Annex 55
Reliability of Energy Efficient Building Retrofitting-Probability Assessment of Performance and Cost (RAP-RETRO)

Practice and guidelines

MARCUS FINK Fraunhofer, IBP, Germany
ANDREAS HOLM FIW, Munich, Germany
FLORIAN ANTRETTER Fraunhofer, IBP, Germany

International Energy Agency

Energy in Buildings and Communities Programme

Department of Civil and Environmental Engineering
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2015

Practice and guidelines
Editors: Marcus Fink, Andreas Holm, Florian Antretter
Reviewers: Thomas Bednar, Nathan Mendes, Kristina Mjörnell, Targo Kalamees

Report 2015:6
ISSN 1652-9162

Department of Civil and Environmental Engineering
Division of Building Technology
Chalmers University of Technology
SE-412 96 Gothenburg
Sweden
Telephone + 46 (0)31-772 1000

Published by Chalmers University of Technology, SE-412 96 Göteborg, Sweden

Disclaimer Notice: This publication has been compiled with reasonable skill and care. However, neither Chalmers University of Technology nor the EBC Contracting Parties (of the International Energy Agency Implementing Agreement for a Programme of Research and Development on Energy in Buildings and Communities) make any representation as to the adequacy or accuracy of the information contained herein, or as to its suitability for any particular application, and accept no responsibility or liability arising out of the use of this publication. The information contained herein does not supersede the requirements given in any national codes, regulations or standards, and should not be regarded as a substitute for the need to obtain specific professional advice for any particular application.

ISSN 1652-9162

Participating countries in EBC:

Australia, Austria, Belgium, Canada, P.R. China, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Republic of Korea, the Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom and the United States of America.

Additional copies of this report may be obtained from:

EBC Bookshop

C/o AECOM Ltd

Colmore Plaza

Colmore Circus Queensway

Birmingham B4 6AT

United Kingdom

Web: www.iea-ebc.org

Email: essu@iea-ebc.org

Preface

The International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. A basic aim of the IEA is to foster international co-operation among the 28 IEA participating countries and to increase energy security through energy research, development and demonstration in the fields of technologies for energy efficiency and renewable energy sources.

The IEA Energy in Buildings and Communities Programme

The IEA co-ordinates research and development in a number of areas related to energy. The mission of the Energy in Buildings and Communities (EBC) Programme is to develop and facilitate the integration of technologies and processes for energy efficiency and conservation into healthy, low emission, and sustainable buildings and communities, through innovation and research. (Until March 2013, the IEA-EBC Programme was known as the Energy in Buildings and Community Systems Programme, ECBCS.)

The research and development strategies of the IEA-EBC Programme are derived from research drivers, national programmes within IEA countries, and the IEA Future Buildings Forum Think Tank Workshops. The research and development (R&D) strategies of IEA-EBC aim to exploit technological opportunities to save energy in the buildings sector, and to remove technical obstacles to market penetration of new energy efficient technologies. The R&D strategies apply to residential, commercial, office buildings and community systems, and will impact the building industry in five focus areas for R&D activities:

- Integrated planning and building design
- Building energy systems
- Building envelope
- Community scale methods
- Real building energy use

The Executive Committee

Overall control of the IEA-EBC Programme is maintained by an Executive Committee, which not only monitors existing projects, but also identifies new strategic areas in which collaborative efforts may be beneficial. As the Programme is based on a contract with the IEA, the projects are legally established as Annexes to the IEA-EBC Implementing Agreement. At the present time, the following projects have been initiated by the IEA-EBC Executive Committee, with completed projects identified by (*):

Annex 1: Load Energy Determination of Buildings (*)
Annex 2: Ekistics and Advanced Community Energy Systems (*)
Annex 3: Energy Conservation in Residential Buildings (*)
Annex 4: Glasgow Commercial Building Monitoring (*)
Annex 5: Air Infiltration and Ventilation Centre
Annex 6: Energy Systems and Design of Communities (*)
Annex 7: Local Government Energy Planning (*)
Annex 8: Inhabitants Behaviour with Regard to Ventilation (*)
Annex 9: Minimum Ventilation Rates (*)
Annex 10: Building HVAC System Simulation (*)

Annex 11: Energy Auditing (*)
Annex 12: Windows and Fenestration (*)
Annex 13: Energy Management in Hospitals (*)
Annex 14: Condensation and Energy (*)
Annex 15: Energy Efficiency in Schools (*)
Annex 16: BEMS 1- User Interfaces and System Integration (*)
Annex 17: BEMS 2- Evaluation and Emulation Techniques (*)
Annex 18: Demand Controlled Ventilation Systems (*)
Annex 19: Low Slope Roof Systems (*)
Annex 20: Air Flow Patterns within Buildings (*)
Annex 21: Thermal Modelling (*)
Annex 22: Energy Efficient Communities (*)
Annex 23: Multi Zone Air Flow Modelling (COMIS) (*)
Annex 24: Heat, Air and Moisture Transfer in Envelopes (*)
Annex 25: Real time HVAC Simulation (*)
Annex 26: Energy Efficient Ventilation of Large Enclosures (*)
Annex 27: Evaluation and Demonstration of Domestic Ventilation Systems (*)
Annex 28: Low Energy Cooling Systems (*)
Annex 29: Daylight in Buildings (*)
Annex 30: Bringing Simulation to Application (*)
Annex 31: Energy-Related Environmental Impact of Buildings (*)
Annex 32: Integral Building Envelope Performance Assessment (*)
Annex 33: Advanced Local Energy Planning (*)
Annex 34: Computer-Aided Evaluation of HVAC System Performance (*)
Annex 35: Design of Energy Efficient Hybrid Ventilation (HYBVENT) (*)
Annex 36: Retrofitting of Educational Buildings (*)
Annex 37: Low Exergy Systems for Heating and Cooling of Buildings (LowEx) (*)
Annex 38: Solar Sustainable Housing (*)
Annex 39: High Performance Insulation Systems (*)
Annex 40: Building Commissioning to Improve Energy Performance (*)
Annex 41: Whole Building Heat, Air and Moisture Response (MOIST-ENG) (*)
Annex 42: The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems (FC+COGEN-SIM) (*)
Annex 43: Testing and Validation of Building Energy Simulation Tools (*)
Annex 44: Integrating Environmentally Responsive Elements in Buildings (*)
Annex 45: Energy Efficient Electric Lighting for Buildings (*)
Annex 46: Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo) (*)
Annex 47: Cost-Effective Commissioning for Existing and Low Energy Buildings (*)
Annex 48: Heat Pumping and Reversible Air Conditioning (*)
Annex 49: Low Exergy Systems for High Performance Buildings and Communities (*)
Annex 50: Prefabricated Systems for Low Energy Renovation of Residential Buildings (*)
Annex 51: Energy Efficient Communities (*)
Annex 52: Towards Net Zero Energy Solar Buildings (*)
Annex 53: Total Energy Use in Buildings: Analysis & Evaluation Methods (*)
Annex 54: Integration of Micro-Generation & Related Energy Technologies in Buildings

Annex 55: Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance & Cost (RAP-RETRO)

Annex 56: Cost Effective Energy & CO2 Emissions Optimization in Building Renovation

Annex 57: Evaluation of Embodied Energy & Greenhouse Gas Emissions for Building Construction

Annex 58: Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements

Annex 59: High Temperature Cooling & Low Temperature Heating in Buildings

Annex 60: New Generation Computational Tools for Building & Community Energy Systems
Annex 61: Business and Technical Concepts for Deep Energy Retrofit of Public Buildings
Annex 62: Ventilative Cooling
Annex 63: Implementation of Energy Strategies in Communities
Annex 64: LowEx Communities - Optimised Performance of Energy Supply Systems with Exergy Principles
Annex 65: Long-Term Performance of Super-Insulating Materials in Building Components and Systems
Annex 66: Definition and Simulation of Occupant Behavior in Buildings
Annex 67: Energy Flexible Buildings
Working Group - Energy Efficiency in Educational Buildings (*)
Working Group - Indicators of Energy Efficiency in Cold Climate Buildings (*)
Working Group - Annex 36 Extension: The Energy Concept Adviser (*)

Table of Content

1 BACKGROUND

1.1 Country representatives

The following table lists the country representatives which were participating in Annex 55. Most of the countries contributed to Subtask 4 which is presented in this report.

Table 1.1: Country representatives

Country	Institute/University	Last Name	First Name
Austria	Vienna University of Technology	Bednar	Thomas
Belgium	Katholieke Universiteit Leuven	Roels	Staf
Brazil	Pontifical Catholic University of Paraná (PUCPR)	Mendes	Nathan
Canada	British Columbia Institute of Technology	Tariku	Fitsum
Denmark	Danmarks Tekniske Universitet (DTU)	Rode	Carsten
Estonia	Tallinn University of Technology	Kalamees	Targo
Finland	Tampere University of Technology	Vinha	Juha
Germany	Fraunhofer Institute	Holm	Andreas
Japan	Kyoto University	Shuichi	Hokoi
The Netherlands	Eindhoven University of Technology	Heijden	M.G.M.
Portugal	University of Porto	Ramos	Nuno
Slovakia	Slovak Academy of Sciences	Matiasovsky	Peter
Sweden	Chalmers University of Technology	Hagentoft	Carl-Eric
United Kingdom	London's Global University	Davies	Michael
The United States	Oak Ridge National Laboratory	Karagiozis	Achilles

1.2 Introduction

The best kind of energy is energy that is not used at all. Worldwide, the building sector stands for a significant share of primary and final energy consumption, especially space heating (SH) and domestic hot water (DHW) remain the most important energy users. Up to 75 percent of energy, used in a residential building, is used for heating. Therefore increasing energy efficiency of buildings is of particular importance.

Since the first oil crisis, the implementation of Building Regulations through a combination of higher efficiencies of equipment's and improved thermal performance of building envelope leads to a significant reduction in the per capita energy requirement for space heating. In the whole building area the potential of energy saving is 50% and more, but this target can only be achieved by fully exploiting all opportunities, like efficient insulation of building envelopes, window modernization and the use of modern technology for space conditioning and lighting. The current challenge is to make this potential a reality.

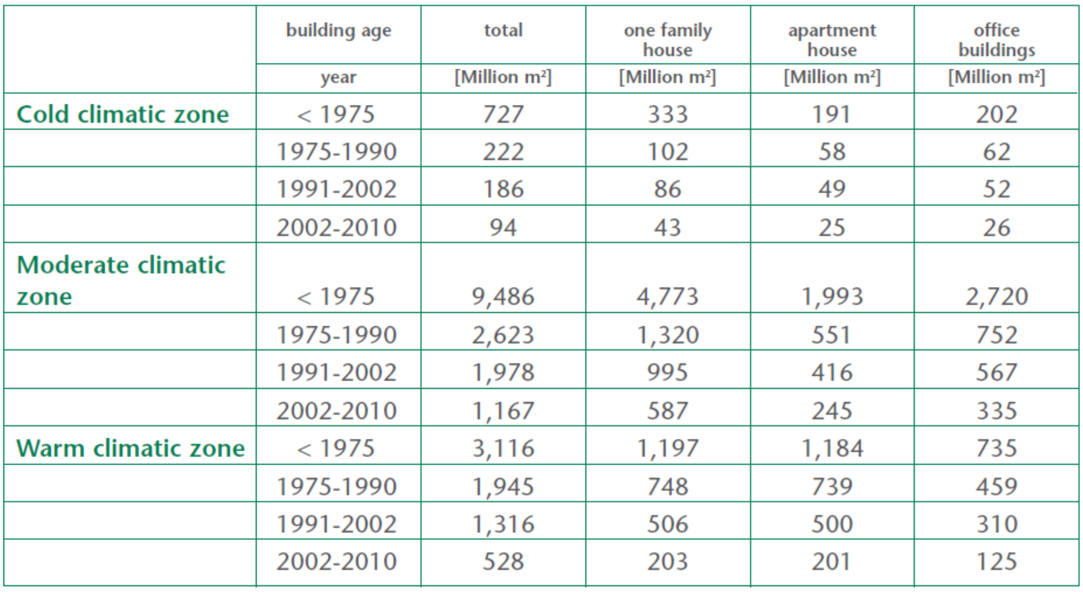
The first target is to ensure that new buildings do not place additional strain upon energy resources. This goal should be reached by developing NZEB (Net Zero Energy Building) as defined in the Annex 52 and promoted in the new EPBD (Energy Performance of Buildings Directive).

The second and even more important target is improve the existing building stock because in most industrialized countries new buildings will only contribute between 10 % to 20 % additional energy consumption by 2050. 80% will be influenced by the existing building stock. In almost all countries the existing stock is predominantly of poor energy performance and consequently in need of renovation work.

Accordingly, building renovation as a key element in reaching the long-term energy and climate goals, as well as having a positive economic impact has a high priority in many countries, and it plays an important role in the building related IEA R&D programs. Also, the more recent Energy Efficiency Directive (2012) (which replaces the Energy Services and Co-generation Directives) requires European Union member states to establish by April 2014 a long-term strategy to mobilize investment in the renovation of national building stocks.

It is interesting that in spite of all obvious advantages, the implementation is still very unsatisfactory. Yet there is great inertia, since only around 1% of the existing floor area is renovated annually. In order to fulfil the overall goals the retrofitting rate must go up to 2-3 %.

One reason is that many one and two family homes (In Germany for example 80% of all buildings and 61% of the inhabited area) play an outstanding role in reducing the building energy consumption in Europe. . The current energy efficiency level of the existing one and two family houses, built before 1995 is – considering the discussed savings potentials - extremely inadequate. 65% of these buildings are not or only slightly modernized.



	building age	total	one family house	apartment house	office buildings
	year	[Million m²]	[Million m²]	[Million m²]	[Million m²]
Cold climatic zone	< 1975	727	333	191	202
	1975-1990	222	102	58	62
	1991-2002	186	86	49	52
	2002-2010	94	43	25	26
Moderate climatic zone	< 1975	9,486	4,773	1,993	2,720
	1975-1990	2,623	1,320	551	752
	1991-2002	1,978	995	416	567
	2002-2010	1,167	587	245	335
Warm climatic zone	< 1975	3,116	1,197	1,184	735
	1975-1990	1,945	748	739	459
	1991-2002	1,316	506	500	310
	2002-2010	528	203	201	125

Figure 1.1: Characterization of the European building stock. Main source for residential sector: Finnish Ministry of the Environment, Housing statistics in the European Union 2001; main source for office buildings: Eurostat, statistical yearbook 2001 and Employment in Europe 2001.

It must be pointed out that single and semi-detached houses are normally inhabited by their owners, which means they have to finance the necessary renovation all by themselves and they are often afraid that retrofitting a house is not without technical risks.

It is obvious that the design, construction and operation of a new building is much easier than the successful renovation of an existing one. Especially in older buildings, the number of unknown parameters should not to be underestimated and a successful retrofitting method requires a high-quality planning process, good coordination of the materials used and especially trained craftsmen.

There are some current developments which require further discussion.

According to the results of the Annex 55 questionnaire, most buildings of current building stock have been built 1960-1980 and a significant proportion before 1930. Assuming that the estimated average lifespan of residential buildings is around 60 years and the energy standards are getting more and more stringent, it is to conclude that in the near future, lots of buildings will have to be replaced or retrofitted.

Secondly, the worse the building energy standards are, the energy consumption for space conditioning increases. As energy prices have steadily been rising over the last decades (Figure 1.2) and fossil energy sources are finite, dealing with domestic heating more efficiently is essential.

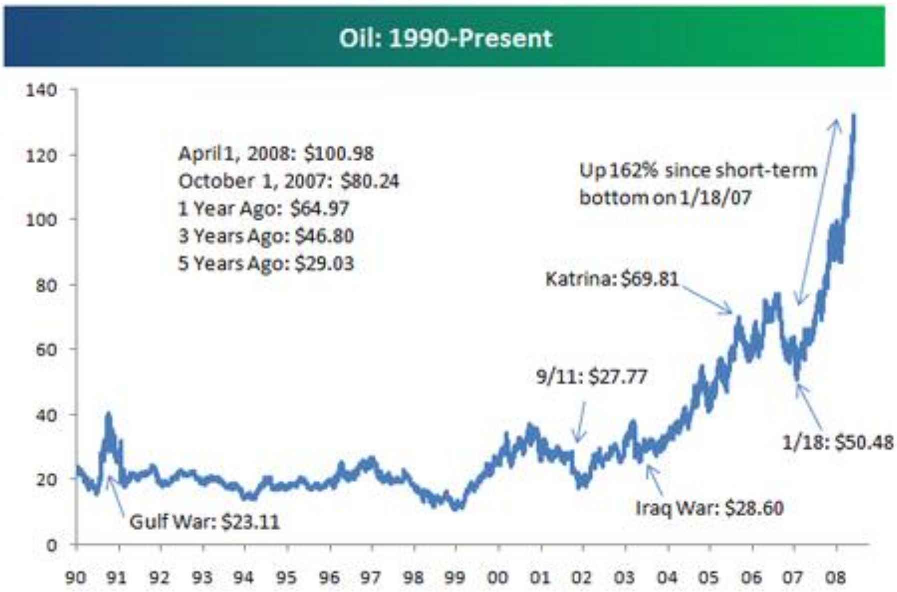


Figure 1.2: Chart for oil price from 1990 to 2008 (graph from bespokeinvest.com)

Furthermore, a change in user behaviour of the last decades can be recognized. The living area in residential buildings per person is constantly increasing (according to Annex 55 questionnaire) and in addition, the average indoor air temperature has been rising, apparently due to increased demand for more comfortable living conditions..

Retrofitting can solve many of those problems, as less heating energy is needed, existing building structures can be used and the indoor air quality and comfort conditions can be improved. A better indoor climate is caused by consistent indoor temperature distribution and less draft, which can be achieved by adequate insulation and sealing of leaky envelopes.

However, in order to support the decision making on retrofitting, an overall understanding of potential risks and benefits is of great assistance. This report could be used as a guideline for building owners on the possible risks and benefits of various energy retrofit options available to them.

There are also best-practice examples provided which show projects of retrofitting and what should be considered and how the improvements can be implemented.

Potential risks for retrofitting will be addressed later in detail; most of them are related to:

- Thermal bridges;
- Moisture damages;
- Uncertain cost calculation;
- Improvement on ventilation (airflow, efficiency, thermal comfort).

The advantages can be summarized as:

- Increased living thermal comfort (indoor climate);
- Use of existing building structure;
- Cost savings for heating energy.

These aspects are illustrated from different views of the Annex 55 participating countries.

The energy consumption for the space conditioning of buildings can be reduced by the appropriate combination of several measures:

- insulation of components: roof, wall and floor,
- application of insulating glazing
- airtightness of buildings,
- orientation of buildings and rooms for the use of passive solar energy, (not a retrofit option)
- use of an efficient and environment-friendly heating system,
- installation of comfortable and efficient ventilation,
- use of renewable energy as heating support,
- use of heat pumps as heating support,
- solar shading to avoid overheating in dwellings.

Several studies have shown that the most efficient way to curb the energy consumption in the residential building sector (new & existing) remain the reduction of the heat loss by improving the insulation of the building envelope (roof, floor, wall & windows). Thermal insulation (combined with the application of high performance windows) holds a key position among these measures, which lay the foundation of low-energy building.

The basic rules for low-energy building are

- the reduction of energy demand and
- production of the remaining demand more effectively and preferably
- from renewable sources.

A large number of insulation materials and constructional options are available for insulating of building components, such as exterior walls and roofs. The numerous materials and products available allow architects, developers, craftsmen and homeowners to offer an individually tailored solution which provides the optimal retrofitting package for any building project. Panel- and batt insulation are very suitable for insulating roofs, walls, ceilings and floors. Backfilling with granular insulation is mostly used for wooden beam ceilings as well as for certain cavity insulation of external walls and insulation of flat roofs. Loose-fill insulation materials are blown into spacious cavities. These products, tested and certified according to technical standard regulations and professionally applied, not only add to improved energy efficiency but also help avoid damage to the building and contribute to an improvement of cosiness and comfort of the living space.

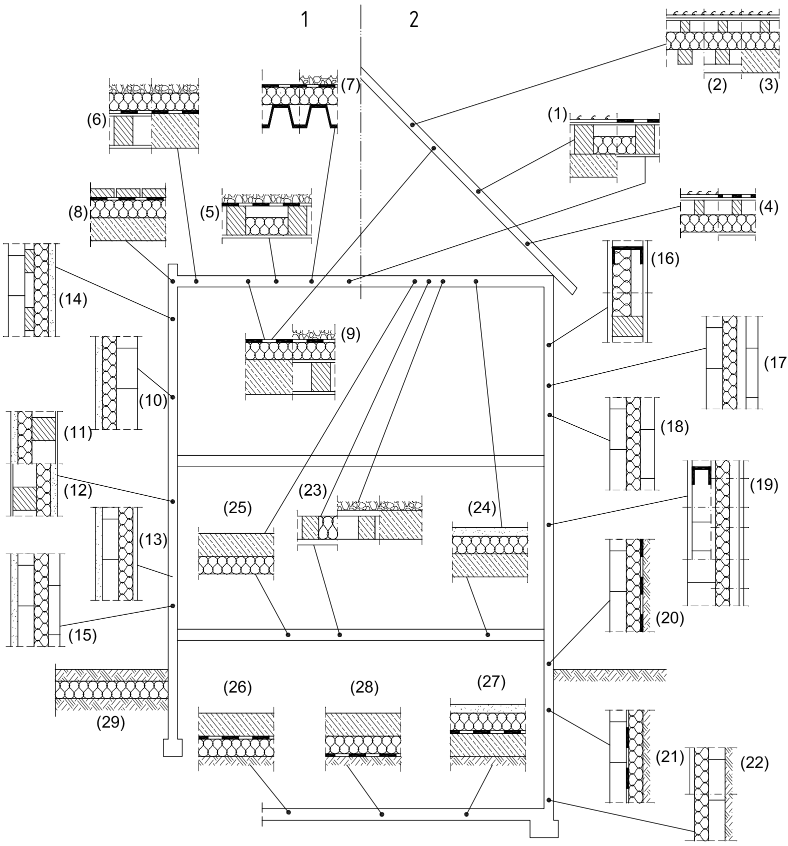


Figure 1.3: Examples of the most common applications of thermal-insulation products in buildings

For example in the 1970's, the first buildings with modern thermal insulation were built in Northern and Central Europe. The thickness of the insulation layers has increased continually ever since. However, due to the warmer climate, energy saving in Southern European buildings is not advancing significantly. In Europe, it appears that the optimum thermal transmittances lie between 0.15 W/m²K to 0.3 W/m²K, with an average value close to 0.2 W/m²K. Using traditional insulating materials such as mineral wool or cellular foams results in a range of insulation thicknesses from 100 to 200 mm.

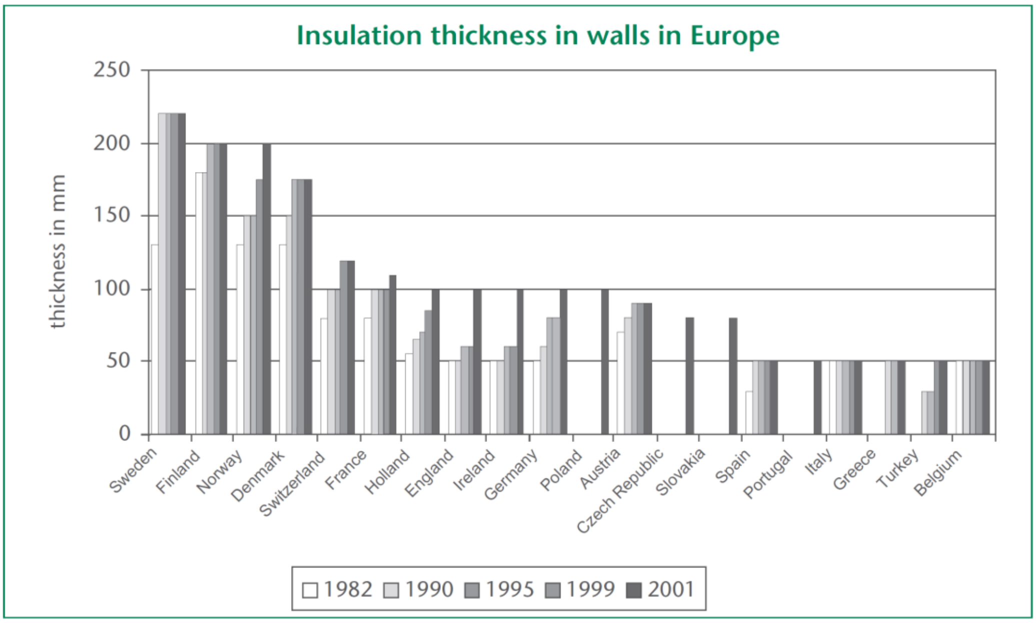


Figure 1.4: Examples Increase in insulation material thicknesses (standards and / or use)

The following chapters are organized by country to quickly guide the reader to find information which is relevant for to the reader or to inform about the statistics of other countries. In the end of each chapter, there is a compilation and overview of all countries, which summarizes the overall similarities and trends and points out major differences.

Most of the contributing countries are located in Europe: Austria, Belgium, Denmark, Estonia, Finland, Germany, Great Britain, The Netherlands, Portugal, Slovakia and Sweden; while three countries are from North-/ South- America: Brazil, Canada and the USA (Figure 1.5).

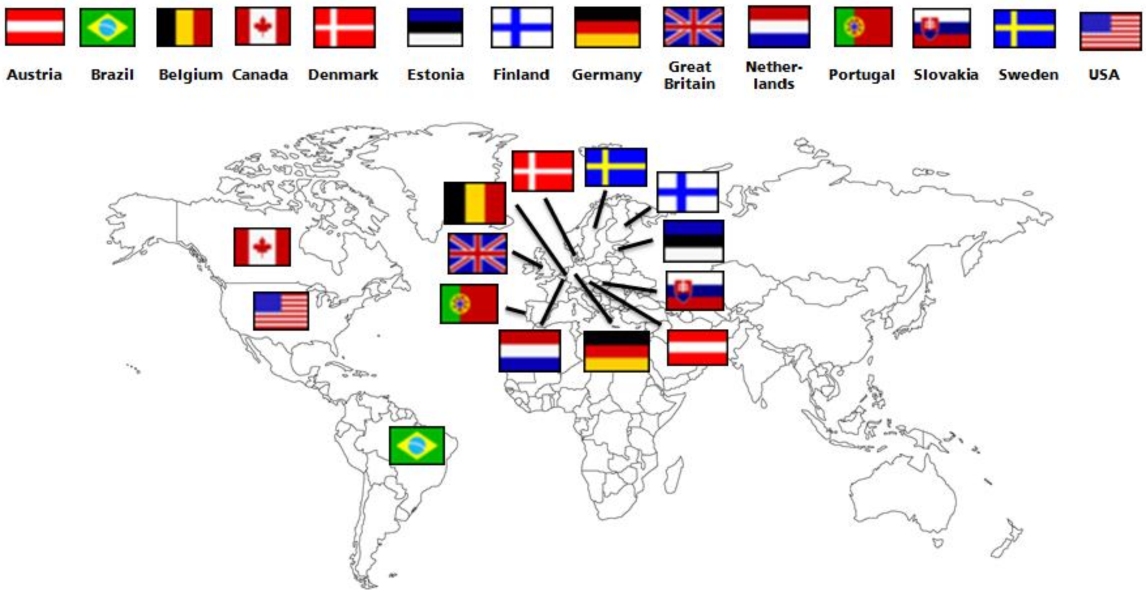


Figure 1.5: World map - Contributing countries

Organization of the Following Chapters

Chapter 2 provides an overview of the energy consumption in residential buildings. This chapter should help to estimate the total effort and potential for each country in general.

Chapter 3 covers the national regulation standards in order to provide the designer a scheme where to look for relevant standards and general references. The national regulations are birefly summarized and the most important information is highlighted.

Chapter 4 highlights the most important data which should be considered when building new residential buildings or retrofit existing ones. Mainly thermal transmittances of the envelope, thermal bridges and ventilation regulations are addressed.
Chapter 5 lists questions regarding testing of retrofitting. This might be relevant for building owners and architects or manufactures.

Chapter 6 is divided into retrofitting certain building envelope parts. Contributing countries present typical examples of retrofitting including their risks and benefits from a national perspective.

In addition, further local examples and references can be found in chapter 7.

Finally, the last chapter summarizes this document, points out the most relevant information and provides a guideline on how to write guidelines for building owners, constructors and decision makers.

2 GENERAL INFORMATION REGARDING BUILDING STOCK AND ENERGY CONSUMPTION IN BUILDINGS

2.1 Austria

With a population of 8.3 million, Austria is located in central Europe. The current building stock consists mostly of residential buildings (77%), whereas the majority of those buildings are single and two family houses (87%).

There are roughly 19.000 new residential buildings built each year which have to fulfil a certain energy standard. This standard also regulates the minimum requirements for retrofitting existing buildings. The retrofitting rate in Austria is currently estimated at 1.0% per year.

In Austria the total energy consumption (primary energy) is estimated to 1.354 PJ per year, whereas 261 PJ (19%) is consumed in buildings.

2.2 Brazil

With a population of 191 million, Brazil is the highest populated country in Latin America. Unfortunately, there is no data available about the current building stock. In Brazil the total energy consumption (primary energy) is estimated to 10.830 PJ per year, whereas only 330 PJ (3%) is consumed in buildings. Due to the hot climate almost no heating is needed around the year and no insulation is used in building envelopes.

The focus lays primarily on cooling and the envelope efficiency level for summer is obtained for each of the 8 Brazilian Bioclimatic Zones (Figure 2.1)

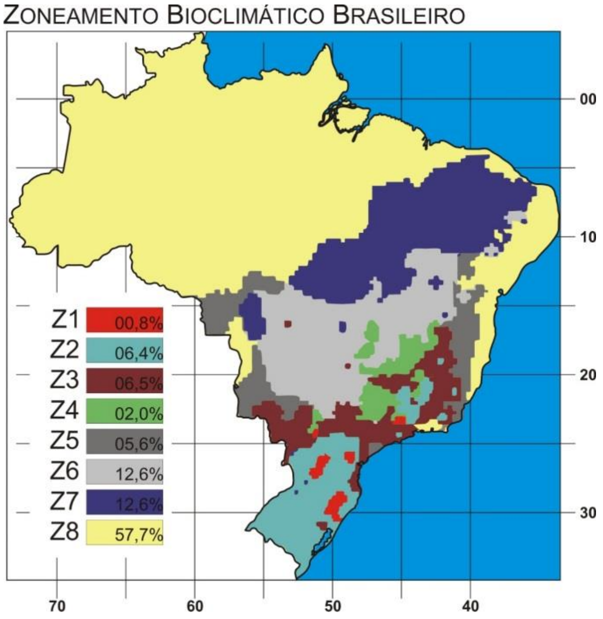


Figure 2.1: Brazilian Bioclimatic Zones (Source: NBR 15.220-3)

2.3 Canada

With a population of 34.5 million, Canada is located in the northern part of America. The current building stock consists mostly of residential buildings (92%), whereas the majority of those buildings are single and two family houses (83%).

There are roughly 190.000 new residential buildings built each year which have to fulfil a certain energy standard - NBCC. The retrofitting rate in Canada is currently estimated at 1.7% per year.

In Canada the total energy consumption (primary energy) is estimated to 8.720 PJ per year, whereas 17% is consumed in buildings.

2.4 Denmark

With a population of 5.6 million, Denmark is located in central Europe. The current building stock consists mostly of residential buildings (75%), whereas the majority of those buildings are single and two family houses (76%). The chart in Figure 2.2 shows the development of individual homes in Denmark over time; one building may contain several homes.

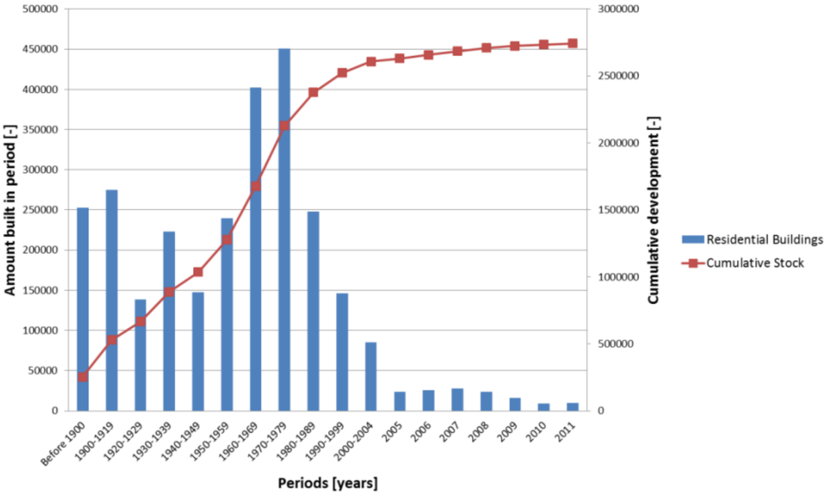


Figure 2.2: DENMARK – Residential Building Stock

In Denmark the total energy consumption (primary energy) is estimated to 815 PJ per year, whereas 300 PJ (37%) is consumed in buildings.

2.5 Estonia

With a population of 1.3 million, Estonia is a relatively low populated country in Europe. 60% of the current building stock consists of residential buildings and non-residential buildings form 40% of the building stock. The passive house standard is not very common yet in Estonia. There are roughly 1.000 new residential buildings built each year which have to fulfil a certain energy standard - Estonian Government ordinance no 68 Minimum Requirements of Energy Performance. The retrofitting rate in Estonia is currently estimated at 1.6% per year.

In Estonia the total energy consumption (primary energy) is estimated to 118 PJ per year, whereas 47 PJ (40%) is consumed in buildings. The heating energy consumption in apartment buildings can be found in Figure 2.3.

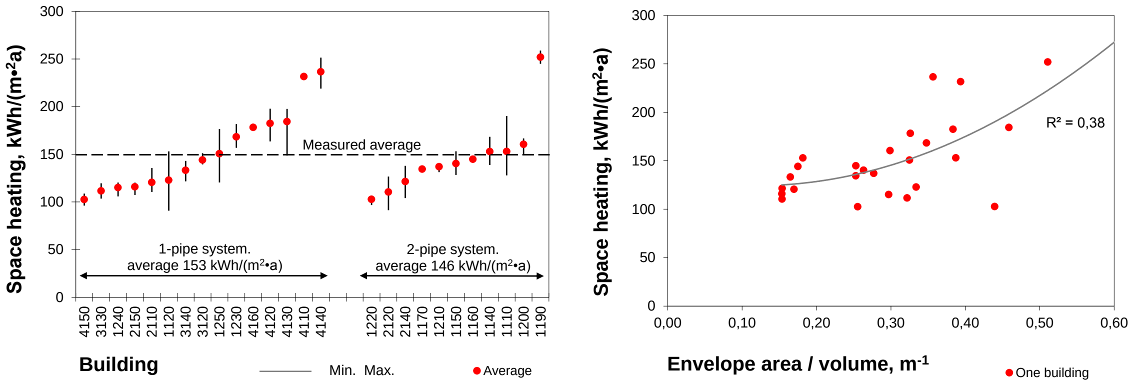


Figure 2.3: *ESTONIA - Energy use for space heating in old (<1990) apartment buildings depending on heat distribution system (left) and compactness of building (right).*

2.6 Finland

With a population of 5.4 million, Finland is located in the northern part of Europe. The current building stock consists mostly of residential buildings (85%), whereas the majority of those buildings are single and two family houses (89%). The passive house standard is only marginal.

There are roughly 31.000 new residential buildings built each year which have to fulfil a certain energy standard. The retrofitting rate in Finland is currently estimated at 1.6% per year. In 2011, 8 % of new residential buildings were built according to very low-energy standard and 31 % according to low-energy standard.

In Finland the total energy consumption (primary energy) is estimated to 1.463 PJ per year, whereas 298 PJ (20%) is consumed in buildings. More detailed information is shown in Figure 2.4.

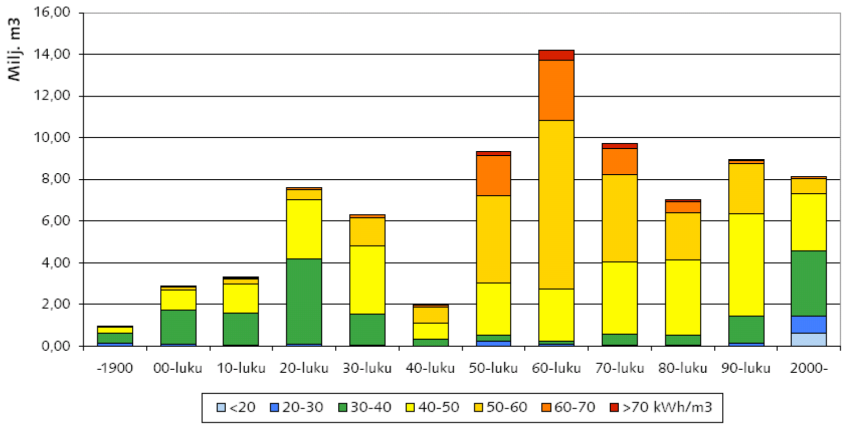


Figure 2.4: FINLAND - Energy Consumption of buildings per age group (Primary Energy) in [kWh/m3]

2.7 Germany

With a population of 80.5 million, Germany is the highest populated country in Europe. The current building stock consists mostly of residential buildings (92%), whereas the majority of those buildings are single and two family houses (83%).

There are roughly 165,000 new residential buildings built each year which have to fulfil a certain energy standard - EnEV. This standard also regulates the minimum requirements for retrofitting existing buildings. The retrofitting rate in Germany is currently estimated at 1.3% per year.

The population in Germany is currently stagnating and the total living area is gradually increasing. There is also a tendency, which indicates that there is a decreasingly number of occupants living in a household (currently 2.03).

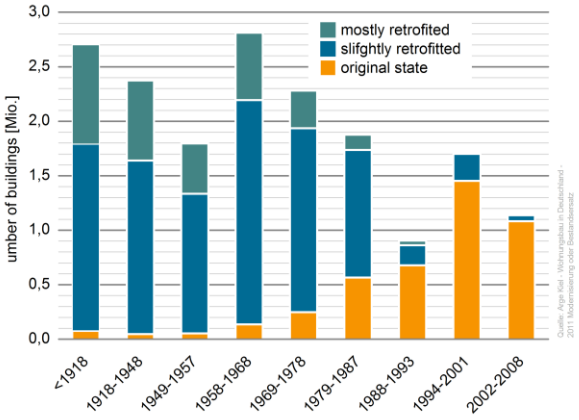


Figure 2.5: GERMANY - Number of residential buildings in Germany categorized regarding age of building and stage of refurbishment

In Germany the total energy consumption (primary energy) is estimated to 13,400 PJ per year, whereas 3,600 PJ (27%) is consumed in buildings.

2.8 The Netherlands

With a population of 16.7 million, the Netherlands is the densest populated country in Europe. The current building stock consists mostly of residential buildings (94%), whereas the majority of those buildings are single and two family houses (71%).

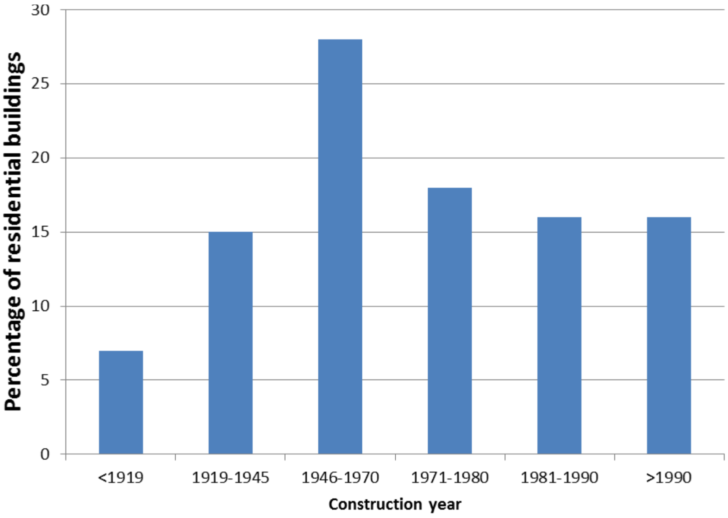


Figure 2.6: THE NETHERLANDS - Specific final energy consumption of residential dwellings in [MJ/m²] or [kWh/m²]

Figure 2.6 shows that most of the existing buildings are constructed between 1946 and 1970, which indicates a high potential of retrofitting need in the nearer future.

In the Netherlands the total energy consumption (primary energy) is estimated to 3.723 PJ per year, whereas 37% is consumed in buildings.

2.9 Portugal

With a population of 10.6 million, Portugal is located in the south-west part of Europe. The current building stock consists mostly of residential buildings (99%), whereas the majority of those buildings are single and two family houses (92%). The passive house standard is only marginal.

There are roughly 16,600 new residential buildings built each year which have to fulfil a certain energy standard. The retrofitting rate in Portugal is currently estimated at 0.2% per year. There is also a tendency, which indicates that the total living area is continuously increasing, although the increasing rate is decreasing.

In Portugal the total energy consumption (primary energy) is projected to 950 PJ per year, whereas only 120 PJ (13%) is consumed in buildings.

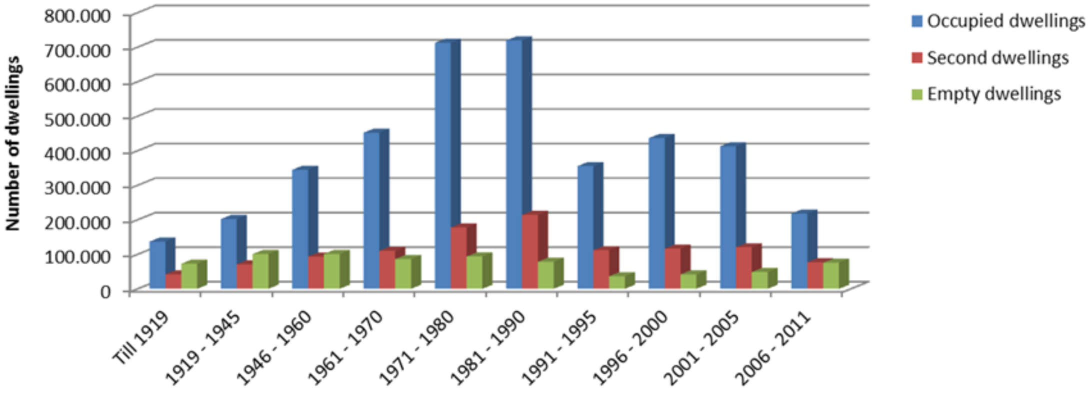


Figure 2.7: PORTUGAL - Residential building stock. Source: INE, Census 2001.

2.10 Slovakia

With a population of 5.4 million, Slovakia is located in the eastern part of Europe. The current building stock consists mostly of residential buildings (98%), whereas half of those buildings are single and two family houses (52%). The passive house standard is only marginal.

There are roughly 17.000 new residential buildings built each year which have to fulfil a certain energy standard. The development of buildings in Slovakia is displayed in Figure 2.8.

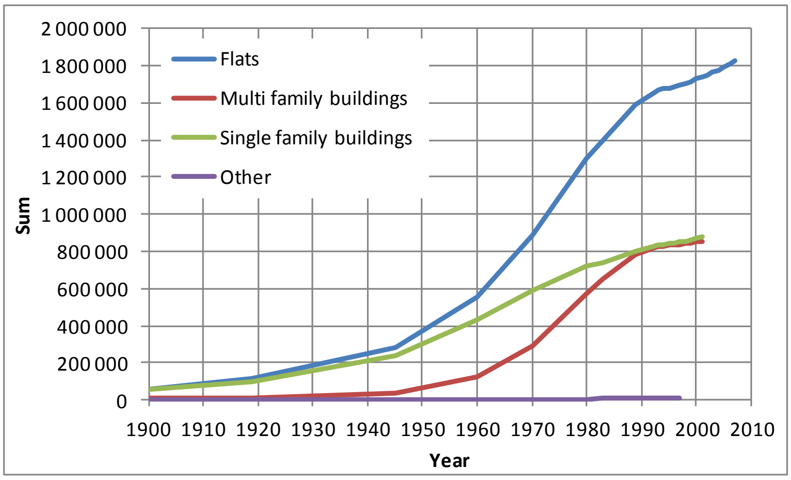


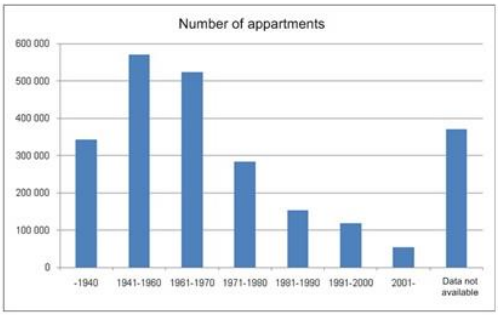
Figure 2.8: SLOVAKIA - Age of Building Stock (residential)

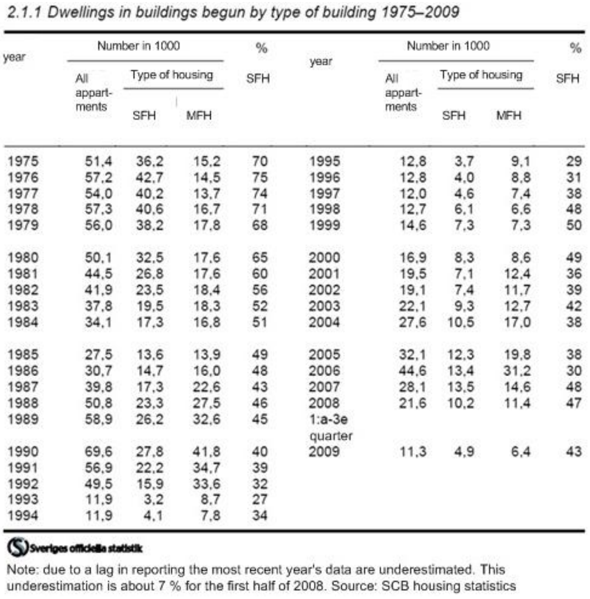
In Slovakia the total energy consumption (primary energy) is estimated to 550 PJ per year, whereas 200 PJ (38%) is consumed in buildings.

2.11 Sweden

With a population of 9.7 million, Sweden is highest populated country in Scandinavia. The current building stock consists mostly of residential buildings (98%), whereas the majority of those buildings are single and two family houses (90%). For further information see Figure 2.9.

There are roughly 30,000 new residential buildings built each year which have to fulfil a certain energy standard - BBR2012. 1,400 of them are classified as passive houses.




2.1.1 Dwellings in buildings begun by type of building 1975–2009

year	Number in 1000			%
	All appart-ments	Type of housing		SFH
		SFH	MFH	
1975	51,4	36,2	15,2	70
1976	57,2	42,7	14,5	75
1977	54,0	40,2	13,7	74
1978	57,3	40,6	16,7	71
1979	56,0	38,2	17,8	68
1980	50,1	32,5	17,6	65
1981	44,5	26,8	17,6	60
1982	41,9	23,5	18,4	56
1983	37,8	19,5	18,3	52
1984	34,1	17,3	16,8	51
1985	27,5	13,6	13,9	49
1986	30,7	14,7	16,0	48
1987	39,8	17,3	22,6	43
1988	50,8	23,3	27,5	46
1989	58,9	26,2	32,6	45
1990	69,6	27,8	41,8	40
1991	56,9	22,2	34,7	39
1992	49,5	15,9	33,6	32
1993	11,9	3,2	8,7	27
1994	11,9	4,1	7,8	34
1995	12,8	3,7	9,1	29
1996	12,8	4,0	8,8	31
1997	12,0	4,6	7,4	38
1998	12,7	6,1	6,6	48
1999	14,6	7,3	7,3	50
2000	16,9	8,3	8,6	49
2001	19,5	7,1	12,4	36
2002	19,1	7,4	11,7	39
2003	22,1	9,3	12,7	42
2004	27,6	10,5	17,0	38
2005	32,1	12,3	19,8	38
2006	44,6	13,4	31,2	30
2007	28,1	13,5	14,6	48
2008	21,6	10,2	11,4	47
1:a-3e quarter 2009	11,3	4,9	6,4	43

Sveriges officiella statistik

Note: due to a lag in reporting the most recent year's data are underestimated. This underestimation is about 7 % for the first half of 2008. Source: SCB housing statistics

Figure 2.9: SWEDEN - Number of apartments divided by year

In Sweden 38% or 577 TWh (2077 PJ) of the total energy consumption is used in buildings and services-sector. Of this 60% is used for heating and domestic hot water. Figure 2.10 indicates that the specific energy consumption for residential buildings is steadily decreasing.

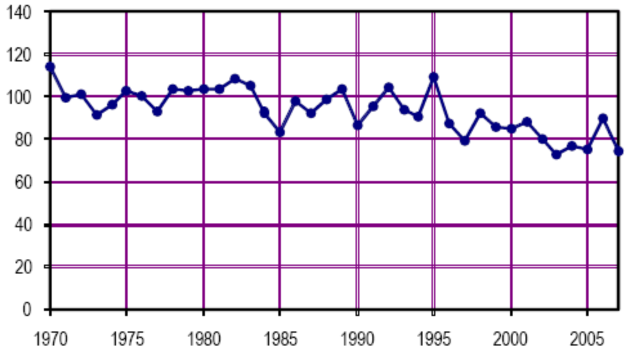


Figure 2.10: SWEDEN - Average energy use for heating and hot water in kWh/m² (house hold electricity excluded) in single family housed 2008, divided into year of construction.

2.12 United Kingdom

62 million residents are currently living in the United Kingdom which is located in the north western part of Europe. The climate can be described as volatile with many rainy and windy periods and influences from maritime air and dry continental air.

There are roughly 165.000 new residential buildings built each year which have to fulfil a certain energy standard. The retrofitting rate in UK is currently varies between at 2.9% and 5.0% per year.

In the UK the total energy consumption (primary energy) is estimated to 8.499 PJ per year, whereas 1.626 PJ (19%) is consumed in buildings. More detailed data can be found in Figure 2.11.

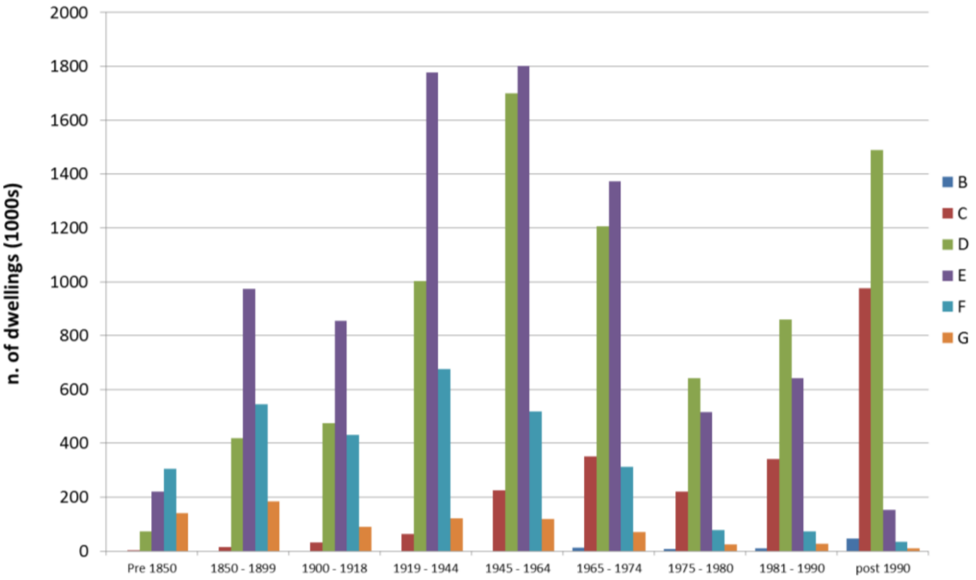


Figure 2.11: UK – Energy consumption of buildings per age group (EPC rating)

2.13 The United States

With a population of 314.6 million, the USA is highest populated country participating in Annex 55. The current building stock consists mostly of residential buildings (96%), whereas the majority of those buildings are single and two family houses (66%).

There are roughly 647.000 new residential buildings built each year which have to fulfil a certain energy standard. The retrofitting rate in the USA is currently estimated at 3.7% per year. There is also a tendency, which states that median age of the current building stock is gradually increasing, which indicates a further need retrofitting.

In the USA the total energy consumption (primary energy) is estimated to 103.000 PJ per year, whereas 42.000 PJ (40%) is consumed in buildings.

2.14 Summary

Table 2.1 Building stock summary

Building Stock	**Austria**	**Brazil**	**Canada**	**Denmark**	**Estonia**	**Finland**	**Germany**	**Netherlands**	**Portugal**	**Slovakia**	**Sweden**	**UK**	**USA**
Population [Mio.]	8.281	190.759	34.483	5.581	1.318	5.401	80.524	16.727	10.562	5.430	9.700	62.262	314.638
Number of existing Buildings [Mio.]	2.046	-	13.633	2.531	0.672	1.460	19.500	7.708	3.544	1.897	2.1	24.339	120.705
Number of dwellings [Mio.]	3.863	-	13.164	2.748	0.263	2.556	40.000	-	5.878	1.877	4.524	27.230	115.904
Commercial Buildings [Mio.]	0.277	-	0.469	0.621	0.408	0.214	1.500	0.440	0.038	0.029	0.047	1.828	4.800
Residential Buildings [Mio.]	1.574	-	9.346	1.909	0.222	1.245	18.000	7.268	3.505	1.867	2.053	22.511	115.904
Single and Two family houses [Mio.]	1.373	-	7.898	1.443	0.194	1.111	15.000	5.160	3.214	0.877	1.888	18.097	76.313
Multifamily houses [Mio.]	0.200	-	1.448	0.089	0.028	0.134	3.000	2.108	0.291	0.852	0.166	4.414	30.549
Passive Houses (if available)	11.800	0		149	-	<500	13.500	-	-	50	200	70 +	100
Number of occupants per household	2.28	3.31	2.62	2.20	2.04	2.07	2.03	2.4	1.83	2.83	1.97	2.4	2.58
Total Primary Energy Consumption [PJ]	1 354	10 830	8 720	815	52.6	1 463	13 374	3 723	949	550	1655	8,499	103 115
Energy used in buildings [%]	19	3	17	37	40	20	27	37	13	38	38	19	41
Retrofitting Rate [%]	1.0	-	1.7	2.4	1.6	1.6	1.3	0.8 - 2.2	0.2	-	-	-	3.7
Number of new residential buildings per year	19 000	-	190 000	-	1 029	31 117	164 178	57 703	16 587	17 184	30 000	165 000	647 000
New Passive Houses built per year	~5.000	0	-	-	~2	-	~500	~500	-	-	-	-	25

3 NATIONAL BUILDING REGULATIONS FOR ENERGY EFFICIENT BUILDINGS

The following chapter will try to compare the different national building regulations for energy efficient buildings.

The Value in for the question “Is there a calculation procedure for new dwellings?” can either be “Norm” or “Sim”. “Norm” means that the calculation procedure is described in a national norm (normative) whereas “Sim” stands for a simulated performance assessment procedure.

3.1 Austria

The OIB (Austrian Institute of Construction Engineering) guidelines serve to harmonize the construction engineering regulations across all of Austria. They are issued by the OIB and adopted by the federal states into their Construction Law. The OIB Guidelines 2011 were resolved in the General Assembly of the OIB on 6 October 2011 in the presence of representatives of all federal states. OIB Guideline 6 contains regulations for the energy demand of buildings.

Table 3.1: AUSTRIA - National Building Code Summary

National Building Code	**Value**	**Reference / Comments**
What is the name of the building regulation and when did it come into force?	The date depends on the province. New regulations came into force after 2011.	Austria is a federal state consisting of nine federal provinces. Each province has its own Building Code. The OIB (Austrian Institute of Construction Engineering) guidelines serve to harmonize the construction engineering regulations across all of Austria. They are issued by the OIB and adopted by the federal states into their Construction Law. http://www.oib.or.at/de/oib-richtlinien/inkrafttreten
Who is required to confirm regulations compliance?	-	The experts, who are not explicitly approved by any organization but should be qualified architects, engineers or can be trained craftsmen in the case of dwellings, issue the EP certificate. Only qualified architects and engineers can deal with non-residential buildings. The building owners have to send the certificate together with the building application to the Municipality and the building permit will be issued by them if the requirements are met.
What are the main requirements for compliance (elemental or overall heat loss method)		Max. thermal transmittance of building constructions (W/m^2K) Max. allowed annual heating energy demand HWB in kWh/m² gross floor area
For new dwellings:	-	Details can be found in OIB RL 6
For existing dwellings:	-	Details can be found in OIB RL 6
What is the methodology used to comply with current building regulations in dwellings?		Calculation
Is there a calculation procedure for new dwellings?		There are Austrian Standards which are listed in the OIB Guidelines which have to be used. The Austrian Standards are related to European and International standards.

3.2 Brazil

The national building standards for Brazil are regulated in the *Regulamento Técnico da Qualidade para o Nível de Eficiência Energética de Edificações Residenciais* (RTQ-R) which came into force in 2009/10. The energy efficiency classification of dwellings is based on an evaluation of the thermal performance of the envelope and water heating system. Both individual systems and the overall rating range from level “A” (most efficient) to “E” (least efficient). The regulation provides the maximum transmittance and solar absorption of the walls and roofs, and minimum percentage for openings for natural lighting and ventilation, according to the Bioclimatic Zone.

Table 3.2: BRAZIL - National Building Code Summary

National Building Code	Value	Reference / Comments
What is the name of the building regulation and when did it come into force?	2009/10	• Regulamento Técnico da Qualidade para o Nível de Eficiência Energética de Edificações Residenciais (RTQ-R). (Residential Buildings) Published on 25th Nov. 2010 • Regulamento Técnico da Qualidade para o Nível de Eficiência Energética de Edifícios Comerciais, de Serviços e Públicos (RTQ-C). (Commercial, Public and Services Buildings) Published on 27th February 2009
Who is required to confirm regulations compliance?	-	Inspection Organisms, accredited by the Government (Inmetro - Instituto Nacional de Metrologia, Qualidade e Tecnologia). The application of regulation is on a voluntary basis, except for federal public buildings, which came into force on 4th June 2014 (Instrução Normativa MPOG/SLTI nº2).
What are the main requirements for compliance (elemental or overall heat loss method)		The evaluation of naturally ventilated buildings, bioclimatic strategies for encouraging natural ventilation and day lighting, and evaluation of the water heating system.
For new dwellings:	-	
For existing dwellings:	-	
What is the methodology used to comply with current building regulations in dwellings?		The energy efficiency classification of dwellings is based on an evaluation of the thermal performance of the envelope and water heating system. Both individual systems and the overall rating range from level “A” (most efficient) to “E” (least efficient). The evaluation of the envelope is based on performance requirements and prerequisites that must be met in order to maintain the level achieved. As prerequisites, the regulation provides the maximum transmittance as a function of thermal capacity levels and solar absorption of the walls and roofs, and minimum percentage for openings for natural lighting and ventilation, according to the Bioclimatic Zone where the building is located.
Is there a calculation procedure for new dwellings?		Yes, it is the same for new and existing dwellings.

For solar and gas systems the proper sizing of the system is evaluated in an attempt to avoid under or overestimation, and also the equipment used: solar collectors and tanks and gas equipment should be included in the Brazilian Labeling Program and should achieve levels A or B. Heat pumps are evaluated according to the COP (Coefficient Of Performance) of the equipment. Systems for electrical resistance reached a maximum level D and boilers that use liquid fluids such as diesel or other petroleum derivate reached a maximum level E.

The energy rating in Brazil is specified in degree hours (for natural ventilated buildings) and in kWh/m².a (artificially cooled buildings). Water heating system: levels from A to E. The overall rating for the building also range from level “A” (most efficient) to “E” (least efficient).

The assessment of the summer comfort is currently not regulated but a standard considering adaptive comfort potential is under development.

3.3 Canada

The national building standards for Canada are regulated in National Building Code of Canada (NBCC) which came into force in 2010. Basically, there are two options for compliance: minimum requirements that are set for the reference building (prescriptive compliance path) shall be met, or the annual energy consumption of the proposed building shall be lower than the reference building. The calculation procedure is done by determination of overall transmittance values using table values in NBC Section 9.36.2 to 9.36.4, and whole-building simulation using computer code that is tested with ANSI/ASHRAE 140.

Table 3.3: CANADA - National Building Code Summary

National Building Code	**Value**	**Reference / Comments**
What is the name of the building regulation and when did it come into force?	2010	National Building Code of Canada (NBCC). Amended in June 2012 to include Energy Efficiency Requirements for Housing and Small Buildings (Section 9.36.).
Who is required to confirm regulations compliance?	-	Houses and small buildings (three stores or less, and floor area of under 600 m^2) that are designed following the prescriptive code requirements, don't require an engineer or architect review and approval, but rather a city building official will check for compliance. In all other cases, i.e., all large buildings and small buildings with performance based design need qualified engineer or architect review and sign off the design for compliance. The building owners have to send the certificate together with the building application to the Municipality and the building permit will be issued by them if the requirements are met.
What are the main requirements for compliance (elemental or overall heat loss method)	Elemental	Two compliance paths are available: Prescriptive—maximum thermal transmittance values (set based on heating degree days). Tradeoff option for Above-Ground Building Envelope components and assemblies is available Energy performance --Annual total energy consumption
For new dwellings:	-	
For existing dwellings:	-	
What is the methodology used to comply with current building regulations in dwellings?	Reference Building	The proposed building shall meet the minimum requirements that are set for the reference building (prescriptive compliance path), or the annual energy consumption of the proposed building shall be lower than the reference building (Whole Building performance path)
Is there a calculation procedure for new dwellings?	Norm	Determination of overall transmittance values using table values in NBC Section 9.36.2 to 9.36.4, and whole-building simulation using computer code that is tested with ANSI/ASHRAE 140 (Energy performance Compliance path)

The energy rating in Canada is specified in delivered secondary energy and the value is referring to the treated floor area in [kWh/m²/a].

There is no separate calculation to assess the summer comfort.

3.4 Denmark

The national building standards for Denmark are regulated in the Bygningsreglementet (BR) which came into force in 2010. Basically, it defines limits for the overall energy consumption depending on the intended use of the building. In addition, the building envelope or new / retrofitted building components are required to fulfill a certain thermal transmittance. The calculation of the thermal transmittance is defined in the Danish Building Code (BR10) which is based on EN ISO 13790.

Table 3.4: DENMARK - National Building Code Summary

National Building Code	Value	Reference / Comments
What is the name of the building regulation and when did it come into force?	2010	Bygningsreglementet (BR). Published 2010; amended 29 August 2011.
Who is required to confirm regulations compliance?	-	"Ultimately, the developer holds the responsibility. However, often this responsibility is passed on to a contractor. Common practice in Denmark distinguishes between retrofitting and development. For more detail, see under the question How is Enforcement Conducted?"
What are the main requirements for compliance (elemental or overall heat loss method)	Overall	Overall energy consumption [kWh/(m²·a)]; what levels the limits for compliance are fixed at are dependent on the intended use of the building. Also, requirements for compliance includes more than simple heat loss calculations; e.g. for an office building the energy consumption for lighting, ventilation, etc. must also be considered.
For new dwellings:	-	In the case of dwellings, student accommodation, hotels etc., the total demand of the building for energy supply for heating, ventilation, cooling and domestic hot water per m² of heated floor area must not exceed 52.5 kWh/m²/a plus 1650 kWh/a divided by the heated floor area.
For existing dwellings:	-	Thermal transmittances for retrofitted parts are specified in BR10. Special rules for windows also apply; they are not allowed to have an energy gain lower than -33 kWh/(m^2·a) during the heating season
What is the methodology used to comply with current building regulations in dwellings?	-	BR10 stipulates the standard levels for energy consumption in buildings. The Danish Building Research Institute SBi Direction 213 along with the calculation program Be10 are the tools that are used to document that the requirements stipulated in the Danish Building Code (BR10) and other related legislation are met.
Is there a calculation procedure for new dwellings?	Norm+ Sim.	Yes; see the above question and answer (based on EN ISO 13790 with national adaptions).

As Denmark only having one design climate zone, those values are valid for the entire country. For design heat loss calculations, the outdoor climatic conditions are stipulated in Danish Standard DS418:2011 Calculation of Heat Loss from Buildings. E.g. outdoor air temperature should be -12 °C, and ground temperature should be 10 °C.

For prediction of annual energy requirement for heating it is compulsory to calculate using the Be10-program (or similar program with the very same calculation “engine”) using its monthly climatic data set for outdoor air temperature and solar gains representative for Denmark (one data set). The climatic data set is known as the Design Reference Year (DRY). (http://www.byg.dtu.dk/upload/institutter/byg/publications/rapporter/lfv-281.pdf)

There are two different energy rating systems operating in Denmark: Energy Class' and Energy Marks. The Energy Class' are described in BR10 and are used for granting building permits and knowing if the building complies with current and/or future versions of the Danish Building Code regulations. The Energy Marks were introduced as tools for the consumers; Energy Marks range from A to G with A being the best. Energy Marks are compulsory when subletting or selling dwellings larger than 60 m^2. Energy Class' are determined from an energy demand [kWh/(m^2·a)] measured in primary energy. Appliances are disregarded in calculating the energy consumption but not when designing the heating and cooling systems; peak load rooms must be able to cope with occupation.

To assess the summer comfort, a method using design activity and clothing is used to determine the optimal operational temperatures; the method can be found described in Danish Standard DS474 with additional information available in DS/EN ISO 7730. A standard office would be designed so that temperatures during operation in the summer time would be in the interval $23 < \theta < 26$ °C (clothing: 0.5 clo), allowing for the temperatures to exceed the design 26 °C for no more than 100 hours and 27 °C no more than 25 hours during operating hours. Also, for this configuration, the design limit for air indoor air speeds in the work environment is 0.2 m/s.

3.5 Estonia

The national building standards for Estonia are regulated in the Estonian Government ordinance no 68 which base version came into force in 2007.

Table 3.5: ESTONIA - National Building Code Summary

National Building Code	**Value**	**Reference / Comments**
What is the name of the building regulation and when did it come into force?	2007	Estonian Government ordinance no 68, Energiatõhususe miinimumnõuded. (Minimum requirements for energy performance of buildings) (20.12.2007; RT I 2007, 72, 445; RT - State Gazette of the Republic of Estonia)
Who is required to confirm regulations compliance?	-	Designer (architect, civil engineer or designer of service systems) calculates energy performance value before municipality gives the building permit.
What are the main requirements for compliance (elemental or overall heat loss method)	Overall	Since year 2008 the energy performance requirements are determined for the whole building not for different components. Requirements are given for the maximum weighted delivered energy consumption per square meter of heated area. Energy performance requirements are expressed as an energy performance value: annual kilowatt hour per square meter. The energy performance value takes into account primary energy for indoor climate (heating, cooling (humidifying, drying), ventilation, lighting), domestic hot water, and electrical facilities. Weighting factors takes into account the use of primary energy for producing the delivered energy and its environmental impact. For example wood has weighting factor 0.75, fossil fuel 1, and electricity 2.0 (1.5 before 2013). There are different requirements for new buildings as well as major renovations.
For new dwellings:	-	Primary energy requirement for detached houses ≤ 160 kWh/m^2 a, for apartment building ≤ 150 kWh/m^2 a.
For existing dwellings:	-	Major renovation primary energy requirement for detached houses ≤ 210 kWh/m^2 year, for apartment building ≤ 180 kWh/m^2 a.
What is the methodology used to comply with current building regulations in dwellings?	General Value	There are three different calculation procedures to show the fulfillment of energy efficiency requirements. Dynamic simulation with validated software is allowed for all building types. Energy calculations for residential buildings may also be performed by simplified calculations per months or per degree days. Detached houses energy efficiency can be proved with specific heat loss calculation. Specific heat loss takes into account all heat losses through the building envelope: due to conduction, thermal bridges and airtightness. Maximum values of specific heat loss coefficients for five different types of energy sources for heating and domestic hot water are given. For example, if the house is heated by gas, the specific heat loss coefficient can be at most 0.6. If the ground source heat pump is used, the heat loss of the building envelope can be larger (1.0). For log houses the maximum values of specific heat loss are multiplied by 1.15. In addition requirements for ventilation system are determined: the efficiency of heat recovery should be at least 0.8 and the specific fan power can be at most 2.0. And high temperatures during summer should be avoided.
Is there a calculation procedure for new dwellings?	Norm+ Sim.	Similar procedure for new and existing buildings, see above

The energy rating in Estonia is specified in primary energy and the value is referring to the treated floor area in [kWh/(m^2·a)]. The CHP is already covered by primary energy factor.

To assess the summer comfort, the regulation specifies limits for operative temperature. This means that it is allowed to have up to 100 or 150 degree-hours(°C·h) over cooling set-point temperature during summer months (from June to August) depending on building type. Residential buildings are allowed to have up to 150 (°C·h) per year when indoor operative temperature exceeds cooling set-point limit. All other buildings must meet the 100 (°C·h) limit. To evaluate the meeting of this requirement it is assumed that a computer simulation is carried out for a sample room. Dwellings are allowed to be checked with simplified way by using specific graphs.

3.6 Finland

The national building standards for Finland are regulated in the Rakentamismääräyskokoelma which came into force in 2010-2012. Basically, it defines a specific maximum primary energy demand for new buildings which has to be lower than a comparable reference building. Energy requirements for renovations are still under development.

The energy rating in Finland is specified in primary energy and the value is referring to the treated floor area in [kWh/m²/a]. In regulations it is stated that buildings must be designed in a way that room temperatures won’t rise to a critical level. This has to be proven with calculations (No calculations are needed in detached houses). Calculations have to be done with dynamic calculation programs. No simple formulas are presented.

Table 3.6: FINLAND - National Building Code Summary

National Building Code	**Reference / Comments**
What is the name of the building regulation and when did it come into force?	National Building Code of Finland (Rakentamismääräyskokoelma). There are different sections A General section B The strength of structures C Insulation D Hepac and energy management E Structural fire safety F General building planning G Housing planning and building Regulations related to energy: • Thermal insulation is considered in section C3 (Thermal insulation in a building, Regulations 2010). This part came into force in 1st of January 2010. • Indoor climate and ventilation is considered in section D2 (Indoor climate and ventilation of buildings , Regulations and guidelines 2012). This part came into force in 1st of July 2012. • Energy consumption is considered in section D3 (Energy management in buildings, Regulations and guidelines 2012). This part came into force in 1st of July 2012. • Energy calculations are considered in section D5 (Calculation of power and energy needs for heating of buildings, Guidelines 2012). This part came into force in 1st of July 2012.
Who is required to confirm regulations compliance?	When the building permit is applied it must be shown that the building meets the energy regulations. This means that there must be an energy report attached to the building permit application. Verification is done by head designer of building project. Head designer is usually the architect. An energy report usually contains following reports: • Total primary energy consumption, E-value [kWh/m²a] (E-value must be lower than limit value, limit values are different for different types of buildings) • Source information and results of the energy calculation • Estimation for the inside temperature during summer and if necessary cooling power • Heat loss calculations (heat loss must be less than the reference heat loss) • Heating power of the building • Energy certificate
What are the main requirements for compliance (elemental or overall method)	Overall
For new dwellings:	Usual requirements in new buildings are stated above. Main requirements from those are: • Heat losses in new buildings must be less than the reference buildings heat losses. • Total primary energy consumption (E-value) must be lower than limit value.
For existing dwellings:	At the moment there is no energy related requirements for existing buildings. Energy requirements for renovations are being developed right now and the estimated time for coming into force is the beginning of year 2013.
What is the methodology used to comply with current building regulations in dwellings?	Reference Building: "Heat losses in new buildings must be less than the reference buildings heat losses.
Is there a calculation procedure for new dwellings?	Norm: Calculated total primary energy consumption (E-value) has to be equal to or lower than a defined maximum value.

3.7 Germany

The national building standards for Germany are regulated in the Energieeinsparverordnung (EnEV) which came into force in 2009. Basically, it defines a specific maximum primary energy demand for new buildings which has to be lower than a comparable reference building. In addition, the building envelope or new / retrofitted building components are required to fulfill a certain thermal transmittance (U-value). The calculation of the thermal transmittance is defined in DIN V 4108-6 and DIN 4701-10.

Table 3.7: GERMANY - National Building Code Summary

National Building Code	Value	Reference / Comments
What is the name of the building regulation and when did it come into force?	2009	Energieeinsparverordnung (EnEV) published in the official paper of the Government
Who is required to confirm regulations compliance?	-	For residential buildings: experts, who are not explicitly approved by any organization but should be qualified architects, engineers or can be trained craftsmen. For non-residential buildings: only qualified architects and engineers The building owners have to send the certificate together with the building application to the Municipality and the building permit will be issued by them if the requirements are met.
What are the main requirements for compliance (elemental or overall heat loss method)	Elemental	Max. allowed primary energy demand compared to a reference building by EnEV Max. transmission/building envelope area (W/m²K) relates to net floor area
For new dwellings:	-	Max. specific Transmission Heat Loss (H'_T) = 0.4 (W/m²K) (detached house) - 0.65 (W/m²K) (other residential buildings) thermal transmittances specified in EnEV
For existing dwellings:	-	Thermal transmittances specified in EnEV
What is the methodology used to comply with current building regulations in dwellings?	Reference Building	Calculated primary energy demand has to be equal to or lower than a defined maximum value compared to a reference building. Also limitation transmission loss relates to building surface
Is there a calculation procedure for new dwellings?	Norm	There are two national standards which can be used for calculation. DIN V 4108-6 offers monthly calculation method – starting with the net energy demand for heating DIN 4701-10 offers detailed calculation methods with formulas, tabular, figures, diagrams. For certain often used heating system combinations it offers a final energy demand by multiplying parts with primary energy factors = total primary energy.

Thermal transmittances are specified depending on the building type (non-/residential) and construction situation. As Germany only having one design climate zone (for the monthly based calculation method), those values are valid for the entire country.

The energy rating in Germany is specified in primary energy and the value is referring to the treated floor area in [kWh/m²/a]. The CHP is already covered by primary energy factor.

A specific calculation method (DIN 4108-2) is required to assess the summer comfort.

For the compliance there is no testing required in particular. The person conducting the certification is responsible for the correct input data.

3.8 The Netherlands

The recent national building standards for the Netherlands are regulated in the Bouwbesluit which came into force in April 2012.

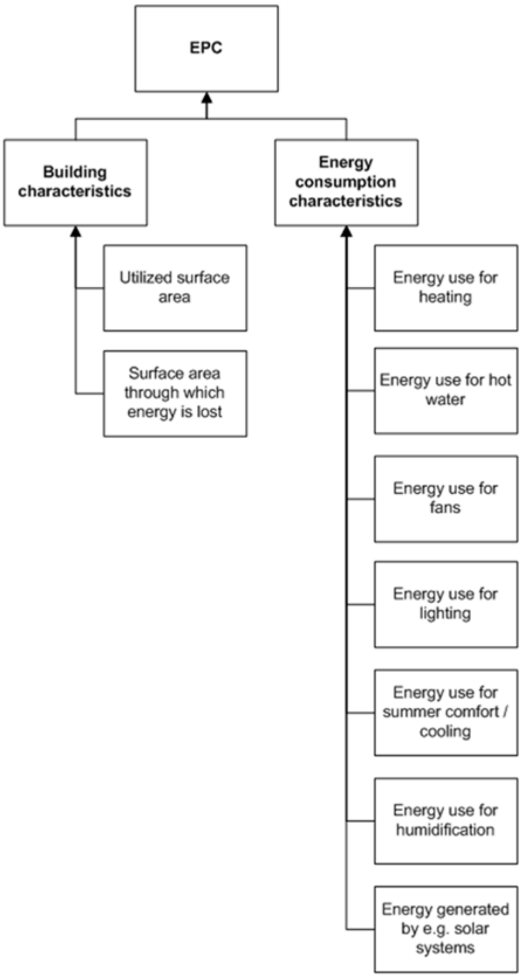


Figure 3.1: Methodology for calculating the EPC (Energy Performance Coefficient) based on NEN, 2004

Table 3.8: THE NETHERLANDS - National Building Code Summary

National Building Code	Value	Reference / Comments
What is the name of the building regulation and when did it come into force?	Bouwbesluit 2012	Bouwbesluit 2012, 1 April 2012
Who is required to confirm regulations compliance?		In principle everyone is authorized to perform the energy performance calculation, however the software used for this calculation should be attested by a certified authority in conformity with the BRL9501. Moreover, the performed calculation is assessed by the building / housing inspection of the municipality where the building will be build. (ISSO, 2006, Nationale BRL voor het KOMO-attest voor energiegebruikberekenings-methoden, BRL9501)
What are the main requirements for compliance (elemental or overall heat loss method)	Overall	EPC (energy performance coefficient) <= 0.6 [MJ/m²], Source: Bouwbesluit 2012, Article 5.2
For new dwellings:	EPC<=0.6	EPC = 0.6 [MJ/m²] (2011 to 2015) / Thermal insulation>= 3.5 [m2K/W], Source: Bouwbesluit 2012, Article 5.2
For existing dwellings:	1.3 [m²K/W]	No EPC requirement, energy performance should be indicated with an energy label / Thermal insulation>=1.3 [m²K/W], Source: Bouwbesluit 2012, Article 5.6
What is the methodology used to comply with current building regulations in dwellings?	General Value	For the EPC calculation basically two types of characteristics are used namely, building characteristics and energy characteristics. This is illustrated in Figure 3.1.
Is there a calculation procedure for new dwellings?		Yes. EPC=Q_(total)/(330·A_utilized+65·A_loss)·1/C_epc , Q_total is calculated by the sum of the energy consumption characteristics which were illustrated in Figure 1 of the "Other Tables" in this document, generated energy is negative in this sum. The exact calculation procedure of each part of this sum is explained in NEN5128. A_utilized is calculated by the sum of the surface areas of each of the heated zones in the building. A_loss is the sum of each of the projected surface areas of the construction parts which form a boundary of the building (as explained in NEN1068 [9]) multiplied with a reduction factor. The reduction factor is 1 when the construction forms a boundary between a heated zone and the outdoor air of water. The factor is 0.7 when the construction forms a boundary between a heated zone and the ground or crawl space. The factor is 0 when the construction forms a boundary between a heated zone of the building and another heated zone in another building.

The energy rating EPC in the Netherlands is specified in primary energy and the value is referring to the treated floor area in [MJ/m²/a].

Three different methods have been published and applied in the Netherlands, namely the TO, GTO and ATG method which assess the summer comfort. These methods have been put forward by the Rijksgebouwendienst (Dutch Government Building Department) as a guideline for assessing the indoor climate of new buildings, however these do not have to be met for residential buildings.

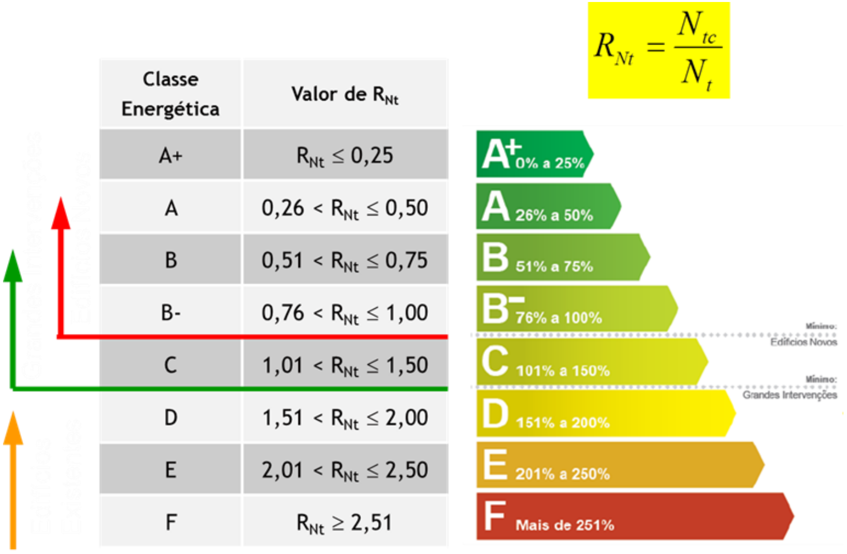
3.9 Portugal

The national building standards for Portugal are regulated in the Sistema Nacional de Certificação Energética e da Qualidade do Ar Interior nos Edifícios which came into force in 2006.

Table 3.9: PORTUGAL - National Building Code Summary

National Building Code	**Value**	**Reference / Comments**
What is the name of the building regulation and when did it come into force?	2013	A new building regulation was published in December 2013 – Decreto-Lei nº 118/2013 which includes: Sistema de Certificação Energética de Edifícios (SCE – energy certification); Regulamento de Desempenho Energético dos Edifícios de Habitação (REH – residencial buildings); Regulamento de Desempenho Energético dos Edifícios de Comércio e Serviços (RECS – comercial buildings).
Who is required to confirm regulations compliance?	-	Qualified engineers or architects acknowledged by the correspondent professional organization are responsible for the building design. In addition it is mandatory to have a pre-certificate emitted by a qualified expert (certified by ADENE and introduced in the national electronic platform) when submitting the building design to the Municipality. A qualified expert must be an engineer or architect approved by the governmental organization for energy (ADENE - Portuguese Energy Agency). When the building is complete the final energy certificate must be submitted by a qualified expert through the national electronic platform of ADENE. After following these procedures a "building use license" can be issued.
What are the main requirements for compliance (elemental or overall heat loss method)		
For new dwellings:	Overall	The overall calculation of buildings is mandatory and it includes heating energy, cooling energy and domestic hot water energy.
For existing dwellings:	Overall	The same as with new dwellings but with some simplifications. The new building regulation – Decreto-Lei nº 118/2013 – is more flexible for existing buildings.
What is the methodology used to comply with current building regulations in dwellings?	Reference Building based in real geometry	The calculated energy needs in a dwelling have to be equal or lower than the maximum allowable value. The following requirements must be fulfilled: - Nic (annual heating energy nominal needs of the dwelling) ≤ Ni (maximum allowable value for heating energy needs) [kWh/m^2.a] - Nvc (annual cooling energy nominal needs of the dwelling) ≤ Nv (maximum allowable value for cooling energy needs) [kWh/m^2.a] - Ntc (annual primary energy needs of the dwelling) ≤ Nt (maximum allowable value for primary energy needs) [kWhEP/m^2.a] The new building regulation – Decreto-Lei nº 118/2013 – allows the deduction of all possible contributions from renewable sources for producing domestic hot water, spacing heating or cooling.
Is there a calculation procedure for new dwellings?	Norm	Yes, the calculation procedure is similar, excluding the historical buildings.

Portugal has an Energy Rating =Ntc/Nt which is a energy performance indicator of the dwelling class in primary energy. Existing buildings can have the following energy classes: A+, A, B, B-, C, D, E and F (A+ corresponds to the class with the best building energy performance). In new buildings the energy classes can only vary between A+ and B- and between A+ and C for retrofitted buildings. The energy indicators Nic, Ni, Nvc and Nv are expressed in kWh/m²a. Ntc and Nt are expressed in kWhEP/m^2.ano.



$$R_{Nt} = \frac{N_{tc}}{N_t}$$

Classe Energética	Valor de R_{Nt}
A+	$R_{Nt} \leq 0{,}25$
A	$0{,}26 < R_{Nt} \leq 0{,}50$
B	$0{,}51 < R_{Nt} \leq 0{,}75$
B-	$0{,}76 < R_{Nt} \leq 1{,}00$
C	$1{,}01 < R_{Nt} \leq 1{,}50$
D	$1{,}51 < R_{Nt} \leq 2{,}00$
E	$2{,}01 < R_{Nt} \leq 2{,}50$
F	$R_{Nt} \geq 2{,}51$

Figure 3.2: Energy Classes in Portugal

Summer comfort is regulated by Nvc (annual energy calculated for cooling the dwelling) and Nv (maximum annual energy value for cooling) which are defined in RCCTE.

3.10 Slovakia

The national building standards for Slovakia are regulated in Act no. 555/2005 which came into force in 2006. Basically, it defines a specific maximum primary energy demand for new buildings which has to be lower than a comparable reference building. The procedure of calculation is defined in STN EN ISO 13790, issued in 1.5.2009 and National supplement STN EN ISO 13790/NA issued in 1.3.2010.

Calculated energy need should not be higher than the allowed value in dependence on the building shape factor, specified in STN 730540 (2002).

The energy rating in Slovakia is specified in a calculated delivered energy and the value is referring to the treated floor area in [kWh/m²/a].

The thermal stability in winter period is assessed according to STN 73 0540. It is necessary to demonstrate the maximum increase of fair temperature in summer period. Slovakia is divided into 2 climatic regions. At the national level there are defined optimum and allowable conditions of hygrothermal climate for cold and warm seasons, in dependence on an activity (Notice No. 259/2008).

Table 3.10: SLOVAKIA - National Building Code Summary

National Building Code	**Value**	**Reference / Comments**
What is the name of the building regulation and when did it come into force?		The Act no. 555/2005 About energy performance of buildings and amending certain laws. Published in 8th November 2005, entry into force 1st January 2006.
Who is required to confirm regulations compliance?	-	Only the qualified persons issue the EP certificate. The qualification is divided into four professions: 1. Thermal protection of structures and buildings, 2. Heating and hot water supply, 3. Ventilation and air conditioning, 4. Build-in lighting. For residential buildings only professions 1 and 2 are necessary. The qualified person in profession no. 1 provides registration of EP certificate to the internal registration system, which then generates unique number.
What are the main requirements for compliance (elemental or overall heat loss method)		The maximum allowed primary energy demand compared to a reference building. For new buildings it is required that calculated total supplied energy in kWh/m².a is lower than the allowed value, defined as the upper limit of the energy class B. Complementary requirement: the calculated energy need should not be higher than the allowed value in dependence on the building shape factor.
For new dwellings:	-	Calculated energy need should not be higher than the allowed value in dependence on the building shape factor, Thermal transmittances, specified in STN 730540 (2002)
For existing dwellings:	-	Calculated energy need should not be higher than the allowed value in dependence on the building shape factor, Thermal transmittances, specified in STN 730540 (2002)
What is the methodology used to comply with current building regulations in dwellings?	Reference Building	Calculated primary energy demand has to be equal to or lower than defined maximum value compared to the reference value. For significant renovated buildings energy class B is required, if it is realistic from the aspect of technology, function and economy.
Is there a calculation procedure for new dwellings?	Norm	The procedure of calculation is defined in STN EN ISO 13790, issued in 1.5.2009 and National supplement STN EN ISO 13790/NA issued in 1.3.2010. For residential buildings the calculation is carried out for the heating season, for other buildings the time step is 1 month. Other professions have their specific standards. The determination of primary energy from total supplied energy serve conversion factors defined in Notice No. 311/2009.

3.11 Sweden

The national building standards for Sweden are regulated in the BBR2012 which came into force in Jan 2012. As there is no standard compliance in Sweden, the type of input data depends on the building simulation tool used.

Sweden is divided into 3 design climate zone those, the specific energy use is separated depending on the climate zone as well.

The energy rating in Sweden is specified in delivered (bought) energy (system boundaries are set at the building) and the value is referring to the treated floor area in [kWh/m²/a] where area is defined as a heated floor area and encloses the floor areas in all building zones with indoor temperatures 10 °C and above. The CHP is already covered by primary energy factor. The following table provides the input parameter required for the estimation of the energy rating.

Table 3.11: SWEDEN - National Building Code Summary

National Building Code	**Reference / Comments**
What is the name of the building regulation and when did it come into force?	BBR2012, Jan 2012
Who is required to confirm regulations compliance?	Energy declarations should only be performed by companies that are accredited by the Swedish Board for Accreditation and Conformity Assessment (Swedac). The inspection body is at least one certified person. This means that the system is based on the standards of independence, competence and regular follow-up in both the accreditation and the certification.
What are the main requirements for compliance (elemental or overall heat loss method)	Overall energy demand and mean thermal transmittance of a building envelope, as shown in Table 3 and Table 4. Elemental requirements are specified for smaller buildings without cooling systems
For new dwellings:	"
For existing dwellings:	"
What is the methodology used to comply with current building regulations in dwellings?	Calculated energy for heating, cooling, operation of HVAC systems and production of hot water should be equal to or lower than a defined maximum value when compared to a reference building, in a reference year and in a reference climate zone). Maximum average heat transmittances for the whole building envelope are also specified Average heat transmittance of a building envelope should be calculated according to SS-EN ISO 13789:2007 and SS 02 42 30 (2). For energy declarations, calculated energy demands should be verified by measurements which are performed during at least 12 and up to 24 consecutive months. Measured data should also be corrected to a reference year.
Is there a calculation procedure for new dwellings?	Calculation procedure for energy use in buildings is not specified. Designers are free to choose energy simulation programs and input data. In practice, designers often use a compilation of input data which is developed by the construction and property industry (Sveby, 2009). For energy declaration, it is up to the accredited body and the house owner to choose the calculation method. As mentioned above, the validity of calculations is checked by measurements. For new buildings, the measurements of the energy use should not be performed during the first year the building is used

3.12 The United Kingdom

The national building standards for UK are regulated in the Building Regulations which came into force in 2010. It is subdivided into three jurisdictions (England and Wales, Scotland and Northern Ireland).

The basic approach is to demonstrate that the Dwelling Emissions Rate (DER) does not exceed that a Target Emissions Rate (TER). The national calculation methodology (NCM) is applied through the Standard Assessment Procedure SAP.

Table 3.12: UK - National Building Code Summary

National Building Code	**Value**	**Reference / Comments**
What is the name of the building regulation and when did it come into force?	Building Regulations; approved document part L and approved document part F (2010)	"The legislative structure is based on a system of primary and secondary legislation supported by non-mandatory technical guidance (Billington 2005). Approved Document Part L (Conservation of Fuel and Power) is the relevant second-tier guidance document affecting energy efficiency in buildings. The document is subdivided into four separate documents: - for residential buildings: Part L1A (new dwellings) and Part L1B (existing dwellings); - for non-residential buildings: Part L2A (new buildings) and Part L2B (existing buildings). Approved Document Part F (ventilation) is the relevant second-tier guidance document affecting ventilation requirements in buildings. On the domestic level, legislation implementation is based on a devolved administration structure subdivided into three jurisdictions (England and Wales, Scotland and Northern Ireland) each governed by a separate body and regulation documents (BRC 2003).
Who is required to confirm regulations compliance?	Building control officers	Building control officers ensure that the requirements of the building regulations are met, through the "Building Control Service"; the person carry out building work (e.g. designer, builder, installer) which is subject to the Building Regulations is required by law to make sure it complies with the regulations and to use a Building Control Service, either from a local authority or an approved inspector. In addition the building owner may also have responsibility to ensure compliance and will be served with an enforcement notice in cases of non-compliance. SAP (Standard Assessment Procedures) are carried out by an Authorized SAP/ OC DEA assessor.

What are the main requirements for compliance (elemental or overall heat loss method)	
For new dwellings:	Full SAP assessment required. CO2 emissions: whole building approach to demonstrate that the Dwelling Emissions Rate (DER) does not exceed that a Target Emissions Rate (TER). Elemental approach to demonstrate compliance to Part L1a building regulations in respect of thermal elements, controlled fittings and services.
For existing dwellings:	· When building an extension with more than the permitted openings area (25% of new floor area + openings covered by extension) or a non-separated conservatory a Full SAP report demonstrating compliance with Part L1b through elemental trade-off and, or whole dwelling trade-off is required and submitted to building control by an Authorized SAP assessor. · When renovating and refurbishing a property if more than 25% of any existing thermal element is affected by works then the whole element should be improved to the required target Thermal transmittance for that element. Controlled fitting (windows etc.) are also governed by minimum Thermal transmittances when replaced as are controlled services (heating and hot water systems etc.) with the efficiency of a new system not more than 2% worse than the original and no less than 86%.
What is the methodology used to comply with current building regulations in dwellings?	The national calculation methodology (NCM) as applied through the Standard Assessment Procedure SAP
Is there a calculation procedure for new dwellings?	Norm+Sim.: The Standard Assessment Procedure (SAP) is DECC's methodology for assessing and comparing the energy and environmental performance and demonstrating compliance of dwellings. A reduced data version (rdSAP) id used for existing dwellings. The procedure used for the calculation is based on the BRE Domestic Energy Model (BREDEM), which provides a framework for the calculation of energy use in dwellings. The procedure is consistent with the standard BS EN ISO 13790.

According to the Building Regulations, reasonable provision should be made to limit solar gains. SAP 2009 Appendix P contains a procedure for the assessment of internal temperature in summer which check whether solar gains are excessive. The procedure is not integral to SAP and does not affect the calculated SAP rating or CO_2 emissions. Reasonable provision would be achieved if the SAP assessment indicates that the dwelling will not have a high risk of high internal temperatures.

The energy rating system in the UK is specified in a SAP rating (0 to 100 points or bands G to A) scaled in the following ranges:

- Band G: 1 to 20 (low efficiency)
- Band F: 21 to 38
- Band E: 39 to 54
- Band D: 55 to 68
- Band C: 69 to 80
- Band B: 81 to 91
- Band A: 92 or more (high efficiency)

The SAP methodology allows the calculation of primary energy but the SAP rating itself is an energy cost rating.

3.13 The United States

In the USA there is no general national building code. However, the most common (regional) codes are the I-Codes, but many rural areas have no enforcement at all. The methodology mostly adopted is specified in IECC 2009.

Table 3.13: THE USA - National Building Code Summary

National Building Code	**Value**	**Reference / Comments**
What is the name of the building regulation and when did it come into force?		There is not one national code. The I-Codes are the most commonly adopted codes, but adopted editions vary by jurisdiction.
Who is required to confirm regulations compliance?	-	Each individual jurisdiction (State, County, City) may be responsible for enforcement of codes. Many rural areas have no enforcement at all. Each state is responsible to determine extent of that state's control over code enforcement.
What are the main requirements for compliance (elemental or overall heat loss method)	-	When an energy code is adopted and enforced, a performance and a prescriptive approach are permitted.
For new dwellings:	-	Depending on State Code adoption year.
For existing dwellings:	-	If updates are made to an envelope, in states where a code is required the envelope needs to be upgraded to existing energy codes
What is the methodology used to comply with current building regulations in dwellings?		IECC 2009 is what most states have adopted. State of Maryland adopted the IECC 2012
Is there a calculation procedure for new dwellings?	Norm	Yes

The energy rating in the USA is specified in delivered energy which only includes heating, cooling and SWH. The value is referring to the conditioned space in [Btu/ft²/a].

The only requirement to assess the summer comfort is a central air conditioning system.

4 REQUIREMENTS REGARDING THERMAL TRANSMITTANCES AND THERMAL BRIDGES

The following chapter will give an overview and comparison of national regulations regarding the building envelope and ventilation. Thermal transmittances are occasionally given in a range meaning they depend either on the location in the country or on other boundary conditions of the building.

4.1 Austria

The thermal transmittances in the following table describe the maximum values of building constructions. In addition there is a maximum allowed annual heating energy demand related to the gross floor area and depending on the geometry. This value is calculated using and reference climate for Austria.

Table 4.1: AUSTRIA - Maximum thermal transmittances and thermal bridges

What are the maximum thermal transmittances required? (if required, specify range) and Repeat for each Climate Zone in [W/(m²•K)]				
Wall (exterior)	Wall (interior)	Wall (soil)	Windows / Doors	Pitched roof
0.35	0.90	0.40	1.40	0.20
Flat roof	Basement	Floor to unconditioned space	Ceiling to unconditioned space	Other
0.20	0.40	0.40	0.40	-
Minimum requirement for thermal bridging at junctions between envelope elements?		thermal bridges should be avoided. Harmfull condensation under normal usage has to be prevented.		

Table 4.2: AUSTRIA – Ventilation

Is there a specified minimum rate for naturally ventilated dwellings?	No	Dwellings have openable windows. To avoid summertime overheating the necessary openable area has to be calculated.
Minimum mechanical ventilation requirements?	-	No

4.2 Brazil

Due to hot climate and low heating demand in Brazil, the focus is primarily on the natural ventilation system and less on the insulation of the building envelope. In addition the evaluation of the water heating system is required.

Thermal transmittances are specified depending on the Bioclimatic Zone.

Table 4.3: BRAZIL - Maximum thermal transmittances and thermal bridges

Bioclimatic Zone	**Component**	**Solar Absorptance (dimensionless)**	**Thermal transmittance [W/(m^{2}K)]**	**Thermal capacity [kJ/(m²K)]**
Z1 and Z2	Wall	no requirement	U ≤ 2.50	CT ≥ 130
	Roof	no requirement	U ≤ 2.30	no requirement
Z3 to Z6	Wall	α ≤ 0.6	U ≤ 3.70	CT ≥ 130
		α > 0.6	U ≤ 2.50	CT ≥ 130
	Roof	α ≤ 0.6	U ≤ 2.30	no requirement
		α > 0.6	U ≤ 1.50	no requirement
ZB7	Wall	α ≤ 0.6	U ≤ 3.70	CT ≥ 130
		α > 0.6	U ≤ 2.50	CT ≥ 130
	Roof	α ≤ 0.4	U ≤ 2.30	no requirement
		α > 0.4	U ≤ 1.50	no requirement
ZB8	Wall	α ≤ 0.6	U ≤ 3.70	no requirement
		α > 0.6	U ≤ 2.50	no requirement
	Roof	α ≤ 0.4	U ≤ 2.30	no requirement
		α > 0.4	U ≤ 1.50	no requirement
Minimum requirement for thermal bridging at junctions between envelope elements?			No	

In Brazil, there is no general minimum air change rate decreed. Instead, minimum areas of ventilations are established by local buildings codes. The thermal bridges are not considered in the calculation in any ways.

Table 4.4: BRAZIL – Ventilation

Is there a specified minimum rate for naturally ventilated dwellings?		Dwellings in Brazil are naturally ventilated and minimum areas of ventilations are established by local buildings codes
Minimum mechanical ventilation requirements?	-	No.

4.3 Canada

As mentioned above, two compliance paths are available in Canada. The prescriptive way specifies maximum thermal transmittance values (based on heating degree days). For the energy performance option, the annual total energy consumption is evaluated.

Canada is divided in six climate zones. For the compilations an average of 10 years of measured data collected at the weather station nearest to the region of in which the proposed building is located. For simulation, the climate date is obtained from the Canadian Weather Year for Energy Calculations (CWEC) or Canadian Weather Energy and Engineering Database (CWEEDS)

Table 4.5: CANADA - Maximum Thermal transmittances and thermal bridges

What are the maximum thermal transmittances required? (if required, specify range) and Repeat for each Climate Zone in [W/(m²•K)] *				
Wall (exterior)	Wall (interior)	Wall (soil)	Windows / Doors	Pitched roof
0.26 – 0.36 (0.32 – 0.36)	-	-	1.40 – 1.80	0.20 – 0.21
Flat roof	Basement	Floor to unconditioned space	Ceiling to unconditioned space	Other
0.20 – 0.21	0.25 – 0.50 (0.34 – 0.50)	0.20 – 0.21	0.10 – 0.14	-
Minimum requirement for thermal bridging at junctions between envelope elements?		No minimum requirement, but included in the calculation of total transmittance in the prescriptive compliance path or total energy consumption calculations		

* Varies by climate zone. Column 'C' is for Zone 4 and Column 'D' is for Zone 8. Values in brackets are for the cases where Heat-Recovery Ventilator is included otherwise the values outside of the bracket are used.

In Canada, there is no general minimum prescribed air change rate. When using a mechanical ventilation system, the minimum requirements are based on number of bedrooms.

Table 4.6: CANADA – Ventilation

Is there a specified minimum rate for naturally ventilated dwellings?	5.0 – 10.0 L/s	Minimum natural ventilation rate is not specified. But, minimum ventilation areas for different rooms are defined (for non-heating-season). Rooms that won't have the required natural ventilation area are required to achieve code specified air-exchange rate through mechanical ventilation: Master bedroom and basement are required to have to have an air exchange rate of 10 L/s and other rooms 5 L/s
Minimum mechanical ventilation requirements?	-	The minimum and maximum ventilation rates of the principal ventilation system are defined. The limits are based on number of bedrooms. For example dwelling with • one bedroom—Min 16 L/s and Max 24 L/s a • two bedrooms—Min 18 L/s and Max 28 L/s five bedrooms –Min 30 L/s and Max 45 L/s

4.4 Denmark

The compliance in Denmark is performance based, meaning the given Thermal transmittances are used to estimate the overall energy consumption depending on the intended use of the building. Therefore parameters for e.g. energy consumption for lighting, ventilation, etc. must also be considered.

The Danish Building Research Institute SBi Direction 213 along with the calculation program Be10 are the tools that are used to document that the requirements are met.

Table 4.7: DENMARK - Maximum Thermal transmittances and thermal bridges

What are the maximum thermal transmittances required? (if required, specify range) and Repeat for each Climate Zone in [W/(m²•K)]				
Wall (exterior)	Wall (interior)	Wall (soil)	Windows / Doors **	Pitched roof
0.3	0.4 *	0.3		0.20
Flat roof	Basement	Floor to unconditioned space	Ceiling to unconditioned space	Other
0.20	0.30	0.20 – 0.40 ***	0.20	-
Minimum requirement for thermal bridging at junctions between envelope elements?		BR10 states maximum values for the line losses that are allowed in new buildings: Foundations (internal measurements on deck and exterior wall): 0.40 Foundations for floors with floor heating: 0.20 Joints between exterior walls, windows or doors, gates, etc.: 0.06 Joints between the roof construction and skylight: 0.20		

* For partitions and horizontal divisions facing rooms > 8 K colder

** Windows and exterior walls of glass must not have an energy gain lower than -33 kWh/(m^2·a).

*** Left: Ground slabs, basement floors in contact with the soil and suspended upper floors above open air or a ventilated crawl space. Right: Suspended upper floors and partitions to rooms/spaces which are unheated or heated to a temperature more than 8 K lower than the temperature in the room/space concerned.

In Denmark, there is a general minimum air change of 0.3 L/(s•m²), decreed. In addition, maximum values for thermal bridges are specified that are allowed in new buildings.

Table 4.8: DENMARK – Ventilation

Is there a specified minimum rate for naturally ventilated dwellings?	~ 0.5 h^{-1}	Yes, this minimum is stated in BR10: All dwellings, disregarding how they are ventilated, must have a minimum air change of 0.3 L/(s·m^2), where the area is the gross area. Kitchens must be equipped with a range hood; this must be able to exhaust 20 L/s. In bathrooms it must be possible to reach and an air change of 15 L/s
Minimum mechanical ventilation requirements?	-	See the above question and answer.

4.5 Estonia

As stated above, the energy performance requirements are performance based meaning they are determined for the whole building not for different components. The energy performance value takes into account primary energy for indoor climate (heating, cooling (humidifying, drying), ventilation, lighting), domestic hot water, and electrical facilities.

Dynamic simulation with validated software is allowed for all building types. Energy calculations for apartment buildings may also be performed by simplified calculations per months or per degree days. And high temperatures during summer should be avoided.

There are no specific requirements for U-values (there are some recommendations). Even there are no requirements for thermal transmittance in Estonian energy performance regulation; still some requirements are given for building envelope.

*Table 4.9: ESTONIA - Recommended values of thermal transmittance of building envelope and thermal bridges for starting the design**

Recommendation values of thermal transmittance for starting the design of dwellings. Final result depends on architecture and building service systems. required? *				
Wall (exterior)	Wall (interior)	Wall (soil)	Windows / Doors	Pitched roof
0.12 – 0.22	-	0.12 – 0.22	0.60 - 1.10	0.10 – 0.15
Flat roof	Basement	Floor to unconditioned space	Ceiling to unconditioned space	Other
0.10 – 0.15	0.10 – 0.15	0.10 – 0.15	0.10 – 0.15	-
Minimum requirement for thermal bridging at junctions between envelope elements?		In order to avoid mold growth the temperature factor of the internal surface of thermal bridge should not be below f_{Rsi}0.8.		

The building envelope should be air-tight in long term and in order to avoid moisture convection risks, the critical elements of structures shall be made practically completely air-tight. The building envelope should have sufficient thermal insulation. When determining sufficient thermal insulation the thermal comfort, the prevention of mold and condensation at cold bridges, interior surfaces and structures, compactness of the building and the heating and ventilation solutions should be taken into account.

Table 4.10: ESTONIA – Ventilation

Is there a specified minimum rate for naturally ventilated dwellings?	0.35 l/s, m^2	There are no specific requirements for natural ventilation. According to EVA EN 15251 "Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics", existing dwellings should have air change rate 0,5 h^{-1} (0,35 l/s,m^2)
Minimum mechanical ventilation requirements?	0,42 l/s, m^2	There are no specific requirements for mechanical ventilation. According to EVA EN 15251 "Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics", new and renovated dwellings should have air change rate 0,6 h^{-1} (0,42 l/s, m^2)

4.6 Finland

The energy rating is performance based, thus, the given thermal transmittances in the following table are used to evaluate the overall energy consumption relating to a reference house. Main requirements from those are:

- Heat losses in new buildings must be less than the reference buildings heat losses.
- Total primary energy consumption (E-value) must be lower than limit value.

At the moment there is no energy related requirements for existing buildings. Energy requirements for renovations are being developed.

Average monthly values for different climate zones are available. If no cooling systems are used in the buildings, monthly values can be used. If cooling systems are used, a dynamic calculation method has to be used (energy reference year with hourly time interval). When checking if the energy consumption is in accordance with energy regulations, the climate zone 1 is used always.

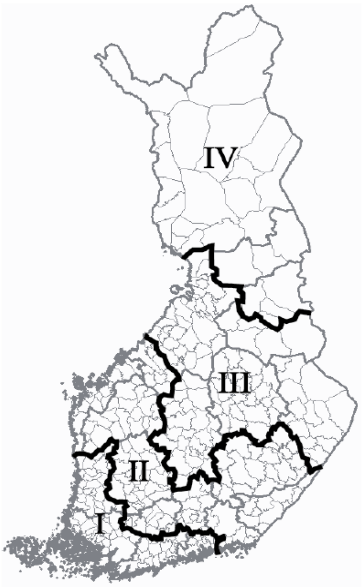


Figure 4.1: Finland - Climate zones

The methodology to create design climate data is based on SFS EN ISO 15927-4 with few alterations.

Table 4.11: FINLAND - Maximum thermal transmittances and thermal bridges

What are the maximum thermal transmittances required? (if required, specify range) and Repeat for each Climate Zone in [W/(m²•K)]				
Wall (exterior)	Wall (interior)	Wall (soil)	Windows / Doors	Pitched roof
0.17 – 0.40*	-	0.16	1.00	0.09
Flat roof	Basement or slab on ground	Floor with a crawl space**	Floor connected to outside air***	Other
0.09	0.16	0.17	0.09	-
Minimum requirement for thermal bridging at junctions between envelope elements?		There is no minimum requirement. Thermal bridges have to be taken into consideration when calculating the heat loss through structures. If design values are unknown, there are stated values in regulations which have to be used.		

* Wall / exterior: 0.4 for wooden log walls, 0.17 for all the other wall types

** A floor with a crawl space underneath with ventilation area less than 8‰ out of the floor area.

*** A floor with outside air underneath

In Finland, there is a general minimum air change rate of 0.5 h^{-1} decreed. When using a mechanical ventilation system, the minimum requirements depend on the room type. For the mechanical cooling there are no regulations implemented.

The thermal bridges are considered in the calculation in different ways. Standard values which increase the thermal transmittance of the component are taken when thermal bridges are unknown or built according to a catalogue. If detailed calculations are available, those values can be used as well.

Table 4.12: FINLAND – Ventilation

Is there a specified minimum rate for naturally ventilated dwellings?	0.5 h^{-1}	Ventilation rate in dwellings must be 0,5 h^{-1}
Minimum mechanical ventilation requirements?	0.5 h^{-1}	Ventilation rate in dwellings must be 0,5 h^{-1}

4.7 Germany

There are two requirements in Germany according to EnEV. Calculated primary energy demand has to be equal to or lower than a defined maximum value compared to a reference building. In addition, there is a limitation regarding the transmission loss relating to building surface.

Thermal transmittances are specified depending on the building type (non-/residential) and construction situation. As Germany only having one design climate zone (for the monthly based calculation method), those values are valid for the entire country.

Table 4.13: GERMANY - Maximum thermal transmittances and thermal bridges

What are the maximum thermal transmittances required? (if required, specify range) and Repeat for each Climate Zone in [W/(m²•K)]				
Wall (exterior)	Wall (interior)	Wall (soil)	Windows / Doors	Pitched roof
0.24 – 0.35	-	0.24 – 0.35	1.30 - 1.40	0,25 – 0.35
Flat roof	Basement	Floor to unconditioned space	Ceiling to unconditioned space	Other
0.20 – 0.35	0.50	0.50	0.30	-
Minimum requirement for thermal bridging at junctions between envelope elements?		Thermal bridges should be equal to or lower than 0.05 W/m^2K of the building surface. No requirements fixed but thermal bridge effects have to be included by either fixed values or detailed calculations. In order to avoid mold growth the f-value (temperature factor f_{Rsi} , -)should not be below 0.7 (DIN 4108-2). $f_{Rsi} = (\theta\_(s,i)-\theta\_e)/(\theta\_i-\theta\_e)$ $\Theta s,i$ - Surface temperature 0 [°C] Θi - Indoor temperature, usually 20 [°C] Θe - Outdoor temperature, usually -5 [°C]		

In Germany, there is a general minimum air change rate of 0.5 h^{-1} decreed. When using a mechanical ventilation system, the minimum requirements depend on the room type. For the mechanical cooling there are no regulations implemented.

The thermal bridges are considered in the calculation in different ways. Standard values which increase the thermal transmittance of the component are taken when thermal bridges are unknown or built according to a catalogue. If detailed calculations are available, those values can be used as well.

Table 4.14: GERMANY – Ventilation

Is there a specified minimum rate for naturally ventilated dwellings?	0.5 h^{-1}	The German DIN 4108-2 requires a minimum air change rate of 0.5 h^{-1} for residential buildings.
Minimum mechanical ventilation requirements?	-	Minimum values depend on the type of room.

4.8 The Netherlands

For the EPC (energy performance coefficient) calculation basically two types of characteristics are used namely, building characteristics and energy characteristics.

The design climate data is regulated in NEN5060. NEN. 2008. Hygrothermal performance of buildings - Climatic reference data. ICS 07.060; 91.120.10; 91.140.30.As the Netherlands only having one design climate zone, those values are valid for the entire country.

Table 4.15: THE NETHERLANDS - Maximum thermal transmittances and thermal bridges

What are the maximum thermal transmittances required? (if required, specify range) and Repeat for each Climate Zone in [W/(m^2•K)] *				
Wall (exterior)	Wall (interior)	Wall (soil)	Windows / Doors	Pitched roof
3.5	-	3.5	2.2	3.5
Flat roof	Basement	Floor to unconditioned space	Ceiling to unconditioned space	Other
3.5	3.5	3.5	3.5	-
Minimum requirement for thermal bridging at junctions between envelope elements?		In order to avoid mold growth the f-value should not be below f_{Rsi}>0.65. f_{Rsi} = (θ_(s,i)-θ_e)/(θ_i-θ_e) with ϴs,i - Surface temperature 0[°C] ϴi - Indoor temperature, usually 18[°C] ϴe - Outdoor temperature, usually 0[°C] Source: bouwbesluit 2012, Article 3.22, section 1		

* Minimum according to Bouwbesluit 2012, Article 5.3, section 1 to 3, calculated according to NEN1068.

In the Netherlands, there is a general minimum ventilation rate of 7l/s decreed or 0.9 l/s per m^2. The thermal bridges are not directly considered in the calculation. However, the “f-value” should not deceed 0.65.

Table 4.16: THE NETHERLANDS – Ventilation

Is there a specified minimum rate for naturally ventilated dwellings?	0.9 l/s per m^2 - min 7l/s	minimum according to Bouwbesluit 2012, Article 3.29, section 1 to 5, calculated according to NEN1078
Minimum mechanical ventilation requirements?	0.9 l/s per m^2 - min 7l/s	minimum according to Bouwbesluit 2012, Article 3.29, section 1 to 5, calculated according to NEN1078

4.9 Portugal

The calculation of four energy demands (Nic, Nvc, Nac, Ntc) are mandatory. They include heating energy, cooling energy, domestic hot water energy and primary energy.

The final compliance requires several input parameters. The following table displays the mandatory data in general. Also included are the solar collectors calculated with the software SolTerm LNEG. The Portuguese thermal regulation sets maximum allowable Thermal transmittances for building elements and reference Thermal transmittances.

Table 4.17: PORTUGAL - Maximum Thermal transmittances and thermal bridges

What are the maximum U- values required? (if required, specify range) and Repeat for each Climate Zone in [W/(m²•K)]				
Wall (exterior)	Wall (interior)	Wall (soil)	Windows / Doors	Pitched roof
1.45 – 1.80	1.90 – 2.00	-	-	0.90 – 1.25
Flat roof	Basement	Floor to unconditioned space	Ceiling to unconditioned space	Other
0.90 – 1.25	-	1.20 – 1.65	1.20 – 1.65	-
Minimum requirement for thermal bridging at junctions between envelope elements?		The calculation of linear thermal transmittance (Ψ-value, thermal bridges effects) is mandatory but there are no requirements. The thermal code presents the most common situations of thermal bridges. There is also the possibility of detailed calculations according to the EN.		

In Portugal, the RCCTE requires a minimum air change air change rate of 0.4 h^{-1} for natural ventilation as well as for a mechanical ventilation system.

The heat loss through thermal bridges is considered with a linear coefficient (Ψ – value). Default values which increase the Thermal transmittance of the component are used when thermal bridges are unknown or built according to a catalogue. If detailed calculations complying to EN ISO 10211 are available, those values can be used as well.

Table 4.18: PORTUGAL – Ventilation

Is there a specified minimum rate for naturally ventilated dwellings?	0.4 h^{-1}	The RCCTE requires a minimum air change rate of 0.4 h^{-1}.
Minimum mechanical ventilation requirements?	0.4 h^{-1}	The RCCTE requires a minimum air change rate of 0.4 h^{-1}.

4.10 Slovakia

The Thermal transmittances given in the following table are used to determine the maximum allowed primary energy demand compared to a reference building. Calculated energy demand should not be higher than the allowed value in dependence on the building shape factor, Thermal transmittances, specified in STN 730540 (2002)

Slovakia does not have multiple climate design zones for normalized calculation, normalized climate data are in Notice No. 311/2009, design of building structures and details - 5 zones

Table 4.19: SLOVAKIA - Maximum thermal transmittances

What are the maximum thermal transmittances required? (if required, specify range) and Repeat for each Climate Zone in [W/(m²•K)]				
Wall (exterior) *	Wall (interior) *	Wall (soil) *	Windows / Doors *	Pitched roof *
0.46 (0.32)	0.8 - 2.75 ** (0.45 - 1.5)	1.7 - 2.5 *** (1.2 - 2.0)	2.00 (1.7)	0.30 - 0.46 (0.20 - 0.30)
Flat roof *	Basement *	Floor to unconditioned space *	Ceiling to unconditioned space *	Other *
0.30 (0.20)	1.0 - 1.5 (0.45 - 1.35)	0.75 - 2.30 ** (0.45 - 1.35)	0.35 (0.25)	-

* in brackets () = recommended values for new buildings

** depending on temperature difference

*** depending on the depth below the terrain

**** 0.46 / 0.32 W/m^{2}K at an inclination over 45°

***** 1.5 /1.35 m^{2}K/W at the level of 0,5 m from the external ground and within a distance of 2.0 m from the inner surface of the outer wall, other cases 1.0 / 0.45

In Slovakia, there is a general minimum air change rate of 0.5 h^{-1} decreed. When using a mechanical ventilation system, the minimum requirements depend on the room type. The thermal bridges are considered in the calculation in different ways and the internal surface temperature should be high enough to avoid condensation water.

Table 4.20: SLOVAKIA – Ventilation

Is there a specified minimum rate for naturally ventilated dwellings?	0.5 h^{-1}	The Slovak STN 730540 requires a minimum air change rate of 0.5 for residential buildings. If it is not possible to provide this requirement by infiltration, it is necessary to use other mean, for example natural ventilation through windows or mech. ventilation.
Minimum mechanical ventilation requirements?	-	Minimum values depend on the type of room.

Table 4.21: SLOVAKIA - Thermal bridges

Minimum requirement for thermal bridging at junctions between envelope elements?	Walls, ceilings and floors in spaces with the air relative humidity ≤ 80 % must to have at any location of their internal surface the temperature which is safely higher than the dew point temperature and excludes the mold growth risk (STN 730540). $\theta si \geq \theta si,N = \theta si,80 + \Delta\theta si$ where $\theta si,N$ is the lowest internal surface temperature $\theta si,80$ is the surface temperature critical for mold growth corresponding to 80 % relative humidity close to the internal surface of building structure $\Delta\theta si$ is the safety surcharge considering the way of heating and the exploitation of a room In spaces with the air rel. humidity > 80 % the thermal bridges are designed and assessed with the requirement of exclusion of surface water vapour condensation. In other cases the perfect performance of structures at surface condensation must be provided. At the calculation of energy need for heating the influence of thermal bridges can be considered by thermal transmittance increase: ΔU=0.05 W/m^{2}K in case of continuous thermal insulation layer at external surface and in cases of structures with the correct design of thermal bridges ΔU=0.10 W/m^{2}K in case of single layer masonry structures, sandwich structure, lightweight timber structures, not satisfying thermal bridges, etc. ΔU=0.20 W/m^{2}K in case of structures with internal thermal insulation. Walls, ceilings and floors in spaces with the air rel. humidity ≤ 80 % must to have at any location of their internal surface the temperature which is safely higher than the dew point temperature and excludes the mold growth risk (STN 730540). $\theta si \geq \theta si,N = \theta si,80 + \Delta\theta si$ where $\theta si,N$ is the lowest internal surface temperature $\theta si,80$ is the surface temperature critical for mold growth corresponding to 80 % relative humidity close to the internal surface of building structure $\Delta\theta si$ is the safety surcharge considering the way of heating and the exploitation of a room In spaces with the air rel. humidity > 80 % the thermal bridges are designed and assessed with the requirement of exclusion of surface water vapour condensation. In other cases the perfect performance of structures at surface condensation must be provided. At the calculation of energy need for heating the influence of thermal bridges can be considered by thermal transmittance increase: deltaU=0.05 W/m^{2}K in case of continuous thermal insulation layer at external surface and in cases of structures with the correct design of thermal bridges deltaU=0.10 W/m^{2}K in case of single layer masonry structures, sandwich structure, lightweight timber structures, not satisfying thermal bridges, etc. deltaU=0.20 W/m^{2}K in case of structures with internal thermal insulation.

4.11 Sweden

Calculated energy for heating, cooling, operation of HVAC systems and production of hot water should be equal to or lower than a defined maximum value when compared to a reference building, in a reference year and in a reference climate zone. Maximum average heat transmittances for the whole building envelope are also specified.

As Sweden is divided into 3 design climate zone those, the specific energy use is separated depending on the climate zone as well.

In Sweden the ventilation system should be designed to fulfil a minimum fresh air supply.

Table 4.22: SWEDEN – Ventilation

Is there a specified minimum rate for naturally ventilated dwellings?		There are no specific regulations
Minimum mechanical ventilation requirements?	0.10 - 0.35 l / s per m^2	BBR19: Ventilation systems should be designed for a minimum fresh air supply of 0.35 l/s per m^2 of the floor area. Rooms should be able to have continuous ventilation when used. In residential buildings where ventilation can be controlled separately for each dwelling, the ventilation system could be regulated by a presence and demand regulators. However, in such cases outside air supply must not be lower than 0.10 l / s per m^2 of the floor area when there are no persons, no lower than 0.35 l / s per m^2 floor area where persons are present. Sveby: min. values for mechanically ventilated rooms depend on the type of room.

The energy rating in Sweden is specified in delivered (bought) energy (system boundaries are set at the building) and the value is referring to the treated floor area in [kWh/m²/a] where area is defined as a heated floor area and encloses the floor areas in all building zones with indoor temperatures 10 °C and above. The CHP is already covered by primary energy factor. The following table provides the input parameter required for the estimation of the energy rating.

4.12 The United Kingdom

If more than 25% of any existing thermal element is affected by renovating and refurbishing a property then the whole element should be improved to the required target Thermal transmittance for that element. Controlled fitting (windows etc.) are also governed by minimum Thermal transmittances when replaced as are controlled services (heating and hot water systems etc.).

The Standard Assessment Procedure (SAP) is DECC's methodology can be done via simulation or according to norm.

The UK is divided into 14 climate zones for SAP using historical climate data averaged over 20 years to produce weather files. Thermal transmittances are specified depending on the building type (new / existing building).

Table 4.23: UK - Maximum thermal transmittances and thermal bridges

What are the maximum thermal transmittances required? (if required, specify range) and Repeat for each Climate Zone in [W/(m²•K)]				
Wall (exterior)	Wall (interior)	Wall (soil)	Windows / Doors	Pitched roof
0.28 – 0.55	0.2	-	2.00	0,16 – 0.2
Flat roof	Basement	Floor to unconditioned space	Ceiling to unconditioned space	Other
0.18 – 0.2	-	0.22 – 0.25	-	-
Minimum requirement for thermal bridging at junctions between envelope elements?		The PSI value is dwelling specific, hence it must be calculated individually for each dwelling. The temperature factor of the specific details must be no worse than the performance set out in BRE IP 1/06 e.g. f_{Rsi} = 0.75 for dwellings		

Regarding the upgrade of retained thermal elements: if achievement of the relevant reference U-value is not technically of functionally feasible or would not achieve a simple payback of 15 years or less, the element should be upgraded to the best standard that is technically and functionally feasible and which can be achieved within a simple payback of no greater than 15 years. The thermal bridges are assessed with the Y value (temperature factor) which must be no worse than the performance set out in BRE IP 1/06.

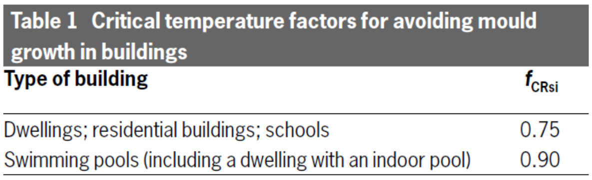


Table 1 Critical temperature factors for avoiding mould growth in buildings

Type of building	f_{CRsi}
Dwellings; residential buildings; schools	0.75
Swimming pools (including a dwelling with an indoor pool)	0.90

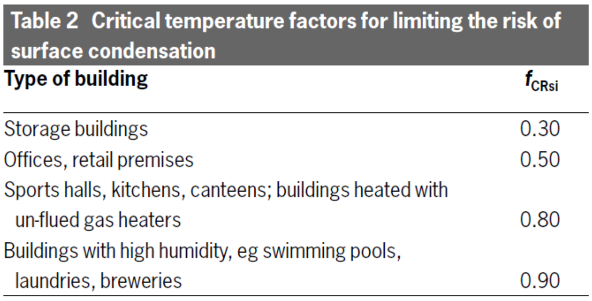


Table 2 Critical temperature factors for limiting the risk of surface condensation

Type of building	f_{CRsi}
Storage buildings	0.30
Offices, retail premises	0.50
Sports halls, kitchens, canteens; buildings heated with un-flued gas heaters	0.80
Buildings with high humidity, eg swimming pools, laundries, breweries	0.90

In the UK, the minimum values for mechanically ventilated rooms depend on the type of room and system.

Table 4.24: UK – Ventilation

Is there a specified minimum rate for naturally ventilated dwellings?	13 l/s to 29 l/s	Whole dwelling ventilation rates (depending on the number of bedrooms in dwelling). Additional information in "other tables".
Minimum mechanical ventilation requirements?	-	Minimum values for mechanically ventilated rooms depend on the type of room and system. The same figures as above apply.

Table 4.25: UK – Extract ventilation rates

Room	**Intermittent extract**	**Continuous extract**	
	Minimum rate	Minimum high rate	Minimum low rate
Kitchen	30 l/s adjacent to hob; or 60 l/s elsewhere	13 l/s	Total extract rate should be at least the whole dwelling ventilation rate given in the Table below
Utility room	30 l/s	8 l/s	
Bathroom	15 l/s	8 l/s	
Sanitary accommodation	6 l/s	6 l/s	

Table 4.26: UK – Whole dwelling ventilation rates

Number of bedrooms in dwelling	**1**	**2**	**3**	**4**	**5**
Whole dwelling ventilation rate (l/s)	13	17	21	25	29

Table 4.27: UK – Whole dwelling ventilation rates

Item	**Ventilation rate m³/hour**
Chimney	40
Open flue	20
Intermittent extract fan	10
Passive vent	10
Flueless gas combustion appliance	40

4.13 The United States

When an energy code is adopted and enforced, a performance and a prescriptive approach are permitted. The final compliance requires several input parameters. The following tables display the obligatory data in general for Energy Conservation Codes 2009, 2012. A.

Thermal transmittances are specified depending on the climate zone. The USA is divided into 8 IECC Climate Zones as shown in Figure 4.2.

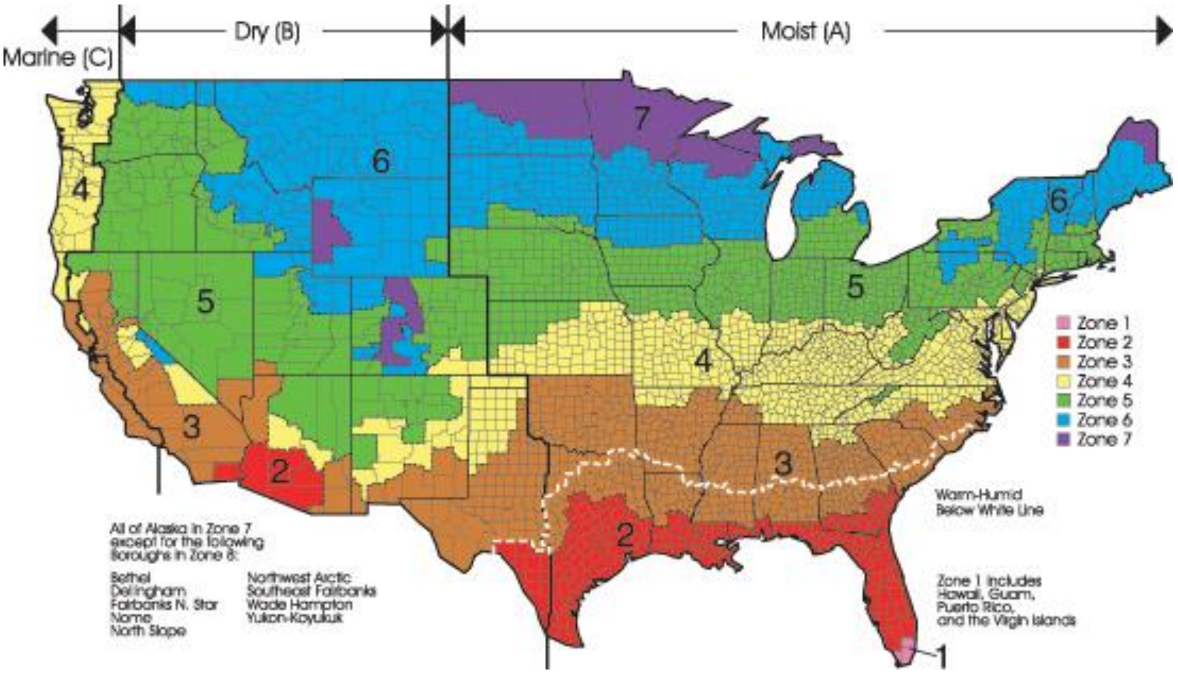


Figure 4.2: 8 Climate Zones in the USA according to IECC

Table 4.28: THE USA - Maximum thermal transmittances and thermal bridges

What are the maximum thermal transmittances required? (if required, specify range) and Repeat for each Climate Zone in [W/(m²•K)]				
Wall (exterior)	Wall (interior)	Wall (soil)	Windows / Doors	Pitched roof
0.24 – 0.35	-	0.24 – 0.35	1.30 - 1.40	0,25 – 0.35
Flat roof	Basement	Floor to unconditioned space	Ceiling to unconditioned space	Other
0.20 – 0.35	0.50	0.50	0.30	-
Minimum requirement for thermal bridging at junctions between envelope elements?		None specified.		

In the USA, there is no general specification for natural or mechanical ventilation as well as for thermal bridges.

Table 4.29: THE USA – Ventilation

Is there a specified minimum rate for naturally ventilated dwellings?		No specifications other than a window or fan in bathrooms and a ventilation system for the kitchen.
Minimum mechanical ventilation requirements?	-	None specified in the energy code, refers to Std. 62.

4.14 Summary

Most countries specify the maximum thermal transmittances regarding a reference building. The estimated energy demand referring to the treated floor area should be lower than a reference value.

The comparison of the average thermal transmittance (mean of the thermal transmittance range) in Figure 3 shows divergences between the participating countries. A tendency can be recognized which indicates the colder the outdoor climate, the stricter the requirements for the building envelope are.

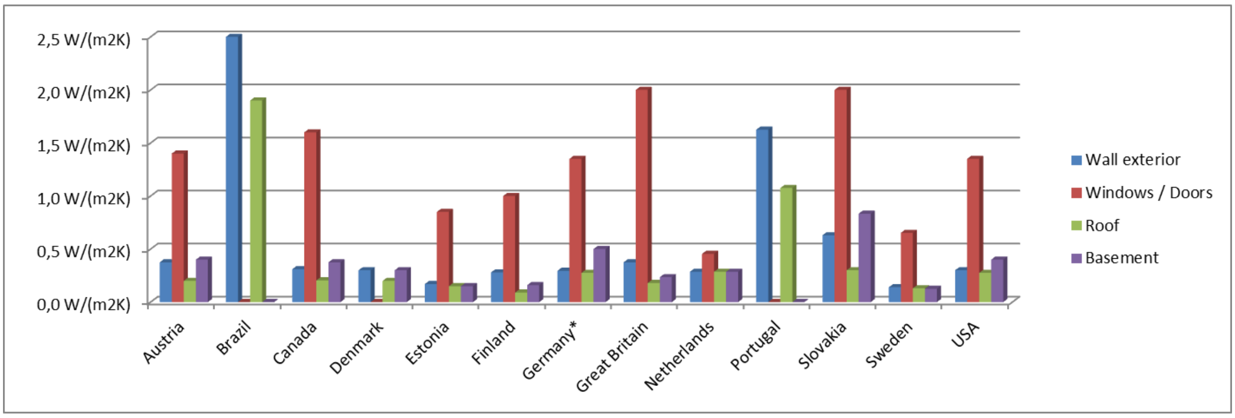


Figure 3: Comparison of Thermal transmittances. Please note, that there are no prescribed maximum values for windows, doors and basements in Brazil and Portugal, and no maximum value for windows in Denmark

The consideration of thermal bridges into the calculation of linear thermal transmittance (Ψ, W/(mK)) is not mandatory in every country. Often recommendations for minimum temperature factor (f_{Rsi}, -) to avoid moisture damages are given.

Almost every country specifies requirements for ventilation airflow. However, they are often given in different units, e.g. air change rate [h^{-1}] or air flow rate [L/h], which makes a general comparison impossible.

5 TESTING AND RETROFITTING

It is crucial, that energy efficiency measures are not only required by code, but also checked, tested and enforced on site. The following chapter describes the measures in place in each country to test implementation quality of different measures.

5.1 How is retrofitting defined?

The execution of energy building performance assessment is enforced in different ways in the participating countries. In some countries an energy assessment needs to be conducted to obtain a building permit. How well this pre-construction energy assessment is implemented in practice is only enforced in few countries.

Table 5.1: Summary retrofitting definition

Country	Comment
Austria	Renovation during which more than 25% of the building envelope will be renovated, unless the total cost of the renovation (building envelope and the building systems) are less than 25% of the building value (without property value).
Brazil	There is no definition
Canada	Changing of existing building for upgrading its energy and/or moisture performance
Denmark	Modernization or rehabilitation of buildings in order to remove damages and/or to increase the living standard. In many cases, the energy retrofitting is the primary objective in Denmark.
Estonia	Renovation is defined as building structure modification and replacement. Major renovation is defined as renovation with a value that exceeds more than one fourth of the renovated building average construction cost.
Finland	Energy regulations are not applied in renovations.
Germany	Modernization or rehabilitation of a building in order to remove damages and/or to increase the living standard. In many cases, the energy retrofitting is the primary objective of retrofitting in Germany. Apart from maintenance, this also might include changing the basic structure of a building (e.g. demolition and rebuilding of whole facades)
The Netherlands	-
Portugal	If the rehabilitation of the building has a cost higher than 160 - 200 €/m^2, the building code must be applied. If the cost of retrofitting is lower than 160 - 200€/m^2, it is only necessary to issue the energy certificate with improvement recommendations.

Slovakia	-
Sweden	-
United Kingdom	Retrofitting is defined as "substituting new or modernized parts or equipment for older ones", "fit in or on an existing structure, such as an older house" or "provide with parts, devices, or equipment not available or in use at the time of the original manufacture"(Collins dictionary); low carbon retrofit is defined as ”incremental improvements to the building fabric and systems with primary intention of improving energy efficiency and reducing carbon emissions.” (Rhoads 2010. Low carbon retrofit toolkit. http://www.betterbuildingspartnership.co.uk/download/bbp_low_carbon_retrofit_toolkit.pdf)
The United States	-

5.2 How is building energy performance assessment enforced?

Building energy performance assessment is enforced in different ways in the participating countries. In some countries an energy assessment needs to be conducted to obtain a building permit. The enforcement of pre-construction energy assessment only implemented in a few countries.

Table 5.2: Summary enforcement conduction

Country	Comment
Austria	A contractor of the building owner is responsible that the building is built as designed
Brazil	The application of regulation for residential buildings is still on a voluntary basis. Inspectors from the Accredited Inspection Organism are engaged from those who wish for the assessment.
Canada	Building permit issued after a certified engineer signs-off code compliance of the design (takes the responsibility of the design)
Denmark	If a building is retrofitted, no official actions will be taken. If a retrofitted building is put on the market for sale, then an examination by an Energy Consultant is mandatory; if the consultant finds that the retrofitting did not adhere to standards at the time of instalment, the building will not be issued a permit for use. If this happens then the current owner and prospective buyer must come to some (financial) agreement that will compensate for the extra expenses that the prospective owners would have to pay.
Estonia	For new buildings and major renovations Energy Performance Certification is needed to obtain building permit. Energy Performance Certification confirms that building meets minimum requirements for energy performance of buildings.

Finland	Building permits must be applied. It must be shown that the building meets the energy regulations. Energy regulations are not applied in renovations.
Germany	For new buildings & renovations cities' administration collects planning & energy performance calculations & Energy Performance Cert. Person who issues the EPC takes responsibility.
The Netherlands	The EPC calculation should be shown in order to obtain a building permit.
Portugal	Before construction: the building design and the first pre-certificate energy declaration must be submitted to the Municipality – ADENE for approval. During construction: Qualified expert may inspect the construction, but it is mandatory in the end. Site manager must control the works during the whole construction. After construction: the final energy certificate must be submitted in the electronic national platform - ADENE. Qualified expert who issues the final energy certificate takes responsibility.
Slovakia	For new buildings, renovation, rent and for sale is necessary to develop energy passport certificate. Person who issues the EPC takes responsibility.
Sweden	House owner is responsible for having an EPC. Accredited and certified person or body is responsible for the quality of EPC. Municipality is responsible for the implementation of EPC laws and regulations.
United Kingdom	• The relevant Building Control Body must issue approval based on submitted evidence before the start of building work on the construction of a new building and after completion of the work. • EPC must be commissioned if a building is sold, rented out, constructed or refurbished. The energy assessor is responsible for recording the EPC in the central online register of EPCs. The accreditation body to which the energy assessor belongs is responsible for investigating any concerns relating to the registration or authenticity of an EPC. Trading standards officers are responsible for enforcing EPC regulations.
The United States	Inspections by code officials.

5.3 Is there particular post-construction testing required as part of compliance with Building Regulations?

Post construction compliance testing ensures that all the requirements stated in the energy certificate are met on site. Most participating countries have no post-construction testing as a general requirement. In some there is an airtightness measurement required, in some others there is testing if a consumer disputes the correct implementation of all required and agreed upon measures.

Table 5.3: Summary post- construction testing required?

Country	Answer	Comment
Austria	No	If public funding is used there might be obligatory test
Brazil	Yes	Yes, there is an inspection.
Canada	No	There might be testing necessary in case of legal proceedings or detailed building analyses.
Denmark	Yes	Yes, an airtightness test according to DS/EN 13829, but only random samples; around 10 %, but this figure varies from municipality to municipality.
Estonia	Yes	Ventilation airflows should be measured.
Finland	Yes	In regulations it is stated that air leakage rate (q50) must be lower than 4 $m^3/h\text{-}m^2$. It is also stated that if airtightness is not measured the value 4 $m^3/h\text{-}m^2$must be used in calculation. Therefore it is not clear if airtightness measurements are obligatory. Tests are anyway coming more and more popular.
Germany	No	There might be testing necessary in case of legal proceedings or detailed building analyses.
The Netherlands	No	
Portugal	No	The qualified expert must observe the dwelling and possibly confirm with the "construction director" in order to emit the final energy certificate confirming that the dwelling complies with the regulation and design.
Slovakia	No	There might be testing necessary in case of legal proceedings or detailed building analyses. Mandatory measurement of illuminance.
Sweden	No	Only measurements of delivered energy
United Kingdom	Yes	
The United States	No	Duct leakage tightness.

5.4 Is it an airtightness test? If yes, what minimum requirement?

During or post-construction airtightness measurements ensure an air tight building envelope, thus reducing infiltration heat losses and comfort effects like draught. Some of the participating countries require an airtightness test, in some more the test is voluntary but positive results can be included in the building energy calculations.

Table 5.4: Summary airtightness test

Country	Answer	Comment
Austria	Yes	The minimum requirement for residential buildings is $n_{50}<3$ ach and if mechanical ventilation is used $n_{50}<1.5$ ach.
Brazil	No	
Canada	No	It is only possible to include the positive effect of a mech. ventilated system if airtightness of building has been confirmed. Values which have to be met are defined in Appendix 4 of EnEV.
Denmark	Yes	BR10 states that the municipality will ask for documentation proving that the new building will leak no more than 1.5 L/(s-m^2) at 50-Pa pressure difference across the building envelope. A blower door test is to be done in accordance with the method described in DS/EN 13829.
Estonia	Yes	Voluntarily, resulting mainly from the requirements of final user
Finland	Yes	Maximum value for airtightness (q50) is 4 m^3/h-m^2. The value 2 m^3/h-m^2 is used in the reference building.
Germany	No	It is only possible to include the positive effect of a mech. ventilated system if airtightness of building has been confirmed. Values which have to be met are defined in Appendix 4 of EnEV.
The Netherlands	No	However, In case a blower door test is performed it should be done according to NEN 2686 (NEN, 1988, Luchtdoorlatendheid van gebouwen – Meetmethode, NEN2686, Nederlands Norm)
Portugal	No	
Slovakia	No	Voluntarily, resulting mainly from the requirements to fulfil criteria of standard passive house
Sweden	No	No, only voluntarily, but the results are not considered in the calculations
United Kingdom	Yes	Minimum requirement: 10 m^3/h-m^2 at 50 Pa
The United States	No	Not for the whole house.

5.5 Is thermography used as part of testing?

Thermography which is a graphical way of showing surface temperatures can point out possible construction errors or problems in the thermal building envelope. Thermography is not mandatory in any of the participating countries, only voluntarily and the results are not considered in the calculations.

5.6 Are there any other testing requirements?

In general, there are no other testing requirements in any of the participating countries.

Table 5.5: Summary thermography

Country	Answer	Comment
Austria	No	
Brazil	No	There is inspection carried out by an accredited organism.
Canada	No	
Denmark	No	No, but testing might be necessary in case of trials or detailed building analyses.
Estonia	No	
Finland	No	
Germany	No	
The Netherlands	No	
Portugal	No	There is no other requirement for residential buildings.
Slovakia	No	
Sweden	No	
United Kingdom	No	Commissioning of building services: fixed building services are tested and adjusted to ensure that they use reasonable fuel and power
The United States	No	

5.7 Is inspection on site undertaken? If so, by whom?

An inspection on site is not required in every participating country. How and by whom the inspection is conducted in particular, is shown in Table 5.6.

Table 5.6: Summary site inspection

Country	Answer	Comment
Austria	Yes	The architect or contractor is responsible. There has to be a final Energy Performance Certificate (EPC) which documents the status of the building
Brazil	Yes	There is no definition
Canada	-	
Denmark	No	
Estonia	No	
Finland		
Germany	Yes	The architect or contractor is responsible. There has to be a final Energy Performance Certificate (EPC) which documents the status of the building
The Netherlands	Yes	The EPC calculation should be shown in order to obtain a building permit.
Portugal	Yes	Before renovation: the building design and the first energy declaration must be submitted to the Municipality – ADENE for approval. During construction: Qualified expert may inspect the construction, but it is mandatory in the end. "Construction director" may inspect the works during all construction. After construction: the final energy certificate must be submitted in the electronic national platform - ADENE. Qualified expert who issues the final energy certificate takes responsibility.
Slovakia	-	-
Sweden	-	-
United Kingdom	Yes	The designer/ person responsible for carrying out works is responsible of the inspection; evidence can be requested by Building Control Bodies.
The United States	Yes	Inspected by code officials.

5.8 Summary

If a building performance assessment regarding energy, comfort and moisture related issues is required for retrofitting cases, this assessment is conducted pre-construction in almost all participating countries. A during and post-construction inspection of the implementation of recommended measures is rarely required. Even if there are ways to check, test and improve implementation and workmanship, there are no mandatory processes to ensure that those crucial examinations are conducted. The fulfilment of all requirements of the certification process is usually not enforced on site.

This results in a huge uncertainty of real implementation of measures and of workmanship. Successful retrofits are put in danger. A risk assessment of possible retrofitting actions is highly influenced by the often unquantifiable executions of planned measures on site.

6 THE RISK AND BENEFITS OF DIFFERENT RETROFITTING METHODS – INTERNATIONAL PERSPECTIVE

6.1 Overview

Especially for private owned residential buildings the needs for retrofitting can be viewed from the following aspects:

- urgent repairs to guarantee safety of buildings (mechanical resistance and stability, safety in use, safety in case of fire);
- improvement of indoor climate (hygiene and health aspects, fulfilment of requirements to ventilation air rates and room temperatures);
- improvement of energy performance of buildings and HVAC systems;
- improvement of architectural planning, visual quality, overall living quality, and additional thermal comfort.

Despite knowing what needs to be done to improve energy efficiency of existing buildings, the necessary changes are generally not being carried out. The reasons for this are varied and can be summarized mainly under the following keywords:

- costs: the private economic profitability of many measures is not given
- user disturbance caused by noise and dirt
- ownership
- gap in knowledge of effects: the savings potential of energy-saving renovation measures in buildings is usually underestimated.
- gap in knowledge of the positive side effects :
- Increase of the thermal comfort in winter but also in summer.
- Contribution to the building fabric maintenance (value preservation).
- Increase of the value of a building and make it more attractive.
- conflict with cultural heritage

The general public opinion is that energy efficient retrofitted buildings will cause damage and an unhygienic indoor air quality

Especially mold and moisture problems are repeatedly linked to retrofitting methods but this is in most of the cases not true. Fact is that the occurrence of damage to residential buildings is reduced by retrofitting. Insulated components are exposed to lower temperature fluctuations, which reduces the hygrothermal load on the building materials. An increase of the inner wall temperature leads to a lower risk of condensation failure which also minimizes the risk of mold growth.

Through professional planning and workmanship as well adapted use, damage can be safely avoided by retrofitting. Nevertheless, in practice again and again damages occur. A breakdown into "planning", "workmanship" and "use" categorized the damage occurring after their origin.

If the owner is willing to retrofit his house he wants to be sure that this measure is durable and without any risk. Due to the different climate zones and the different type of building materials used in every country a general recommendation which is the correct and most risk free method cannot be given. The same is valid for the benefit. In the following chapters different national examples for some retrofitting methods are given. The following table gives an overview of the touched topics.

Table 6.1: Overview the national risk and benefit reports

Country	Ventilation System	Exterior Insulation	Interior Insulation	Cold attics	Cavity Walls	Loft Insulation
Austria						
Brazil						
Canada				X		
Denmark						
Estonia	X	X	X			
Finland				X		
Germany		X	X			
The Netherlands		X				
Portugal		X	X			
Slovakia		X	X			
Sweden		X	X	X		
United Kingdom		X	X		X	X
The United States		X	X			

6.2 Facades

6.2.1 The Netherlands

Roughly half of the Dutch building stock was constructed before 1970 (VROM 2010), resulting in a high potential for energy saving by retrofitting older dwellings. This is shown in Figure 6.1 which indicates the estimated savings in primary energy use when different dwellings types are retrofitted with façade, roof and floor insulation of 2.53 [m^2K/W], installing HR++ glazing and a HR107 combination boiler (data adapted from AgentschapNL 2011). Figure 6.1 shows the high potential for energy savings, especially for the older dwellings built before 1974. The typical exterior wall construction in the Netherlands consists of two layers of masonry between which an insulation layer and air cavity is constructed. A typical method for improving the insulation is not available in a Dutch guideline; the method might therefore consist of either improving the exterior or interior insulation, which is a decision made by the consulting engineer. A rough estimate of the retrofitting rate in the Netherlands can be made based on the average rate in which the 'insulation degree' is improved from 2000 to 2006. The insulation degree is defined as the percentage of the Dutch building residential building stock of which more than 50% of the external surfaces is covered with insulation. The highest increase was visible in the roof insulation degree which increased with 13.3% from 2000 to 2006 (VROM 2006). The lowest increase was visible in facade insulation degree which increased with 4.6% from 2000 to 2006 (VROM 2006). Based on this data, and assumption that the change in insulation degree does represent the retrofitting rate it might be concluded that the retrofitting rate in the Netherlands from 2000 to 2006 was between 0.8% and 2.2%.

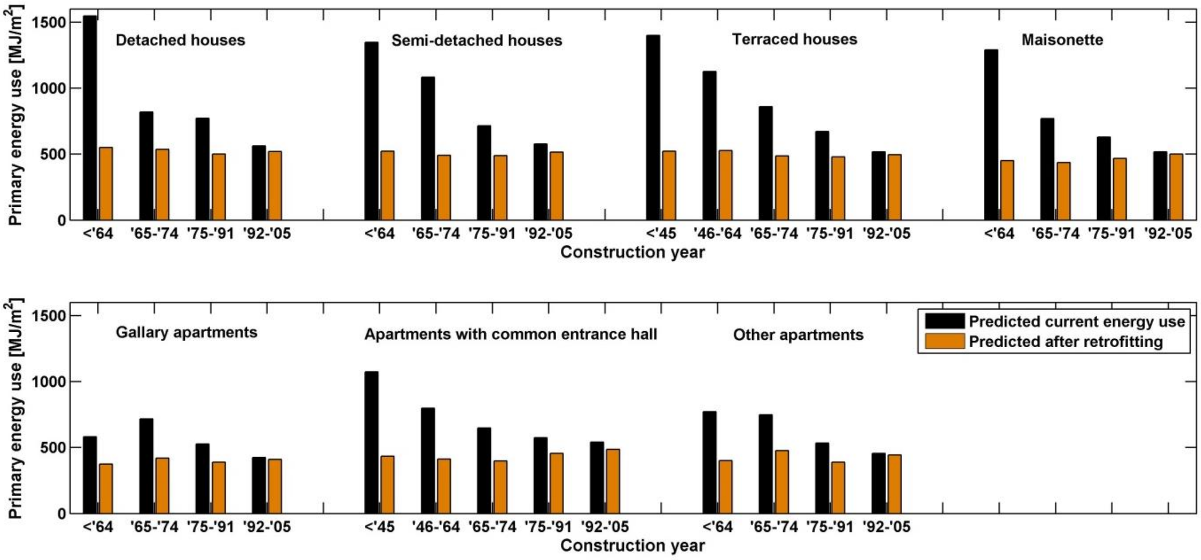


Figure 6.1: Primary energy use of existing and retrofitted dwellings in the Netherlands (adapted from AgentschapNL 2011)

Exterior Insulation

Risks:

- Moisture related risk: -
- Mechanical risk: durability, storm
- Other risks: animals, hail
- Architectural design

Benefits:

- Higher insulation standard
- Less thermal bridges
- No loss of interior living space
- Full use of heat storage capacity of walls

Interior Insulation

Risks:

- Moisture related risk: -
- Complex detailed solution
- Possible enhanced heat flux trough thermal bridges
- Exhaust of harmful substances
- Less benefit of the thermal mass of the construction of the building

Benefits:

- Installation less dependent of outer weather conditions.
- Appearance of the façade not affected.
- Uneven wall surfaces can be adjusted

6.2.2 Estonia

Despite the overall acceptable condition of external surface of external walls, serious problems with joints in facade (lack of wind- and water-tightness) exist. Because of low frost resistance brick and concrete facades and carbonization of concrete facades, it is necessary to repair and/or protect them. Thermal transmittance of buildings built before ~1990 is quite high, especially comparing with future requirements on energy performance of buildings. Serious thermal bridges are a major problem in old concrete and brick apartment buildings, resulting in mold growth, surface condensation, soiling of surfaces, larger energy loss etc. Improving thermal insulation of the building envelope (roof and walls), additional thermal insulation is unavoidable to remove serious thermal bridges. Therefore, additional thermal insulation is needed first of all to protect facades and to liquidate thermal bridges. As additional thermal insulation improves also the energy efficiency, the renovation work is advantageous twice.

Additional insulation is typically applied as exterior insulation system either with ventilated cavity or with external thermal insulation composite system (ETICS). Interior insulation is used sometimes in wooden log walls. In rare cases inhabitants insulate their apartments from inside also in brick or concrete apartment buildings.

Exterior Insulation (ETICS)

Benefits:

- Eliminating of serious thermal bridges;
- Protecting of facades from future degradation (frost resistance, corrosion, carbonization);
- "Business as usual" solution, many companies can do the work with satisfactory quality;
- Higher insulation standard;
- Fresh outlook for the building can increase the prize of the real estate;
- Improvement of thermal comfort;

Risks:

- Water leakages though ETICS system;
- Durability of ETICS system in lower areas of façade;
- Drying out of constructional moisture after insulation's installation;
- Fixing of weighty insulation system (insulation between wooden beams and weighly façade plate) on the façade layer if façade connections are broken;
- Loss of space in balconies;
- Frost resistance of exterior finishing;

Interior Insulation

Benefits:

- Can improve thermal comfort indoors (higher indoor surface temperature);
- Installation can be done independently from other apartments;
- Can be possible solution when building is under heritage protection;
- Faster heating up;

Risks:

- Very risky solutions in cold climate: condensation, mold, (frost);
- reduces the drying potential to indoor
- Need extremely quality workmanship and experience that is difficult or impossible to find;
- Usually insufficient thermal transmittance;
- Intensify of problems with thermal bridges and air leakages;
- Complex and specific detailed solution;
- Loss of living space;

6.2.3 Slovakia

A large part of façades in Slovakia is not thermally insulated. For the former Czecho-Slovakia a mass construction of panel residential buildings is characteristic by various building systems. In 90-ties the complex analysis of the mass construction of prefabricated apartment houses was realized (Sternova 2002), the results gave summarization of their so called system failures (http://www.zpzb.sk/zateplovanie-obnova/systemove-poruchy).

A typical external wall in Slovakia at prefabricated apartment houses consists of the lightweight concrete panels or the sandwich panels with integrated thermal insulation. For single family houses, the external walls composed of burnt clay bricks or lightweight concrete (AAC) blocks are typical.

Besides the system failures the original envelope structures do not fulfil the requirements of contemporary thermal protection standards, the low thermal insulation level, the thermal bridges (corners, joints of external structures and slabs, joints of windows and doors with walls, loggias, etc.). To combine reconstruction activities with additional thermal insulation and new surface finishing – in such a way several problem of durability of constructional joints, airtightness and weather influence protection, condensation and mold growth can be solved. As additional thermal insulation may change the appearance of the building, thus the aspects of the cultural heritage should be carefully handled.

The most common way to retrofit external walls is exterior insulation (ETICS). In a case of historical buildings, only interior insulation can be applied, however this approach is realized very rarely. The thermal insulation is applied mainly for the energy efficiency purpose. The related risks and benefits are summarized below.

Exterior Insulation

Risks:

- Fire
- Moisture related risk: algae, mold
- Mechanical Risk: durability, storm
- Other risks: animals, hail
- Architectural design
- Overheating risk in summer
- Expanded polystyrene is preferred, as less expensive material than mineral wool
- Similarly in a case of large window systems renovation an application of the cheapest PVC frames instead of metallic ones is preferred

Benefits:

- Solution of the “system failures”
- Cheap installation
- Higher insulation standard
- Less thermal bridges
- No loss of interior living space
- Full use of heat storage capacity of walls

Interior Insulation

Risks:

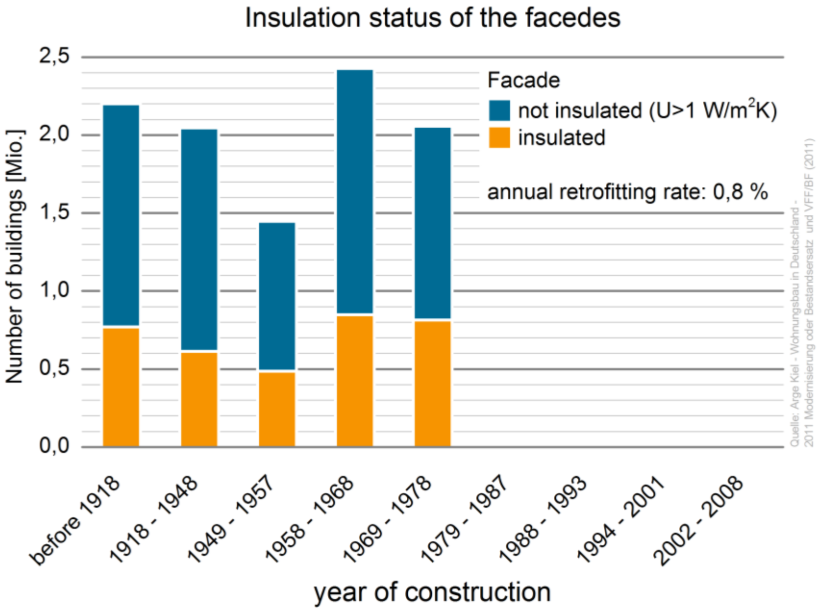
- No regulations in standards, no experience in practice, skepticism
- Moisture damages: mold, frost
- No protection against driving rain
- Insufficient thermal transmittances
- Complex detailed solution
- Fire protection

Benefits:

- In apartment houses it can be applied in particular flats
- Installation independent of outer weather conditions (possible during winter times)
- Appearance of the façade not affected (sometimes the only possible solution when building is under monumental protection)
- Faster heating up
- Uneven wall surfaces can be adjusted

6.2.4 Germany

The majority of building facades in Germany are not insulated according to the state of the art (see Figure 6.2). So there is a huge potential for retrofitting these walls. According to the statistical evaluation a total of 1.8 billion m² of facades need to be retrofitted to meet the current requirements. The typical exterior wall in Germany is brick masonry with layers of plaster on the in and outside. Especially in northern Germany an exterior clinker brick facing is often found.



Quelle: Arge Kiel - Wohnungsbau in Deutschland - 2011 Modernisierung oder Bestandsersatz und VFF/BF (2011)

Figure 6.2: Insulation status of existing facades in Germany

Additional insulation can be applied as exterior insulation system, cavity insulation or interior insulation. The most common way to retrofit walls is with exterior insulation. Due to several reasons (e.g. historical buildings) approximately 1/5th of these facades cannot be retrofitted from the outside. Therefore interior insulation is the only alternative. Both insulation options are mainly used for energy improvement but impose new issues related to the moisture performance of the building. The related risks and benefits are summarized below.

Exterior Insulation

Risks:

- Fire
- Moisture related risk: algae, mold
- Mechanical Risk: durability, storm
- Other risks: animals, hail
- Architectural design

Benefits:

- Cheap installation
- Higher insulation standard
- Less thermal bridges
- No loss of interior living space
- Full use of heat storage capacity of walls

Interior Insulation

Risks:

- Moisture damages: mold, frost
- No protection against driving rain
- Insufficient thermal transmittances
- Complex detailed solution
- Exhaust of harmful substances => indoor air quality (EPS, XPS, PUR)
- Fire protection

Benefits:

- Installation independent of outer weather conditions (possible during winter times)
- Appearance of the façade not affected (sometimes the only possible solution when building is under monumental protection)
- Faster heating up
- Uneven wall surfaces can be adjusted

6.2.5 Portugal

Energy retrofitting by adding thermal insulation to an existing wall

Common design and concerns

The majority of building facades in Portugal were not insulated until 1990 and a lot of buildings need large repairs (see Figure 6.3, Figure 6.4 and Figure 6.5). So there is a huge potential for retrofitting these walls. Nevertheless, the energy spent for heating the dwellings is small because the majority of the population doesn't have a tradition or even enough money to heat the houses continuously during winter. The typical walls in Portugal until 1990 were double wall without insulation.

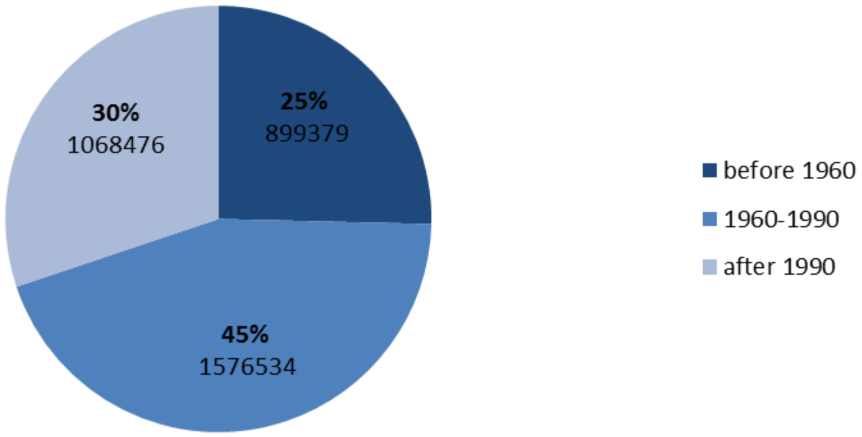


Figure 6.3: Building distribution in Portugal (Percentage and number of buildings)

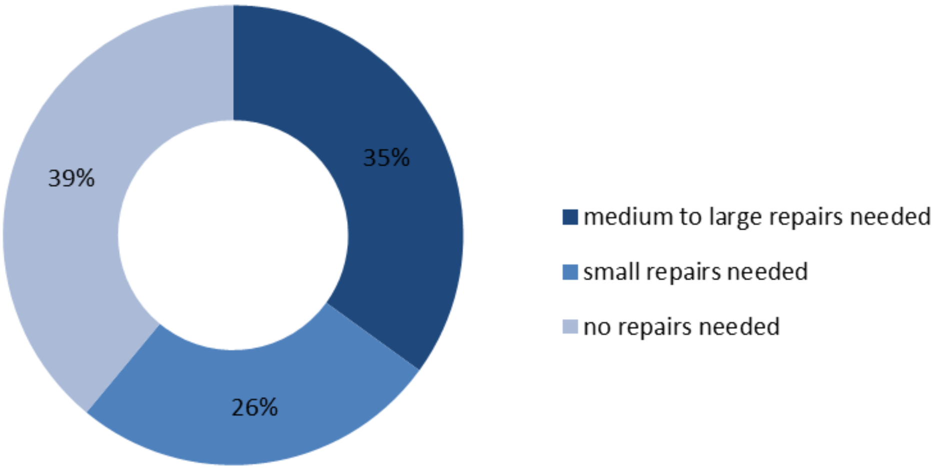


Figure 6.4: Buildings over 50 years in Portugal - 899379(Census 2011, INE)

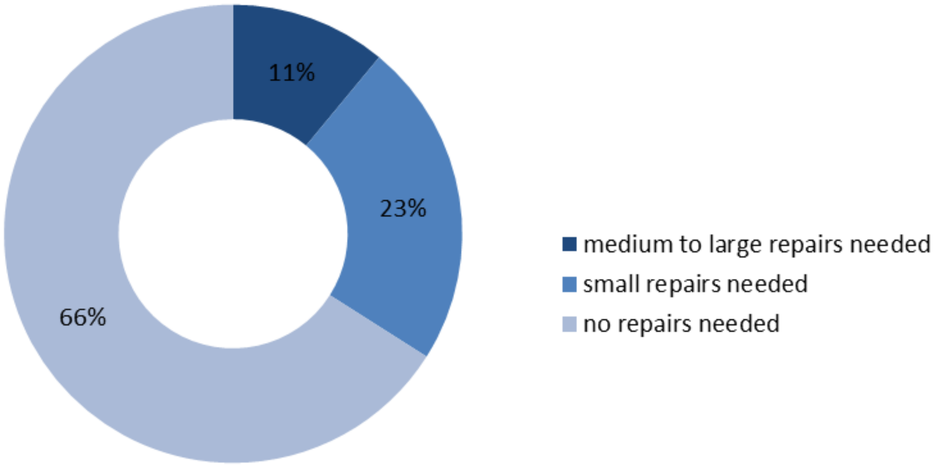


Figure 6.5: Buildings built between 1960 and 1990 in Portugal – 173 750 (Census 2011, INE)

The most common way to retrofit walls is exterior insulation – ETICS (External Thermal Insulation Composite Systems), taking in account the fact that it is the cheapest technique. The related risks and benefits are summarized below.

Exterior Insulation

Risks:

- Fire limitations
- Moisture related risk: algae, mold
- Mechanical Risk: low impact resistance and cracks

Benefits:

- Cheap installation
- Retrofitting with people living inside
- Higher insulation standard
- Less thermal bridges
- No loss of interior living space

Interior Insulation

Risks:

- Moisture damages: mold and condensations
- Joints opening
- Complex detailed solution – Air permeability
- Interior visualization of the metallic structure after some years

Benefits:

- Appearance of the façade not affected (sometimes the only possible solution when building is under monumental protection)
- Uneven wall surfaces can be adjusted

6.2.6 Sweden

Despite the many different ways an external wall can be built there are some common properties in the Swedish building stock. For example almost 70% of the Swedish single-family buildings have wood cladding. For multi-family buildings, bricks and render- each represents approx. 40% of the buildings' exterior surfaces. (Boverket, 2009:1)

The thermal properties are in general fairly consistent for building types and age groups. (See Table 6.2)

Table 6.2: Thermal transmittances for external walls by building type and age. Source: Boverket 2009:1

Year of construction	Single family houses		Block of flats	
	$W/(m^2 \cdot K)$	$W/(m^2 \cdot K)$	$W/(m^2 \cdot K)$	$W/(m^2 \cdot K)$
-60	0.47	± 0.15	0.58	± 0.07
61-75	0.31	± 0.03	0.41	± 0.07
76-85	0.21	± 0.02	0.33	± 0.17
86-95	0.17	± 0.01	0.22	± 0.03
96-05	0.20	± 0.03	0.20	± 0.05
Total	0.36	± 0.08	0.44	± 0.05

Commercial and public buildings		
Offices	0.51	± 0.07
Health care	0.39	± 0.09
Public	0.31	± 0.07
Total	0.43	± 0.06

Wood is commonly used within exterior walls in most types of buildings. Even when load-bearing structures are made out of concrete, non-load-bearing exterior walls (which can make up most of the exterior surface) can often be constructed with wood. From the 1960's and onwards brick- facades have commonly become veneered and load-bearing brick construction has become very rare in new builds.

In 2009 the Swedish National Board of Building, Housing and Planning (Boverket) presented the initial report from a national study of the technical characteristics of the Swedish building stock, BETSI. It is based on the inspection of 1800 buildings. For further information a subset of the report is available in English at:

http://www.boverket.se/Global/Om_Boverket/Dokument/about_boverket/betsi_study/building_stock.pdf

Concerns

The Swedish planning and building act demands that changes made on any building should be made gently and consider the character of the building as well as aspects of construction techniques, history, cultural history, environment and artistic values (Sverige 2009). These regulations and demands on preservation can make interior insulation the only viable option.

Adding interior insulation is not an optimal solution in cold climate since the existing structure becomes colder and wetter (Statens råd för byggnadsforskning 1988). Since wood is commonly used in many wall types, even modest layers of interior insulation might cause problems or aggravate existing ones. It is also for this reason important to reduce moisture transport due to convection and diffusion.

In cold climate the stack effect becomes accentuated and to avoid moisture problems airtightness must be good. In a retrofit this can be difficult to achieve due to, for example, uneven or rough surfaces. If exterior insulations have been chosen to avoid having to relocate tenants, it might be difficult to get access to the interior layers of the wall.

Brick veneer has been considered low-maintenance, and if a wall has no apparent spalling or deterioration, choosing interior insulation might seem cost-efficient. Over time, however, cracks form between bricks and mortar allowing for increased rain penetration. Some buildings have had problems with excess mortar spanning the airspace and wicking moisture into the structure in addition to reducing air movement in the air-gap. Additionally, brick veneer walls where the brick ties have corroded, have had large parts of multi-story walls come crashing down. (Werner and Sveriges byggindustrier. FoU-syd 2006).

Moisture damage in exterior walls was shown to be most frequent in joints by for example Karpe (1990). This applies to wall modules but also detailing around windows etc. where rain can penetrate into the structure, as well as airtightness discussed above. As a general principle is should always be possible for water to drain or at least dry out.

A specific problem is the placement of wet rooms by an exterior wall. Care must be taken when choosing moisture barriers so that moisture isn’t trapped in layers of the wall over time - more specifically between the barrier of the exterior wall and the moisture barrier of the wet room. (Jansson 2006)

A further general concern in planning renovation projects is the lack of documentation of buildings. During a national study of 1800 buildings presented in 2009 (Boverket 2009:1 & 2) it was found that 30% of the drawings were missing or of poor quality. Of the technical descriptions almost 60% were missing and another 20% were only “fairly good”.

Risk handling

As exterior walls are very diverse in both construction and state only general advice is given:

- Examine and understand the construction at hand – there are enormous amounts of variations and also changes that have been made over time.
- Examine the actual state of materials in the structure.

- Ventilated structures should *be* ventilated if designed as such.
- Good detailing in necessary and must be planned, especially where components meet.
- Make planned trial-runs to test viability of solutions.

Example: Exterior wall with vacuum insulation panels

Future retrofitting measures need to be more adjusted to the special features of each building than what they were before. Vacuum insulation panels (VIP) is a novel thermal insulation component that adds much insulation in a limited thickness. The center-of-panel thermal conductivity of a VIP is around 4 mW/(m·K). However, with regard to the thermal conductivity of the film around the VIP and connections between panels, a recommended design value of 8 mW/(m·K) should be used (Simmler et al., 2005). The panels are fragile and the thermal conductivity of a perforated panel is 20 mW/(m·K) which is still lower than e.g. mineral wool with a thermal conductivity of around 40 mW/(m·K).

VIP has been used both in new constructions and in retrofitting applications. A detailed technical drawing of where each VIP should be installed in the construction is needed before construction can start since the panels cannot be adjusted on the construction site. VIP is interesting to use in floors where the requirements on the thermal resistance are high, alternatively where the construction thickness is limited. In floors where floor heating is used, VIP could be used to increase the efficiency of the floor heating system. VIP could also be used in doors to decrease the heat losses with up to 50%. In dormer windows, the VIP could be used to make the construction thinner (Johansson, 2012b).

One of the major possible constructions where VIP could be used is in exterior walls. Glazed façades can be made thinner while maintaining the thermal resistance. VIP could be used in new buildings, both in light-weight timber frame walls and in heavy concrete walls. In old buildings VIP could be used on the exterior or interior of the existing wall. So far, the most common wall application with VIP is on the exterior of the existing wall. It is also possible to integrate the VIP in a structural sandwich panel, e.g. made of concrete, to increase the protection of the VIP (Johansson, 2012b).

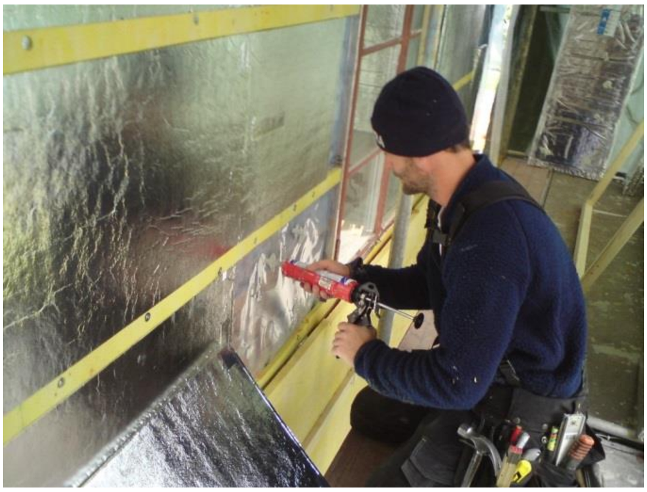


Figure 6.6: Retrofitted wall with 20 mm VIP covered by 30 mm glass wool boards. Between the VIP are 20x50 mm strips of high density glass wool attached to allow attachment of the wooden cover boarding. Photo: Pär Johansson.

Benefits

The heat losses through the building envelope can be substantially reduced by using VIP while maintaining the original features of the building. A gable wall of an old building in Nuremberg was retrofitted using VIP in 2000. The system for attaching the 15 mm VIP to the façade was based on a plastic rail system which was covered on the exterior with a 35 mm thick layer of EPS. The Thermal transmittance of the wall was improved from 0.70 to 0.19 W/(m^2K) which would increase to 0.32 W/(m^2K) if the panels were punctured (Binz et al., 2005). In a case study by Johansson (2012a) VIP was installed on the exterior of a wall in a three story 1930s multi-family building in Gothenburg, Sweden. The ground floor wall was built using 1.5 stone brick masonry and the two upper floors had walls of 80 mm standing wooden planks. A layer of 20 mm VIP and 30 mm mineral wool was installed on the exterior of the structural wall. Between the VIP, stripes of 50 mm wide glass wool boards were fitted to allow the exterior wooden cover boarding to be attached. The Thermal transmittances before retrofitting was 1.10 W/(m^2K) and the final Thermal transmittance was 0.40 W/(m^2K), 0.23 W/(m^2K) without considering the thermal bridges. The Thermal transmittance of the wall increased to 0.54 W/(m^2K) if the panels were punctured (Johansson, 2012a).

Risks

The vapor permeability of the panels is virtually zero since the film around the VIP has low gas permeability. This may cause problems around the panels if the connection between them is insufficiently sealed and allows for air and vapor transport through the VIP layer. In some cases sealing tape has been used to increase the airtightness of the connections. Another option is to use an additional layer of vapor retarder to ensure a vapor tight layer. It might also be worth to investigate if a dynamic vapor barrier could be used, i.e. a material that let the vapor through when it is in moist environment and stop the vapor when it is dry. Especially this solution could be worthwhile if there is a risk of condensation in the construction.

If a VIP is damaged in the construction, the heat flow through the construction will increase. In the design process this have to be treated and if it has an unacceptable consequence for the energy use for heating of the building, the construction should be prepared for easy exchange of the damaged panel. In that case the construction has to be flexible and designed in a way that the VIP is easily accessible and possible to remove. It should also be possible to detect the damaged VIP with e.g.

infrared thermography, which means that the VIP should not be covered on both sides with high conductive materials or be placed behind a ventilated air space (Binz et al., 2005).

The moisture and heat flow through the construction where the VIP is integrated will change substantially. The risk of damages to the construction in case of a punctured VIP has to be investigated with hygrothermal simulations. In Johansson (2012a), a theoretical study of a wall retrofitted with VIP was performed. The study showed that the risk for moisture damages was decreased when VIP was added to the exterior of an old exterior wall. If the VIP was punctured, only a small change in the moisture performance of the wall could be found.

A way to avoid unnecessary risks on the construction site is to integrate the VIP in prefabricated constructions. Industrial treatment of the VIP means they will be in a controlled environment where the staff involved in the handling of the panels can gain experience and be trained to treat the VIP with care. Also the surroundings of the site of assembly can be equipped with the right protective equipment such as protective mats and felt shoes (Binz et al., 2005).

All attachments and joint details need to be carefully designed since brackets, window attachments and such components may harm the envelope of the VIP. A good design can ensure this which means the designers and builders have to be aware of the special requirements of the VIP early in the design process. If the design and construction are performed following the recommendations from producers VIP can be feasible and an important mean for building energy efficient buildings (Binz et al., 2005).

Risk mitigation

The following factors mitigate the risk:

- Careful design and construction of attachment details
- Careful handling of the VIP on the construction site
- Vapor tight connections between the VIP
- Smooth surfaces around the VIP
- Inspection of the pressure in the VIP before covering them
- Integrating the VIP in e.g. boards of EPS
- Lower moisture supply in the indoor air
- Avoiding building damp
- Make it possible to exchange the VIP after their service life has expired

6.2.7 The United States

In the recent past a number of spray foam applications were intended to simply replace past proven insulation systems such as fiberglass in stud cavities. The motivation for this retrofit was to improve airtightness and R-value performance of the stud cavity. Documented moisture induced problems were reported, some still in litigation. A retrofit/new insulation study was undertaken by Dr, Yuan and Karagiozis by the Oak Ridge National Laboratory in 2008-2010 to develop some guidance. The walls were instrumented with temperature, relative humidity and condensation sensors in Puyallup WA (close to Seattle WA). Field results clearly demonstrated that excessive moisture accumulation was building up in walls with stud cavities filled with 5.5 inches of open cell polyurethane insulation or a hybrid insulation systems deploying at least 2.5 inches of closed cell polyurethane foam and 3 inches of fiberglass insulation.

Moisture accumulation exceeded 20 % by mass in the wood sheathing for many months during the year. It is important to recognize that for installing higher R-value insulation systems (Closed Cell) one needs to develop designs that work with the particular insulation system. This applies especially to all retrofits walls especially in humid cool climates.

Exterior Insulation

Risks:

- Fire Related Concerns. When close proximity to neighboring lots. Risk still is minimal at best.
- Adding insulation reduces the drying potential of the wall.
- Adding exterior insulation with an EIFS cladding can increase the risks for moisture induced algae growth and mold. This is very prevalent in hot and humid climate zones as found in the southeast and humid northwest of the USA.
- Proper design with other parts of the wall. All air barriers, drainage planes and water barriers need to be designed with the specific type of exterior insulation.
- The exterior insulation can provide a number of additional wall functions if taped or sealed.
- Installation is more expensive but could be less disruptive during retrofit with inhabited building.
- Application of exterior insulation may be prohibited if heritage building.

Benefits:

- Better thermal performance and substantial reduction in thermal bridges
- Thermal mass structures can enhance the thermal design.

Internal Insulation

Risks:

- Adding insulation reduces the drying potential of the wall.
- Cladding prone damages in cold climates with spalling and ice crystal formations.
- Requires interior space.
- Again needs a detail hygrothermal analysis for each design.
- Cheaper to install but may require inhabitant to be evacuated during the retrofit process.
- Reduces the impact of thermal mass.

Benefits:

- Installation independent of outer weather conditions (possible during winter times)
- Faster heating up

6.2.8 United Kingdom

Cavity wall constructions

Cavity wall insulation, one of the most common wall insulation systems in the UK, can be installed in most buildings built from 1919 onwards. Cavity wall constructions in the UK account for 69 % of building stock (around 15.4millions buildings) (English Housing Survey, DCLG, 2011). More than half of those buildings (11.2 millions) have been already insulated thanks to subsidies (e.g. “decent homes” or “WarmFront” programs) and to energy obligation schemes such as CERT (carbon emission reduction target). However, concerns have arisen regarding the quality of installation under private schemes or the Government’s CERT scheme. Occupants seems to believe ‘installers and energy suppliers have an incentive to get a certain number of measures installed to meet their targets, rather than necessarily to install insulation to meet individual consumers’ needs“(Office of Fair Trading, 2012).

Risks:

- Reduction of thermal performance due to inhomogeneous fill and bad workmanship in general (from holes around wall ties and details to lack of CWI in entire walls)
- Water penetration through insulation material due to inhomogeneous fill and inappropriate material used as filler (e.g. mineral wool for exposed areas)

Benefits:

- Ease of application
- Low cost
- No loss of interior living space
- No an intrusive solution (occupants can continue with their activities)…

Solid wall constructions

On the other hand, 31% of the remaining UK building stock were built using solid walls systems; most buildings built before 1919 (21.6%) (DCLG 2011) and others built in recent years (10%) (reference). To date, only 2% of solid wall constructions have been insulated (112,000 installations). Usually, solid brick walls are unrendered, leaving the brick exposed. Solid wall buildings can be thermally improved by the use of external (EWI) or internal wall insulation (IWI); however, in the case of conservation areas, listed buildings, decorative façades, or traditional buildings, planning permission for external wall insulation is often denied.

Risks for external insulation:

- Water penetration in details that are hard to insulate
- Thermal bridges in details that are hard to insulate
- High installation cost

Benefits for external insulation:

- Low thermal transmittance
- Less thermal bridges than IWI
- No loss of interior living space
- Protection from wind driven rain

Due to several reasons (e.g. historical buildings) a lot of the facades in the UK cannot be retrofitted from the outside. Therefore interior insulation is the only alternative.

Risk for internal insulation:

- No protection against wind driven rain
- Moisture accumulation due to wind driven rain, construction moisture and moisture leaks (due to air gaps/bad workmanship)
- Mold growth risk
- Wood joists and lintels decay
- Freeze-thaw damage due to lower wall temperature.
- High thermal transmittances (for reasonable thicknesses)
- Loss of living space
- Higher thermal bridges than EWI
- Indoor overheating if the room is heavily occupied especially during daytime (due to low thermal mass of most IWI materials)
- Exhaust of harmful substances => indoor air quality (EPS, XPS, PUR)

Benefits for internal insulation:

- Appearance of the façade not affected
- Lower installation cost than EWI
- Faster heating up of the room

6.3 Attics Insulation and Crawl Space

6.3.1 Sweden

Most buildings in Sweden have a pitched roof, giving protection from precipitation, a thermally insulated ceiling floor and an outdoor ventilated attic. Originally the attic was ventilated in order to avoid thawing of snow and ice damming. The most common load baring roof construction is made of wood. The roof, starting from the inside, is typically constructed with wooden T&G board (15-25 mm), base board, batten and counter batten and roof tiles. Metal, shingle and other surface protection materials are also common.

Today, houses are frequently retrofitted with additional attic insulation, which leads to a colder attic space. Furthermore, furnace heating is often replaced in favor of heat pumps or district heat. This may alter the air-pressure balance of the house, resulting in an increased thermal pressure on the ceiling with subsequent air-leakage up to the attic. Typical leakage areas of the attic floor (100 m^2) are in the order of 2x2 cm to 10x10 cm. Both air-tighter ceilings in newly built and more leaky buildings of course exists. For well insulated attics the hygrothermal climate is rather close to the exterior one i.e. the relative humidity will be quite high during the cold part of the year. This gives favorable conditions for biological growth on the roof underlay, especially during the spring and autumn.

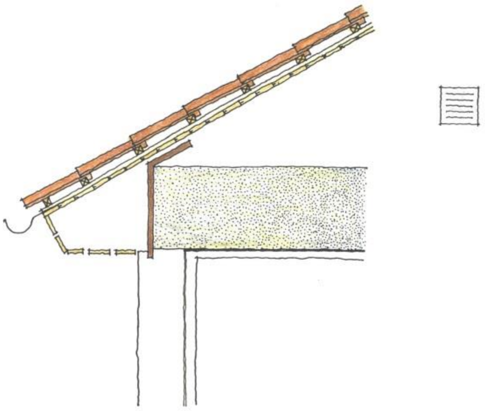


Figure 6.7: Traditional design of a cold attic roof. Both the eaves and the gables have openings for natural ventilation

Benefits

Adding insulation on the attic floor is a quite fast, convenient and inexpensive measure. The reduction of heat loss through the attic floor can be quite substantial. In Sweden, a total insulation thickness can reach 0.7 m but 0.4-0.5 m is quite common as an energy retrofitting action. This also means that the heat loss might be reduced by a factor of two to three.

For a 100 m^2 attic floor in the Stockholm region the reduction in heat loss during a heating season might go from 2700 kWh for an old building with a insulation thickness of 0.15 m to 800 kWh for a one using 0.5 m.

Risks

Problems with high humidity levels in cold attics have been remarkably increasing in Sweden over the last decade. The high humidity levels are to a large extent a consequence of the increasing demand on energy efficiency. Undoubtedly – the significant mold growth on the wooden parts of cold attics, which is recently confirmed in about 60-80 % single-family houses in Västra Götaland region (largely, the Gothenburg region; Ahrnens C & Borglund E, 2007).

Mold odors in indoor air seem to be one of the most frequent side effects ("Så mår våra hus", the National Housing Board - Boverket, 2009). Thus, cold attics are singled out as one of the worst constructions in existing buildings with large existing and future mold problems. In the Swedish building stock 88 % of the buildings have a roof construction with a cold attic and mold is visible in about 15 % of them. These numbers are based on in-situ inspections performed in a recent national investigation (Åberg, 2011).

Leaks of indoor air up to the attic through the attic floor, and the under cooling of the roof due to sky radiation, increase the problem (Holm and Lengsfeld 2006, Sanders *et al.*, 2006; Essah *et al.*, 2009). The moist air might condensate at the underlay and small droplets of liquid water can build up. The water will then be absorbed and accumulated in the surface area. High moisture content can even lead to rot.

Another important moisture source influencing the attic hygrothermal condition is the water vapor in the surrounding air. The advice given to the building sector in Sweden today is to have a not too high or not too low ventilation rate, by outdoor air, of the attic. A too high ventilation rate, in combination with under cooling, results in high relative humidity (Samuelsson, 1995; Larsson, 1996; Sasic, 2004). Too low ventilation is also risky in case of construction damp or leaky attic floor (Arfvidsson and Harderup, 2005). The optimal air exchange rate varies with the outdoor climate, and fixed ventilation through open eaves and/or gable and ridge vents are not always the best choice (Hagentoft *et al.*, 2008, 2010). Besides, the last 15-20 years have been mild and wet in Sweden compared to the previous period (Alexandersson, 2006). Precipitation and temperature increased considerably during the period (+11 % and +0.7 ^{o}C respectively) and, thus, the drying potential of outdoor air decreased. The direction in which the most recent decade deviated from earlier observations is to a large degree consistent with what is suggested for the future climate scenarios (Persson *et al.*, 2007). We can expect more and more problems in cold attics, along with demands for increased energy efficiency and future climate change (Nik, 2010).

Risk mitigation

The following factors mitigate the risk:

- Air tight attic floor
- Exhaust ventilation system in the area below the attic
- Lower moisture supply in the indoor air
- Less amount of insulation on the attic floor
- Heating of the attic space
- Adaptive/controlled ventilation of the attic space
- Avoiding building damp

There are some suggested other action under investigation in Sweden, however not yet validated:

- Reduced area of the ventilation openings of the attic
- Diffusion open membrane in the roof underlay
- Thermal insulation of the roof structure
- Moisture buffering material and insulation inside the attic

Crawl-space foundation - Swedish experience

Background

A crawl-space is a foundation with low foundation walls or beams and plinths below the rest of the building. With this type of foundation we have one or a few cavities below the rest of the building. The crawl-space can be designed with outdoor or indoor ventilation or in rare occasions without any ventilation at all. In most Swedish buildings the crawl-space is ventilated by outdoor air through a number of evenly distributed air holes through the foundation walls. This design have been used for hundreds of years in Sweden and where in its early form called “croft foundation”. However, the modern version of the crawl-space differs from the old one in many ways. The thermal insulation in the floor structure is much thicker and we have no heat source in the foundation from a warm chimney. In spite of the chances the old buildings where not without problem. The thermal comfort was very poor and they often suffer from musty odours from organic material in the foundation that where leaking up to the living space.

Modern outdoor ventilated crawl-space foundations are often subjected to moisture and mold problems, especially the ones with a floor structure made of wood. The risk for damages and nuisance can be decreased if the surface of the soil in the foundation is thoroughly cleaned and completely covered with plastic foil of good quality and with sufficient overlap in the junctions. By putting thermal insulation on top of the soil and on the outside of the foundation walls the risk for moisture damages can be further reduced. In spite of all these measures the moisture conditions in the foundation is sometimes too high, especially in the summer. Therefore, the traditional outdoor ventilated crawl-space foundation has to be considered as a risk construction concerning mold and odours, especially if the floor structure is made of wood. The main reasons for the problem in the crawl-space are the temperature- and moisture conditions during the warm period of the year which are favorable for mold growth. Furthermore, the air pressure distribution in the building will normally give transport of air, odours and even mold spores from the foundation to the living space. In areas with radon in the soil the air can also transport radon from the foundation to the living space. The fundamental problem with the outdoor ventilated crawl-space is the high thermal capacity of the soil. With a high thermal capacity the crawl-space will “remember” the outdoor temperature from last winter. This will result in a lower temperature in the crawl-space than outdoors during spring and early summer. When outdoor air enters the crawl-space in spring and early summer it is cooled and the relative humidity increases –often up to 80-100%. During winter the conditions are reversed. General measures to decrease the relative humidity in outdoor ventilated crawl-space foundations are to decrease the vapor concentration or increase the temperature.

Measures to decrease the vapor concentration in the foundation

The traditional measure to decrease the vapor concentration in the crawl-space is to stop the moisture supply from the soil by placing a vapor barrier on top of the soil and preferably also on the foundation walls to prevent evaporation. This measure has been commonly used in Sweden for many years. Calculations with the PC-program Crawl (Hagentoft & Blomberg, 2003) show, that these measures are not enough to give acceptable moisture levels in the foundation.

As for all types of foundation it is also recommended with inclination of site from the building and a drainage system in the soil to prevent surface water and ground water in the foundation.

With a dehumidifier in the crawl-space the relative humidity can be kept in a low level to prevent mold growth. Since the dehumidifier is controlled by a hygrostat the RH-level can always be kept on an acceptable level. To accomplish under pressure in the foundation compared to the living space dehumidifiers with mechanical exhaust air fan is used. The drawback with this method is a continuous working expense. Furthermore, efforts and solutions for surveillance, operation and maintenance and a wise placing of the exhaust air have to be considered. It is also essential that the foundation is air tightened from the outdoor air and to keep the moisture load on a low level. The negative pressure prevents polluted air and radon from leaking into the living space. The operating time for the dehumidifier can probably be reduced if this measure is combined with plastic foil and thermal insulation on the both the ground and on the foundation walls.

6.3.2 Canada

Common design and concerns

Sloped roof assembly is typical in Canadian house construction. The attic space is usually filled with fiberglass batt insulation or blown-in fiberglass or cellulose insulation. As can be shown in Figure 6.8 below, the level of attic insulation in Canadian houses is steadily increasing from 2.5 RSI in 1940's to the current minimum code requirement of 6.91 RSI.

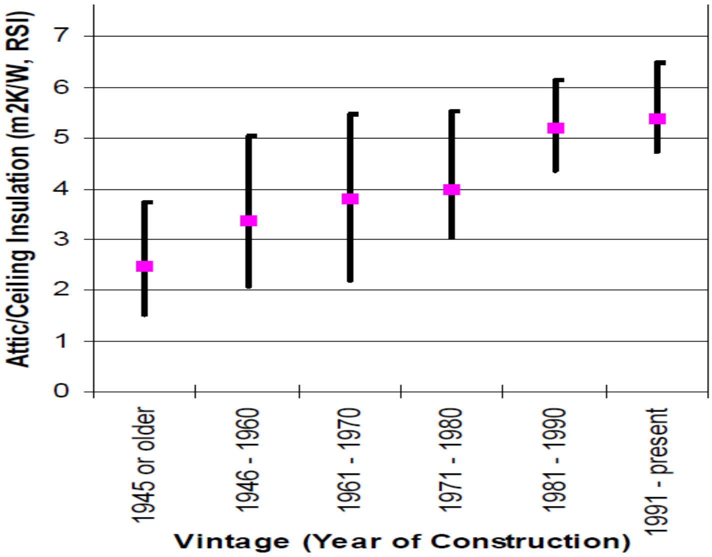


Figure 6.8: CANADA - Attic insulation level in Canadian houses (Anil Perkin, NRCan, 2007)

As the government of Canada's ecoENERGY Retrofit program data shows (Figure 6.9), the number of houses that have been retrofitted in recent years to a minimum attic insulation level of RSI of 7.0 are increasing year by year. The trend is expected to continue as 85% of the Canadian housing stock is at least 15 years old, and need to implement energy efficiency measures.

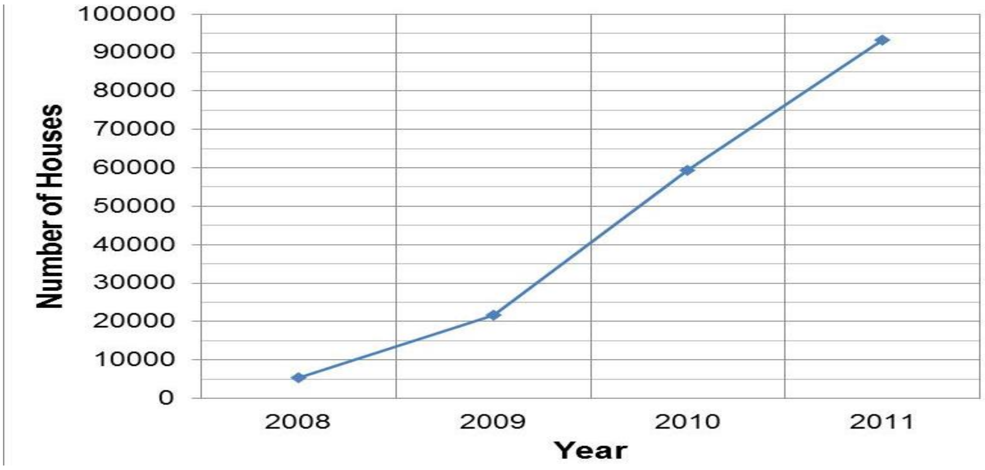


Figure 6.9: CANADA -Number of houses that have increased attic insulation to a min. value of RSI 7.0.

The risk and benefits of increasing attic insulation are summarized below:

Risks:

- Cold sheathing board and roof frame
- Moisture damage (mold & rot) on the sheathing & framing if moisture leaks through the ceiling to the attic
- Possible condensation of outdoor air on the underside of the sheathing board and on the exterior surface of the roof as a result of night-time cooling (long-wave radiation exchange with the sky)
- Algae growth on the exterior surface of the roof
- Require detailed airtight design and workmanship at the ceiling level and openings around pipes and service lines
- Require detailed attic ventilation design and workmanship (*e.g.* location and size of ventilation grilles at the soffit and roof vents, supplemental mechanical ventilation system required?)
- May need to increase ventilation (over ventilate) to control indoor moisture load

Benefits:

- No need to install new frame and application of insulation in the attic space is relatively easy
- Different kinds of insulation types and thickness can be used
- Relatively low disturbance to occupants during the retrofit process
- Heat loss reduction - Energy and cost saving
- Increase occupants' thermal comfort

6.3.3 Finland

A ventilated wooden ceiling is one of the most common ceiling types in Finland. This structure is used in one-family houses as well as in apartment buildings. It has been estimated that heat losses through the ceiling cover 5 % of the total heat loss in an apartment building (Figure 6.10), 9 % in a commercial multistory building and 13 % in a single-family house. Adding insulation in a ventilated cold attic is cost-effective and easy because of the extra room. There is a large energy saving potential and this is why it is one of the most common ways to improve the energy consumption of a building with such a roof structure.

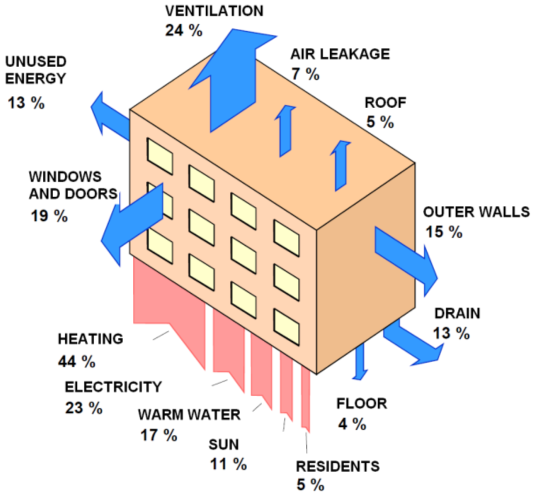


Figure 6.10: Distribution of heat losses in apartment buildings.

Figure 6.11: Ventilated cold attic with added insulation.

Risks:

- There isn't enough room for extra insulation
- Ventilation in the attic is reduced
- Vapour barrier is damaged during installation
- Airtightness of the ceiling is poor

  → Excess moisture in ventilated attic

  → Risk of condensed moisture and mold growth

- Temperature in the attic gets lower due to reduction of heat losses

  → Conditions become more favorable to moisture condensation and mold growth

Benefits:

- Easy to install (no structural alterations needed) → low investment costs
- Reduces energy consumption
- Improves indoor air quality and living environment
- Does not change externally the house

6.4 Windows

6.4.1 Sweden

Glazed windows date back to the Roman times. Around 100CE they began to appear in Alexandria, and gradually spread over the Empire. Hence, they have a long history and good practice has been established. Nevertheless, failures still occur. They are partly due to poor understanding of the physical phenomena by some craftsman, and partly to the unexpected results of applying newer technology. Certain design changes, aiming at achieving improvement in one performance aspect, can have unexpected and not studied negative effects on windows. This is usually the case when the system approach to the design change was not adopted. A certain design change, truly beneficial for one performance aspect, can have strongly negative effect to other systems. For example in eighties to improve the energy efficiency of buildings the design promoted small area of windows sometimes not adequate to deep spaces.

Window is the part of the façade which is a component of the building/environment system. The main function of the system is to ensure comfort and health of inhabitants. Because the system failure leads to the functional failure, they can be analyzed from the user perspective.

Windows face the demands concerning

- Provision of:
    - sufficient access of natural light,
    - attractive aesthetics,
    - linking to outdoors,
    - security,
    - energy, when glass is used as an energy system (collecting and producing).
- Protection against the impact from environment through:
    - thermal insulation,
    - sound insulation,
    - durability – keeping form, strength and functions through varying interior-exterior climate conditions during specified time,
    - protection against wind and rain,
    - protection against pollutants.

The problems encountered with windows depend on their construction (product level), its interaction with the façade (component level) and the whole building and its nearest environment (whole system level).

Five kinds of failures can be listed:

1. Design failures (for the new and retrofitted objects)
2. Durability failures
3. Manufacturing failures (defects)
4. Installation failures
5. System failures resulting from application of a window in a specific building/environment system

In table below some failures are listed, together with the explanation of their roots and suggested remedies. They refer to the presented classification of failures. Most of the problems encountered today with windows are related to the destructive action of moisture. Those are reviewed at the SP website given in references. The examples given in table are based also on other literature (Andersson *et al.,* 1982; Berge, 2009; Richardson, 2001).

The table contains the qualitative description of the problems and their consequences. The quantitative evaluation for the specific case can be carried out using calculation models. For example for the problem of condensation on interior surface of glass pane of low insulated window or condensation on exterior of glass pane of well insulated window (3- glass with low thermal transmittance) deterministic models given in literature (Hagentoft , 2001; Jonsson, 1999) can be used. However to evaluate the risk of condensation in terms of probability, the stochastic character of climatic conditions and probabilistic risk assessment model could be applied (Pietrzyk *et al*., 2004). The chosen construction solution is then evaluated in the context of random environmental load relevant to the building location. Greatly facilitated distribution of products across different climatic zones can sometimes lead to system failure. Those can occur, when products developed and applied in one climatic condition are being used in a radically different climate zone.

Table 6.3: Windows – failures - causes, consequences, how to minimize the risk of failure

System level failure kind	Product -Construction details (contributing to failure)	Mechanism of failure	Physical description of failure	Functional description of failure	Mitigation of risk of failure (by improved construction)
Window (3)	Glazing that has not been cut strictly square and has snags, with metal frames	Thermal movement for an aluminum frame is much higher than for glass causing excessive stress through the frame in cold weather	Glass fracture	Decreased thermal Decreased security Decreased aesthetics Decreased access of day lighting	Quality control of glazing
(2)	Steel frames Wood frames with steel sprigs	Rusting of steel frames can result in local stresses Rusting of the steel fixing sprigs used to retain the glass while the putty bedding is applied causes local stresses	Glass fracture	Decreased thermal Decreased security Decreased aesthetics Decreased access of day lighting	Use galvanized steel
(1)	Secondary double glazing by additional frame attached to the inner side of an existing single-glazed window frame Other weaknesses of a design	Reduces the temperature of the inner surface of the original single glazing while normal room air is closed in a gap between glazing that leads to condensation (inside a window) Allowing warm moist air to leak to the inter pane space	Water drops on the inner glazing	Decreased aesthetics Decreased access of day light	Efficiently sealing both the original and the secondary glazing and providing a moisture absorbent within the air gap
(2)	Glazing compounds	Poor adhesion between putty and glass	Not tight, possible moisture intrusion	Decreased thermal and acoustical comfort	Using non-setting mastic
(2)	Wood frame	Weathering, deteriorating Interstitial condensation	Fungal decay on the frame Physical damage	Decreased aesthetics	Preservation treatment Wood coatings, using impermeable vapor barrier paint on the interior surface and permeable paint on the exterior surfaces
	Wood frame	Weathering, deteriorating	Physical damage	Decreased aesthetics	Maintenance needed Frequent painting
(1)	Wood frame	Internal condensation caused by	Water drops on the	Decreased aesthetics	Improving thermal

		surface temperature decreasing below dew point	internal glazing Fungal decay	Decreased view	insulation of window
(2)	Steel frame	Water penetration causing corrosion	Rust on the frame	Decreased aesthetics	Using appropriate coatings, galvanizing
(2)	Aluminum frame	Oxide formation dulls the polished surface	Changes in appearance Cracks	Decreased aesthetics	The coating systems
(1)	PVC frame	Too low strength		Decreased thermal comfort	Stiffening with steel reinforcement
Façade (3)	Façade that contains unreacted lime	Water saturated with lime runs down	Etching of glass by lime	Decreased view and aesthetics	Quality control
(3,1)	Built in moisture, cracks in the façade, material properties	High moisture content of the façade	Fungal decay of wood frame	Decreased aesthetics	Quality control of material Façade-window system interaction
Building/ Environment (5)	Exposure of a window to sun radiation	Electromagnetic waves come through the glass and after absorption by material are converted to heat	Increased heat gain	Overheating	Applying reflective film, solar shading devices
(5)	Exposure of a window to wind	Wind cooling	Increased heat loss	Decreased thermal comfort	Adding storm sashes Improving thermal
		Wind noise is caused by air passing through or over orifices	Noise (whining)	Deterioration of comfort	Applying weather strip for exclusion of draught
		Wind pressure	Increased air infiltration	draft	Applying weather strip Storm sashes
(5)	Exposure of a window to driving rain	Wind driven rain is pushed to the façade causing enhanced moisture penetration	Frame material deterioration (Fungal decay, corrosion etc.)	Decreased aesthetics	Adding storm sashes Applying weather strip Limit exposure, ensure construction easy to dry
(5)	Exposure of a well-insulated window to the clear sky	Glass pane surface is cooled below dew point while emitting long-wave radiation during clear nights - external condensation	Water drops on the extern glazing	Decreased view Decreased aesthetics	Limit exposure (shelters)

6.5 Ventilation system

6.5.1 Estonia

Typically, older apartment buildings have natural passive stack ventilation. In some apartments kitchens are supplied with a hood. Typically in all of the dwellings, windows are also opened for airing purposes. Though mechanical exhaust ventilation has been the standard installation in new dwellings in Estonia during the last decade, old apartment buildings have preserved natural ventilation due to the complexity of the ventilation renovation.

In multi-story apartment buildings with natural ventilation the air change is typically very low. In the bedrooms of such buildings with doors and windows closed, measurements have been carried out showing that CO_2 concentration levels may increase up to more than 4000 ppm, and moisture excess up to $\Delta\nu$ 7g/m^3 during cold periods.

It is practically impossible to increase airflow if necessary in apartments with natural ventilation. A possibility is to use window airing, but this may worsen the thermal comfort during winter. The performance of ventilation has worsened dramatically after the replacement of old windows. The replacement of windows made without renovation of ventilation results in lower air leakage and ventilation airflows.

To improve the air change in old apartment buildings, it is necessary to use either central or more flexible individual mechanical ventilation with heat recovery. Mainly three types of improvements are used for ventilation systems:

- apartment based mechanical balanced ventilation with heat recovery;
- room based mechanical balanced ventilation with heat recovery in living- and bedrooms + intermittent mechanical exhausts from WC, kitchen, bathrooms;
- centralized mechanical exhaust ventilation with exhaust air heat pump to heat the domestic hot water of radiators and natural supply through fresh air radiators.

In additions to technical questions, also social/human questions need to be solved: occupants have different possibilities and motivations to pay the cost of renovation. Typically occupants do not accept any additional ventilation channels in their apartment. Their understanding of the importance of ventilation is very low. Together with the increase of the air tightness of building envelopes more attention should be paid to the real performance of ventilation. Quite often it is noise that may prevent the use of ventilation in a proper way.

Apartment based mechanical balanced ventilation with heat recovery (HR)

Benefits:

- High efficiency of heat recovery;
- Can lower fan speed if inhabitants are out of home: use according to the real need;
- The lowest life cycle cost;
- Preheated supply air.

Risks:

- Finding space for ventilation units (small apartments) and air channels (rooms height of 2.5m);
- Sound pressure level of ventilation units;
- Acceptance of inhabitants: works inside the apartments, extra interior finishing works;

Room based mechanical balanced ventilation with HR in living- and bedrooms + intermittent exhaust from “wet&dirty” rooms

Benefits:

- No or minimal ductworks in apartment;
- Can lower fan speed if inhabitants are out of home: use according to the real need;
- A little preheated supply air.

Risks:

- The required airflow of 23 $m^3/(h\cdot pers)$ delivered by conventional fans is associated with noise levels of 30…40dBA. However, occupants prefer sound levels that are less than 25dB), and may therefore deactivate the fan.
- Small pressure rise of fan
- Unbalanced system
- Finding space for ventilation units (less space, aside of windows the area can be covered with curtain);
- Sound pressure level of room units;
- Low energy efficiency;
- Low temperature rise during winter;
- No adequate ventilation solution exists.

Centralized mechanical exhaust ventilation with exhaust air heat pump + natural supply through fresh air radiators

Benefits:

- Less works in apartment;
- Use of old exhaust ducts;

Risks:

- Possible thermal comfort problems (draft, low temperature) if the supply air is not enough preheated in fresh air radiators;
- Average energy efficiency;
- Energy efficiency and controlling of heat pump;
- No demand control possibility;
- Need improvement of heating system.

7 BEST PRACTICE EXAMPLES

This chapter provides a set of best practice examples, presenting country or climate specific solutions.

7.1 Austria

A “Technical Guide”, which offers a description of all Austrian demonstration, can be seen under: http://www.hausderzukunft.at/publikationen/view.html/id1058

Link:	http://www.hausderzukunft.at/results.html/id4582
Description:	Tschechenring
Summary (important message):	The complex of residential buildings at “Tschechenring” is optimally embedded into the existing infrastructure due to its central location in the municipality of Felixdorf. The single buildings enclose a wide green area in their middle, which ensures an optimal microclimate due to its dimension and the existing old tree. The aforementioned location factors make this complex of residential buildings very attractive and are a good argument in favor of an advanced renovation of the complex. Starting point for the refurbishment decision was the necessary preservation work on the complex of residential buildings. The old-fashioned floor plans as well as the substandard flats led to the decision of the municipality of Felixdorf to start an advanced renovation project. A basic condition of the renovation project is the building substance that is monument-protected, which causes special measures and extra costs. The municipality of Felixdorf as builder attempted to realize an ecologically high-quality renovation in coordination with the interests of the housing subsidies of the Federal State of Lower Austria, considering requirements for listed buildings as well as comfort requirements. The realization period for part A of the project (consisting totally of three parts A, B and C) was October 2005 - June 2007. Part B and C will be renovated following the same concept. The starting point for the renovation of part B was October 1st 2009, after the Federal Government gave its OK for the subsidies on January 19th 2009. Part B was finished in spring 2011, because of delays due to bad weather conditions. The renovation of part C could be started in 2011 after the inhabitants of this building part had been resettled. Completion of works is planned for spring 2013. Delays were due to the long time it took for moving the inhabitants and could not be influenced by the builder. Apart from preparatory work like demolition works, pipe trenches, inlets, the following measures were accomplished: • extension of usable floor area by attic development • energetic optimization of the thermal envelope (complex internal insulation due to monument-protected facade) • exchange of windows: Installation of certified wooden-windows (part A: U=1,1; part B and C triple glazing: U-Value glass: 0,7 W/m2K, psi 0,034 W/mK) instead of plastic windows • installation of a comfort ventilation • use of building materials from renewable raw materials for interior fittings • installation of a wood pellet heating system. The high requirements for the renovation of residential buildings from the late 19th

	century (comparable with workers' housing estates of the 1930s) require a new handling of renovation processes, in order to keep existing qualities of the buildings and at the same time assure an ecological standard up-to-date and meet the needs of the housing market. One of the central challenges is to achieve a cost structure competitive to that from new buildings. With the choice of the measures for this renovation project, the persons in charge of this project want to show that ecologically optimized renovation projects can meet the market trends and can be realized within a range of justifiable costs. Crucially are amongst others the framework conditions of housing subsidies, here the funding of the Federal State of Lower Austria made this project possible. The renovation concept developed in the context of the demo project is a best-practice example for further projects of this kind. A respective change of the housing subsidies of Lower Austria is being discussed. **Aims and results** • clear reduction of the energy and material • intensified employment of renewable sources of energy • higher and efficient use of regenerating and/or ecological materials • consideration of social aspects and increase of the quality of life • comparable costs to the conventional building method and thus high economical potential. **Project partners** Applicant Gemeinde Felixdorf On-site building inspection and project management Gemeinnützige Bau- und Wohnungsgenossenschaft "Wien Süd" - GesmbH Hr. Ing. Eisenmenger, Fr. Bmst. Ing. Weber Project or cooperation partner • Bmstr. Ing. Günter Spielmann stadtbau • DI Georg Tappeiner - Ökologie-Institut • DI Dr. Bernhard Lipp, Ing. Mag. Maria Fellner- IBO
Link:	http://www.hausderzukunft.at/results.html/id6517
Description:	Dieselweg
Summary (important message):	**Starting Point / Motivation** Built in the period from 1950 to 1970, the 204 flats within 4 storey buildings without elevators, were provided with a roomheating based on electricity, oil and coal. At this time the CO2 emission was 700t/a, and the energy key data was between 142 and 255 kWHh/m²a. GIWOG bought the settlement in the year 2007 with the aim to reduce the energy consumption in big scale and to eliminate the domestic fuel and respirable dust emission. Source: GIWOG Source: GIWOG Contents and Goals The solution from GIWOG was a combination from thermal insulation and solar energy

production, groundwater heat pump, supported by a pressure less storage technology and heat regaining fresh air supply. The result was the elimination of the harmful substances and a much better air quality to release the inhabitants.

Methods of Treatment

The loss of heat was minimized by a solar façade, covering the houses by glass, wood and a cardboard comb with integrated passive house windows and ventilation canals. Large scale solar collectors and a groundwater heat pump with a pressure less storage tank were installed. The heating line and the hot water feeding were built into the former outside wall (“climate wall”). Also the cellar ceiling and the attic ceiling were insulated. Every living room was supplied with a heat regaining fresh air appliance. Monitoring the heat consumption operating the heat production can be done by the internet. Other important points in the project were the annex for the elevators, the integration of the former balconies in the living room area and first of all the participation of the inhabitants.

Source: GIWOG

Expected Results / Conclusions

GIWOG comes up to a reduction of the thermal energy consumption (old energy key data 142 to 255 kWh/m²a, new energy key data: from 9,6 to 13,6 kWh/m²a). and the costs for heat- and warm water for more than 90% and reached a high acceptance of the inhabitants.

Project partners

Project management

Bmst. Ing. Alfred Willensdorfer

GIWOG - Gemeinnützige Industrie-Wohnungs-AG

Project- and cooperation partners

- GAP-Solar GmbH, DI Mag. Johann Aschauer
- Architekturbüro Hohensinn, Arch. DI Josef Hohensinn
- AEE Intec, Dr. Karl Höfler

Contact address

GIWOG - Gemeinnützige Industrie-Wohnungs-AG
Bmst. Ing. Alfred Willensdorfer
Adresse: Welser Straße 41, A-4060 Leonding
Tel.: +43 (50) 8888-142, Fax: +43 (50) 8888 197, E-Mail: bauwesen@giwog.at
Web: http://www.giwog.at/

Link:	http://www.hausderzukunft.at/results.html/id6207
Description:	Wissgrillgasse, This project is a sub project of the flagship project "Gründerzeit with future: Innovative Modernisation of Wilhelminian style "Gründerzeit" Buildings"
Summary (important message):	**Starting point / motivation** Wilhelminian style or "Gründerzeit" buildings with typically decorated façades represent a considerable part of the total building and housing stock in Austria. These buildings were constructed between 1850 and 1918 and are in poor thermo-technical conditions.

Hence, possible savings are huge with regard to a CO2-neutral building stock. However, with application of usual refurbishment measures (replacement of windows) the energetic performance may be improved slightly. This demonstration project Wißgrillgasse shows how innovative refurbishment of Wilhelminian style buildings can overcome technical, economical, social and legal barriers and achieve a great performance. The demonstration project is part of the flagship project "Gründerzeit mit Zukunft".

Contents and goals

An integral modernization of the building was put forward by applying innovative technical and organizational solutions, which assure a modern living standard with high comfort. The building was refurbished energetically and a high efficient attic was developed. Goal of the project was a comprehensive and sustainable system solution, which allows a broad reproduction to further Wilhelminian style buildings.

Methods of treatment

Optimization of thermal quality of the building shell was keen. Therefore, insulation of all exterior building elements were risen up to a very high level in order to reduce energy demand for thermal heat. Due to usage of high efficient insulation materials losses of surface area could be reduced. Special attention was given to insulation of the fire-proof wall, because this wall accounts for 32% of all exterior walls. In order to secure interests of the neighborhood special neighborhood arrangements were made. This was especially important to enable insulation beyond property lines. Exclusively heat insulation triple glazing was used. Thus, transmission heat losses could be kept little. Additionally a central comfort ventilation system and a local incoming and outgoing ventilation system with thermal heat recovery was installed in the top floor. Thus heat losses due to ventilation could be reduced significantly. High noise pollution due to the railway junction was a further reason to install such ventilation systems.

Given that Wißgrillgasse is not covered by the supply of district heating the developer decided in favor of a central biomass heating system, which ensures a resource efficient allocation of energy for thermal heat and hot water. Drainage of the cellar was important to maintain the building substance, which proved to be very extensive, but was keen in order to guarantee a dry storage of wood pellets. Additionally 30 m² solar thermal collectors were integrated into the façade and cover a part of the required energy demand for thermal heat and hot water.

It has to be highlighted that the development of an attractive living space in the top floor is keen to realize such projects. This project accomplished a development of additional 800 m² useable surface by restructuring the existing building and development of a two-storied top floor in nearly zero energy standard.

Results

Initially the heating demand was 186 kWh/m²a. Due to the application of above mentioned measures the heating demand could be reduced to 28 kWh/m²a, what corresponds to a refurbishment with factor 7 and hence a nearly zero energy building. This demonstrates far better performance compared with conventional new buildings. The building convinces with its high thermal quality and usage of renewable energies but also with its high comfort of living and pleasant architecture. Furthermore success may be proven by the residents, who are highly satisfied with the building and and experts show strong interests in viewings.

The high thermal-energetical quality of this demonstration project with innovative technical and organizational solutions shows fair possibilities how the refurbishment of Wilhelminian style buildings could make an important contribution to a CO2-neutral building sector.

Prospects / Suggestions for future research

In order to draw serious conclusions about the factual performance of the building the project will be subject to a technical energy demand and comfort monitoring within the framework of the flagship project “Gründerzeit mit Zukunft” for a period of two years. Beside energy demands satisfaction of users and economical efficiency will be evaluated.

The experiences gained during the construction and accompanying monitoring phase will be incorporated immediately in further development projects of the builder Ulreich Bauträger GmbH and the Gassner & Partner Baumanagement GmbH. In addition, to the in-house usage of gained experiences and use for further demonstration projects within the knowledge about refurbishment of Wilhelminian style buildings will be disseminated by excursions, publications in journals and presentations.

Project partners

Project management

Mag. Hans Jörg Ulreich / Ulreich Bauträger GmbH, Wien

Project or cooperation partner

- Ing. Robert Gassner / Gassner und Partner GmbH, Wien

Contact address

Mag. Hans Jörg Ulreich
Ulreich Bauträger GmbH
Obere Amtshausgasse 20-24, 1050 Wien
Tel.: +43 (1) 7866110, Fax: +43 (1) 7866110-10, E-Mail: office@ulreich.at
Web: www.ulreich.at

Link:	http://www.hausderzukunft.at/results.html/id6232
Description:	Klosterneuburg
Summary (important message):	**Starting point / motivation** The residential complex in Klosterneuburg-Kierling was built between 1977 and 1979 and had shown significant defects. The heating energy costs were high, as the building is insulated insufficiently and the apartments had been heated with electricity (floor heating) – the most expensive way of heating, which has reached the limit of the service life. The only average architectural quality of the building in combination with the age of the building caused increasing marketing problems. The apartments were not accessible for disabled and elderly residents because of their location on a steep slope.

Using the example of demonstrational renovation, Kierling tests the possibilities of a renovation in passive house standard in technical, organizational and financial terms as an outstanding example of a comprehensive renovation.

Contents and objectives

- External envelope
    - The implementation of full thermal insulation on all facades and in the roof and basement areas;
    - the replacement of windows with passive-house windows;
    - the reduction of thermal bridges;
    - airtight design with passive-house quality.
- Controlled ventilation with highly efficient heat recovery (substitution of electric floor heating).
- Hot-water supply
  Solar panels and subsequent heating/auxiliary heating with a central pellet boiler with automatic feeding – energy supply for heating is 100% from renewable resources.
- Layout and comfort
  Winter gardens instead of existing balconies and installation of new lifts. All measures also form part of the energy-technological refurbishment (reduction of thermal bridges, renovation of facades).
- Addition of the loft
  The addition of the loft is a central component of the redensification of the location; at the same time, the roof is very well insulated with passive-house quality, using wood extensively as a renewable raw material.

Methods

The renovation project builds on the submitted refurbishment concept. Construction begins on 01/04/2012, completion on 31.08.2013.

Results

Implementation of the measures developed in the refurbishment plan: refurbishment to a passive house, high proportion of renewable raw materials / renewable energy sources for the supply of the required auxiliary heat / user-friendliness.

The result of the project is that passive house renovations with active use of solar energy and biomass heating (Active House) are possible even under difficult conditions. In the specific case the electric floor heating offers the execution of a thermal insulation in passive house standard and has the advantage that a heating via the ventilation system is possible and no plumbing is required in the living areas.

Basis for a quality refurbishment as in this case is planning beyond the usual level.

To keep construction costs low for residents, existing “reserves” present on the property can be used.

Prospects / Suggestions for future research

The refurbishment provides significantly higher energy savings than the new building. By conjunction with other objects (as in this case with the new building) significant synergy effects can be achieved.

	Project partners Project management Florian Kühr BUWOG Bauen und Wohnen Ges.m.b.H. Project or cooperation partners • Prof. Arch. DI. Georg W. Reinberg Lindengasse 36/10, 1070 Wien, Tel.: +43 (1) 5248280, E-Mail: architekt@reinberg.net, Website: www.reinberg.net • Prof. DI. Dr. Manfred Bruck, Prinz Eugen-Straße 66, 1040 Wien • Rowa Gebäudetechnische Planungs-GmbH., Ing. Walter Ganneshofer, Am Schönberg 15, 2500 Baden Tel.: +43 (2252) 206526, E-Mail: office@rowa-hkls.at • Österreichisches Ökologie-Institut, DI Georg Tappeiner Seidengasse 13, 1070 Wien Tel.: +43 (1) 5236105, E-Mail: tappeiner@ecology.at • AEE INTEC, Ing. Waldemar Wagner Feldgasse 19, 8200 Gleisdorf Tel.: +43 (3112) 5886-14, E-Mail: w.wagner@aee.at **Contact address** BUWOG Bauen und Wohnen Ges.m.b.H., Florian Kühr 1130 Wien, Hietzinger Kai 131 Tel.: +43 (1) 87828-1115, Mobil: +43 (664) 60928 1115, E-Mail: florian.kuehr@buwog.at Website: www.buwog.at
Link:	www.hausderzukunft.at/results.html/id6219
Description:	Purkersdorf
Summary (important message):	**Summary** The project shows in an exemplary way that existing buildings of the „Gründerzeit“ can be conserved in an economic way and are by far superior to new buildings in respect to their environmental balance. This includes much better living conditions and offers advantages for the protection of the appearance of the village (“Ortsbild”) and the avoidance of traffic. A villa of the type “Wienerwald” is renovated in an exemplary way and in connection of an entire housing project (14 units) by using the Passivhouse-Concept, passive solar use and active solar use for warm water. Point of departure was on the one hand the conservation of the exterior and interior appearance of the existing building and on the other hand the refurbishment to passive house standard with the latest state of the technology. The passive house standard regarding materials and details was nearlyrealized. It was possible to conserve the different kinds of double windows and restore them within 2 different variants.The decoration of the facades was re-established and a combination of the existing building

	and the new one was achieved. The representative rooms on the south side could preserve their proportions and their typical character (for example: by the old wooden floors, the typical shadows of the partition of the old windows, the window shutters, etc.). **Project management** • DI Ralph Baumgärtner Aufbauwerk der österreichischen Jungarbeiterbewegung Bau-, Wohnungs- und Siedlungsges.m.b.H **Project or cooperation partner** • Arch. DI Georg W. Reinberg, Architekturbüro Reinberg ZT GmbH Lindengasse 19/10, 1070 Wien • Ing. Hannes Schwahofer, BPS Engineering Zeleborgasse 26/8, 1120 Wien • DI Thomas Zelger, IBO Wien Alserbachstraße 5/8, 1090 Wien

Link:	http://www.hausderzukunft.at/results.html/id3951
Description:	Makartstrasse
Summary (important message):	**Motivation** The thermally consistent redevelopment of old buildings can be seen as the most important contribution to an effective reduction of CO2 emissions. But it also provides the opportunity to enhance the energetic standard and therewith the comfort of these building. This project was the first redevelopment of a multifamily residence on passive house standard and that is why it should be considered as an ideal example. **Content** The discovery of economically possible cost reductions and the implementation of the large- volume buildings in Linz based on passive house standard as a pilot project was a big step within the lasting building redevelopment industry. This project includes all aspects of an effective concept of redevelopment in consideration of forward- looking methods of redevelopment. These methods lead to an at most saving of energy while the quality, usability and functionality are increased at the same time. **Aims** With the first redevelopment of a multifamily residence based on passive house standard in Austria all efforts have been made to enhance air quality, comfort and usability with the energy demand decreasing even of existing buildings where this has not been achieved before. The aim of this project was to state an example for other old buildings. • First redevelopment of an old building based on passive house standard • Optimized ventilation and house automatic concept in order to obtain best air quality

- Ecological refurbishment with renewable raw materials
- Reasonable use of prefabricated materials
- Refurbishment without disturbance of residents

Methodology

- Alternative project outline based on passive house standard
- Calculation of possible constructions with PHPP
- Comparison and analysis of different ventilation concepts
- Examination of different decentral hot water conditioning
- Development of prefabricated parts of the façade with built-in windows and a duct system for controlled ventilation of the housing space
- Use of solar comb facades for redevelopment of old buildings

Modernisation of a multi- storey building with 50 accomodation units

Because of the prefabricated and ventilated GAP solar façade, an increased insulation of the ceiling on the roof and in the basement, an enlargement of existing balconies with parapet insulation, glazing with passive house windows with integrated sun protection, new roof covering and a controlled ventilation of the housing space with single room ventilators, the building (constructed in 1957/58) meets the requirements of a passive house.

Modern and future- orientated design of "old property".

Enhancement of quality of living conditions is possible because of an increase of sound insulation and good ventilation through high quality single room ventilation even with closed windows.

Multiuse of existing balconies is possible, because of an enlargement and enclosure built with thermally insulated parapet and side frame.The open spaces were closed with passive house windows and fixed glazing panels. A qualitative use of the balconies was not possible so far, because of the immense contamination and noise exposure due to the location of the building close to the highly frequented Makartstrasse. The total useable living area was increased from 2.755,68 m² to 3.106,11 m² thanks to the enclosure of the balconies.

Findings/Evaluation of heat consumption after the first period of heating

- Energy figure reduction of room temperature from 179kWh/ma to 13,3 kWh/ma (with a practically reached air density n50<1,30 1/h)
- Saving of 446.800 kWh/a - comes to factor <10
- Reduction of CO2 emissions from approx. 160.000 kg/a to 13.000 kg/a
- Additional costs to achieve passive house standard of approx. 27%
- Additional costs for passive house and ecological actions in total approx. 30%

Information of the tenants/Feedback

During the phase of planning the tenants were informed about the planned passive house refurbishment through organised meetings. As there has not been a similar project in Austria before, people were concerned whether such a refurbishment project can be successful at all. Thanks to presentations and clearing discussions we reached the acceptance of the tenants.

Shortly before refurbishment work was finished there was another meeting with the tenants, where the feedback about achievements so far was very positive. The way of living in a passive house was explained to them again and people had the opportunity to exchange experiences.

Finally GIWOG received the certificate of BMVIT from Mr. Zillner (Dipl.-Ing) at the final celebrations on the 14th of September 2006. During this event the tenants took the opportunity to thank the construction management of GIWOG for the smooth construction sequence.

Thanks to the implementing of the ventilation system a decrease of heating costs as well as the abatement of a tenant ´s dust allergy were noticed.

"Living has become worth living again."

Conclusion

The final report for this project comes to the conclusion that the refurbishment of the social housing based on passive house standard leads to an immense improvement of the quality standard.

That is why the tenant ´s benefit up to 100% from the saving of heating costs between 80 and 90%.

During this project a promotion for the refurbishment based on the passive house concept was newly implemented through OÖ WBF. It is because of this promotion in connection with the rent regulation of WGG that the extra costs of this ideal refurbishment were held fairly low, so that there were no additional monthly charges for the tenants, also due to the saved maintenance provision in connection with the additional support of BMVIT.

Project management

Bmst. Ing. Alfred Willensdorfer
GIWOG Gemeinnützige Industrie-Wohnungs-AG

Project or cooperation partner

- Architekturbüro ARCH+MORE, Puchenau
- Arch.DI Ingrid Domenig-Meisinger
- Planungsteam E-Plus, Egg
- DI Bernd Krauß
- gap-solar GmbH, Perg
- DI Mag. Johann Aschauer
- LANG consulting, Wien
- Ing. Günter Lang

Contact

GIWOG Gemeinnützige Industrie-Wohnungs-AG
Bmst. Ing. Alfred Willensdorfer
Welser Straße 41, A-4060 Leonding
Tel.: +43 (50) 8888 0
Fax: +43 (50) 8888 197
E-Mail: a.willensdorfer@giwog.at

7.2 Canada

Link	https://www03.cmhc-schl.gc.ca/catalog/productDetail.cfm?lang=en&cat=174&itm=1&fr=1348378703584
Description	Highly Energy Efficient Building Envelope Retrofits for Houses
Summary	The research investigates high insulation building envelope retrofits; develops targets for insulation and airtightness values for foundations, walls, windows, doors and roofs; considers building code and zoning implications of changes to the building envelope; and presents details and specifications of practical retrofit strategies for common housing archetypes
Link	http://www.cmhc-schl.gc.ca/en/inpr/bude/himu/waensati/waensati_044.cfm http://www.bere.co.uk/sites/default/files/blog_attachments/110614dg Flash Retrofit talk combined as presented.pdf
Description	Retrofitting High-Performance Windows
Summary	Benefit, consideration and implementation of high performance window system are discussed
Link	http://nparc.cisti-icist.nrc-cnrc.gc.ca/npsi/ctrl?action=avsere&k1=6815&i1=browse_authority_id&b1=&k2=&i2=&b2=&k3=&i3=&on_in=&st_ge=&so_prvw=&st_sc=&page=2
Description	A Field Monitoring Investigation of the Effect of Adding Different Exterior Thermal Insulation Materials on the Hygrothermal Response of Wood-Frame Walls in a Cold Climate
Summary	Comparison of exterior insulations with different vapour permeance. Based on the experimental study, higher permeable exterior insulations are preferred in building envelope exterior insulations

7.3 Denmark

Link	energiplus.net/Dokumenter/Erfaringer_fra_proevelejlighed_Ryesgade_30C_1tv_juli_2011.pdf
Description	Energy renovation of an old town house using advanced solutions (in Danish)
Summary	
Link	http://www.byg.dtu.dk/upload/institutter/byg/publications/rapporter/byg-r165.pdf http://www.byg.dtu.dk/upload/institutter/byg/publications/rapporter/byg-r166.pdf http://www.bere.co.uk/sites/default/files/blog_attachments/110614dg Flash Retrofit talk combined as presented.pdf
Description	Energy renovation of a typical detached residence from the period 1960-1980
Summary	
Link	http://www.byg.dtu.dk/upload/institutter/byg/publications/rapporter/byg-r225.pdf

	http://www.byg.dtu.dk/upload/institutter/byg/publications/rapporter/byg-r224.pdf
Description	Energy renovation of an old detached building (one of our case studies for the Annex) Energy renovation of a school building
Summary	

7.4 Estonia

Link:	http://www.kredex.ee/public/Uuringud/Suurpaneelelamute_uuringu_loppraport_trukk.pdf
Description:	The technical conditions and service life of Estonian concrete large panel apartment buildings (in Estonian).
Link:	http://www.kredex.ee/public/Uuringud/ttu.pdf
Description:	The technical conditions and service life of Estonian brick apartment buildings (in Estonian).
Link:	http://www.kredex.ee/public/Uuringud/TTY_Puitelamute_uuring.pdf
Description:	The technical conditions and service life of Estonian wooden apartment buildings (in Estonian).
Link:	http://www.kredex.ee/public/Uuringud/Uute_korterelamute_uuring_2012.pdf
Description:	The technical conditions of apartment buildings built 1990 - 2010 (in Estonian).

7.5 Finland

Link	http://www.ecobuild.co.uk/var/uploads/exhibitor/4224/oeoxv1ty3t.pdf
Description	Raahe Kummatti 2008-2013
Summary	In this project, located in the city of Raahe, Finland, a combination of 13 blocks of apartments, service buildings and senior citizen homes are planned for renovation between 2008 and 2013. The objective is to improve the aesthetic appearance of the area as well as the buildings' energy efficiency, thus influencing desirability. Environmental consciousness and recycling play a key role in this project which involves a number of European construction research institutions and universities as well as The Housing Finance and Development Centre of Finland (ARA). According to the architect, Harri Hagan, these suburban precast concrete apartment buildings are ideal objects for renovations as they permit the development of new repair technology, particularly to improve energy efficiency (Betoni magazine). The real estate company, Kummatti, therefore experimented with partial demolishment of the buildings and renovations instead of establishing new buildings. Through new technology, good results can be accomplished which provide both economic and environmental advantages. The company also chose to recycle and reuse as much of the existing materials as possible as well as installing solar collectors and wind turbines for local production of electricity.

7.6 Germany

Link	http://www.co2sparhaus.de/Beispielobjekte.45.0.html
Description	Examples of energy retrofitting and economic valuation (in German)
Summary	Lots of Examples in numbers. Amortization of investment through energy savings not until 25 years (to 150 years)
Link	http://www.bere.co.uk/sites/default/files/blog_attachments/ 110614dg%20Flash%20Retrofit%20talk%20combined%20as%20presented.pdf http://www.bere.co.uk/sites/default/files/blog_attachments/110614dg Flash Retrofit talk combined as presented.pdf
Description	Presentation from Dan Gibbons, bere:architects: "Scaling up Retrofit: Passivhaus Examples from Germany" Sep. 2011
Summary	Retrofitting at Passive House Standard. Lots of details + pictures. Old buildings (1930-1950). Comparison costs (per m^2): new passive house - retrofitting at passive house standard
Link	Link: http://www.ibp.fraunhofer.de/Images/FZ%20eng%203_tcm45-30935.pdf
Description	Abstract from Andreas Kaufmann, Hartwig M. Künzel, Jan Radon: "PREVENTING MOISTURE PROBLEMS IN RETROFITTED PITCHED ROOFS"
Summary	Dealing with moisture problems when installing thermal insulation

7.7 Portugal

Link	https://feupload.fe.up.pt/get/Q1S8TRsO6nOs8Uq
Description	Bairro de Lordelo - A social housing neighbourhood retrofit in Porto [in Portuguese]
Summary	Description of the case study, including a detailed description and pictures of the old and new adopted solutions.
Link	https://feupload.fe.up.pt/get/IbKR3RjKjfv4Dv5 http://www.bere.co.uk/sites/default/files/blog_attachments/110614dg Flash Retrofit talk combined as presented.pdf
Description	Example of retrofitting measures applied to a family house in Porto [in Portuguese]
Summary	Description of the building and the building elements. Comparison of the energy consumption and costs between the old solution and the improved solution.
Link	http://www.portovivosru.pt/Guia_Termos_Referencia.pdf
Description	Reference Guide for retrofitting buildings in Porto old town [in Portuguese]
Summary	Pages 23 to 34. Description of retrofitting solutions used in old buildings.

7.8 Slovakia

Link:	www.tsus.sk
Description:	research institution dedicated to retrofit existing buildings
Summary (important message):	Several publications aimed at building retrofit

7.9 The United Kingdom

Link:	http://www.retrofitforthefuture.org/
Description:	Database of low energy retrofits fully funded by Technology Strategy Board under the "Retrofit for the Future" project
Summary (important message):	127 deeply retrofitted properties are described, in terms of: design strategy (retrofit measures); energy target; previous, forecast and measured primary energy consumption and CO_2 emissions. 11 properties are retrofitted to Passivhaus standard.
Link:	http://discovery.ucl.ac.uk/2100/
Description:	Results of WarmFront project: "The impact of energy efficient refurbishment on the space heating fuel consumption in English dwellings"
Summary (important message):	In the UK, improving the energy efficiency of the existing stock through schemes such as the WarmFront is one of the main strategies for delivering affordable warmth to the fuel poor households. However, this paper suggests that the WF energy efficiency improvements may not be achieving the reductions in space heating fuel consumption that are theoretically assumed even after the effects of increased comfort have been taken into account. Although loft and cavity wall insulation appear to reduce space heating fuel consumption by 10–17%, it is still significantly less than the theoretically predicted level of 45 to 49%. This discrepancy is in part thought to be due to the incomplete insulation of the properties because in practice, it is difficult to insulate 100% of the exterior wall and roof when insulation work is carried out as a retrofit measure.
Link:	http://www.stbauk.org/what-we-do/index
Description:	"Responsible Retrofit of Traditional Buildings" STBA on behalf of the Department of Energy and Climate Change
Summary:	Report on existing research and guidance on traditional buildings retrofit
Link:	http://www.historic-scotland.gov.uk/index/heritage/technicalconservation/conservationpublications/refurbcasestudies.htm
Description:	7 refurbishment case studies on Scottish listed buildings (buildings of architectural/historical interest).
Summary:	Listed buildings require special attention when retrofitted; unlike most UK retrofit projects, here natural and capillary active materials are used.
Link:	http://www.decc.gov.uk/en/content/cms/statistics/energy_stats/en_effic_stats/need/need.aspx

Description:	Website of the Department of Energy and Climate Change; DECC has constructed a National Energy Efficiency Data framework to enable detailed statistical analysis of energy efficiency
Link:	www.dclg.gov.uk
Description:	Website of the Department for Communities and Local Government

8 FINAL REMARKS

8.1 Summary risks and benefits

The energy retrofit of the existing buildings is a key measure to sustainably decrease the use of fossil fuel and to reduce the dependence from expensive imported energy. As an example, when the savings potentials are added up proportionally, the result is a possible reduction of 190 TWh a year in Germany, only by using insulation for the opaque building shell.

This does not come at zero cost - it requires considerable investments which will, in the long term, lead to significant cumulative savings. The implementation of this strategy needs suitable and reliable legal frameworks, time and money. It requires a long term renovation roadmap to give orientation framework for investments as well as the necessary flexibility to the stakeholders.

With the ever rising needs towards energy efficiency of buildings, there has been a development of new materials and systems during the last decades; their use has been extensive and new process technologies have been developed. The areas of energy retrofit of the existing buildings and of energy efficiency of new buildings are important political issues in the course of further reduction of primary energy demand. At the same time, there is a rise of concern about alleged construction problems, insulation deficiencies, and unsubstantiated opinions expressed that energy savings through the use of insulation is physically impossible. Statements of a more general nature about different potentials of retrofit measures (insulation of envelope surfaces, replacement of windows and upgrading of heating systems) cannot be made because of a big difference in specific material and equipment characteristics. The fact however, remains: Thermal insulation is essential and if it is done professionally there won´t be any problems or damages - and last, but not least, it is economic.

Concerning moisture damage to facades – these are not a specific or typical problem of heat insulation composite systems, neither for resin-bounded nor for mineral plaster. Damage occurring in ETIC-Systems with, for instance, ceramic coating and their exploration have already proven in 1997 that moisture, coming from outside, can be minimized by a coating of tiles or chipboard with a proper porosity, combined with hydrophobic elasticised grout (Cziesielski , 1997). Numerous studies have shown that professional long life processing, maintenance and repair is quite comparable to simple plastered masonry. Experiences from the last 50 years with approx. 800 Million m^2 WDVS in Germany show, that WDVS is a proven system with a minimum of damages (e.g. Künzel, 2003). Mechanical damages through storm, rain, hail do not occur more often as with other facades. Damages through holes, for example caused by woodpeckers, are not a specific insulation - or EPS issue, as they can also occur with wooden or wooden based coating or shuttering. Low frost durability of ETICS in cold climate…

Also algae build-up at facades is a general problem and shows up at simple plastered masonry as well as at massive stone walls as can be easily seen at historical buildings turned green or black. A permanent moist surface film is the ideal basis for algae. This film should evaporate outwards and especially not get dried from the inside caused by the buildings heat loss. The building up of algae depends on many factors such as roof overhang, render, shading, roughness and structure of the plaster, heat capacity of the system and so on. First of all, it is an optical problem and does not affect the energy saving. Nowadays render systems can be adjusted to minimize the danger of algae and fungi formation.

Table 8.1 summarizes the risks of failure or difficulties when retrofitting building elements such as walls, roofs, basements, floors and ceilings**.**

Table 8.1: Summary retrofitting risks and benefits

Which are the risks of failure or difficulties when retrofitting a	
Wall / exterior	condensation, moisture, thermal bridges, leakages - mechanical behaviour and aesthetic defacement (Portugal)
Wall / Interior	often no insulation => otherwise possible moisture damages - Area / thermal mass reduction
Windows	condensation, moisture, frost, airtightness (reduces convection),
Pitched roof	condensation, water (rain) leakages, thermal bridges, construction mistakes (e.g. vapor barrier, connection to other components...)
Flat roof	condensation, water (rain) leakages, thermal bridges, construction mistakes (e.g. vapor barrier, connection to other components...)
Basement	condensation, water issues, thermal bridges
Floor to unconditioned space	condensation, water issues, thermal bridges, ventilation
Ceiling to unconditioned space	condensation, thermal bridges, construction issues

When it comes to cost discussion the following can be noted: A WDV-System is usually applied in the course of a new coat of paint, repair of plaster or a complete restoration. A more complex renovation should also include an energetic renovation of the whole building. If there will be renovation costs concerning painting, plastering and scaffolding, the WDV system will increase them but only in a moderate way. The additional financial load will amortize within a reasonable time period, especially considering the energy costs, which will, there is no doubt about it, further rise in future.

Besides the energy factor, also aspects of structural preservation, increasing value and living comfort often are of importance. We must never forget or even deliberately ignore the fact that thermal insulation of facades demonstrably increases thermal comfort not only in winter but also during summer.

9 REFERENCES

Åberg O. 2011. Moisture and mold problems a threat against sustainable buildings. The BETSI study in Sweden. Available on www.boverket.se (http://www.boverket.se/Sok/?quicksearchquery=moisture+and+mold, 2011-10-17)

Ahrnens C & Borglund E (2007). *Fukt på kallvindar – En kartläggning av småhus i Västra Götalands län*, Examensarbete 2007:11, Institutionen för bygg- och miljöteknik, Chalmers tekniska högskola. (In Swedish)

Alexandersson, H., 2006. Klimat i förändring: En jämförelse av temperatur och nederbörd 1991-2005 med 1961-1990. Faktablad i Meteorologi nr 29 Oktober 2006. SMHI, SE-601 76 Norrköping, Sweden, 8 pp.

Andersson A.C., Sentler L. Riskanalys av fönster. Rapport av Byggforskningsrådet R43:1982.

Arfvidsson, J. and Harderup, L-E. 2005. Moisture Safety in Attics Ventilated by Outdoor Air. 7th Symposium in Building Physics, Reykjavik, Island.

Berge, Bjørn. The ecology of building materials. Elsevier/Architectural Press, c2009.

Binz, A., Moosmann, A., Steinke, G., Schonhardt, U., Fregnan, F., Simmler, H., Brunner, S., Ghazi, K., Bundi, R., Heinemann, U., Schwab, H., Cauberg, J. J. M., Tenpierik, M. J., Jóhannesson, G. A., Thorsell, T. I., Erb, M., and Nussbaumer, B. (2005). *Vacuum Insulation in the Building Sector. Systems and Applications (Subtask B)*: IEA/ECBCS Annex 39 High Performance Thermal Insulation (HiPTI).

Boverket, the National Board of Housing, Building and Planning. 2009. Så mår våra hus. Available on www.boverket.se

BOVERKET (2009:1) *Description of the Swedish building stock using material from a Swedish Statistical Survey of 1800 buildings*, Karlskrona, Boverket. Available at: http://www.boverket.se/Global/Om_Boverket/Dokument/about_boverket/betsi_study/building_stock.pdf

BOVERKET (2009:2) Så mår våra hus : redovisning av regeringsuppdrag beträffande byggnaders tekniska utformning, Karlskrona, Boverket.
JANSSON, A. (2006) Tätskikt bakom kakel i våtrumsytterväggar - SP RAPPORT 2006:46, Borås : SP

Cziesielski E., Conrad F., Lehrbuch der Hochbaukonstruktionen. 1997

Essah, E., Sanders C., Baker, P., Sasic Kalagasidis, A. Condensation and moisture transport in cold roofs: effects of roof underlay. Building Research & Information, Vol 37-2, March-April 2009.

G. Verbeeck, H. Hens, Energy savings in retrofitted dwellings: economically viable? Energy & Building – 2004

Hagentoft C.E., Sasic Kalagasidis A., Nilsson S.F., Thorin M. Mould growth control in cold attics through adaptive ventilation. 8th Symposium on Building Physics in the Nordic Countries, Copenhagen, Denmark, June 2008.

Hagentoft, C.-E. (2001). Introduction to Building Physics. ISBN 91-44-01896-7, Sweden, Lund, Studentliteratur.

Hagentoft C-E, Sasic Kalagasidis A. Mould Growth Control in Cold Attics through Adaptive Ventilation. Validation by Field Measurements. 12th International Conference on Performance of the Exterior Envelopes of Whole Buildings, 2010, Clearwater Beach, Florida.

Holm, A., Lengsfeld, K. 2006. Hygrothermal performance of unfinished attics (ventilated roofs) – an experimental study. Research in Building Physics and Building Engineering. Proceedings from the third International Building Physics Conference, Montreal, Canada.

Johansson, P. (2012a). *Retrofitting of old Exterior Wall with Vacuum Insulation Panels: Meaurements of Thermal Properties, Moisture Performance and Practical Considerations* (Lic. Thesis). Gothenburg, Sweden: Chalmers University of Technology, Department of Civil and Environmental Engineering.

Johansson, P. (2012b). *Vacuum Insulation Panels in Buildings: Literature Review* (Report 2012:1). Gothenburg, Sweden: Chalmers University of Technology, Department of Civil and Environmental Engineering.

Jonsson Bertil. Calculating the occurrence of external condensation on high-performance windows. SP AR 1999:40, Building Physics Borås, 1999.

KARPE, J. (1990) Fukt och mögel i flerbostadshus : etapp 1 : inventering av skador och kunskapsläge, Stockholm :, Statens råd för byggnadsforskning

Künzel , H. Außenputz. Untersuchungen - Erfahrungen – Überlegungen. 2003

Larsson, L-E. 1996. Cold attics. Calculation model for moisture transfer analysis and practical implementations. In Swedish. Publication P-96:1. Department of Building Physics, Chalmers University of Technology, Sweden

Nik, V.M. 2010.Climate Simulation of an Attic Using Future Weather Data Sets. Statistical Methods for Data Processing and Analysis. Licentiate thesis. Chalmers University of Technology, Gothenburg, Sweden.

P.A Enkvist, T Naucler, J. Rosander, A cost curve for greenhouse gas reduction, The Mc Kinsey Quaterly, 2007

Parekh A., Roux, L., Gallant, P. Thermal and air leackage – Characteristics if Canadian Housing. 2007 http://www.nbec.net/documents/THERMALANDAIRLEAKAGECHARACTERISTICSOFCANADIANHOUSING-LOUISEROUXAnilParekh.pdf

Persson, G., Bärring, L., Kjellström, E., Strandberg, G. and Rummukainen, M. 2007. Climate indices for vulnerability assessments. SMHI Reports Meteorology and Climatology RMK No 111.

Petersdorff, C., Boermans, T., Harnisch, J., Joosen, S. und Wouters, F.: The contribution of Mineral Wool and other Thermal Insulation Materials to Energy Saving and climate Protection in Europe. ECOFYS GmbH, Cologne, December 2002.

Pietrzyk K., Kurkinen K., Hagentoft C.-E. An example of application of limit state approach for reliability analysis of moisture performance of a building component. Journal of Thermal Envelope and Building Science. Vol. 28, No.1, pp 9-26, 2004.
Richardson B. Defects and deterioration in buildings. London and New York, Spon Press. 2001.

Samuelson, I. 1995. Hygrothermal performance of attics. In Swedish. SP Report 1995:68, Sweden. (In Swedish)

Sanders, C. 1996. IAE Annex 24, Final Report, Volume 2, Environmental conditions. KU Leuven. Belgium, Laboratorium Bouwfysica.

Sanders, C.H. 2006. Modelling condensation and airflow in pitched roofs – Building Research and Establishment (BRE) information paper, IP 05/06. BRE Press, Garston, Watford – UK. ISBN 1-86081-912-5, pp. 1-7

Sasic Kalagasidis A. 2004. HAM-Tools. An Integrated Simulation Tool for Heat, Air and Moisture Transfer Analyses in Building Physics. Doctoral thesis. Chalmers University of Technology, Sweden.

Simmler, H., Brunner, S., Heinemann, U., Schwab, H., Kumaran, K., Mukhopadhyaya, P., Quénard, D., Sallée, H., Noller, K., Kücükpinar-Niarchos, E., Stramm, C., Tenpierik, M. J., Cauberg, J. J. M., and Erb, M. (2005). *Vacuum Insulation Panels. Study on VIP-components and Panels for Service Life Prediction of VIP in Building Applications (Subtask A)*: IEA/ECBCS Annex 39 High Performance Thermal Insulation (HiPTI).

SP Technical Research Institute of Sweden. Windows, Moisture and Interior Climate (in Swedish).

SVERIGE (2009) Plan- och bygglagen. Plan- och byggförordningen. Lag och förordning om tekniska egenskapskrav på byggnadsverk, Vadstena, Förlagshusen.
SVERIGE. BOVERKET (2003) Flerbostadshusens förnyelse : behov och förutsättningar 2002/03, Karlskrona, Boverket.

WERNER, E. & SVERIGES BYGGINDUSTRIER. FOU-SYD (2006) *Undvik misstag i murat och putsat byggande,* Malmö, FoU Syd, Sveriges byggindustrier.

VIDÉN, S., SCHÖNNING, K. & NÖRE, K. (1985) *Flerbostadshusen i Sverige : kvaliteter och brister, ombyggnadsbehov och möjligheter,* Stockholm, Statens råd för byggnadsforskning : Sv. byggtjänst (distr.).

9.1 Further links

SHC Task 40:
http://task40.iea-shc.org/about

The Lead Market Initiative (LMI) and sustainable construction: Screening of national building regulations:
http://ec.europa.eu/enterprise/sectors/construction/studies/national-building-regulations_en.htm

Improving and implementing national energy efficiency strategies in the EU – Framework:
http://www.energy-efficiency-watch.org/fileadmin/eew_documents/images/Event_pictures/EEW2_Logos/EEW-Final_Report.pdf

English Housing Survey, DCLG:
https://www.gov.uk/government/collections/english-housing-survey

Office of fair trading:
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/246793/0023.pdf