-	-	E ≤ 25 kWh/m²a	$A_{br,h}$	-
	south-Finland	-	-	E ≤ 21,25 kWh/m²a	$A_{br,h}$	-
	north-Finland	-	-	E ≤ 33,25 kWh/m²a	$A_{br,h}$	-

GERMANY

	P_{max}	primary energy	E end energy	final energy
RAL Low-energy				
	-	-	-	$H'_T \leq 0{,}21 + 0{,}1\ V_e/A$ W/m^2K A **OR** $Q_h \leq 40\ kWh/m^2a$ A_{net}
RAL Passive house				
	-	$Q_{P\ PHPP} \leq 120\ kWh/m^2a$ A_{net}	-	$Q_h \leq 15\ kWh/m^2a$ A_{net}
Passive house				
	$P_H \leq 10\ W/m^2$ A_{net} **OR** Q_h	$Q_{P\ PHPP} \leq 120\ kWh/m^2a$ A_{net}	-	$Q_h \leq 15\ kWh/m^2a$ A_{net} **OR** P_H
3-litre house				
	-	$Q_{P\ 3L} \leq 33{,}3\ kWh/m^2a$ A_N	-	-
Effizienzhaus 70				
	-	$Q_P \leq 70\%$ of the limit value in EnEV 2009	-	$H'_T \leq 85\%$ of the limit value in EnEV 2009
Effizienzhaus 85				
	-	$Q_P \leq 85\%$ of the limit value in EnEV 2009	-	$H'_T \leq 100\%$ of the limit value in EnEV 2009

AUSTRIA

	P_{max}	primary energy	E end energy	final energy
Low-energy, state-aided				
	-	-	-	*with "Wohnraumlüftung"* $HWB_{BGF,WG} \leq 11 \times (1 + 2{,}5 / l_c)\ kWh/m^2a$ $A_{BGF,\ cond}$ *without "Wohnraumlüftung"* $HWB_{BGF,WG} \leq 15 \times (1 + 2{,}5 / l_c)\ kWh/m^2a$ $A_{BGF,\ cond}$
Passive house, state-aided				
	$P_H < 10\ W/m^2$ A_{net}	$PEB_{PHPP} < 120\ kWh/m^2a$ A_{net} **OR** $PEB_{PHPP\ building\ services} < 40\ kWh/m^2a$ A_{net}	-	$HWB_{PHPP} < 15\ kWh/m^2a$ A_{net}
3-litre house				
	-	-	-	$HEB_{3L} \leq 30\ kWh/m^2a$ $A_{net} / A_{BGF,cond}$
k:a passive house				
	-	$PEB_{PHPP\ building\ services} \leq 65\ kWh/m^2a$ A_{net}	-	$HWB_{PHPP} \leq 15\ kWh/m^2a$ A_{net}
k:a house				
	-	-	-	$HWB_{BGF,WG,Ref} = 25\text{-}45\ kWh/m^2a$ $A_{BFG,\ cond}$ relating to the buildings l_c value

SWITZERLAND

	P_{max}	E primary energy	E end energy	E final energy
Minergie / Minergie-ECO				
System verification	-	-	$E_{Minergie} \leq$ 38 kWh/m²a A_E	Q_h (Standard) ≤ 90% $Q_{h,li}$ A_E
Standard solutions	- peak load for space heating, regulated in national building regulation SIA 383.201	-	-	-
Minergie-P / Minergie P-ECO				
	$q_{h\text{-}MP\ max} \leq$ 10 W/m² A_E	-	$E_{P\text{-}Minergie} \leq$ 30 kWh/m²a A_E	Q_h (Standard) ≤ 60% $Q_{h,li}$ A_E **OR** $Q_h \leq$ 15 kWh/m² A_E

GREAT BRITAIN and POLAND

Energy values referred to the German passive house, PHI.

4.2.3 Ventilation

SWEDEN	Minienergi	Passive house	Zero-energy
Ventilation			
Prescribed ventilation system	-	-	-
	Type FTX	*Type FTX*	*Type FTX*
Air flow rate	-	-	-
Airflow rate / air exchange rate	0.35 l/s m^2 when occupied (BR16)	0.35 l/s m^2 when occupied (BR16)	0.35 l/s m^2 when occupied (BR16)
RH indoors	-	-	-
Imbalance	-	-	-
Regulation / Control system	-	-	-
Efficiency of units	-	-	-
Efficiency of heat exchanger	*60 %*	*70 %*	*70 %*
SFP-factor	*≤ 2.0 kW/(m^3/s)*	*≤ 1.5 kW/(m^3/s)*	*≤ 1.5 kW/(m^3/s)*
COP of electrical heat pump *if used with outdoor air as heat source*	-	-	-
Filter	-	-	-
Frost protection	-	-	-
Air temperatures			
Supply air	≤ 52°C	≤ 52°C	≤ 52°C
Exhaust air	-	-	-
Return air	-	-	-
Noise levels			
in bedrooms	B [27]	B [27]	B [27]
in living areas (supply air)	-	-	-
in functional areas (extract air)	-	-	-
Installation room	-	-	-

[27] according to SS 025267; sound class B equates to 26 dB(A)

Air diffusers	-	-	-
Power requirement	-	-	-
Type of energy supply	-	-	-
Demand control	-	-	-
Attendance check	-	-	-

NORWAY	Low-energy	Passive house	Passive house
Italic – not mandatory yet			***current***
Ventilation			
Prescribed ventilation system	-	-	German PHI
Air flow rate	[28]	[28]	German PHI
Airflow rate / Air exchange rate	*per apartment* *A_{fl}<110m²:* *n ≥ 1.6-0.007·(A_{fl}-50) m³/(h m²)* *A_{fl}>110m²:* *n ≥1.2 m³/(h m²)*	*per apartment* *A_{fl}<110m²:* *n ≥ 1.6-0.007·(A_{fl}-50) m³/(h m²)* *A_{fl}>110m²:* *n ≥1.2 m³/(h m²)*	
RH indoors	-	-	
Imbalance	-	-	
Regulation / Control system	-	-	German PHI
Efficiency of units			German PHI
Efficiency of heat exchanger	*η_t ≥ 70 %*	*η_t ≥ 80 %*	
SFP-factor	*≤ 2.0 kW/(m³/s)*	*≤ 1.5 kW/(m³/s)*	
COP of electrical heat pump *if used with outdoor air as heat source*	-	-	
Filter	-	-	German PHI
Frost protection	-	-	German PHI
Air temperatures	-	-	German PHI
Noise levels	-	-	German PHI
Air diffusers	-	-	German PHI
Power requirement	-	-	German PHI

[28] initial minimum air flow rates for calculation (Regulation prNS 3700)

Type of energy supply	-	-	German PHI
Demand control	-	-	German PHI
Attendance check	-	-	German PHI

DENMARK	Low-energy class 1	Low-energy class 1	Passive house
Ventilation			
Prescribed ventilation system	-	-	German PHI
Air flow rate	(BR08)	(BR08)	German PHI
Airflow / air exchange rate	0.35 l/s m^2 when occupied	0.35 l/s m^2 when occupied	
RH indoors	-	-	
Imbalance	-	-	
Regulation / Control system	-	-	German PHI
Efficiency of units	-	-	German PHI
Filter	-	-	German PHI
Frost protection	-	-	German PHI
Air temperatures	-	-	German PHI
Noise levels	-	-	German PHI
Air diffusers	-	-	German PHI
Power requirement	-	-	German PHI
Type of energy supply	-	-	German PHI
Demand control	-	-	German PHI
Attendance check	-	-	German PHI

FINLAND	Low-energy house - RIL	Passive house - RIL
Ventilation		
Prescribed ventilation system	- [29]	- [29]
Air flow rate	-	-
Airflow rate / Air exchange rate	0.5 ach (building code)	0.5 ach (building code)
RH indoors	-	-
Imbalance	-	-
Regulation / Control system	-	-
Efficiency of units	-	-
Efficiency of heat exchanger	*Apartment house < 65%* *Detached house < 70%*	*Apartment house < 75%* *Detached house < 80%*
SFP-factor	*< 2.0 kW/(m^3s)*	*< 2.0 kW/(m^3s)*
COP of electrical heat pump-*if used with outdoor air as heat source*	-	-
Filter	(building code)	(building code)
	F7	F7
	G4 - outside of cities	G4 - outside of cities
Frost protection	-	-
Air temperatures	-	-
Noise levels	-	-
in bedrooms	28 dB(A) (building code)	28 dB(A) (building code)
in living areas (supply air)	28 dB(A) (building code)	28 dB(A) (building code)
in functional areas (extract air)	-	-
Installation room	-	-
Air diffusers	-	-
Power requirement	-	-

[29] The national building code prescribes a heat recovery of 45 %, which indirectly refers to a mechanical ventilation with supply and exhaust air, Type FT.

Type of energy supply	-	-
Demand control	-	-
Attendance check	-	-

Finland

Prescribed ventilation system: No, but the national building regulation D2 prescribes that at least 45% of the buildings energy demand for heating shall be covered by heat gained from exhaust air. The value is low, because also separated exhausts not having heat recovery are included.
Due to this regulation the ventilation system for low-energy and passive houses of the RIL 249-2009 are *indirectly* prescribed having a mechanical ventilation system with exhaust- and supply air.

GERMANY	**Low-energy house - RAL**	**Passive house - RAL**
Ventilation		
Prescribed ventilation system	Type FTX	Type FTX
Air flow rate	per apartment	per apartment
Airflow rate / air exchange rate	$n_{mech} \geq 0.5\ h^{-1}$	$n_{mech} \geq 0.5\ h^{-1}$
RH indoors	-	-
Imbalance	-	-
Regulation / Control system		
	minimum required is a two-stage regulation, between the ratio 0.2 and 0.5 h^{-1}, *3 levels are recommended*	minimum required is a two-stage regulation, between the ratio 0.2 and 0.5 h^{-1}, *3 levels are recommended*
Additional:	Ventilation systems must be regulated before initiation; the reference values shall be denoted on the controllers	Ventilation systems must be regulated before initiation; the reference values shall be denoted on the controllers
Efficiency of units		
Efficiency of heat exchanger	$\eta'_W \geq 70\ \%$ [30]	$\eta'_W \geq 70\ \%$ [30]
SFP-factor	-	-
COP of electrical heat pump - *if used with outdoor air as heat source*	≥ 3.3 [31]	≥ 3.3 [31]
Filter		
Air intake	F7	F7
Frost protection	-	-

[30] Heat providing efficiency according to DIN V 4701-10, uncorrected
[31] For calculation of the seasonal performance factor not only the heat pump shall be accounted but also energy posts as: domestic water heating, circulating pump for solar panels or wells, included electrical heating rod grooves or other direct-electrical heating systems

Air temperatures	-	-
Noise levels	referred to VDI 4100	referred to VDI 4100
in bedrooms	25 dB (A)	25 dB (A)
in living areas (supply air)	25 dB (A)	25 dB (A)
in functional areas (extract air)	25 dB (A)	25 dB (A)
Installation room	-	-
Air diffusers	-	-
Power requirement		
Exhaust air fan	-	-
Ventilation unit (including controls and essential external systems)	-	-
Ventilation system (all fans, controls, any essential external systems)	≤ 0.50 Wh/m^3	≤ 0.50 Wh/m^3
Type of energy supply	-	-
Demand control	-	-
Attendance check	-	-

GERMANY	Passive house	Passive house suitable component
Ventilation		
Prescribed ventilation system	Type FTX *	Type FTX
Air flow rate		
Airflow rate / Air exchange rate	$n \geq 0.3\ h^{-1}$ [32]	-
	Mean airflow should be 20-30 m^3/h per person	
RH indoors	-	-
Imbalance	≤ 10 %	≤ 10 %
Regulation / Control system	-	
		Regulation on at least 3 levels (basic ventilation (70-80%), standard ventilation (100%) and increased ventilation (130%))
additional:		For the user shall be possible: - switching-on and -off - regulation of supply and extract air fan (3 levels) *- Filter exchange should be displayed for user*
Efficiency of units		
Efficiency of heat exchanger	$\eta_{WBG,t,eff} \geq 75$ % *	$\eta_{WBG,t,eff} \geq 75$ %
SFP-factor	-	-
COP of electrical heat pump *if used with outdoor air as heat source*	-	-
Filter	-	
Air intake		F7
Extract air		G4
Frost protection	-	✓

[32] Air exchange rate n – relating to the area A_{net} and a room height of 2.5 m

		Frost protection device for the heat exchanger shall be installed; If this is not possible, an external frost protection with all relevant controls is to be specified and delivered by the manufacturer and integrated
Additional:		Emergency shutdown if the supply air temperature falls below +5°C (e.g. malfunction of exhaust air fan)
Air temperatures		
Supply air	≥ 17°C *	≥ 16.5 °C (even at -10°C outdoor temperature)
Exhaust air	-	-
Return air	-	-
Noise levels		
in bedrooms	≤ 25 dB(A) *	≤ 25 dB(A)
in living areas (supply air)	≤ 25 dB(A) *	≤ 25 dB(A)
in functional areas (extract air)	-	≤ 30 dB(A)
Installation room	-	≤ 35 dB(A) [33]
Air diffusers	-	-
Power requirement	-	
Exhaust air fan		-
Ventilation unit (including controls and essential external systems)		≤ 1 W in stand-by mode
Ventilation system (all fans, controls, any essential external systems)		0.45 W/(m^3/h) for transported supply air flow
Type of energy supply	-	-
Demand control	-	-
Attendance check	-	-

[33] Installation room - with equivalent absorption area of 4 m^2

Germany

3-litre-house, Effizienzhaus 70 and **85** have no specific requirements concerning ventilation.

$\eta_{WRG,t,eff}$ the "*effective dry heat recovery rate*", laboratory measured under the conditions defined in the regulation Testing procedure ventilation central, 2009.

The limit value of the $\eta_{WRG,t,eff}$ refers to the precondition: balanced mass flows of the outdoor air and exhaust air, at outdoor air temperatures between – 15 and + 10 °C and dry extract air (ca. 20 °C) and shall be calculated as in the equation below. If ventilation units with constant flow rate fans show an imbalance of more than 10%, the exhaust air temperature ϑ_{FO} shall be corrected by an additional equation (Regulation Testing procedure ventilation central, 2009).

$$\eta_{WRG,t,eff} = \frac{(\vartheta_{AB} - \vartheta_{FO}) + \dfrac{P_{el}}{\dot{m} \cdot c_p}}{(\vartheta_{AB} - \vartheta_{AU})}$$

(Regulation Testing procedure ventilation central, 2009, p.4)

ϑ_{AB}= extract air temperature, °C
ϑ_{FO} = exhaust air temperature, °C
ϑ_{AU} = outdoor air temperature, °C
P_{el} = real electrical power, W
$\dot{m}$ = mass flow, kg/h
c_p = specific thermal capacity of air, Wh/(kg K)

Annotation: Additional requirements on testing and efficiency of frost protection are listed in the regulation Testing procedure ventilation central, 2009, p. 6.

Additional: A checklist for Planning and construction phase / Ventilation, provided by the PHI to make it easier to reach the certification standard, see appendix I.

AUSTRIA	Low-energy house state-aided	Passive house state-aided	3-litre house
Ventilation			
Prescribed ventilation system	Type FT or FTX	Type FTX	-
Air flow rate	for FTX		-
Airflow rate / air exchange rate	n=0.3 or 30 m^3/h per person	n=0.3 or 30 m^3/h per person	
RH indoors	-	-	
Imbalance	-	-	
Regulation / Control system	-	-	-
	3 levels (30%, 70%, 100%)	*3 levels (30%, 70%, 100%)*	
Efficiency of units	for FTX		-
Efficiency of heat exchanger	η_{WRG} > 75 % [34]	η_{WRG} > 75 % [34]	
SFP-factor	-	-	
COP of electrical heat pump *if used with outdoor air as heat source*	-	-	
Filter	-	-	-
	Air intake F7, extract air G4	*Air intake F7, extract air G4*	
Frost protection	-	-	-
Air temperatures	for FTX	-	-
Supply air	≤ 52°C, *≥ 17°C*	≤ 52°C, *≥ 17°C*	
Exhaust air	-	-	
Return air	-	-	-
Noise levels	-	-	-
in bedrooms	*≤ 23 dB (A)*	*≤ 23 dB (A)*	
in living areas (supply air)	*≤ 25 dB (A)*	*≤ 25 dB (A)*	

[34] Calculated according to EN 308

in functional areas (extract air)			
Installation room			
Air diffusers	-	-	-
Location			
Throw			
Velocities	*< 0.3 m/s*	*< 0.3 m/s*	
Power requirement	-	-	-
Exhaust air fan			
Ventilation unit (including controls and essential external systems)			
Ventilation system (all fans, controls, any essential external systems)	*≤ 0.4 Wh/m^3*	*≤ 0.4 Wh/m^3*	
Type of energy supply	-	-	-
Demand control	-	-	-
Attendance check	-	-	-

	klima:aktiv Passive house	klima:aktiv house	
Ventilation			
Prescribed ventilation system	Type FTX *(comfort ventilation)*	Type FT [35] or Type FTX [36]	
Air flow rate		Type FT	Type FTX
Airflow rate / air exchange rate	$n \geq 0.3\ h^{-1}$	-	$n \geq 0.3\ h^{-1}$
	precondition $n \geq 30\ m^3/h$	precondition $n \geq 30\ m^3/h$	Precondition $n \geq 30\ m^3/h$
	supply air rate according to ÖNORM H 6038	supply air rate according to ÖNORM H 6038	supply air rate according to ÖNORM H 6038
	extract air rate according to ÖNORM H 6038	extract air rate according to ÖNORM H 6038	extract air rate according to ÖNORM H 6038
RH indoors	-	-	-
Imbalance	≤ 10 %	-	≤ 10 %
Regulation / Control system			
	at least 3 levels	at least 3 levels	at least 3 levels
Efficiency of units			
Efficiency of heat exchanger	*additional points if* $\eta_{WRG,t,eff} \geq 75\%$	-	*additional points if $\eta \geq 75\%$ (counter flow), $\eta \geq 50\%$ (cross flow), $\eta \geq 50\%$ (other types)* [37] [38].
SFP-factor	-	-	-

[35] defined as *fresh-air plant* - according to the national building regulation OIB 6 not allowed any more; all new mechanical supply and exhaust air ventilation systems must be equipped with heat recovery (Regulation OIB 6, 2007)
[36] defined as *comfort ventilation*
[37] For systems with a certification report the following parameters shall be listed: heat losses through fan-case, imbalance - leakage of heat exchanger, and possible subtraction of 0-9% according to ÖNORM B 811:6-2007
[38] For certificated systems not having listed: heat losses through fan-case, imbalance - leakage of heat exchanger a subtraction of 9% must be made

COP of electrical heat pump *if used with outdoor air as heat source*	-	-	-
Filter			
Air intake	F7	-	F7
Extract air	G4	-	G4
Frost protection	-	-	-
Air temperatures	-	-	-
Noise levels			
in bedrooms	≤ 25 dB(A)	≤ 25 dB(A)	≤ 25 dB(A)
in living areas (supply air)	≤ 25 dB(A)	≤ 25 dB(A)	≤ 25 dB(A)
in functional areas (extract air)	≤ 25 dB(A)	-	≤ 25 dB(A)
Installation room	-	-	-
Air diffusers	-	-	-
Power requirement	-		
Exhaust air fan	-	-	
Ventilation unit (including controls and essential external systems)	-	-	
Ventilation system (all fans, controls, any essential external systems)	*additional points if ≤ 0.45 Wh/m^3*	*additional points if ≤ 0.25 Wh/m^3*	*additional points if ≤ 0.45 Wh/m^3*
Type of energy supply	-	-	-
Demand control	-	Type FT [39] Controlled per housing unit: e.g. by CO_2 or humidity	-
Attendance check	-	-	-

[39] Type FT - according to the national building regulation OIB 6 not allowed any more (Regulation OIB 6, 2007)

Austria

η	efficiency according to ÖNORM B 811:6-2007
η_{WRG}	efficiency of heat recovery according to EN 308
$\eta_{WRG,t,eff}$	efficiency according to German PHI

Comfort ventilation germ.: *Komfortlüftung;* term used at klima:aktiv. Defined as mechanical ventilation with heat recovery (after consultation with klima:aktiv contacts).

In the Glossary it is defined as mechanical ventilation with exhaust and supply air. If heat recovery is a must is not explained (Regulation Klima:aktiv Summary, Glossary). After consultation the definition is mechanical ventilation with heat recovery.

Certified *comfort ventilation* systems are provided by e.g. komfortlüftung.at, with highly detailed criteria on the ventilation system and its components. The installation of a certified comfort ventilation is not a must in k:a houses and k:a passive houses.

Fresh-air plant germ.: *Frischluftanlage;* term used at klima:aktiv houses; includes a mechanical ventilation system with exhaust- and supply-air without heat recovery.

Annotation: In the klima:aktiv house either a fresh-air plant or a comfort ventilation is a must; Due to the latest amendment of the OIB 6, fresh-air plants without heat recovery are no longer allowed; all new mechanical ventilation systems must be equipped with heat recovery. Therefore the option *fresh-air plants* in klima:aktiv houses actually is out of date. A new amendment of the criteria-regulation is ongoing and will probably be released in April 2010 (E-mail correspondence Julia Lindenthal).

SWITZERLAND	**Minergie / Minergie-ECO**		**Minergie-P / P-ECO**
	System verification	*Standard sol 5* [40]	
Ventilation			
Prescribed ventilation system	Type FT	Type FTX	Type FT
Air flow rate	-	-	-
Airflow rate / air exchange rate	≥ 30 m^3/h per room [41]	≥ 30 m^3/h per room [41]	≥ 30 m^3/h per room [41]
RH indoors	-	-	-
Imbalance	-	-	-
Regulation / Control system	-	-	-
Efficiency of units	-		
Efficiency of heat exchanger	-	≥ 80 %	-
SFP-factor	-	-	-
COP of electrical heat pump *if used with outdoor air as heat source*	-	3.0 [42]	-
Filter			
	F7	F7	F7
Frost protection	-	-	-
Air temperatures	-	-	-
Noise levels			
in bedrooms	≤ 25 dB(A)	≤ 25 dB(A)	≤ 25 dB(A)
in living areas (supply air)	≤ 25 dB(A)	≤ 25 dB(A)	≤ 25 dB(A)
in functional areas (extract air)	-	-	-

[40] Standard solution 5: water-air-heat pump using outdoor air as heat source; only available for residential buildings up to 500 m^2

[41] Minimum airflow rates according to SIA 2023, but the ventilation system has to be able to provide at least 30 m^3/h per room

[42] Heat pumps have to be certified by D-A-CH (Regulation EHPA-DACH, 2009)

Installation room	-	-	-
Air diffusers	-	-	-
Power requirement	-	-	-
Type of energy supply	-	fans: co-current flow or EC motor	-
Demand control	for decentralized FTX demand-controlled per housing unit for centralized FTX under longer periods (days) of absence, the airflow rate must be able to be lowered	for decentralized FTX demand-controlled per housing unit for centralized FTX under longer periods (days) of absence, the airflow rate must be able to be lowered	for decentralized FTX demand-controlled per housing unit for centralized FTX under longer periods (days) of absence, the airflow rate must be able to be lowered
Attendance check	-	-	-

Switzerland

Comfort ventilation germ.: *Komfortlüftung*.
On the Minergie-homepage it is defined as a mechanical ventilation system with heat recovery (Minergie, 2009).

Centralized FTX In multi-family buildings; Ventilation and heat recovery is provided from a central, supplying more than one apartment (Minergie Standard Lüftungssysteme, 2009).

Decentralized FTX Every apartment is supplied by its own ventilation system with heat recovery (Minergie Standard Lüftungssysteme, 2009).

4.2.4 Follow-up

Is follow-up required – and if yes, how. By n_{50}, measurement of the n_{50}-rate is meant.

SWEDEN	Follow-up required	Requirements
Low-energy / Minienergi	- / ✓	
For certification	-	-
For verification	✓	Measurements: • P_{max} • n_{50} Verification of: • Noise levels • Mean U-value windows • Maximum supply air temperature The monthly energy use must be available for reading; separately divided into: • household energy • auxiliary energy (laundry rooms not included) • heating energy • water volume for domestic hot water Additional: • number of persons living in the household shall be listed
Passive house	- / ✓	
For certification	-	-
For verification	✓	see: Minienergi
Zero-energy house		
For verification	✓	see: Minienergi
	Additional:	Verification that used energy is below or equal to produced energy

NORWAY	Follow-up required	Requirements
Low-energy	✓	
		n_{50}
Passive house	✓	
		n_{50}
Passive house *current*	✓	
		German PHI
DENMARK	Follow-up required	Requirements
Low-energy class 1	-	
Low-energy class 2	-	
Passive house	✓	
		German PHI
FINLAND	Follow-up required	Requirements
Low-energy	-	
		n_{50} strongly recommended
Passive house RIL	-	
		n_{50} strongly recommended
GERMANY	Follow-up required	Requirements
RAL Low-energy, RAL passive house	- / ✓	
For “Planning” certification	-	-
For “Construction” certification	✓	n_{50}
		Self-documentation by the user; have to be saved/kept for at least 5 years after verification. Documents of: planning, calculations, protocols, bills, and photos during construction.
	✓	When using electrical heat pumps for heating, circulating pump for solar panels or wells, electrical heating rod grooves or other direct-electrical heating systems; the total ratio of energy use and delivered heat must me measurable

Passive house	- / ✓	
For "Planning" certification	-	-
For "Construction" certification	✓	n_{50} Photos during construction
3-litre house	-	
Effizienzhaus 70	-	
Effizienzhaus 85	-	
AUSTRIA	Follow-up required	Requirements
Low-energy (state-aided)	✓	
		n_{50}
Passive house (state-aided)	✓	
		n_{50}
3-litre house	✓	
		n_{50} Documentation of: Bills for • Insulation • Solar energy plant • Comfort ventilation • Additional heating systems Photos • Of all 4 views
k:a passive house	✓	
		n_{50} *
* in apartment buildings - blower door test shall be made in at least 20% of the housing units (and at least 4 units)		
k:a house	✓	
		n_{50} *
* in apartment buildings - blower door test shall be made in at least 20% of the housing units (and at least 4 units)		

SWITZERLAND	Follow-up required	Requirements
Minergie	✓	
		Spot tests
Minergie-P	✓	
		n_{50} Spot tests
Minergie-ECO	✓	
		Spot tests : Measurements of TVOC, formaldehyde, radon
Minergie-P-ECO	✓	
		n_{50} Spot tests : Measurements of TVOC, formaldehyde, radon
GREAT BRITAIN	Follow-up required	Requirements
Passive house	✓	
		German PHI
POLAND	Follow-up required	Requirements
Passive house	✓	
		German PHI

4.3 Compilation

In the following chapters, a compilation relating to the building types rated energy level and included energy posts, and related areas will be given. Additionally, a compilation of the must-requirements on the ventilation system has been made, with a resulting list of criteria that a ventilation system has to meet for suiting all, or almost all country-specific building types.

4.3.1 Energy level and included energy posts

A compilation of the type of limited energy and its included energy posts are given in the table below. Great Britain and Poland are not included, hence referring to the German PHI.

SWEDEN	Primary energy	End energy	Final energy
All building types		✓	
Space heating		✓	
Ventilation heating		-	
Ventilation		-	
Cooling		✓	
Domestic hot water		✓	
Auxiliary energy		✓	
Lighting		-	
Household energy		-	
NORWAY	Primary energy	End energy	Final energy
Official low-energy	✓		✓
and passive house			
Space heating	✓		✓
Ventilation heating	✓		✓
Ventilation	-		-
Cooling	✓		-
Domestic hot water	✓		-
Auxiliary energy	✓		-
Lighting	✓		-
Household energy	-		-
Semi-official passive house - referred to the German definition			

DENMARK	Primary energy	End energy	Final energy
Official low-energy buildings		✓	
Space heating		✓	
Ventilation heating		-	
Ventilation		✓	
Cooling		✓	
Domestic hot water		✓	
Auxiliary energy		-	
Lighting		-	
Household energy		-	

Semi-official passive house - referred to the German definition

FINLAND	Primary energy	End energy	Final energy
All building types		✓	
Space heating		✓	
Ventilation heating		-	
Ventilation		✓	
Cooling		✓	
Domestic hot water		-	
Auxiliary energy		✓	
Lighting		-	
Household energy		-	

GERMANY	Primary energy	End energy	Final energy
RAL-GZ low-energy			✓
Space heating			✓
Ventilation heating			-
Ventilation			-
Cooling			-
Domestic hot water			-
Auxiliary energy			-
Lighting			-
Household energy			-
Passive house by RAL-GZ and PHI	✓		✓
Space heating	✓		✓
Ventilation heating	-		-
Ventilation	✓		-
Cooling	✓		-
Domestic hot water	✓		-

Auxiliary energy	✓		-
Lighting	-		-
Household energy	✓		-
3-L-house	✓		
Space heating	✓		
Ventilation heating	-		
Ventilation	-		
Cooling	-		
Domestic hot water	-		
Auxiliary energy	✓		
Lighting	-		
Household energy	-		
Effizienz-houses	✓		
Space heating	✓		
Ventilation heating	-		
Ventilation	✓		
Cooling	✓		
Domestic hot water	✓		
Auxiliary energy	-		
Lighting	-		
Household energy	-		
AUSTRIA	Primary energy	End energy	Final energy
Low-energy house - state-aided			✓
Space heating			✓
Ventilation heating			-
Ventilation			-
Cooling			-
Domestic hot water			-
Auxiliary energy			-
Lighting			-
Household energy			-
Passive house – state-aided	✓		✓
Space heating	✓		✓
Ventilation heating	-		-
Ventilation	✓		-
Cooling	✓		-

Domestic hot water	✓		-
Auxiliary energy	✓		-
Lighting	-		-
Household energy	✓		-
3-L-house			✓
Space heating			✓
Ventilation heating			-
Ventilation			-
Cooling			-
Domestic hot water			✓
Auxiliary energy			-
Lighting			-
Household energy			-
klima:aktiv house			✓
Space heating			✓
Ventilation heating			-
Ventilation			-
Cooling			-
Domestic hot water			-
Auxiliary energy			-
Lighting			-
Household energy			-
klima:aktiv passive house	✓		✓
Space heating	✓		✓
Ventilation heating	-		-
Ventilation	✓		-
Cooling	✓		-
Domestic hot water	✓		-
Auxiliary energy	✓		-
Lighting	-		-
Household energy	-		-
SWITZERLAND	Primary energy	End energy	Final energy
All building types		✓	✓
Space heating		✓	✓
Ventilation heating		-	-
Ventilation		✓	-
Cooling		-	-

Domestic hot water	✓	-
Auxiliary energy	-	-
Lighting	-	-
Household energy	-	-

4.3.2 Related areas

A compilation of the country-specific related areas, showing whether the area is measured from the inside or outside of the thermal building envelope, and if only heated or also unheated areas are included is given in the table below. For some countries more than one related area is listed, because some building types use differently related areas within the same country.

b.e.-building	**Inside thermal b.e.**		**Including thermal b.e.**		**Inner walls**
envelope	heated	not heated	heated	not heated	included
SWEDEN					
A_{temp}	✓				✓
$A_{temp+garage}$	✓				✓
NORWAY					
A_{fl}	✓				✓
DENMARK					
A			✓		✓
FINLAND					
$A_{br,h}$			✓		✓
GERMANY					
A_{net}	✓	✓			
A_N	✓				✓
AUSTRIA					
A_{net}	✓	✓			
$A_{BGF,cond}$			✓		✓
SWITZERLAND					
A_E	✓				✓

4.3.3 Ventilation system

Criteria for a ventilation system, suitable for low-energy and passive houses in almost every country with the precondition that the building is equipped with mechanical ventilation and heat recovery are listed in table 4 and 5.

Some annotations to the compilation:

- In the list of low-energy buildings, Switzerland is referred to the Minergie/-ECO building verified by standard solution 5.

- Demand-control is only required for decentralized FTX systems in Switzerland; specific requirements are not given.

- Minimum airflow rates have been converted to ach, under the precondition of 2.5 m room height; for Norway the precondition of a building with an area $A_{fl} > 100\ m^2$ was assumed.

The compilation for low-energy buildings meets the examined criteria-requirements of all building types, except passive houses. The suitable ventilation system meets all examined criteria, except of the Swiss Minergie house verified by standard solution 5, which requires a heat exchange efficiency of 80%; all other criteria are met.

The compilation for passive houses includes the building types classified as passive houses and meets all listed criteria with no exceptions:
FEBY Passive house and zero-energy house (Sweden), **prNS3700 passive house** (Norway), **Passive house by PHI** (Denmark, Germany, Great Britain, Poland), **RIL passive house** (Finland), **RAL passive house** (Germany), **state-aided passive house and k:a passive house** (Austria), **Minergie-P and P-ECO** (Switzerland).

LOW ENERGY	**ALL** except SWI	**SWE**	**NOR**	**DEN**	**FIN**	**GER**	**AUT**	**SWI**	**GB / POL**
Airflow									
Airflow - supply air	n ≥ 0,5 ach	n ≥ 0,5 ach	n ≥ 0,5 ach	n ≥ 0,5 ach	n ≥ 0,5 ach	n_{mech} ≥ 0,5 ach	n ≥ 0,3 / 30 m^3/h p.p.	n ≥ 0,4 ach	-
Disbalance	≤ 10%	-	-	-	-	-	≤ 10%	-	-
Temperatures									
Supply air temperature	≤ 52°C	≤ 52°C	-	-	-	-	≤ 52°C	-	-
Noise									
Noise - bedroom	25 dB(A)	26 dB(A)	-	-	28 dB(A)	25 dB(A)	25 dB(A)	25 dB(A)	-
Noise - living room						25 dB(A)	25 dB(A)	25 dB(A)	-
Heat exchanger efficiency									
η - not specified	-	-	-	-	-	-	-	≥ 80%	-
η_t	≥ 70%	-	η_t) ≥ 70%	-	-	-	-	-	-
η_{WRG} - EN308	≥ 75%	-	-	-	-	-	η_{WRG} ≥ 75%	-	-
η'_W	≥ 70%	-	-	-	-	η'_W ≥ 70%	-	-	-
$\eta_{WBG,t,eff}$	-	-	-	-	-	-	-	-	-
Heat exchanger frost protection									
Frost protection	-	-	-	-	-	-	-	-	-
Power									
Power - system	≤ 0,5 Wh/m^3	-	-	-	-	≤ 0,5 Wh/m^3	-	-	-
SFP-factor	≤ 2,0 kW/m^3s	-	≤ 2,0 kW/m^3s	-	≤ 2,5 kW/m^3s	-	-	-	-
Filter									
Filter - air intake	F7	-	-	-	F7	F7	F7	F7	-
Control									
Regulation	3 levels	-	-	-	-	3 levels	3 levels	-	-
Demand control	✓	-	-	-	-	-	-	✓	-

Table 4. Low-energy building suitable ventilation system

PASSIVE HOUSE	ALL	SWE	NOR	DEN	FIN	GER	AUT	SWI	GB / POL
Airflow									
Airflow - supply air	n ≥ 0,5 ach	n ≥ 0,5 ach	n ≥ 0,5 ach	n ≥ 0,3 ach	n ≥ 0,5 ach	n ≥ 0,3 ach / n_{mech}≥ 0,35 ach	n ≥ 0,3 / 30 m^3/h p.p.	n ≥ 0,4 ach	n ≥ 0,3 ach
Disbalance	≤ 10%	-	-	≤ 10%	-	≤ 10%	≤ 10%	-	≤ 10%
Temperatures									
Supply air temperature	16 - 52°C	≤ 52°C	-	≥ 16,5°C	-	≥ 16,5°C	≤ 52°C	-	≥ 16,5°C
Noise									
Noise - bedroom	25 dB(A)	26 dB(A)	-	25 dB(A)	28 dB(A)	25 dB(A)	25 dB(A)	25 dB(A)	25 dB(A)
Noise - living room				25 dB(A)		25 dB(A)	25 dB(A)	25 dB(A)	25 dB(A)
Heat exchanger efficiency									
η - not specified	-	-	-	-	-	-	-	-	-
η_t	≥ 80%	-	η_t ≥ 80%	-	-	-	-	-	-
η_{WRG} - EN308	≥ 75%	-	-	-	-	-	η_{WRG} ≥ 75%	-	-
η'_W	≥ 70%	-	-	-	-	η'_W ≥ 70%	-	-	-
$\eta_{WBG,t,eff}$	≥ 75%	-	-	$\eta_{WBG,t,eff}$ ≥ 75%	-	$\eta_{WBG,t,eff}$ ≥ 75%	-	-	$\eta_{WBG,t,eff}$ ≥ 75%
Heat exchanger frost protection									
Frost protection	✓	-	-	✓	-	✓	-	-	✓
Power									
Power - system	0,45 Wh/m^3	-	-	0,45 Wh/m^3	-	0,45 Wh/m^3	-	-	0,45 Wh/m^3
SFP-factor	≤ 1,5 kW/m^3s	-	*≤ 1,5 kW/m^3s*	-	≤ 2,5 kW/m3s	-	-	-	-
Filter									
Filter - air intake	F7	-	-	F7	F7	F7	F7	F7	F7
Control									
Regulation	3 levels 1: 70-80% 2: 100% 3: 130%	-	-	3 levels 70-80% 100% 130%	-	3 levels 70-80% 100% 130%	3 levels	-	3 levels 70-80% 100% 130%
Demand control	✓	-	-	-	-	-	-	✓	-

Table 5. Passive house suitable ventilation system

5 Analysis and discussion

Annotation: Analyses and statements about a *country* are always relating to the examined regulations concerning low-energy buildings. If something contradictory is regulated in the national building standard, this is not included.

5.1 Comparison

Comparing the level of specification between the different regulations, it is noticeable that countries as Sweden, Finland, Germany, Austria and Switzerland are the leading countries having specified regulations, not referring the complete definition to another country's. The Norwegian regulation should also be accounted to these countries, as soon as it has been set.

Concerning buildings corresponding to the passive house concept, Sweden, *Norway*, Finland, Germany, Austria and Switzerland are having a specified regulation. – Denmark, Great Britain and Poland have introduced the concept but are still referring to the German definition.

To compare the state of definition between the countries, a short analysis of the country-specific regulations is given, followed by a subject-related analysis.

Sweden — **FEBY-regulations**: focus on energy performance and building envelope. A maximum peak load regulates the energy use; limit values for end energy use are regulated as recommendations. Regarding ventilation the set criteria relate to indoor climate parameters, such as supply air temperature and sound levels. More detailed criteria are listed as recommended values. For verification, a follow-up by measurement of the actual peak load for space heating after construction is required.

Norway — **prNS 3700**: focus on energy performance, with concern on primary energy and building envelope; the energy use is rated on the level of final and primary energy. Concerning ventilation only criteria on the performance of the ventilation system are set.

Denmark — **Low-energy buildings in the building regulation**: only requirements on the buildings annual energy use, no other criteria that differ from the general buildings.

Finland — **RIL**: focus on the energy performance, rated on the level of end energy Regarding building envelope and ventilation, no specific requirements beyond the building regulation are set, only recommended guideline values.

Germany

RAL-GZ: focus on energy performance and the ventilation system; low-energy buildings are rated on the level of final energy, passive houses on the level of final and primary energy according to the PHPP. For low-energy buildings the calculated heat loss by transmission H'_T has to be adhered.

Passive house by the PHI: focus on energy performance, where the limit value for primary energy includes household electricity. Requirements on ventilation include both limit values relating to the performance of the system as indoor climate parameters.

3-litre-house: focus exclusively on energy performance; rated on the level of primary energy, not including energy posts influenced by user habits, such as household electricity and domestic hot water.

Effizienzhaus 70, 85: focus exclusively on the energy performance, as for RAL-GZ houses the calculated heat loss by transmission H'_T has to be adhered.

Austria

State-aided low energy buildings: focus on the energy performance, separate limit values for buildings with or without mechanical ventilation with heat recovery. No limit values on the level of end or primary energy; no requirements on ventilation.

State-aided passive houses: focus on energy performance, calculation method and limit values according to the German PHI. Prescribed ventilation system and some additional requirements on the ventilation system.

3-litre houses: focus on energy performance, though only on the level of final energy. Certification regulations beyond the information on the homepage are not available; no requirements on ventilation.

Klima:aktiv houses: regarding energy performance only a requirement on final energy, but many requirements on the ventilation system. The whole certification system of klima:aktiv houses is evaluating the building as a complete "package", by taking many parameters into account. For passive houses the energy performance additionally is rated on a primary energy level, referring to the calculation method of the German PHI, but with the amendment of excluding household electricity.

Switzerland

Minergie houses: focus on energy performance on the level of end and final energy, regarding ventilation the number of systems is limited but no additional requirements regarding performance or indoor climate are set.

Minergie-P houses: the energy performance is rated on the same levels as Minergie houses, but with additional requirements on peak load for space heating, with the precondition that heating is provided by the ventilation system. Regarding ventilation there is the same number of requirements as for Minergie houses.

Minergie-ECO/P-ECO houses: have to fulfil the same criteria as Minergie or Minergie-P houses, with additional requirements evaluating the building from an ecological perspective and greater focus on people's health, using a rating system.

Great Britain *referring to the German definition*

Poland *referring to the German definition*

A summarised comparison divided into the four subject areas is given below.

Building envelope

Concerning U-values, Sweden, *Norway*, Germany and Switzerland are the only countries having specified U-values for windows and/or outer walls. In Austria they are listed as referred to the building regulation; in Denmark, Finland and some German building types they are either not listed at all or given in form of recommended values.

In the pointing system of the Austrian klima:aktiv buildings, thermal quality points are available by observing the limit values for the buildings mean U-value increasing, caused by thermal bridges.

Concerning air leakage, Sweden, *Norway* and Austria are the only one's having specified an air-leakage rate for all building types; in Germany the rate is set for RAL-GZ and Passive houses, in Switzerland for the passive house type Minergie-P/P-ECO houses. In Denmark it is annotated, but referred to the building regulation; Finland has only guideline values.

Energy

Concerning peak load for space heating, Sweden, German passive houses, Austrian passive houses (thus, referring to the German method), and the Swiss Minergie-P passive house have set a limit value – All other building types have no requirements on the peak load.

Concerning energy performance not all countries are accounting primary energy factors when setting limit values. The differences regarding included energy posts and their definitions are sometimes severe, which makes it hard to compare the limit values.

In Sweden the peak load for space heating is the distinctive limit value between low-energy and passive houses; concerning end energy use, which only is a recommended limit value the building types have the same requirements.

In Denmark the limit value is expressed depending on the area; for a building with an area of 150 m^2 the end energy demand must be between 42-61 kWh/m^2a, depending on the low-energy class. For low-energy buildings in Finland the value must lie between 30-64 kWh/m^2a, for passive houses between 15-34 kWh/m^2a; even here depending on the low-energy or passive house class. Minergie-buildings range between 30-38 kWh/m^2a end energy.

Where limit values for final energy are set, only minimal divergences between all building types are noticeable. The limit values for primary energy are hard to compare – Germany and Austria are the only ones setting primary energy limit values, all relating to the calculation method of the German PHPP but with amendments to the included energy posts. Norway will probably use CO_2 factors and requirements on using renewable energies.

Regarding household energy, only buildings whose energy performance is calculated according to the PHPP are including this energy post; with some exceptions as e.g. the German 3-litre house and the Austrian k:a passive house, who refer to the PHPP method but exclude user-habit influenced energy.

Concerning the definition of related areas almost all countries use the same boundary conditions, measuring from the inside of the thermal building envelope, aside from some country-specific regulations, using height-reducing factors etc. Countries **including** the thermal building envelope are Denmark, Finland and Austria (except for passive houses, as the calculation method is related to the German PHPP).
The in Germany used area A_{net} is the only one, where merely the so-called *living area* is accounted, i.e. inner walls are not included; though, even unheated areas are accounted.

Ventilation

Requirements on the buildings ventilation vary severely between the countries, but also between regulations within a country.

I Sweden limit values regarding noise levels and maximum temperature of supply air are set; other values are defined as recommendations. In Denmark low-energy buildings have no specific requirements regarding ventilation; except of passive houses (though, certified according to the German PHI). Finland annotates the importance of ventilation, but has only recommended values.

Within Germany it varies: RAL-GZ low-energy houses and Passive houses, such as passive house suitable components by the PHI include specific requirements on the ventilation system; 3-litre houses and Effizienz-houses have nothing set regarding ventilation.

The same in Austria – State-aided passive houses, klima:aktiv houses and passive houses include regulations regarding ventilation, state-aided low-energy buildings and 3-litre houses have nothing set regarding ventilation.
In Switzerland all building types have requirements regarding the ventilation.

In Norway, Denmark, Finland, Germany, Austria and Switzerland mechanical ventilation systems are a requirement – in almost all of them heat recovery is prescribed. Building types that have requirements on the temperature efficiency of the heat exchanger sometimes refer to differently defined efficiencies.

Demand-control: In Austria demand-controlled ventilation is required for FT-ventilation systems (*fresh-air plants*), but due to the fact that the system type not is allowed any more, this requirement can be neglected. In Switzerland, demand-controlled ventilation is required for decentralized FTX.

Follow-up

Sweden is the only country where buildings certified as *verified* low-energy buildings are being followed-up concerning the actual energy performance after completion. This is performed by measurement of the peak load $P_{\max}$. Additionally the regulations require separately readable monthly energy use, divided into the different energy posts, **including** household electricity. None of the other countries requires that the actual energy use must be proven by measurement after completion. In Switzerland spot tests are made; if these include energy measurement is not specified.

The verification of the n_{50}-air leakage rate is required for all building types except of: Danish low-energy buildings, Finnish low-energy and passive houses (only strongly recommended), German 3-litre and Effizienz-houses, and Swiss Minergie and Minergie-ECO houses.

It is notable that in Germany and Austria self-documentation is listed in some regulations. For German RAL-GZ low-energy and Austria 3-litre houses planning documents, bills and photos have to be kept; for passive houses of the PHI only photos during construction are a requirement for self-documentation.

Minergie-ECO and P-ECO are the only building types where spot test measurements of TVOC, HCHO and Radon are being performed.

5.2 Reasons for different limit values

Besides the consideration that the reason for different limit values is based on the strictness of the regulations, it could also be referred to differences between the definitions.

Values for a buildings energy performance are influenced by two main parameters: the included energy posts and the definition of the related area.
Additionally the calculation method plays a great role – included energy posts, what values for internal heat gains are set, used weighting factors for end or primary energy, etc. – These parameters could be a reason for different limit values besides the strictness.

Differences between airflow- and air exchange rates result from the precondition of the initial value for fresh air required per person. Here it varies a lot how the initial value is expressed. In Sweden, Norway and Denmark the required airflow is relating to the area, either expressed in $l/(s\ m^2)$ or $m^3/(h\ m^2)$. In Switzerland it relates to number of rooms, but with an initial airflow prescribed in m^3/h. In all other countries (Finland, Germany and Austria) it is expressed in ach or h^{-1}; in Austria with an additional requirement of airflow per person. Higher required airflows accordingly result in a higher energy demand, with the positive side effect of a better indoor climate.

All these differences, both between definitions as between used units are hinders for comparing values but also for the future development of a common standard.

5.3 Consequences on indoor climate

Regarding indoor temperature no requirements are set in the regulations; besides for those who must verify thermal comfort in summer. This criterion has not been examined in this study.

Regarding sound levels in living areas and bedrooms all set limit values range between *23-28* dB (A), recommended values included, which satisfies a good acoustic climate according to the guideline values for high comfort classes. Higher limit values are allowed in e.g. Finland (28 dB (A)), the lowest required limit values are set in Germany, Austria and Switzerland (25 dB (A)).

Regarding the required airflow and air-exchange rate not all building types have specified this in the regulation. For comparing how the limit values are set (for building types where no requirement is specified, the limit value set in the building regulation has been looked up and is written in *italic* font), a compilation divided into low-energy buildings and passive houses has been made in table 6.

In the section of passive houses these building types are included: Sweden - **FEBY Passive house,** Norway - **prNS3700 passive house**, Denmark - **Passive house by PHI**, Finland - **RIL passive house**, Germany - **RAL passive house and PHI passive house**, Austria - **state-aided passive house and k:a passive house**, Switzerland - **Minergie-P and P-ECO**.

The airflow rates are listed in their original unit of the requirement in **bold** font and are then all converted to the unit of h^{-1} und the precondition of a room with 30 m^2 area and a height of 2.5 m. Great Britain and Poland are not listed, by reason of referring to the German passive house.

V=75 m^3	**R** (l/s m^2)	(l/s)	**R** (m^3/h m^2)	(m^3/h)	**n** (h^{-1})	**additional requirement**
Low-energy						
Sweden	***0.35***	10.5	→	37.8	0.5	-
Denmark	***0.35***	10.5	→	37.8	0.5	-
Norway			***1.74***	52.2	0.7	-
Finland					***0.5***	-
Germany					**0.5**	-
Austria					**0.3**	**30 m^3/h per person**
Switzerland				**30** →	0.4	-
Passive house						
Sweden	***0.35***	10.5	→	37.8	0.5	-
Denmark	***0.35***	10.5	→	37.8	0.5	-
Norway			***1.74***	52.2	0.7	-
Finland					***0.5***	-

Germany			
RAL		**0.5**	-
PHI		**0.3**	-
Austria			
State-aided		**0.3**	**30 m³/h per person**
K:a		**0.3**	**at least 30 m³/h**
Switzerland	**30 →**	0.4	-

Table 6. Minimum airflow rates in low-energy and passive houses.

For low-energy buildings Sweden, Denmark, Finland, Germany and Switzerland show the same air exchange rate per hour, lying between 0.4 and 0.5 h^{-1}. In Austria the rate is lower, but has the additional requirement of 30 m^3/h per person, which at occupancy of one person in the room, raises the ach-rate to the same level as for the other countries. – Norway shows a **higher** rate of 0.7 h^{-1}.

For passive houses in Sweden, Denmark, Norway, Finland and Switzerland there is no difference between the rate for low-energy and passive houses. In Germany it is split – Passive houses by RAL require the same exchange rate as low-energy buildings, passive houses by the PHI have a **lower** limit value of 0.3 h^{-1}. In Austria, state-aided passive houses have the same requirement as low-energy buildings; a comparably lower set air exchange rate, but with the requirement on airflow per person it is raised to the level of the other countries. The same for klima:aktiv passive houses; with the additional requirement of at least 30 m^3/h the air exchange rate is raised to 0.4.

In German passive houses by the PHI, the limit value for air exchange rate is set lower than compared to the other countries. This results in poorer indoor climate due to possible higher concentration of CO_2 and other particles. Though, a mean airflow rate of 20-30 m^3/h per person is *advised*. The air tightness-requirement is the same as for the other passive house types; therefore an explanation of lower air exchange rate due to lower air tightness (whereby air leakage through the building envelope contributes to the air exchange in a room), can be neglected. The quality of the indoor air must not be lowered, but the technical settings have to be adapted to a lower airflow rate to retain a good indoor climate.

The higher airflow rate in Norway can be seen as positive for the indoor climate regarding air quality. The more often the air is being exchanged, it contains less pollutants and is fresher. Though, this is only valid for areas below 110 m^2; otherwise the airflow rate has a lower limit value of 1.2 $m^3/(h\ m^2)$, which is related to an air exchange rate of 0.5 h^{-1}.

Regarding air velocities, throw or location of air diffusers, **no** standard has set specific requirements. Only Austrian state-aided passive houses are referring to a recommended value of < *0.3 m/s* air velocity in the occupied zone. Compared to the recommended values this value is quite high, and exceeds the recommended value even for the lower comfort class.

No regulation contains limit values exceeding 52°C for supply air. – Building types where this criterion is missing, have not secured a good indoor climate, due to possible emissions at higher air temperatures.
Only one building type has requirements on the minimum temperature of supply air, the German passive house and its suitable component; the Austrian state-aided low-energy and passive houses have a recommended lower value. All limit values are between 16.5-17°C, which is rated as a usual value for lower temperature. For the building types missing a lower limit value for supply air temperature this can bring disadvantages if the air diffuser is not adequately regulated to lower temperatures. If the temperature is low and technical settings as throw and mixing effect not are adapted to this, the cold air sinks to fast, which can result in draught and discomfort.

Regarding filter classes no country allows lower filter classes than F7 for air intake, which equates to the recommended values for good air quality. The only exception is Finland, where buildings out of cities are allowed a filter class G4. Due to lower exhaust gases and air pollution on the countryside, this limit value is comprehensible.

Regarding air quality, Minergie-ECO and P-ECO are the only building types where spot-test measurements of TVOC, HCHO and Radon are being performed.

Regarding indoor placing of air diffusers no country has set requirements; neither regarding relative humidity.

5.4 Consequences on ventilation system components

The sound levels must all be held between 25 and 28 dB(A), which are no unusual values for the ventilation system.

The required temperature efficiency of heat exchanger must for low-energy buildings be at least 70%, for passive houses 75-80%. These are quite high but not impossible efficiency rates. Though, high efficiency rates can limit the use of specific exchanger types. When designing a heat exchange system for specific building types, it should be paid attention on the referred definition and calculation method for the efficiency – the PHI refers to corrected heat recovery efficiencies $\eta_{WRG,t,eff}$, RAL-GZ low-energy and passive houses and Austrian state-aided low-energy and passive houses refer to uncorrected heat efficiencies η_{WRG} and η'_W, the Norwegian standard refers to the temperature efficiency η_t. None is referring to the European standard EN 13 053 – and for some building types the calculation method is not specified.

Klima:aktiv buildings are the only ones setting limit values relating to the type of heat exchanger (counter flow or cross flow) – but these are only limit values for achieving additional points in the evaluation system, i.e. no must-criteria.

Imbalance: If a requirement is set concerning imbalance, it is always limited to 10%, which is appropriate – for good for moisture safety, especially in colder climates, and regarding the energy use.

Regarding frost protection of the heat recovery unit the only regulation setting requirements is the one for the passive house suitable component of the PHI, where the component either has to have an installed frost protection or be connected to an external frost protection. In addition the unit has to be equipped with an emergency shutdown if the supply air temperature falls below 5°C.

For control and regulation only Germany and Austria have requirements on the ventilation system. Where specified, the systems have to be able to be manually regulated on 3 levels; an exception makes the RAL-GZ low energy house where only 2 levels are required.

When the lower limit value for airflow rates is set low, as for German passive houses by the PHI, this may influence the performance of the air diffuser. Lower airflow rates need greater velocities to achieve enough throw and a good mixing effect.

5.5 Annotations regarding the regulations

Regarding some regulations additional annotations have been made;

Norway the regulation prNS 3700 refers to a limit value for *heating demand*; the regulation, such as the national building regulation includes the definition of a buildings *heat demand* as energy needed for heating, ventilation and domestic hot water. It is explained that the energy posts heating and ventilation are summed up to one post called *heating demand*, but though it can be confusing in the standard prNS3700.

Germany concerning the criteria document for residential passive house buildings of the PHI some annotations have been made: Though it is clear that a passive house of the PHI must be equipped with a FTX ventilation system, it is not clearly defined in the criteria-document, where the limit values for the energy performance and other criteria are given. Neither it is clear, if the for certification available ”passive house suitable component” must be installed in the defined passive house.

Austria In the Austrian regulation for state-aided passive houses RL MA 25, the limit value regarding energy performance is depending on whether the building is equipped with so-called *Wohnraumlüftung* or not. – A definition of what a *Wohnraumlüftung* includes is not given in the regulation.

The 3-litre-house has no regulation documents available besides the definition and listed criteria on the webpage; the attempts of getting in contact were to no avail. According to the criteria on the webpage the buildings heating energy demand is limited to a certain value; though, there is no reference to which area it relates. The calculation method is restricted to using a number of programs, hereunder an Austrian (mostly using the brut area as related area) and the German PHPP (using the net area as related area).

Switzerland Comfort ventilation (FTX ventilation system) is not a must in Minergie houses. – But on the webpage-description for both Minergie and Minergie-P houses the building types are defined by the statement *“Primary requirements on Minergie-houses are: keeping the Minergie-limit values, mechanical ventilation by comfort ventilation, …”*. This is not responding to the regulation document, where it only is a recommended option; except for Minergie houses verified by standard solution 5, where FTX is a requirement.

In general the standards should be more consequent using *“< ”* and *”≤”* so that it is clear whether a limit value is set below a value or including a value.

6 Conclusions

The result of this study is that there are many existent building types, from low-energy in general to passive houses that are defined by regulations; whereof the state of definition varies from slightly to severe between the countries, but also between different building types within a country. The highest amount of defined low-energy building types is in Germany, Austria and Switzerland; Great Britain and Poland have the very least.

The number of existent definitions of low-energy, passive and zero-energy buildings and their state of definition in the nine countries are:

	Low-energy	Passive house	Zero-energy
Sweden	1 semi-official	1 semi-official	1 semi-official
Norway	1 official *(upcoming year 2010)*	1 official *(upcoming)* 1 semi-official	-
Denmark	2 official	1 semi-official	-
Finland	5 semi-official	3 semi-official	-
Germany	3 semi-official 1 unofficial	2 semi-official	-
Austria	1 official 2 semi-official	1 official 1 semi-official	-
Switzerland	4 semi-official *(whereof 2 are relating to passive houses)*	-	-
Great Britain	-	1 semi-official	-
Poland	-	1 unofficial	-

Whereof the semi- and unofficial passive houses in Norway, Denmark, Great Britain and Poland are referring to the German definition.

The different building types show differences whether only the energy performance is defining, or if the whole building, including its technical systems is being evaluated. The most "complete" evaluation methods are used in Germany, Austria and Switzerland. Due to the circulating interaction between building envelope, air leakage, airflow rates, ventilation system performance and indoor climate, the importance of defining the building as a whole package, beyond its energy performance is demonstrated.

The inclusion of household electricity, which is only being accounted at a few building types, can be seen from two point of views – It may be seen as positive, because all buildings are being rated under the same precondition, not influenced by user habits; from another point of view, great energy rates that influence the energy performance may be missed.

Out of the compilation of set criteria, the conclusion can be drawn that it is possible to design ventilation systems that are suitable for almost all nine countries, as a result of the slightly varying requirements in the countries where requirements are set at all. The required performance parameters include high temperature efficiencies of the heat exchangers, what sets high demands, but is not impossible to meet. An obstacle when designing a ventilation system, suitable for the different building types, may be the differently defined efficiency rates, where great attention must be paid for meeting the correct limit values.

Regarding indoor climate none of the examined criteria show any indication of negative impacts on the indoor climate, but many building types are missing requirements on this subject overall – One consideration would be regarding air velocity, where Austria is the only country giving a recommended value, which lies above recommended comfort values. Regarding the varying airflow and air exchange rates of the standards, e.g. Norway requiring the double of Germany, no exclusive conclusion can be drawn whether this has greater negative impacts on the indoor climate, but studies have indicated that ventilating more has many positive effects on the indoor climate and peoples comfort and health – Concerning this topic further research is needed.

General conclusions regarding setting criteria for low-energy buildings where mechanical ventilation plays a great role can be drawn regarding the interaction between ventilation and indoor climate. – Higher airflows increase the heating effect of the ventilation system at lower supply air temperatures, but also cause higher demands on the performance of the air diffuser (e.g. the mixing effect). In buildings where the supply air temperature is set low, and heating shall be provided by ventilation, the airflow rate must be higher. – What on one side has a positive effect on the indoor climate concerning air quality, but on the other side can have negative effects if the system is not well regulated and the high airflows result in draught. Another negative impact is the raise of energy demand needed for higher airflows. – It is a vicious circle, where the right balance between the different parameters has to be found, not affecting the indoor climate in a negative way – An opportunity to meet this problem are demand-controlled systems.

Regarding the issue of comparability, especially the standards energy rating is hard to compare. Due to different related areas, differently included energy posts and different terms and definitions, both between the countries and within a country, it is hard to compare the different building types. Though the discrepancies sometimes only are minimal, e.g. differing by one energy post that not is included, they accumulate and make the national methods very complex so that a detailed study is needed to understand.

A cross-country comparison is in some countries even hindered by linguistic problems. Regarding low-energy buildings Finland and Poland have not established information in English yet; also in Austria and Germany many building types are only regulated in German.

The conclusions are –

There are many definitions, but only few include a *complete* definition.

There are many different terms and definitions, adjusting these would simplify the internationalisation and understanding between the countries.

A common definition that bases on same criteria levels, related areas and included energy-posts, out of which then national amendments relating to climate etc. can be made, is needed.

At the current state of definition, the set limit values for low-energy buildings do not show any fatal negative impacts on the indoor climate and people's health and comfort. But regarding some subjects more considerations should be made and overall more criteria should be specified.

Low-energy buildings are good – but well defined regulations are necessary to end up there.

7 Future work

A matter of future work to explore the concept of low-energy buildings and their regulations further could be topics as:

Additional research of indoor temperatures in summer – are the regulations including criteria for achieving thermal comfort in summer? And how shall it be verified?

Moisture safety – are there any specified moisture safety design demands?

Calculation methods and implementation – comparing the common EBPD standard with the national building regulations and look how far each country has implemented the common method – To consider the inclusion of household energy and other missing energy post.

Regarding ventilation an interesting topic could be how ventilation systems are regulated **relating to fire** and what is appropriate.

Regarding the building in its completeness, a matter of future work based on this thesis would be:

A complete compilation – by adding all criteria, including those of the national building regulations in detail, comparing if there are any discrepancies between the building regulation and the low-energy building standard, and making a complete compilation for each country relating to the four subject areas of this thesis.

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Appendix

Appendix I – Checklist planning and construction - Ventilation, PHI Germany

5 Planning: ventilation

- **Routing of ventilation ducts:**
  - keep cold ducts outside the heated envelope. If they need to be inside then only for very short lengths and highly insulated
  - keep warm ducts inside the heated envelope. If they need to be outside then only for very short lengths and highly insulated
  - use short ducts with smooth walls
  - keep flow velocities below 3 m/s throughout
  - design measurement and flow balancing facilities into the system
  - consider fire protection
  - consider noise factors, including noise reduction.
- Air inlets:
  - avoid short-circuiting air flows
  - consider throw widths
  - incorporate flow regulation/balancing possibilities.
- Air exhausts:
  - do not place above heating elements (if present).
- Dimension overflow openings for a pressure drop $\Delta_p \leq 1$ Pa.
- Central ventilation/heat recovery unit:
  - position heat exchangers close to or inside the thermal envelope. Good positions are inside the heated envelope or in a basement
  - position air heating units inside the thermal envelope
  - add additional insulation as required in each case
  - the unit should meet or (preferably) exceed these data:
- overall efficiency ≥ 75%
- leakage to surrounding air < 3% of the rated flow volume
- internal leakage (between intake and exhaust air flows) < 3% of the rated flow volume
- high electrical efficiency, power consumption < 0.45 Wh/m³ air
  - have suitable regulation/control facilities
  - low noise rating
  - excellent heat insulation.
- Ventilation user controls:
  - settings: high, normal, low
  - possibly time-limited booster functions in kitchens, toilets and bathrooms.
- Kitchen extractors connected to the ventilation system should have good extraction capabilities at a very low flow rate and be fitted with grease filters. However, it is preferable to use circulation only extractors with active coal and grease filters.
- Optionally, consider installing a ground heat exchanger to keep intake air frost free. This can either be a ground-to-air exchanger or a ground-to-liquid exchanger with a liquid-to-air exchanger close to the ventilation unit. In some climates this will probably not be required. If required, consider:
  - airtightness
  - distance between cold channels and the building
  - summer bypass/cooling facilities
  - extraction of condensate
  - cleaning

8 Construction phase - ventilation

- Airtightness. Check that piping and duct-work conserve the integrity of the airtight envelope.
  - ducts: make sure they are clean and leak free
  - central ventilation unit: check accessibility for filter change and noise reduction measures
  - check duct insulation - is it present where required and correctly installed?
- Flow settings in normal operation:
  - measure intake and exhaust air flows - compare them to ensure they are balanced
  - compare fresh and stale air distribution
  - measure electrical power consumption

(Passiv.de - *Passivehouse Construction Check List*)

Appendix II – Certificated Passive House suitable component

Zertifikat

gültig bis 31.12.2009

Passivhaus Institut
Dr. Wolfgang Feist
Rheinstraße 44/46
D-64283 Darmstadt

Passivhaus geeignete Komponente: **Wärmepumpen-Kompaktgerät**

Hersteller: **Drexel & Weiss, Wolfurt, Österreich**

Produktname: **aerosmart m**

Folgende Kriterien wurden für die Zuerkennung des Zertifikates geprüft:
(Vollständige Anforderungen und Nachweise sind der Anlage zu diesem Zertifikat zu entnehmen.)

Passivhaus-Behaglichkeitskriterium: Mindest-Zulufttemperatur 16,5°C bei -10 °C Außenluf ttemperatur wird erreicht .(**)

Effizienz-Kriterium – Wärmerückgewinnung: Effektiver Wärmebereitstellungsgrad η_{eff} **= 78 %**

Effizienz-Kriterium –Strom: 0.29 W/(m³/h) bei 173 m³/h gefördertem Zuluftvolumenstrom

Luftdichtheit: Interne Leckagen **2.3 % (max. 3 %);** externe Leckagen **1.2 % (max. 3 %)**

Abgleich und Regelbarkeit, Filter, Frostschutzschaltung: geprüft.

Schallschutz: Terzbandanalyse für Schallabstrahlung (Gehäuse und Gerätestutzen) ab 25 Hz

Erdwärmeübertrager: (**) Für dieses Gerät ist ein Erdwärmeübertager mit einer Mindestaustritts-temperatur von **–3 °C** vorzusehen.

Heizung

	Prüfpunkt 1	*Prüfpunkt 2*	*Prüfpunkt 3*	*Prüfpunkt 4*
Außenlufttemperatur	-2 °C	2 °C	7°C	
thermische Leistung WP	1.03	1.18	1.34	
COP Heizung	2.22	2.73	3.07	

Warmwasser

Außenlufttemperatur	-2 °C	2 °C	7 °C	20 °C
thermische Leistung WP WW Speicheraufheizung	0.92	1.13	1.28	1.49
thermische Leistung WP WW Speichernachladung	0.88	1.10	1.28	1.41
COP WW Speicheraufheizung	2.51	2.93	3.26	3.47
COP WW Speichernachladung	2.08	2.39	2.71	2.71

Speicher *spez. Wärmeverluste Speicher inkl. Anschlüsse* 1.60 *W/K* *mittlere Speichertemp. im Bereitschaftsbetrieb* 47.1 °C

Regelung (Vorrangschaltung): Warmwasservorrang / Heizungsvorrang

Maximale Zulufttemperatur im Heizlastfall: 52 °C

Fortluftbeimischung (falls vorhanden): *Volumenstrom der Beimischung* m³/h

PASSIV HAUS geeignete KOMPONENTE Dr. Wolfgang Feist

Wärmepumpen-Kompaktgerät
Einsatzbereich von 160 m² bis 240 m²

Primärenergie gesamt*
47.8 kWh/(m²a)

**Heizung, Warmwasser, Lüftung und Hilfsstrom; Randbedingungen siehe Anlage zum Zertifikat*

(Passiv.de – *Certification of PH suitable components – certificated compact units*)

Appendix III – Certification sample

Passivhaus Institut
Dr. Wolfgang Feist
Rheinstraße 44/46
D-64283 Darmstadt

PH

Zertifikat

gültig bis 31.12.2003

MUSTER

Passivhaus geeignete Komponente: **Wärmerückgewinnungsgerät**

Hersteller: **...**

Produktname: **...**

Folgende Kriterien wurden für die Zuerkennung des Zertifikates geprüft:

1) **Passivhaus-Behaglichkeitskriterium:**

Eine minimale Zulufttemperatur von 16,5°C wird bei -10 °C Außenlufttemperatur erreicht.

Begründung: In Passivhäusern sind keine Heizflächen an Außenbauteilen erforderlich. Um unbehaglichen Kaltlufteinfall zu vermeiden, muß die Zulufttemperatur begrenzt werden.

2) **Effizienz-Kriterium (Wärme):**

Der effektive trockene Wärmebereitstellungsgrad muß mit balancierten Massenströmen bei Außentemperaturen zwischen -15 und 10°C und trockener Abluft (21°C) höher als

$\eta_{WBG,t,eff} \geq$ 75% sein (**hier:** %).

3) **Effizienz-Kriterium (Strom):**

Die gesamte spezifische elektrische Leistungsaufnahme des Gerätes darf in den für Passivhäuser vorgesehenen Betriebszuständen (bei Auslegungs-Massenstrom)

0,45 W/(m³/h) geförderter Zuluftvolumenstrom nicht überschreiten (**hier W/(m³/h)**).

4) **Dichtheit:**

Der interne Leckluftstrom und der externe Leckluftstrom dürfen jeweils 3% des Nenn-Abluftstromes nicht übersteigen.
(Anforderungen und Nachweise sind der Anlage zu diesem Zertifikat zu entnehmen)

5) **Dämmung:**

Die Wärmeabgabe/Wärmeaufnahme über das Gehäuse des Gerätes muß begrenzt sein; d.h. Dämmung als Gesamt-Transmissionsleitwert 5 W/K (bei einem Gerät für eine Wohnung d.h. 120 m³/h Nennvolumenstrom; (**hier W/K**).

6) **Abgleich und Regelbarkeit:** **(Anforderungen und Nachweise sind der Anlage zu diesem Zertifikat zu entnehmen)**

7) **Schallschutz:**

Schalldruckpegel im Aufstellraum < 35 dB(A) bei äquivalenten Raumabsorptionsflächen von 4 m², Schallpegel in Wohnräumen unter 25 dB(A), in Funktionsräumen unter 30 dB(A).
(Erläuterungen und Nachweise sind der Anlage zu diesem Zertifikat zu entnehmen)

8) **Raumlufthygiene:** **(Anforderungen und Nachweise sind der Anlage zu diesem Zertifikat zu entnehmen)**

9) **Frostschutzschaltung:** **(Anforderungen und Nachweise sind der Anlage zu diesem Zertifikat zu entnehmen)**

Das Zertifikat ist wie folgt zu verwenden:

PASSIV HAUS geeignete KOMPONENTE Dr. Wolfgang Feist

Wärmerückgewinnung:
Wärmebereitstellungsgrad (effektiv): ... %
Elektroeffizienz: ... Wh/m³

(Passiv.de – *Certification of PH suitable components – Certification sample*)

Appendix IV – Evaluation system klima:aktiv houses

Kriterienkatalog **klima:**aktiv Haus

Nr.	Titel	PUNKTE Muss-Kriterium	1.000 erreichbare Punkte
A	**PLANUNG UND AUSFÜHRUNG**		**max. 120**
A 1	**Planung**		**max. 100**
A 1.1	Qualität der Infrastruktur (Nähe zu Schule, ÖPNV, etc.)		20
A 1.2	Fahrradabstellplatz		30
A 1.3 a	Barrierefreies Bauen – Teilausbau	nur ein	20
A 1.3 b	Barrierefreies Bauen – Vollausbau	Krit. wählbar	40
A 1.4 a	Gebäudehülle wärmebrückenarm		20
A 1.4 b	Gebäudehülle wärmebrückenfrei		30
A 2.	**Ausführung**		**max. 40**
A 2.1 a	Gebäudehülle luftdicht (Standard)	**M** (nur ein	25
A 2.1 b	Gebäudehülle luftdicht (Passivhaus)	Krit. wählbar)	40
B	**ENERGIE UND VERSORGUNG**		**max. 600**
B 1	**Wärmebedarf und -versorgung**		**max. 575**
B 1.1 a	Heizwärmebedarf (Nachweis für **klima:**aktiv Häuser)	**M**	350
B 1.2	Keine Kohle-, Koks, Stromwiderstandsheizung	**M**	0
B 1.3 a	Gas und Ölbrennwertkessel	**M**	0
B 1.3 b	Wärmepumpe monovalent	(nur ein	60
B 1.3 c	Wärmepumpe monovalent optimiert	Kriterium	110
B 1.3 d	Wärmepumpen-Kompaktaggregat	wählbar)	50
B 1.3 e	Fernwärme aus Abwärme oder KWK		90
B 1.3 f	Fernwärme aus Abwärme oder KWK (optimiert)		140
B 1.3 g	Heizungsanlage für biogene Brennstoffe		150
B 1.4	Keine direkt-elektrische Warmwasserbereitung	**M**	0
B 1.5	Solare Warmwasserbereitung		45
B 1.6 a	Warmwasser/Pufferspeicher (Standard)		20
B 1.6 b	Warmwasser/Pufferspeicher (optimiert)		30
B 2	**Energiebedarf elektrisch**		**max. 40**
B 2.1	Lüftungsanlage energieeffizient		20
B 2.1 a	Lüftungsanlage vorhanden	**M**	0
B 2.2	Beleuchtung der Allgemeinbereiche energiesparend		10
B 2.3	Spülen und Waschen mit Warmwasseranschluss		10
B 2.4	Photovoltaikanlage		35
B 3	**Wasserbedarf**		**max. 40**
B 3.1	Handwaschbecken, Duschkopf Wasser sparend (Standard)	**M**	20
B 3.2	Handwaschbecken Wasser sparend (optimiert)		10
B 3.3	Duschkopf Wasser sparend (optimiert)		10
C	**BAUSTOFFE UND KONSTRUKTION**		**max 160**
C 1	**Baustoffe**		**max. 110**
C 1.1	Dämmstoffe HFKW-frei (inkl. Montageschaum)		20
C 1.2	Fenster, Türen, Rollläden, Rohre – PVC-frei		40
C 1.3	Folien, Fußbodenbeläge, Tapeten – PVC-frei	**M**	40
C 1.4	Bitumenvoranstriche, -anstriche und -klebstoffe – lösemittelfrei		10
C 1.5	Baustoffe ökologisch optimiert		40
C 2	**Konstruktionen und Gebäude**		**max. 100**
C 2.1	Ökologischer Kennwert der thermische Gebäudehülle		100
D	**KOMFORT UND RAUMLUFTQUALITÄT**		**max. 120**
D 1	**Thermischer Komfort**		**max. 30**
D 1.1	Gebäude sommertauglich	**M**	30
D 2	**Raumluftqualität**		**max. 110**
D 2.1 a	Frischluftanlage optimiert (Schall etc.)	**M** (nur ein	35
D 2.1 b	Komfortlüftung mit Wärmerückgewinnung optimiert (Schall, Luftfilter etc.)	Krit. wählbar)	60
D 2.2	Verlegewerkstoffe emissionsarm		10
D 2.3	Bodenbeläge emissionsarm		15
D 2.4	Holzwerkstoffe emissionsarm		15
D 2.5	Wand und Deckenanstriche emissionsarm		15
D 2.6	Messung der flüchtigen Kohlenwasserstoffe und Formaldehyd		25
		GESAMT	**1.000**

Kriterienkatalog klima:aktiv Passivhaus

Nr.	Titel	PUNKTE Muss-Kriterium	1.000 erreichbare Punkte
A	**PLANUNG UND AUSFÜHRUNG**		**max. 120**
A 1	**Planung**		**max. 100**
A 1.1	Qualität der Infrastruktur (Nähe zu Schule, ÖPNV, etc.)		20
A 1.2	Fahrradabstellplatz		30
A 1.3 a	Barrierefreies Bauen – Teilausbau	nur ein	20
A 1.3 b	Barrierefreies Bauen – Vollausbau	Krit. wählbar	40
A 1.4 b	Gebäudehülle wärmebrückenfrei		30
A 2.	**Ausführung**		**max. 40**
A 2.1 b	Gebäudehülle luftdicht (Passivhaus)	**M**	40
B	**ENERGIE UND VERSORGUNG**		**max. 600**
B 1	**Wärmebedarf und -versorgung**		**max. 575**
B 1.1 b	Passivhaus nach PHPP	**M**	575
B 2	**Energiebedarf elektrisch**		**max. 40**
B 2.1	Lüftungsanlage energieeffizient		20
B 2.1 a	Lüftungsanlage vorhanden	**M**	0
B 2.2	Beleuchtung der Allgemeinbereiche energieeffizient		10
B 2.3	Spülen und Waschen mit Warmwasseranschluss		10
B 2.4	Photovoltaikanlage		35
B 3	**Wasserbedarf**		**max. 40**
B 3.1	Handwaschbecken, Duschkopf Wasser sparend (Standard)	**M**	20
B 3.2	Handwaschbecken Wasser sparend (optimiert)		10
B 3.3	Duschkopf Wasser sparend (optimiert)		10
C	**BAUSTOFFE UND KONSTRUKTION**		**max 160**
C 1	**Baustoffe**		**max. 110**
C 1.1	Dämmstoffe HFKW-frei (inkl. Montageschaum)		20
C 1.2	Fenster, Türen, Rollläden, Rohre – PVC-frei		40
C 1.3	Folien, Fußbodenbeläge, Tapeten – PVC-frei	**M**	40
C 1.4	Bitumenvoranstriche, -anstriche und -klebstoffe – lösemittelfrei		10
C 1.5	Baustoffe ökologisch optimiert		40
C 2	**Konstruktionen und Gebäude**		**max. 100**
C 2.1	Ökologischer Kennwert der thermische Gebäudehülle	100	
D	**KOMFORT UND RAUMLUFTQUALITÄT**		**max. 120**
D 1	**Thermischer Komfort**		**max. 30**
D 1.1	Gebäude sommertauglich	**M**	30
D 2	**Raumluftqualität**		**max. 110**
D 2.1 b	Komfortlüftung mit Wärmerückgewinnung optimiert (Schall, Luftfilter etc.)	**M**	60
D 2.2	Verlegewerkstoffe emissionsarm		10
D 2.3	Bodenbeläge emissionsarm		15
D 2.4	Holzwerkstoffe emissionsarm		15
D 2.5	Wand und Deckenanstriche emissionsarm		15
D 2.6	Messung der flüchtigen Kohlenwasserstoffe und Formaldehyd		25
		GESAMT	**1.000**

(Regulation Klima:aktiv Summary)