MSc Program
Environmental Technology & International Affairs

Increasing the Energy Performance of Buildings: European Legislation and its Implementation in Austria

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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Vienna, 21 October 2015

Affidavit

I, **Georg Wolkenstein**, hereby declare

1. that I am the sole author of the present Master's Thesis, "INCREASING THE ENERGY PERFORMANCE OF BUILDINGS: EUROPEAN LEGISLATION AND ITS IMPLEMENTATION IN AUSTRIA", 102 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

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Abstract

In 2007 the European Union launched the 2020 Climate & Energy Package, with three core targets: A 20 % share of renewable energies, a 20 % cut in greenhouse gas emissions from 1990 levels, and a 20 % increase in energy efficiency.

This thesis provides a review of the two legislative pieces that were at the core of the package, the Energy Performance of Buildings Directive of 2010 and the Energy Efficiency Directive of 2012. Buildings account for more than 40 % of the total European energy consumption, making the improvement of building energy performance imperative. The two directives provide a framework for the promotion of energy efficiency by introducing National Energy Efficiency Action Plans, energy efficiency obligation schemes as well as strategies and measures aimed at the improvement of building energy efficiency.

Implementation of the directives is examined based on the Austrian legislation concerning energy efficiency and building energy performance. Traditionally legislation on building matters has been the responsibility of the 9 federal states, but in recent years the Austrian Institute of Construction Engineering has promoted harmonization of construction laws through the release of guidelines. Guideline 6 includes provisions implementing core parts of the EPBD, although doubts about the quality and stringency remain.

As technological advances and laws on building construction greatly evolved since the 1973 oil crisis the majority of energy performance improvements can be achieved with renovations of the existing building stock, particularly buildings constructed before 1990. A combination of improvements to the building envelope and technical building systems, as well as the increased use of alternative energy sources can reduce the energy demand of buildings by up to 90 % and more.

While it is too early to draw conclusions about the effectiveness of regulations that entered into force so recently, financial and administrative barriers and the user-investor-dilemma remain and prevent substantial improvements in the renovation rate of buildings, particularly those privately owned.

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1. Introduction

With the Greek Euro-Crisis, the ongoing conflict between the Ukraine and Russia, and the ever growing humanitarian refugee-catastrophe climate change has taken a backseat in the minds of Europe's leaders in 2015; continued (and too often valid) criticism of climate change reports, e.g. the rising influence of politics and lobbies on the IPPC Reports, has also contributed to skepticism about the level of change needed to help the world's ecosystems stay somehow in balance or recover again.

Nonetheless: The pollution that has been blown into the atmosphere, carried into water bodies and deposited on the land over the last two centuries as well as the climate change are real, even with the extent of mankind's contribution to the latter not yet fully known. It is now more or less universally accepted that fossil fuel reserves and their exploitation will not be able to keep pace with the still growing need for more electricity, and even at the current rate of consumption will eventually run out completely. For Europe, the previously mentioned Russian-Ukrainian conflict and the EU's damaged relationship with Russia was a stark reminder that the availability of fossil fuel imports (namely Russian fossil fuel imports) isn't guaranteed and that Europe's dependence on energy imports could prove to be dangerous.

The efforts to combat global warming can generally be classified into two distinct categories: Adaption and Mitigation. It could be argued that Geo-Engineering represents a third method to combat climate change but it is generally classified as part of climate change mitigation.

Adaption to global warming includes policies that seek to reduce the impact climate change will or may have to social and biological systems, as well as help for developing countries that are predicted to bear the biggest impact of negative effects of global warming and whose adaptive capacity lags significantly behind the capability of developed countries. For the latter part the *Green Climate Fund* (GCF) was established in 2010 during the United Nations Climate Change Conference in Cancun as part of the UNFCCC (United Nations Framework Convention on Climate Change). However, while pledges to the fund are at 10.2 billion USD as of May 2015 (Green Climate Fund, 2015a), the GCF has faced constant criticism regarding its effectiveness as one of many recently founded environmental organizations, the role of the private sector and the additionality of the funds. In June 2015 Executive Director Héla Cheikhrouhou revealed that the fund had received project proposals

and concepts requesting a total of 6 billion USD*, "[…] of which around 500 million USD worth of GCF funding [...] look promising"* (Green Climate Fund, 2015b).

Mitigation of climate change can be achieved through various means, most of them aiming at a reduction of greenhouse gas (GHG) emissions. This can be achieved through changes of both the supply and the demand side of the energy market, which is the biggest contributor to GHG emissions (Environmental Protection Agency, 2015).

On the supply side the switch to alternative (and mostly renewable) energy sources stands at the forefront. The growth there is slow but constant: Between 2002 and 2012 the global share in renewables grew from 18.3 % to 20.8 % (Observ'ER, 2015), and in the EU the growth was even more pronounced as the share increased from 13.9 % to 24.2 % in the same timeframe (European Environment Agency, 2014). According to a study by the International Renewable Energy Agency renewables accounted for more than half of new electricity capacity installed in recent years, with continued falling costs cited as major factor for the current trend towards more renewable electricity generation (International Renewable Energy Agency, 2014). Nuclear power is also often mentioned as the energy source with a very low rate of GHG emissions, but most of the plans for future nuclear plants or the expansion of current reactors were discarded after the Fukushima Daiichi nuclear disaster of 2011. Also in the discussion is a short-term switch from coal to gas as energy source, as gas has roughly half the CO_2 emissions of coal. However, newer studies suggest that the switch may have no or even a negative effect on global warming, as methane leakage into the atmosphere, which occurs mainly during the extraction of natural gas, more than offsets the CO_2 reduction provided by the switch (Wigley, 2011).

The demand side offers more diverse ways to combat global warming. Energy conservation and energy efficiency, which will be the focus of the thesis, aims to reduce the energy consumption of products and services, as well as behavioral changes such as car sharing or heating less during winter. Regulations with the purpose of increasing energy efficiency first were implemented in the mid-1970s, not necessarily in response but certainly influenced by the oil crisis in 1973. They have since been adapted, scraped and re-invented many times to the state they are in today, and newer legislative pieces such as the EU's Energy Performance of Buildings Directive show the emphasis that is put on energy efficiency.

Other demand side changes include fuel-switching on a large scale, which includes replacing furnaces, heaters and pumps that are oil- or gas-fueled with electric ones as well as using electric or hybrid-based vehicles as mode of transportation; stopping the deforestation and additionally reforestation, as forests provide the ecosystems with huge carbon sinks in addition to other benefits; and likewise the creation and maintenance of artificial carbon sinks, e.g. the injection of carbon dioxide into underground layers such as aquifers or depleted oil reservoirs. Geo-engineering, or climate engineering, has also been proposed as possible solution for mitigating climate change. The two proposed forms for geo-engineering have been large-scale carbon dioxide removal from the atmosphere and an artificially changing the amount of solar radiation the earth absorbs. Skepticism about the effectiveness of those measures and uncertainness regarding the side effects on the ecosystem have limited research to computer models and laboratory tests, with many of them confirming that the side-effects of geo-engineering would lead to other problems with consequences not yet foreseeable (US Government Accountability Office, 2011).

1.1 Aim and structure of the thesis

The aim of this thesis is to provide an overview of Europe's striving for improved building energy efficiency. The first part offers a historical view on energy and energy efficiency –early forms of energy usage, the advent and impact of the steam engine, the integration of energy into everyday use, to the oil shock of 1973 when energy efficiency stopped being a purely technical term and became a societal topic. A closer look is taken at the current energy situation in Europe, developments in the last 20 years and the biggest issue Europe currently has, namely its growing dependence on energy imports. And as buildings are at the core of this thesis Europe's building stock is looked at, with an emphasis on residential buildings. The EU (plus Norway and Switzerland) is divided into three regions - North & West, East & Central, and South – and both similarities and differences between the building characteristics of the regions are elaborated.

The second and third parts cover the main European directives concerning energy efficiency and the national implementation of these directives using the example of Austria. The second part offers a short introduction on how Europe developed a common energy policy. The main focus though is on the Energy Efficiency Directive and the Energy Performance of Buildings Directive– their predecessors, their scope and their main provisions. The third part comprises the parts of Austria's legislation that implements the directives introduced in the second part. With the construction and renovation of buildings being mainly under jurisdiction of the federal states the building code and – laws of Vienna are used as example.

The fourth part looks at the technical implementation of energy efficiency improvements of buildings, again using Austria as a reference point. Austria's building stock is analyzed similar to Europe's building stock in the first part, again with an emphasis on residential buildings. The most important energy performance improvement measures are introduced, divided into three categories: Building envelope improvements, improvements of technical building systems, and renewable energy sources.

The fifth and final part shows some examples of state-of-the-art technology in the field of energy efficiency, and offers concluding remarks on this thesis as well as on some barriers and challenges that remain even after the implementation of the directives.

1.2 History of Energy and Energy Efficiency

While the term ‘energy efficiency’ is a relatively new one – especially in an environmental context – the concept of it is as old as mankind itself. The need to only work as much as necessary led to early innovations like the development of agriculture (a more efficient form of gathering), animal husbandry (both as substitute for hunting and to have animals do work) and the wheel (for more efficient forms of transportation).

The earliest non-living sources of energy were fire, earth and water. With fire being used for cooking and heating (among other applications) it was necessary to efficiently control fires, to minimize the gathering of wood or other fuel and to use as much heat as possible while still guaranteeing safety. The first major use of wind power was as ship propulsion, which opened the way for larger-scale trading and was a major factor for technological advance. The use of water as an energy source came the latest, with Hellenistic engineers being the first to use water wheels as a power source and for irrigation.

A specific example of a pre-industrial form of building energy efficiency is the housing of some pre-Columbian Native North American tribes, the tipi. Well known from history classes and wild-west movies, the tipi is a portable housing made of animal skin (historically mainly made out of buffalo skin) which are stretched over a frame of usually three main and several smaller poles to create a conical tent, usually slightly slanted against the wind direction to decrease the overall wind pressure (Pritzker, 2000). The skin has an opening at the top, also placed against the wind, which acts as smoke hole for the use of fire in the tent and better air circulation; an additional piece of leather or skin is sewn near that opening and fixated to provide rain cover.

What made (and still makes) those tipis so interesting from an efficiency point of view was the bottom of the cover, which is double layered and can be staked down (although small seams for air circulation were always present) or rolled up separately (see **Figure 1.1**). During winter the outer layer is rolled up a bit while the inner layer is staked down; this means that when a fire is used to heat the tipi, the cold air entering the tipi from the bottom has to pass through the air space between the layers, heating up before it enters the tent and reducing the draft for people gathered around the fire (Surface Architecture, 2013). On warmer days both layers are rolled up to let cool breezes in, while the warm air rises out the top.

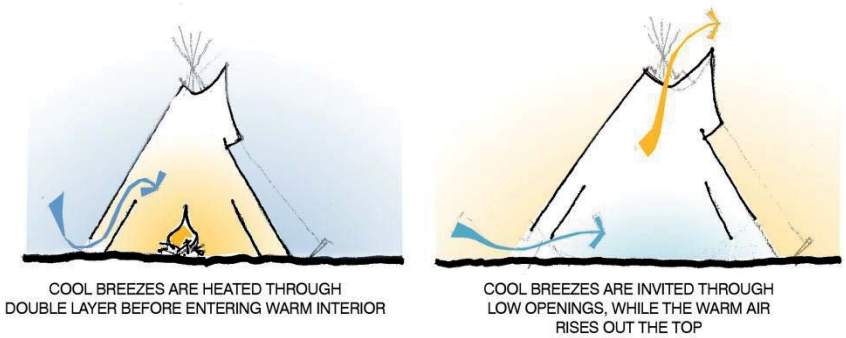


Figure 1.1: Functionality of a Native American tipi

Perhaps the most important energy-related invention (besides the 'invention' of fire) was the steam engine; its rise to prominence in the 18th century marked the beginning of the first industrial revolution, but the first machine that converted steam power into mechanical movement, the *aeolipile*, was described almost two millennia earlier by Heron of Alexandria, a Greek engineer of the 1st century. While some other inventors played with the idea of steam-powered devices, among them Leonardo da Vinci, it was only in the second half of the 17th century when several new advances eventually led to the construction of the first industrial steam engines: The *Miner's Friend* designed by Thomas Savery in 1698 and the Newcomen engine designed by Thomas Newcomen in 1712.

The new machines brought new problems: The steam-powered engines needed fuel to be operated, and the size, inefficiency and increasing availability of steam machinery led to a surge in the demand of fuel which could no longer be satisfied by surrounding wood. The subsequent rise in fuel prices became an added incentive to increase the efficiency on steam engines. James Watt – maybe the first modern pioneer of energy efficiency – modified and improved various parts of the Newcomen engine, finally patenting his designs in 1769. Theoretical understanding of the steam technology lagged a bit behind, it took until 1824 when Sadi Carnot was the first to successfully describe an energy efficient engine with his idealized *Carnot Heat Engine*.

Steam engines also helped with the discovery and exploitation of both new and already known fuel sources, which in turn led to an increased incentive to further push development of new machinery (Wulfinghoff, 2015). Coal mining and – processing became easier, safer and more efficient; petroleum (and accompanying that natural gas) extraction in large quantities started in the mid-19th century, and

expanded rapidly with the invention of the internal combustion engine; and electrical power as secondary fuel source emerged in the late 1800s, Thomas Edison being the first to bring a larger-scale electrical supply network with direct current online. The following years saw the *War of the Currents* between Edison's DC and George Westinghouse's alternating current, which the latter eventually won due to its economic and technical advantages.

The last step towards electrification was the development of electrical motors, in which Nikola Tesla made the largest contributions. It made applications less dependent on primary fuel sources, which meant that mechanical power could now be used almost anywhere and in almost any scale. The beginning of the 20th century saw a rapid rise in energy consumption: New machines increased industrial and agricultural productivity; the invention of automobiles enhanced mobility and became a new major consumer of fuel, as did ships with newer fuel propulsion and later aviation.

The booming demand in energy and energy sources was accompanied by an even bigger growth in availability of fuel. In addition to coal, petroleum and natural gas water became a major source for electricity; once again it was Nikola Tesla who together with George Westinghouse built the first Hydroelectric Power Plant near Niagara Falls in 1881. Half a century later nuclear fission was discovered in 1938 in Berlin, and in 1956, eleven years after the first atomic bomb was detonated in the New Mexico desert, the first full-scale nuclear power plant went online in Great Britain. The seemingly ubiquitous energy sources made energy prices cheap, and the low price of energy made the development of more efficient energy usage an afterthought until the early 1970s.

This began to change with the 1973 oil crisis, when OPEC declared an oil embargo on the USA, the United Kingdom and other countries in response to the US involvement in the Jom-Kippur-War. Apart from the economic effect it had it provided a stark reminder that the availability of fossil fuels couldn't be taken for granted in light of the rapidly rising energy hunger. Energy efficiency as a concept stopped being a purely technical aspect and started being a distinct topic on its own, with political, economic and social implications. In 1973 the state of California founded the Energy Resources Conservation and Development Commission whose duties included the *"[…] forecasting and assessment of energy demands and supplies, and the conservation of energy resources by designated methods"*

(California, 1973), and a year later the EU first picked up the topic in its 1974 *Council Resolution concerning a new energy policy strategy for the Community* (European Council, 1974).

Jevon's Paradox

The increased focus on energy efficiency also led to economist interest in this topic. In the 1980s the two economists Daniel Khazzoom and Leonard Brookes independently revisited the Jevon's paradox, an idea first put forward by William Stanley Jevon (Jevon, 1865). Jevon observed that the increased efficiency of steam engines in the second part of the 17th century coincided with a boom in coal consumption. As less coal was needed to run the engines its relative cost sank, steam engines became more attractive for a wider use and total coal consumption increased even in face of the efficiency increase.

Khazzoom and Brookes argued that a more efficient energy use would create the same behavior: The improved efficiency of a resource (in that case energy) lowers the cost of consumption which in turn leads to an increase in demand and to a bottom line increase in consumption. For example, more fuel-efficient cars lead to a more frequent use of cars (as it is relatively cheaper to travel with) as well as an increased demand in cars (as their cost-effectiveness in comparison to other modes of transportation increases), and the larger demand creates additional incentive for producers to increase their production of all car-related products. Those three reactions to an increased efficiency are together called rebound effect, and in 1992 the economist Harry Saunders described this hypothesis as the *Khazzoom-Brookes-Postulate* (Saunders, 1992). The rising electricity consumption even in the face of decades of efficiency improvements seems to back this postulate and shows that those improvements need to be coupled with governmental regulations and measures to reach a gross consumption decrease.

1.3 The European Energy Market

Thoughts about a single integrated European energy market were first put to paper in the Messina Declaration of 1955, but it was only in 1996 when EU members first put forward a legislative package concerning the harmonization of energy markets (Directive 96/92/EC). Since then the European Union has taken a number of steps towards their goal of a single European market, with the Commission identifying three major matters as the core objectives:

- *"**Sustainability** - to actively combat climate change by promoting renewable energy sources and energy efficiency;*
- ***Competitiveness** - to improve the efficiency of the European energy grid by creating a truly competitive internal energy market;*
- ***Security of supply** - to better coordinate the EU's supply of and demand for energy within an international context."*
  (European Commission, 2006)

1.3.1 Sustainability

Renewable energies have seen a big surge since 1990, with primary energy production of renewable energy almost tripling from 71 Million TOE (tonnes of oil equivalent) in 1990 to 192 MTOE in 2013 (Eurostat, 2015); what makes this development even more remarkable is the fact that total primary energy production dropped by 15 % during the same time period. Between 2003 and 2013 renewables were the only major sources for primary energy recording a growth (**Figure 1.2**), with all other energy sources registering moderate to large drops.

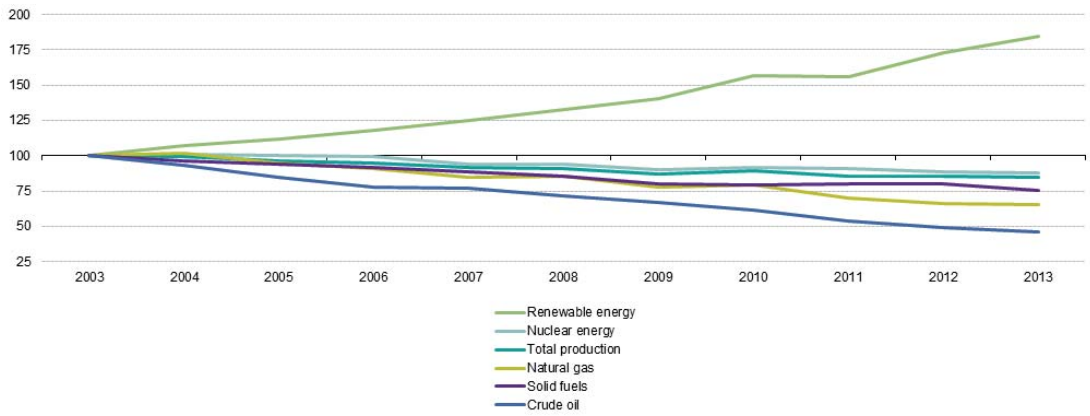


Figure 1.2: Development of the production of primary energy (by fuel type), EU-28, 2003 - 2013

In 2013 renewables made up almost one quarter of the primary energy production in the EU-28 with 24.3 %. Of that, biomass and renewable waste had the biggest share with 64.2 %, followed by hydro power at 16.6 %, wind power at 10.5 % and solar power at 5.5 % (**Figure 1.3**).

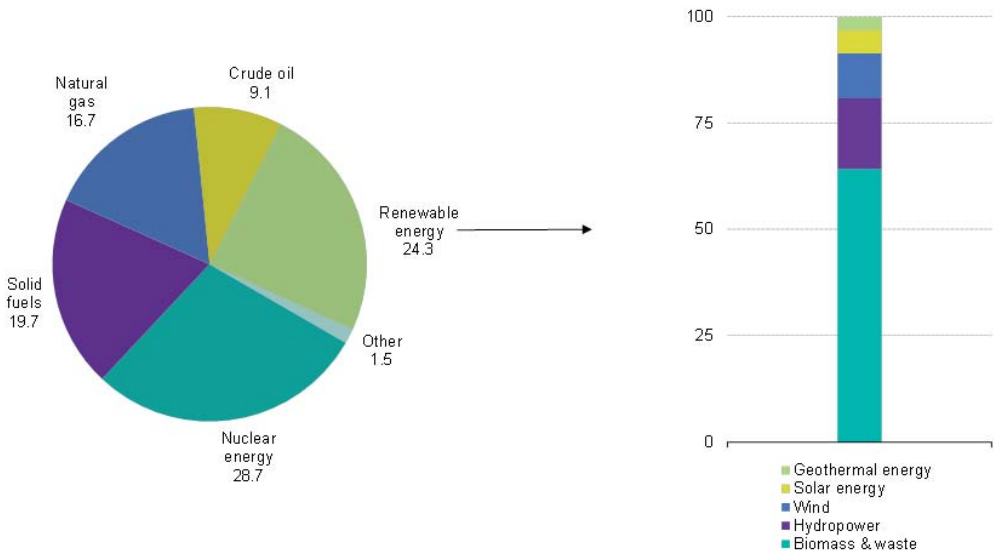


Figure 1.3: Production of primary energy, EU-28, 2013

The numbers are a bit lower for gross final consumption of energy, as solid fuels make up the bulk of energy imports. Still the share of renewables in final consumption has grown at a steady pace reaching 15.0 percent in 2013.

A measure of the energy efficiency of an economy is the energy intensity, which is the ratio between gross inland consumption of energy and gross domestic product. Energy intensity dropped across the board in the EU-28 between 2003 and 2013, with not a single country experiencing an increase in energy intensity (**Figure 1.4**). This cannot be solely attributed to a successful environmental and energy policy, but can also be partly explained by the ongoing shift towards post-industrial societies, with the generally less energy-intensive service sector becoming the dominant contributor to the GDP.

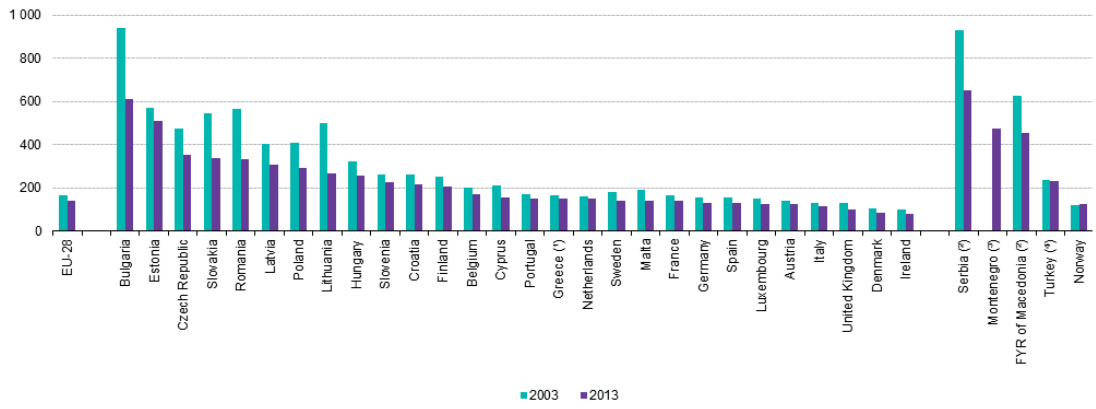


Figure 1.4: Energy intensity of the economy, EU-28, 2003 and 2013 (kg of oil equivalent per thousand EUR of GDP)

1.3.2 Competitiveness

The integration of the energy markets is also progressing: wholesale energy prices have gone down, dropping between 35 – 45 % in price between 2008 and 2012, while gas prices stayed relatively stable (European Commission, 2014a); cross-border energy trade has increased significantly, with23 of the 28 EU-countries recording a growth in electricity imports; A more uniform set of rules on power exchange markets has made movements on the energy markets more transparent and helped to distribute power and gas flows in a more efficient manner.

However there are still some key points that need to be corrected, as the drop in wholesale energy prices has not been passed on to the end customer with retail prices rising significantly, in part because of taxes and surcharges. Much of the legal framework is also still geared towards a unidirectional energy flow from few large producers to many individual consumers, making it harder for micro-generation and modern energy saving equipment to be fully integrated into the energy market. Additionally the energy grid, while improved, needs to be further upgraded to cope with the ever increasing share of renewable energy – unlike conventional fuels, the availability of solar or wind power fluctuates significantly, sometimes pushing the limits of the existing grid.

1.3.3 Security of supply

While the primary energy production has been falling for some time now, this has not held true for total energy consumption. Total gross consumption was at the same level in 2013 as it was in 1990 and was actually continuously growing until the financial crisis of 2007. To accommodate for this discrepancy the EU-28 has increasingly had to depend on energy imports, although they too took a hit after 2007. Since 2004 more energy had to be imported than could be provided internally (**Figure 1.5**).

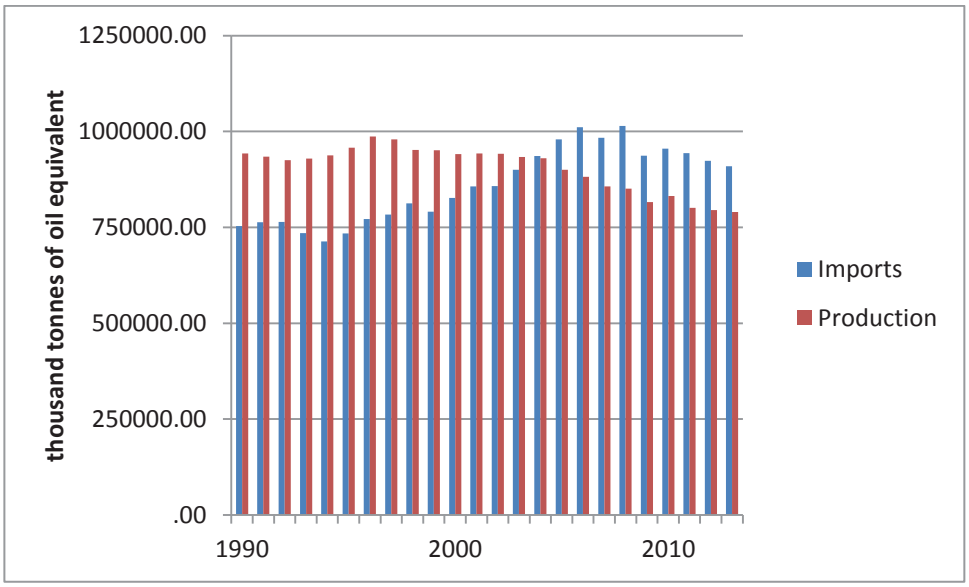


Figure 1.5: Primary energy production and energy imports, EU-28, 1990 - 2013

The main energy imports are fossil fuels; this is nothing new, as Europe (except for a few select countries like Norway) has traditionally depended on oil imports – in 2013 crude oil imports made up more than 88 % of the EU-28's gross inland consumption. With many industries switching from coal to gas as fuel imports have now reached almost two thirds of total consumption, with 65.3 %. The situation with coal and other solid fuels has been better – also due to the aforementioned drop in coal usage – but there, too, imports have increased to 44.2 % in 2013 (see **Figure 1.6**).

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
All products	48.8	50.2	52.2	53.6	52.9	54.7	53.7	52.8	54.0	53.3	53.2
Solid fuels	35.0	38.2	39.4	41.7	41.5	44.9	41.1	39.5	41.7	42.2	44.2
Crude oil	78.5	80.7	82.4	83.8	83.5	85.0	84.1	85.2	86.0	88.2	88.4
Natural gas	52.0	53.6	57.1	60.3	59.5	61.7	63.4	62.2	67.1	65.8	65.3

Figure 1.6: Energy dependency rate, EU-28, 2003 – 2013

Russia is by far the biggest trading partner of the EU-28 for fossil fuels. Traditionally being the biggest supplier of crude oil and natural gas, it recently overtook South Africa as the principal supplier of solid fuels. For all three types of fossil fuel the top three trading partners of the EU provide more than half of the supplies – in the case of coal more than two thirds of total imports and for natural gas even more than 80 %. The dependence on Russia is especially concerning, as its disputes with transit countries have threatened the continuous supply of natural gas in recent years. The conflict in the Eastern Ukraine and the now frosty relationship between the EU and Russia has also provided new incentive to look for new trading partners.

One of the biggest projects in that regard is the Trans Adriatic Pipeline, which aims to connect Turkey and Italy through Greece and Albania by 2018, providing Azerbaijani natural gas to European countries. In May 2014 the Commission released its *Energy Security Strategy* (European Commission, 2014b), reiterating the need for a more diverse energy supply, increased coordination between member countries to prevent shortages or disruptions as well as a continued focus on energy efficiency and the associated climate goals.

1.4 Europe's Building Stock

In 2008 the then-27 heads of state and their governments adopted the 2020 *Climate and Energy Package* (European Council, 2008), centered around three key targets:

- 20 % cut in greenhouse gas emissions from 1990 levels,
- 20 % renewable energy share,
- 20 % improvement in energy efficiency.

One year later the EU went a step further and set itself the goal of reducing greenhouse gas emissions by 80 – 95 %, again based on the 1990 levels. With buildings (households and the service sector) being the biggest contributor to total final energy consumption at 40 % they are a primary target for energy efficiency improvements (**Figure 1.7**). And as Europe's buildings will need an estimated 60 – 100 billion Euros annually to achieve the 20 % improved efficiency goal it is worth the time to take a closer look at the current building stock (Energy Efficiency Financial Institutions Group).

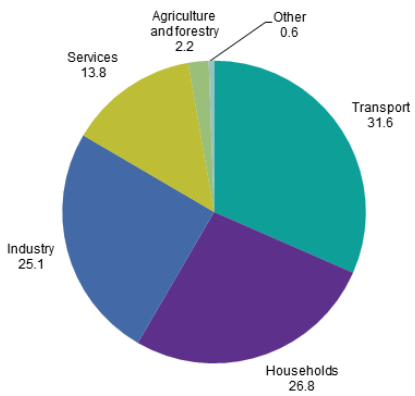


Figure 1.7: Final energy consumption by sector, EU-28, 2013

There are around 503 million people living in the European Union in a land are of more than 4 million km², with different climate zones, cultures and economies. They live and work in a building stock of around 25 billion km² as of 2011 (Buildings Performance Institute Europe, 2011), with big variations in size, age and energy performance.

To make an analysis of the current building stock a bit easier the countries have been divided up in three groups based on climate and economic performance[1]:

- North & West Europe (including Norway and Switzerland)
- South Europe
- Central & East Europe

The composition of each region is listed in **Figure 1.8**.

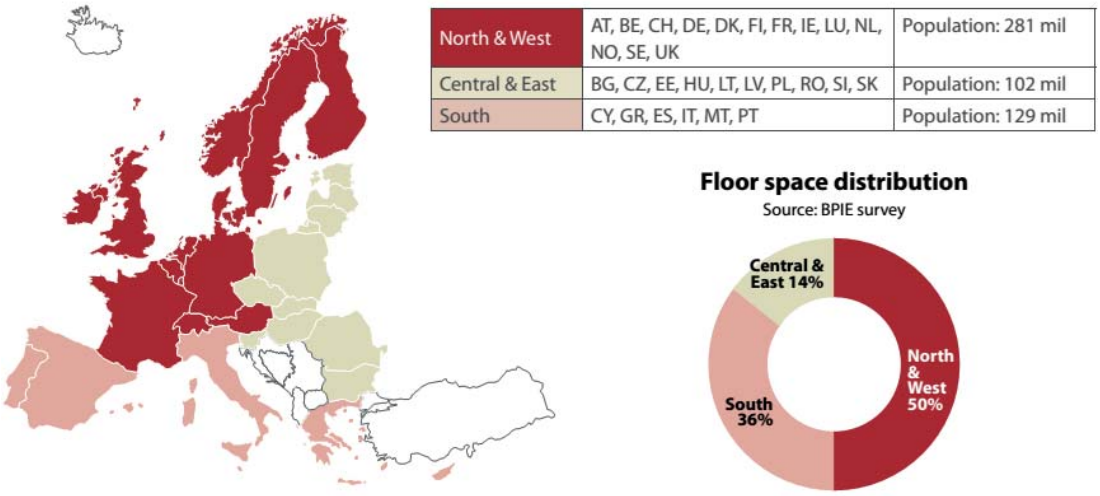


Figure 1.8: Regions and their countries, with population and floor space figures

1.4.1 Classification

European floor space can generally be divided into residential and non-residential buildings, the former being the bigger segment with 75%. Between the three regions, the North & West region has the smallest share of residential buildings at 72.2 %, with the Central & East region at 75.8 % and the South region at 82.4 %. It is notable that the countries within the South and East & Central regions have a similar non-residential floor space per capita but big differences in the residential floor space, with the average South region citizen having around 68 % more floor space than someone from the Central & East region (see also **Figure 1.9**).

[1] As of 2011 Croatia was not part of the EU and is not included. Within this chapter 'EU' means 'EU as of 2011' unless otherwise stated.

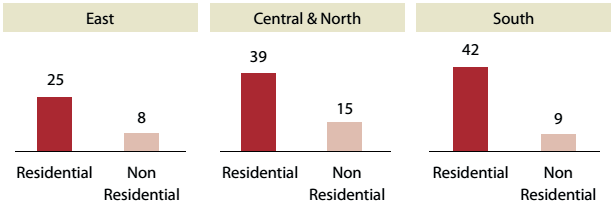


Figure 1.9: Floor space per capita, in m²

Residential

The residential stock itself can be divided into single family houses (ranging from detached houses to terraced houses) and apartment blocks, which house at least 2 and up to 30 or even more units. Across the EU single family houses have a 64 % share of the residential stock, but the individual numbers of the countries differ significantly; on the one end of the spectrum are Ireland and the UK with 89 % and 88 %, respectively, while Baltic States are on the other end with Lithuania at 26 % and Estonia at 31 %. Looking at the floor space per capita, the numbers for single family houses are across the board higher than those for apartment blocks.

Non-Residential

Even though the non-residential building stock represents only a quarter of the European building stock it is far more heterogeneous than the residential stock. Different interpretations on the distinction between categories across Europe make a comparison difficult, but the following broad categories are taken into consideration: Educational buildings, hospitals, hotels & restaurants, offices, sports facilities, wholesale & retail, and other energy-consuming buildings (e.g. warehouses, buildings for public transport, etc.). **Figure 1.10** shows the distribution between the different categories, with wholesale & retail and offices occupying more than half of non-residential floor space. Overall the different classifications between countries and a larger fluctuation of floor space between the categories gives non-residential data a bigger level of uncertainty.

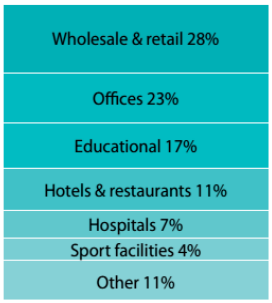


Figure 1.10: Non-residential floor space distribution

1.4.2 Characteristics

Location

On a European level almost half of the population live in densely inhabited areas (> 500 inhabitants/km²) with 49 %, 26 % live in intermediate populated areas (100-500 inhabitants/km²), and 25 % in thinly populated areas. The data from 18 countries shows a large variety in the level of urbanization, ranging from 35 % (Lithuania) and 42 % (Netherlands) to 78% (Norway) and 88 % (UK) (**Figure 1.11**). The urbanization can be a good indicator for the willingness to improve the energy efficiency on a larger scale, as the improvements affect more people in a given area.

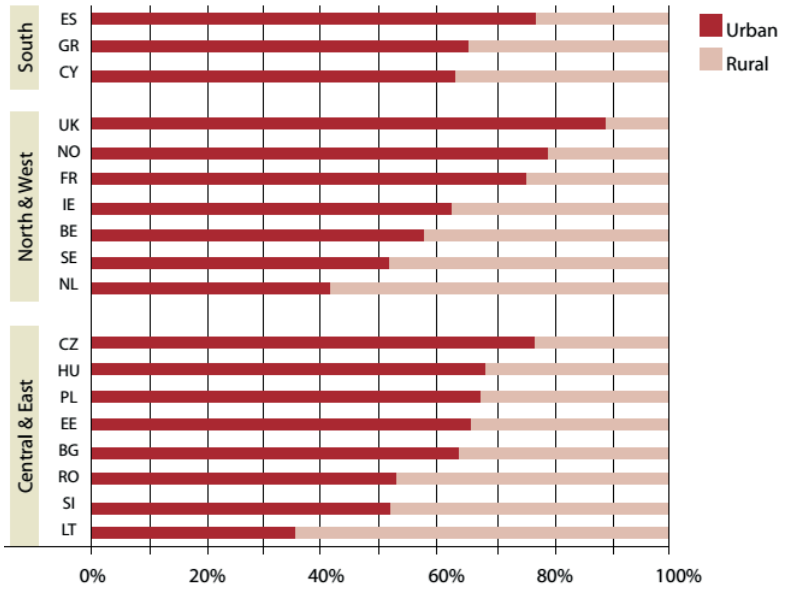


Figure 1.11: Location of residential buildings

Age

Without renovations the age of a building is usually tightly correlated to its energy consumption. This is partly the result of successively stricter regulations and partly a logical consequence of new technologies finding their way into building construction and maintenance. Additionally very old buildings can be of cultural value and be under monumental protection, making improvements and renovations harder and more costly. Between the regions the differences are relatively small, but do vary greatly from country to country (see **Figure 1.12**). Interestingly the North & West region has both the most 'old' (pre-1960) and 'recent' (1991 – 2010) buildings, with

42 % and 19 %, respectively. Whereas the 'modern (1961 – 1990) era saw a doubling of the existing building stock almost across the board the recent period has the South region with 14 % and the Central & East region with 17 % a bit behind the North & West, a result of the collapse of the Soviet Union and economic developments of the past decades.

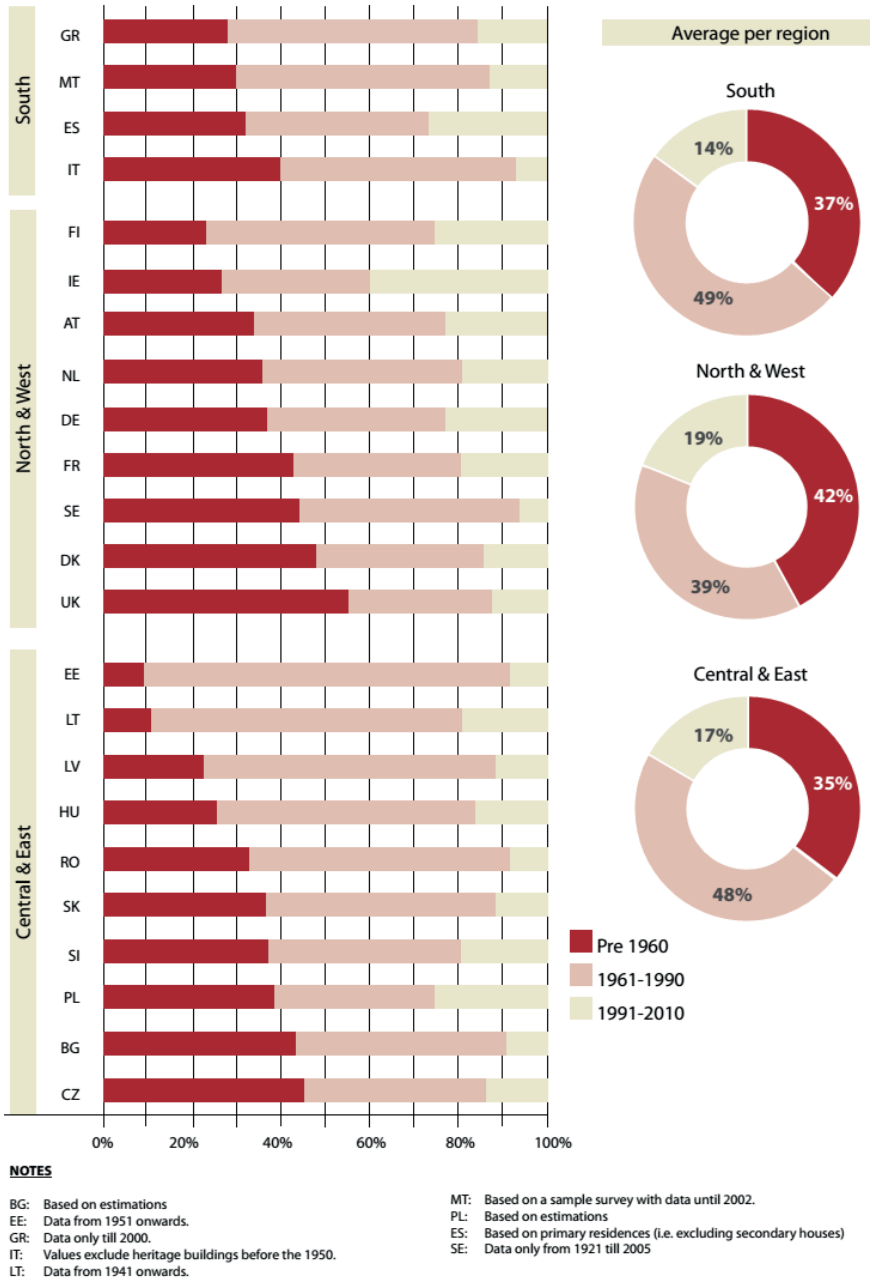


Figure 1.12: Age profile of residential floor space

Size

The South region has the most single family house floor space per capita, but ranks behind the North & West region in terms of apartment blocks (see **Figure 1.13**). As floor space is generally rarer and thus more expensive in an urban environment the higher numbers for apartments are an indicator of the wealth in the different regions.

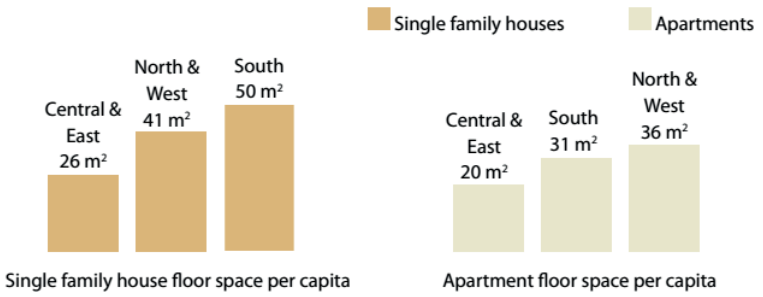


Figure 1.13: Average floor space of single family houses and apartments

Data on the size of non-residential buildings is only available for a few countries, but even this incomplete list shows – once again – a great variance between them (see **Figure 1.14**). Of note is the low percentage of buildings larger than 1000m²; this shows that any measures to improve the energy consumption and energy efficiency of non-residential buildings can only have their full effect if smaller buildings are included in those measures. Size wise educational buildings, hospitals and sports facilities are predominantly large buildings; hotels & restaurants, offices as well as wholesale & retail buildings can come in all sizes.

number	< 200 m²	200 - 1000 m²	> 1000 m²
EE	10	50	40
SI	89.8	8.8	1.4
LT	42	55	3
CY	79		21
AT	11	52	37

NOTES
The figures in the above tables are in % and add up to 100%.

AT: Values based on registered certificates, accounting for 1007 data sets of non-residential buildings, most of which are office buildings.
CY: Values refer to non-residential building permits issued from 2003-2009 (and % refers to <900 m² and > 900 m² of surface area)
SI: The data refer to all real estate units in non-residential use
EE, LT: Values based on estimations by national experts

Figure 1.14: Share of non-residential building sizes, in m²

1.4.3 Energy performance

The final energy consumption of buildings increased from 400 to 450 Mtoe during the last 20 years. Gas and electricity consumption increased dramatically, as did the use of renewable energy sources, albeit on a smaller scale. Solid fuels and oil is slowly being phased out, as the combined share of the two energy sources sank below 25 % (see also **Figure 1.15**).

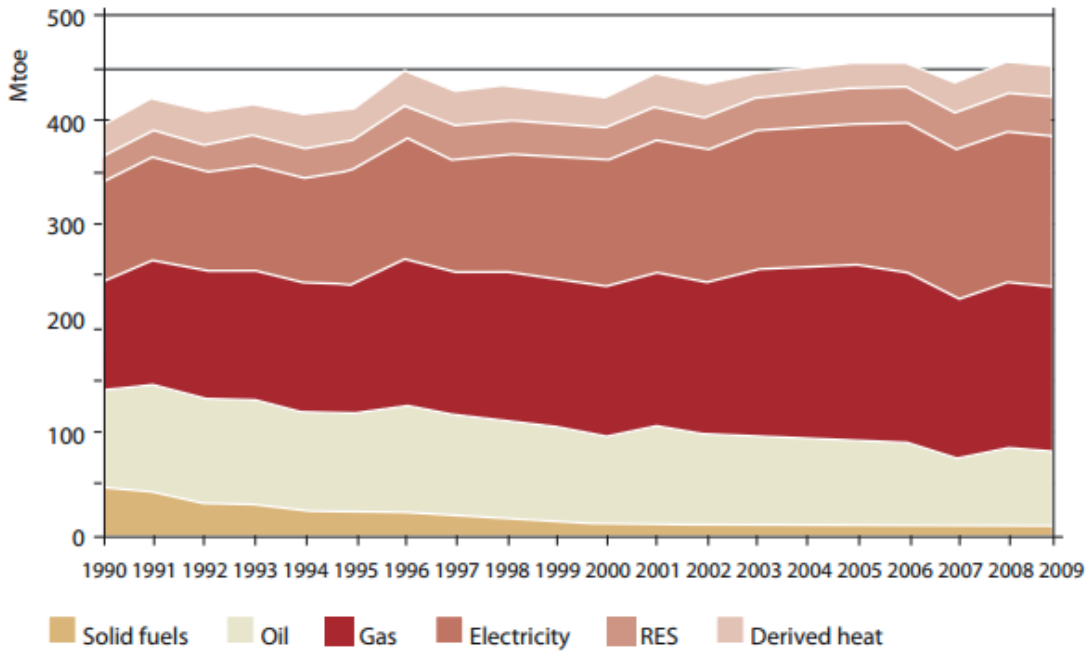


Figure 1.15: Final energy consumption in the building sector, 1990 – 2009

Residential buildings

The energy mix of residential buildings in the different regions is shown in **Figure 1.16**. The Central & East region is the only region with a significant share of solid fuels, but also boasts the highest share in renewable energy sources and district heating. The main fuel sources for both the North & West and the South regions are gas and electricity, with a combined share of 67 % and 68 %, respectively.

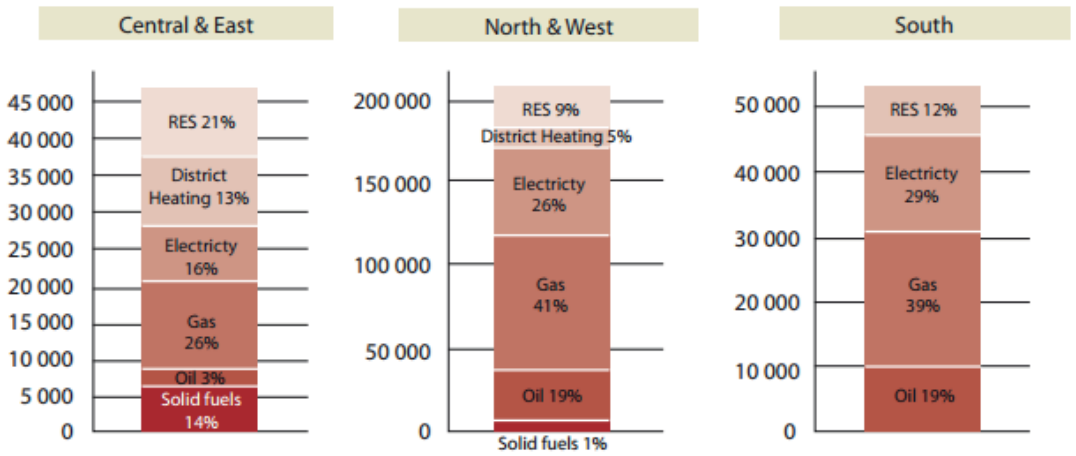


Figure 1.16: Final energy mix in residential buildings by region, in thousand toe

Unfortunately, detailed figures for specific energy performance indicators are difficult to compare between countries due to different categorization of building type and age. Differences in climatic conditions, behavioral characteristics, and social conditions present further difficulties for an accurate energy performance comparison between countries. In general the energy performance of buildings increased substantially over time due to technological advances and increased national regulations.

2. Energy Efficiency in European Legislation

2.1 The Makings of a Common Energy Police in Europe

When the European Coal and Steel Community (ECSC) – the first supranational organization in Europe and one of the precursors of the European Union – was founded in 1951 its focus was the creation of a common market for coal and steel to *"(…) make it plain that any war between France and Germany becomes not merely unthinkable, but materially impossible." (European Coal and Steel Community, 1950).* The European Economic Community (EEC), founded in 1957 in consequence of the Messina conference of 1955, continued the development of an internal common market, while the European Atomic Energy Community (Euratom), also founded in 1957, sought to develop nuclear energy in Europe to ensure energy supply in face of the rising consumption. Beside that energy policy was still a national matter though, and remained so until the oil crisis in 1973 elicited a renewed interest in a common energy policy.

The first step was the 1974 *Council Resolution concerning a new energy policy strategy for the Community*, which emphasized the need to secure the supply of energy as well as the rational use of energy to reduce consumption. The resolution was enhanced a few months later to include goals for 1985 regarding energy consumption and energy import dependency. But while the issue of environmental protection was being recognized as a discrete topic it was still in its infancy stages; energy and energy efficiency policies were mainly seen as economic matters.

The Single European Act of 1987 introduced environmental protection in the treaties for the first time, but member states balked at giving up authority over their national energy policies and these policies explicitly remained priority over the environmental policy of the community (Zacker, 1991). Likewise, the following Treaties of Maastricht (1992), Amsterdam (1999) and Nice (2003) failed to promote a common energy policy. Advances such as directive 2001/77/EC and 2003/30/EC, which aimed at promoting the generation of electricity from renewable resources and the use of renewable fuels, respectively, were predicated upon environmental regulations (Langsdorf, 2011). The only exception was directive 96/92/EC which

established common rules for the generation, transmission and distribution of electricity.

The first big change came in 2005, when the European Council agreed that a more integrated approach towards energy and energy efficiency was needed (European Council, 2005). Subsequently the Treaty of Lisbon (2007) first contained a passage on a common energy policy aiming to:

(a) *ensure the functioning of the energy market;*
(b) *ensure security of energy supply in the Union;*
(c) *promote energy efficiency and energy saving and the development of new and renewable forms of energy; and*
(d) *promote the interconnection of energy networks.*
(Treaty of Lisbon, 2007)

Also in 2007 the first Action Plan for Energy Efficiency was started, the goal being a 20 % reduction of annual consumption of primary energy by 2020, based on consumption forecasts (European Commission, 2007a). The commission proposed the now-famous 20 / 20 / 20 goals in the same year, targeting a 20 % share in renewable energies, a 20 % cut in GHG emissions and a 20 % increase in energy efficiency (the latter two based on 1990 levels) (European Commission, 2007b). A year later the *2020 Climate Energy Package* was adopted by the Union.

As part of the legislative package supporting these goals the Energy Efficiency Directive (2012/27/EU) and the Energy Performance of Buildings Directive (2010/31/EU) were adopted; the next chapters will take a closer look at the two directives and their provisions.

2.2 European Legislation concerning Energy Efficiency

2.2.1 The Energy Efficiency Directive 2012/27/EU

Precursors

The first legal decision leading towards an energy efficiency directive was taken in 1989 when the Council called for the introduction of a community action programme regarding the improvement of efficient electricity use (Decision 91/565/EEC). This was specified two years later as the SAVE (Specific Actions for Vigorous Energy Efficiency) programme, and in 1993 the directive 93/76/EEC to limit carbon dioxide emissions by improving energy efficiency was adopted. It called for the member states to implement programmes to improve energy efficiency, which includes *"laws, regulations, economic and administrative instruments, information, education and voluntary agreements whose impact can be objectively assessed"* (Directive 93/76/EEC).

The next step was decision 2006/32/EC on energy end-use efficiency and energy services (Directive 2006/32/EC), which also repealed 93/76/EEC. It required member states to adopt energy saving targets and for the first time submit National Energy Efficiency Action Plans (NEEAPs) with measures aiming at reaching the targets, with the public sector occupying an essential role in the fulfillment of these targets. In addition national public authorities were obliged to implement measures to promote energy efficiency and energy services.

After the European Union had announced its 2020 goal of 20 % increased energy efficiency the existing legal framework was seen as insufficient to reach the target, and in 2012 directive 2012/27/EU on energy efficiency was adopted, establishing a broader framework of measures aimed at reaching the set objective (Directive 2012/27/EU).

Directive 2012/27/EU

The NEEAPs that were introduced with the directive 2006/32/EC again are a central part. Member states are required to set an indicative national energy efficiency target based on either primary or final energy consumption, with respect to the Union's target figures for 2020 at 1474 Mtoe of primary energy and 1078 Mtoe of final energy, respectively (Article 3).

The targets are influenced by

(a) *“remaining cost-effective energy-saving potential;*
(b) *GDP evolution and forecast;*
(c) *Changes of energy imports and exports;*
(d) *Development of all sources of renewable energies, nuclear energy, carbon capture storage; and*
(e) *Early action.“*
(Directive 2012/27/EU, Article 3)

In 2014 the commission reported in its communication *Energy Efficiency and its contribution to energy security* and the *2030 Framework for climate and energy policy* that based on the member states and forecasts the energy saving estimates are at around 18 – 19 % (European Commission, 2014c), and reinforced that with a complete implementation of the legislation the 20 % target was still in no danger. The next progress review is set to take place in 2017.

Efficiency in Energy Use

Reducing the energy demand of buildings plays a crucial role in the improvement of demand-side energy efficiency. Member states are requested to set up a strategy to renovate the existing national stock of residential and commercial buildings, including an analysis of the best approach, policies and measures that need to be established, and an estimate of the energy savings and secondary benefits (Article 4). The strategy is published as part of the NEEAPs, and is to be updated every three years.

Like in its predecessor 2006/32/EC the public sector again has the duty to have an exemplary role in building stock renovation (Article 5). Member states are required to renovate 3 % of the total floor area of buildings owned by the central government, and of administrative departments a level below if required by a member state, to at least meet the minimum requirements set out in directive 2010/31/EU. Only the total floor area of buildings larger than 250 m² is used to calculate the annual renovation rate needed; before the 9th of July 2015 just buildings with a total floor area of 500 m² were taken into consideration. In addition buildings with special historical value, buildings of the armed forces as well as religious buildings can be exempted from the renovation rate.

In addition to the building renovations public bodies are to be encouraged to establish energy efficiency plans and hold energy audits to improve the energy performance of their buildings. If possible and financially feasible they are to use energy service companies or energy performance contracting to realize those plans. Public bodies are also required to only acquire products, services and buildings with high energy-efficiency performance, and to assess existing services for potential energy savings (Article 6).

Member states are obliged to create an energy efficiency obligation scheme, requiring energy distributors and retail energy sales companies to achieve a cumulative end-use energy saving target, which shall be *"at least equivalent to achieving new savings each year from 1 January 2014 to 31 December 2020 of 1,5 % of the annual energy sales to final customers of all energy distributors or all retail energy sales companies by volume, averaged over the most recent three-year period prior to 1 January 2013"* (2012/27/EU, Article 7). The member states themselves define which energy distributors and retail energy sales companies are to be part of the obligation scheme, and are also encouraged include social requirements, such as a minimum share of efficiency measures to be implemented in households affected by energy poverty.

To further promote energy efficiency the availability of independent energy audits is to be provided by governments, as well as programmes to support small and medium enterprises (SMEs) with energy audits (Article 8); other enterprises are required to hold an energy audit every 4 years. For more transparency on individual energy consumption final costumers are also to be provided with smart meters measuring consumption, either when an existing meter is replaced or when a new connection is made, if technically feasible (Article 9). In addition member states have to ensure the availability of accurate and individual billing information (Article 10 and 11).

Finally, member states have to promote efficient use of energy, through the provision of information, fiscal incentives and exemplary projects (Article 12). For the non-compliance of provisions implementing Articles 7-11 and Article 18 penalties are to be assessed (Article 13).

Efficiency in Energy Supply

On the supply side member states are to carry out an assessment on the national potential for efficient cogeneration and efficient district heating and cooling (Article 14). Member states either have to develop financially feasible projects themselves or at least accommodate for the development of them by third parties. In addition thermal electricity generation installations with a total thermal input exceeding 20 MW that are to be constructed or refurbished, as well as new district heating and cooling systems of the same magnitude, have to undergo a cost-benefit analysis to guarantee their use in the context of energy efficiency.

Member states are also required to assess additional energy efficiency potential of their gas and electricity infrastructure (Article 15). Their national authorities have to provide incentive for grid operators to implement energy efficiency measures and ensure that taxes, network tariffs and regulations aren't detrimental to the development of better grid efficiency. To maintain the reliability and safety of the grid, transmission and distribution operators are also required guaranteeing access, transmission and distribution of electricity from high-efficiency cogeneration.

Other Provisions and Outlook

In addition to the two big chapters previously discussed the Energy Efficiency Directive includes provisions for the availability of qualification, accreditation and certification schemes (Article 16), information and training regarding energy efficiency mechanisms (Article 17), as well as the promotion of the energy services market with emphasis on better access for SME's (Article 18).

Some of the provisions of the energy efficiency directive have included the option for member states to develop and implement alternative approaches than the ones outlined in the directive, provided that the energy savings achieved through them is at least equivalent to the savings achieved through the proposed provisions of the directive. Member states using such an alternative approach have to notify the commission of the alternative and provide calculations and explanations how this equivalent level can be reached.

As of today it is not possible to assess the impact of the energy efficiency directive; most of the provisions had to be implemented into national law by 1 January 2014, but many measures - such as renovation schemes for public buildings - are not yet in effect, or have been in effect for longer than the Energy Efficiency directive; the new provisions already in effect haven't been so for long enough to be properly assessed. The commission is optimistic that proper national implementation of the energy efficiency directive will be sufficient to reach the targets for primary or final energy consumption, and forecasts seem to confirm this sentiment.

2.2.2 Directive 2010/31/EU on the energy performance of buildings

The first building directive

In 1993 Directive 93/76/EEC and the SAVE programme became the first community policies on the energy efficiency of buildings. But while they had a tangible impact on building energy efficiency the general sentiment was that a common framework and more specific actions were needed, and in the wake of the signing of the Kyoto protocol the member states agreed on Directive 2002/91/EC on the energy performance of buildings (Directive 2002/91/EC).

The directive established requirements for:

(a) *the general framework for a methodology of calculation of the integrated energy performance of buildings;*
(b) *the application of minimum requirements on the energy performance of new buildings;*
(c) *the application of minimum requirements on the energy performance of large existing buildings that are subject to major renovation;*
(d) *energy certification of buildings; and*
(e) *regular inspection of boilers and of air-conditioning systems in buildings and in addition an assessment of the heating installation in which the boilers are more than 15 years old.*
(2002/91/EC)

When the European Union started its ‘Action Plan for Energy Efficiency’ in 2007 a strengthening and rework of the building directive was deemed necessary. The result was the Directive 2010/31/EU on the energy performance on buildings (from here on abbreviated EPBD), which added the development of nearly zero-energy buildings and more detailed requirements for existing provisions (Directive 2010/31/EU).

Directive 2010/31/EU

At the core of the EPBD is a common framework for a methodology for the calculation of the energy performance of buildings (Article 3), which is described as:

The energy performance of a building shall be determined on the basis of the calculated or actual annual energy that is consumed in order to meet the different needs associated with its typical use and shall reflect the heating energy needs and cooling energy needs (energy needed to avoid overheating) to maintain the envisaged temperature conditions of the building, and domestic hot water needs. (2010/31/EU, Annex I)

Based on this methodology member states have to establish minimum energy performance requirements for buildings or building units (Article 4), with distinctions between new and existing buildings as well as between different building categories. As in the energy efficiency directive buildings with special historical value and religious buildings can be exempted from these minimum energy performance requirements, as can certain buildings with low energy demand; interestingly the buildings owned by the armed forces can according to the EPBD not be exempted. The requirements are also subject to a review in regular intervals of five years at most, and updated to reflect technical progress on energy efficiency.

Member states are also required to calculate cost-optimal levels of minimum energy performance requirements (Article 5), with cost-optimal being defined as the *"(…) energy performance level which leads to the lowest cost during the estimated economic lifecycle, (…)"* (2010/31/EU, Article 2). The comparative methodology framework for these calculations was supplemented in 2012 via a commission delegated regulation (European Union, 2012). By this framework member states have to:

- define representative reference buildings for different categories of residential and non-residential buildings, both new and existing ones;
- identify energy efficiency measures and/or measures based on renewable energy sources for those reference buildings
- calculate the primary energy demand of the reference buildings both before and after the measures have been applied
- calculate the costs of the measures for each reference building, accounting for investment costs, maintenance and operating costs, energy costs and if applicable disposal costs

The calculations and results have to be reported to the commission in regular intervals, either as part of the National Energy Efficiency Action Plan or as a separate document. Disproportionate differences between the implemented minimum energy performance requirements and the cost-optimal levels of requirements require an explanation of the causes for this difference and steps being taken to reduce the disparity by the next review of the minimum energy performance requirements.

Building and building element requirements

All new buildings are subject to the minimum energy performance requirements (Article 6). Member states are also required to ensure that during planning phase the feasibility of decentralized energy supply systems, cogeneration, district heating and/or cooling, and heat pumps is to be considered. Existing buildings that undergo major renovations likewise have to get their energy performance upgraded to meet the minimum energy performance requirements (Article 7), as long as the measures are technically, economically and functionally viable. This also applies to refitting or replacing of building elements that have a significant impact on energy performance.

Technical building systems, which include systems for heating, hot water, air conditioning, or large ventilation systems, also have system requirements regarding the *"(…) overall energy performance, the proper installation, and the appropriate dimensioning, adjustment and control (…)"* (2010/31/EU, Article 7). These apply mainly for the upgrade or replacement of technical building systems, but member states are free to apply those requirements to new buildings too.

The EPBD also introduces nearly zero-energy buildings (NZEBs), defining them as *"(…) a building that has a very high energy performance (…). The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby"*(2010/31/EU, Article 2). Member states need to ensure that by 2021 all new buildings are NZEBs, and by 2019 all new buildings occupied and owned by public authorities, and develop policies and programmes aimed at encouraging the transformation of buildings undergoing renovation into NZEBs.

Member states are also required to formulate national plans to increase NZEBs and submit them to the commission. They include the national definition of a NZEB, immediate targets for improving energy efficiency of new buildings, and information on policies and measures promoting NZEBs.

Energy Performance Certificates and System Inspections

The EPBD also requires member states to establish a system of energy performance certification of buildings (Article 11). This energy performance certificate includes the energy performance itself as well as reference values, for example the minimum energy performance requirements. It also has to include recommendations for cost-effective improvements of the energy performance, covering both measures carried out during a major renovation and measures for individual building elements that can be replaced independent of a building renovation.

The maximum validity of the energy performance certificates is 10 years, and must be issued for any building larger than 250 m² (before 2015: 500 m²) that is constructed, sold or rented out to a new tenant (Article 12). When sold or rented out, member states have to ensure that an energy performance indicator, which is part of the energy performance, is stated in commercial advertisements.

Buildings occupied and owned by public authorities and larger than 250 m² are required to display the energy performance certificate in a prominent place and clearly visible (Article 13); this also applies to other buildings larger than 500 m² and frequented by the public. Public authorities are also encouraged to implement recommendations included in the energy performance certificate within its validity period to meet their responsibility as role models in the area of energy efficiency.

In addition to the system requirements for technical building systems that are laid down in Article 8, member states are asked to implement regular inspections of heating systems with boilers of an effective rated output of more than 20 kW (Article 14), and of air-conditioning systems of an effective rated output if more than 12 kW (Article 15). The inspection includes an assessment of the system efficiency and the sizing of the system compared to the heating or cooling requirements of the building. Heating systems with a boiler of an effective output rate of more than 100 kW require inspection at least every two years, in the case of gas boilers every four years. As part of the inspections a report is to be issued containing the results of the inspection as well as – if necessary – recommendations for cost-effective improvements of the system's energy performance (Article 16).

The EPBD also requires the energy performance certificates and system inspections to be carried out by qualified experts in an independent manner (Article 17), as well as independent control systems for certificates and inspections (Article 18).

Other Provisions and conclusion

To increase the efficiency of policies promoting the EBPD (not counting those already required by it) member states need to compile a list of measures and financial instruments, and update that list every three years (Article 10). The commission reviews these lists, can issue advice or recommendations on national schemes and coordination with the Union. Member states can also request assistance in the setup of national financial support programmes aimed at increasing energy efficiency in buildings.

Member states also have to provide information on different methods and practices aimed at the improvement of building energy performance, in particular the purpose and objectives of energy performance certificates and inspection reports (Article 20). Public authorities in charge of implementation of the directive have to have access to training and guidance, addressing the importance of energy efficiency and the optimization of energy efficiency measures.

The transposition deadline of the EBPD in member states was set to July 2012, but as of July 2014 9 member states had not yet fully transposed the EBPD into their national laws (Grözinger et al, 2014). The Commission noted the same year in a report on the implementation of a definition and the promotion of NZEBs 21 of the member states included immediate targets for NZEBs in their national plans, but only 15 of them had full definitions in place. In June 2015 an evaluation of the EPBD was initiated by the commission, with a possible revision planned based on the findings of the evaluation (European Commission, 2015a).

3. Austrian Implementation of European Energy Efficiency Laws

3.1 Implementation of 2012/27/EU

The Austrian Bundes-Energieeffizienzgesetz (EEffG), which became fully effective on January 1 2015, is the main law of Austria's Energy Efficiency Package implementing the Energy Efficiency Directive (EEffG, 2014). As required by Article 3 of the Energy Efficiency Directive Austria set its target for final energy consumption at 1050 PJ, and additionally cumulative final energy efficiency savings of 310 PJ are targeted, divided into 159 PJ savings through contributions from energy suppliers and 151 PJ through strategic measures.

Some provisions of the Energy Efficiency Directive were already established by previous laws, and other provisions are still in part under evaluation by the Ministry of Economy, Family and Youth and third parties. To have a better overview on how the directive is implemented into Austrian law articles 4 – 18 are discussed separately, with **Table 3.1** providing a summary. The progress in the implementation of 2012/27/EU is also discussed in the Austrian National Energy Efficiency Action Plan 2014, although that progress report does not yet include the final provisions of the EEffG.

Table 3.1: Status of implementation of the Energy Efficiency Directive

EED Art.	EEffG	Other laws & measures	Under Evaluation
Article 4	x		
Article 5		x	
Article 6	x		
Article 7	x	x	
Article 8	x		
Article 9		x	
Article 10		x	
Article 11		x	
Article 12	x	x	
Article 13			
Article 14		x	x
Article 15		x	x
Article 16		x	x
Article 17	x		
Article 18	x		

Article 4 – Building Renovation

The main laws relevant to the renovation of buildings are the building codes and the Wohnbauförderungs-Gesetze (translated “Laws on residential building subsidies”) of the 9 federal states, who also are responsible for setting a strategy on building renovations.

Additionally there are both federal state and federal initiatives regarding the renovation of buildings. An example for a federal measure is the “Sanierungsoffensive der Österreichischen Bundesregierung”, which provides one-time, non-repayable funding for thermal renovations for buildings older than 20 years; an exemplary federal state measure is the urban energy efficiency programme of the city of Vienna, which includes consultation, funding and information on the improvement of energy efficiency.

Article 5 - Exemplary role of public bodies’ buildings

Austria opted for an alternative approach than the one proposed in the Energy Efficiency Directive; according to § 16 EEffG a package of measures is to be developed until the end of 2015, with the planned energy savings for public buildings calculated to be a cumulative 48.2 GWh between 2014 and 2020. According to the 2014 NEEAP savings made in 2014 accounted for 3.7 GWh (BMWFW, 2014), which were mainly achieved through energy contracting, energy-related renovation

measures and energy management. As the necessary savings per year only need to be at least 1.7 GWh Austria's current savings exceed that benchmark by far.

Of note is that buildings owned by federal states or communities are not included in § 16 EEffG.

Article 6 - Purchasing by public bodies

The purchasing of public bodies is regulated by the Bundesvergabegesetz, which was amended in 2013 to now require certain energy performance standards for products and services that are to be purchased (BVergG, 2006). Additionally § 15 EEffG requires public bodies to take energy efficiency concerns into consideration when purchasing or renting immovable assets, with special emphasis on the acquisition of buildings or building parts.

Article 7 – Energy efficiency obligation schemes

Likewise to the implementation of Article 5, Austria opted for an alternative approach with a combination of an energy obligation scheme and strategic measures. § 10 and 11 EEffG require energy suppliers to adopt energy efficiency measures amounting to yearly savings of 0.6 % of their energy sales, with at least 40 % of those measures targeted at households. Additionally Austria outlined their strategic measures in their NEEAP, those measures being divided into the following groups:

- Residential building subsidies of the federal states,
- Environmental funding for companies,
- Legal regulations on the promotion of district heating,
- Energy taxes,
- Lorry toll,
- Clean power subsidies,
- Improvements in building codes, and
- Additional measures.

Article 8 – Energy audits and energy management system

§ 9 EEffG requires large companies to either hold energy audits at least every four years, or have a certified energy management system in place. Small and medium companies have no obligation, but can utilize energy consultation at least every 4 years.

§ 17 and 18 EEffG lay down quality standards for energy contractors, energy consultations and energy audits, as well as minimum requirements for energy audits.

Article 9 – Metering

The *Intelligente Messgeräte-Einführungsverordnung* (Regulation for the implementation of Smart-meters), adopted in 2012, targets to equip at least 70 % of all meter points with smart meters by the end of 2017, and subject to technical feasibility 95 % by the end of 2019 (IME-VO, 2012).

Article 10 – Billing information, and Article 11 – Cost of access to metering and billing information

Acts regarding billing information and its cost were already implemented by the time of the Energy Efficiency Directive, in laws regarding the electricity industry, the gas industry, and the billing of heating costs.

Article 12 – Consumer information and empowering programme

§ 13 requires the government to provide information to energy suppliers and large companies regarding their obligations, implement programmes to promote energy audits of smaller companies and households, and raise awareness for energy efficiency. In addition to information campaigns of various regional energy agencies the main nationwide programme is *klimaaktiv*, an initiative of the Austrian Energy Agency providing information, consulting and training on energy topics.

Article 13 – Penalties

So far no penalties have been defined for violations of Articles 7 to 11 and 18.

Article 14 – Promotion of efficiency in heating and cooling

As part of Austria's Energy Efficiency Package the laws on cogeneration and the development of cogeneration lines were amended and an additional law for the indemnity of the operation of high-efficiency cogeneration plants was implemented. The Federal Ministry of Science, Research and Economy also commissioned a study on the assessment of the potential of high-efficiency cogeneration and district heating.

Article 15 – Energy transformation, transmission and distribution

The current tariffication of the electricity and gas grids is the duty of the regulatory authority E-Control on base of the laws regarding the electricity and gas industries. As with Article 14 the Federal Ministry of Science, Research and Economy is conducting a study on the potential for energy improvements.

Article 16 - Availability of qualification, accreditation and certification schemes

Apart from the requirements for energy contractors according to § 17, two certification programmes - *Umweltzeichen Contracting* and *Thermoprofit* - are currently in place, as well as training programmes for the qualification of energy consultants as part of *klimaaktiv*. Analogous to the previous articles a study on possible further implementations of Article 16 is currently being conducted.

Article 17 – Information and Training

In addition to the information requirements of § 13 (see Article 12), § 14 requires every national agency to have a qualified energy expert, tasked with the documentation, evaluation and report of energy statistics. The Energy Agencies of the federal states are in charge of the promotion of information and training of energy contractors.

Article 18 – Energy Services

Pursuant to § 13 the government is required to provide information to small and medium enterprises on energy services, as well as providing requirements for model energy contracts. The in 2013 founded DECA, an umbrella organization for energy and energy efficiency contractors, provides a network for the propagation of high-quality energy services, and *klimaaktiv* provides additional information on energy services.

3.2 Implementation of 2010/31/EU

The OIB (Austrian Institute of Construction Engineering)

As previously mentioned legislation on buildings and building codes is mainly a matter of the federal states. This means that there are not one, but nine different sets of building codes, laws and regulations. However in 1993 – two years before Austria joined the European Community - the federal states agreed to implement D*irective 89/106/EEC on the approximation of laws, regulations and administrative provisions of the Member States relating to construction products* (Directive 89/106/EEC), and reached an agreement on a closer cooperation in regards to construction and building laws (Agreement of the federal States, 1993). Part of this agreement was the establishment of the Austrian Institute of Construction Engineering (OIB) as a coordination platform of the federal states. The responsibilities of the OIB are:

- To act as European technical assessment body and National approval body for construction products,
- To promote harmonization of technical requirements in construction laws through guidelines,
- To be a market surveillance authority ensuring that construction products meet the legal requirements, and
- To provide information on technical requirements of construction products.

Part of the harmonization process is the periodical release of guidelines that serve as a template for implementation in the federal states. Overall 6 main guidelines have been released in 2007 and since been updated twice, the first revision coming in 2011 and the second one in 2015. Those guidelines include:

1. Mechanical resistance and stability
2. Safety in case of fire
3. Hygiene, health and preservation of the environment
4. Safety in use and accessibility
5. Protection against noise
6. Energy saving and thermal protection

Guideline 6 on energy savings and thermal protection is the one implementing the Energy Performance of Buildings Directive (OIB, 2015a). The first OIB guidelines were issued in 2007, and since then two revisions have been released, the first in 2011 and the second in 2015. On October 1 2015 the city of Vienna was the first federal state to incorporate the newest revision of the OIB guidelines into their building code via regulation (WBTV, 2015). Because a review of all nine federal state laws would be impractical OIB documents and the building-related legislation of Vienna will be used as references for the implementation of the EBPD; if not otherwise indicated any laws and regulations discussed below are those of Vienna. As with the energy efficiency directive the articles of the EBPD will be discussed one by one, focusing on articles 3 – 16.

Article 3 - Adoption of a methodology for calculating the energy performance of buildings

The methodology of the calculation of the energy performance of buildings is laid down in the OIB handbook on energy-related properties of buildings (OIB, 2015b). It is based on standards released by the Austrian Standards Institute.

Article 4 - Setting of minimum energy performance requirements

For both residential and non-residential buildings, new or renovated, the minimum energy performance requirements are set in chapter 4 of the OIB guideline 6. The requirements are based on four indicators: Heating energy demand (building envelope), the overall energy efficiency factor (building technology), primary energy demand (saving of resources) and carbon dioxide emissions (climate protection). The 2014 numbers in **Tables 3.2-3.5** represent the current minimum energy requirements for residential and non-residential buildings. Additional minimum requirements for the thermal transmittance of building parts are too included.

Additionally § 118 (1) of the building code (abbreviated BO) requires buildings and building parts to be built so that their energy consumption matches the current state of the art, based on the intended use of it (Bauordnung für Wien, 2013).

Article 5 - Calculation of cost-optimal levels of minimum energy performance requirements

The calculations are established in the OIB document for the verification of the cost-optimality of the minimum requirements covered in the OIB guideline 6, which was released in March 2014 (OIB, 2014a).

Article 6 - New buildings, and Article 7 – Existing buildings

Part 9 of the building code lays down basic requirements for constructional requirements, with § 122 BO stating that regulations of the federal state government determine the circumstances under which the constructional requirements are fulfilled. This is the basis for the previously mentioned regulation that incorporates the OIB guidelines into the building code, and thus requires the minimum energy performance requirements described in chapter 4 of OIB guideline 6.

In addition chapter 4 gives out minimum requirements regarding the renewable share of the energy used. It requires either a 50 % share of renewable energy taken from outside the building such as biomass, cogeneration or district heating, or a 10 % share of renewable energy generated on site through heat recovery, photovoltaics or solar thermal collectors. § 118 (3) BO requires any construction or major renovation to use highly-efficiency alternative systems if technically and economically feasible.

Article 8 – Technical building systems

Standards released by the Austrian Institute for Standards are available for water-based heating systems (ÖNORM, 2004), and for heating, ventilation and air condition systems (ÖNORM, 2002). Chapter 9 of OIB guideline 6 has included reference equipment for buildings that describes the current state of the art of technical building systems. The only indirect performance requirements for technical building systems is the overall energy efficiency factor that has to be calculated for new buildings and major renovations.

Article 9 – Nearly Zero Energy Buildings

The OIB released a document on the national definition of a nearly zero-energy building and the establishment of intermediate goals (OIB, 2014b). They include a successive reduction of the minimum requirement of buildings in three steps until 2020, with the 2020 targets representing the Austrian definition of an NZEB. They are shown in **Tables 3.2-3.5**.

Table 3.2: Minimum energy performance requirements for new residential buildings

R-NEW	HWB_{max} [kWh/m²a]	$f_{GEE,max}$ [-]	PEB_{max} [kWh/m²a]	$CO2_{max}$ [kg/m²a]
2014	16 x (1 + 3.0 / l_c)	0.9	190	30
2016	16 x (1 + 3.0 / l_c)	0.85	180	28
2018	16 x (1 + 3.0 / l_c)	0.8	170	26
2020	16 x (1 + 3.0 / l_c)	0.75	160	24

Table 3.3: Minimum energy performance requirements for new non-residential buildings

NR-NEW	HWB_{max} [kWh/m²a]	$f_{GEE,max}$ [-]	PEB_{max} [kWh/m²a]	$CO2_{max}$ [kg/m²a]
2014	5.5 x (1 + 3.0 / l_c)	*	230	36
2016	5.5 x (1 + 3.0 / l_c)	*	210	33
2018	5.5 x (1 + 3.0 / l_c)	*	190	30
2020	5.5 x (1 + 3.0 / l_c)	*	170	27

Table 3.4: Minimum energy performance requirements for existing residential buildings after a major renovation

R-REN	HWB_{max} [kWh/m²a]	$f_{GEE,max}$ [-]	PEB_{max} [kWh/m²a]	$CO2_{max}$ [kg/m²a]
2014	25 x (1 + 2.5 / l_c)	1.1	230	38
2016	25 x (1 + 2.5 / l_c)	1.05	220	36
2018	25 x (1 + 2.5 / l_c)	1	210	34
2020	25 x (1 + 2.5 / l_c)	0.95	200	32

Table 3.5: Minimum energy performance requirements for existing non-residential buildings after a major renovation

NR-REN	HWB_{max} [kWh/m²a]	$f_{GEE,max}$ [-]	PEB_{max} [kWh/m²a]	$CO2_{max}$ [kg/m²a]
2014	8.5 x (1 + 2.5 / l_c)	*	300	48
2016	8.5 x (1 + 2.5 / l_c)	*	280	45
2018	8.5 x (1 + 2.5 / l_c)	*	260	42
2020	8.5 x (1 + 2.5 / l_c)	*	240	39

HWB_{max} heating energy demand, maximum

$f_{gee, max}$ overall energy efficiency factor, maximum

PEB_{max} primary energy demand, maximum

$CO2_{max}$ carbon dioxide emissions, maximum

*The values are based on the HWB_{max}-value and the reference equipment in OIB guideline 6

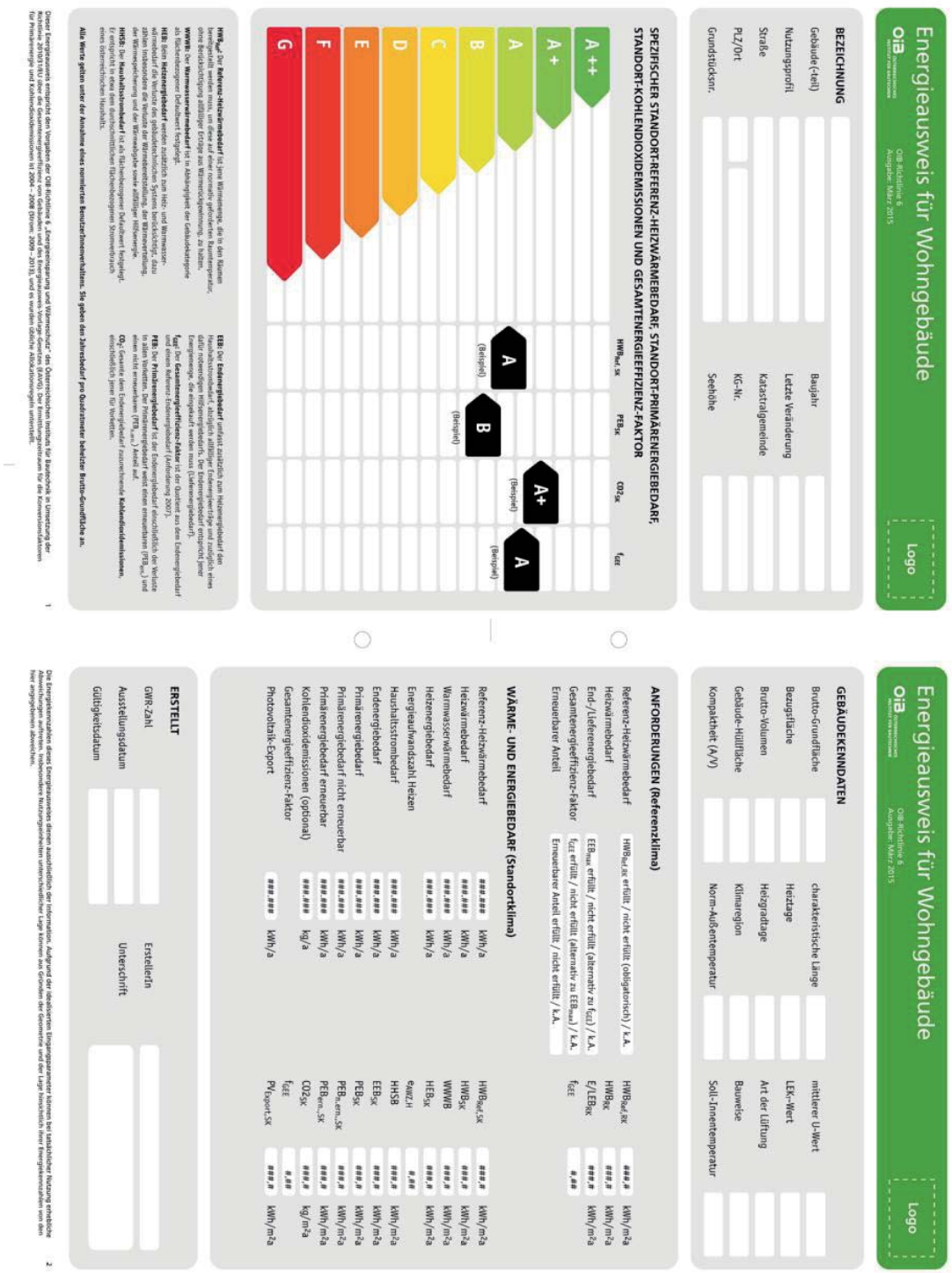
Article 10 – Financial Incentives and Market Barriers

As discussed in the implementation of Article 4 of the EED there are various financial programmes in Austria for the construction or renovation of buildings. In the context of the Wohnbauförderung alone the nine federal states subsidized renovations and constructions worth more than 2.5 billion Euros (BMF, 2015). In addition there are initiatives on the funding of thermal renovations, clean power, and energy efficiency, among others.

Article 11 - Energy performance certificates, and Article 12 – Issue of energy performance certificates

For any new buildings, as well as any renovation including at least 25 % of the building envelope, § 63 of the building code requires the issue of an 'Energieausweis', which is described in chapters 6 and 7 of OIB guideline 6. The layout of the Energieausweis is shown in **Figure 3.1**. In addition to these 2 standardized pages the Energieausweis has to include building data and any used standard for the calculation of the energy values, as well as recommendations on measures that improve the energy performance of the building in question while being financially and technically feasible. The Energieausweis of buildings that are being newly constructed of have just had a major renovation aren't required to include recommendations. § 118 (5) BO requires the Energieausweis to be issued by accredited bodies and puts the maximum validity of one at 10 years.

In addition to the regulations on the Energieausweis of the federal states a federal law, the EAVG, requires anyone selling or renting out a building or building parts to produce an Energieausweis (EAVG, 2012).



Energieausweis für Wohngebäude

OIB Richtlinie 6
Ausgabe: März 2015

Logo

BEZEICHNUNG

Gebäude (-teil)	Baujahr	
Nutzungsprofil	Letzte Veränderung	
Straße	Katastralgemeinde	
PLZ/Ort	KG-Nr.	
Grundstücksnr.	Seehöhe	

SPEZIFISCHER STANDORT-REFERENZ-HEIZWÄRMEBEDARF, STANDORT-PRIMÄRENERGIEBEDARF, STANDORT-KOHLENDIOXIDEMISSIONEN UND GESAMTENERGIEEFFIZIENZ-FAKTOR

$HWB_{Ref,SK}$ PEB_{SK} $CO2_{SK}$ f_{GEE}

A ++
A +
A (Beispiel)
B (Beispiel)
A+ (Beispiel)
A (Beispiel)
C
D
E
F
G

HWB$_{Ref}$: Der **Referenz-Heizwärmebedarf** ist jene Wärmemenge, die in den Räumen benötigt wird, um diese auf einer normativ geforderten Raumtemperatur, ohne Berücksichtigung zusätzlicher Erträge aus Wärmegewinnung, zu halten.

WWWB: Der **Warmwasserwärmebedarf** ist in Abhängigkeit der Gebäudekategorie als flächenbezogener Defaultwert festgelegt.

HEB: Beim **Heizenergiebedarf** werden zusätzlich zum Heiz- und Warmwasserbedarf die Verluste des gebäudetechnischen Systems berücksichtigt, dazu zählen die Verluste der Übergabe, der Speicherung, der Verteilung und der Wärmeabgabe sowie zusätzliche Hilfsenergie.

HHSB: Der **Haushaltsstrombedarf** ist als flächenbezogener Defaultwert festgelegt. Er entspricht in etwa dem durchschnittlichen flächenbezogenen Stromverbrauch eines österreichischen Haushalts.

EEB: Der **Endenergiebedarf** umfasst zusätzlich zum Heizenergiebedarf den Haushaltsstrombedarf, allfällig allfälliger Endenergieverträge und zusätzlich eines dafür notwendigen Hilfsenergiebedarfs. Der Endenergiebedarf entspricht jener Energiemenge, die eingekauft werden muss (Lieferenergiebedarf).

f$_{GEE}$: Der **Gesamtenergieeffizienz-Faktor** ist der Quotient aus dem Endenergiebedarf und einem Referenz-Endenergiebedarf (Arbeitszeitung 2007).

PEB: Der **Primärenergiebedarf** ist der Endenergiebedarf einschließlich der Verluste aus der Bereitstellung der jeweiligen Energieträger. Er gibt einen nicht erneuerbaren (PEB$_{n.ern.}$) und einen nicht erneuerbaren (PEB$_{ern.}$) Anteil auf.

CO$_2$: Gesamte dem Endenergiebedarf zuzurechnende **Kohlendioxidemissionen**, einschließlich jener für Vorketten.

Alle Werte gelten unter der Annahme eines normierten Benutzerverhaltens. Sie geben den Jahresbedarf pro Quadratmeter beheizter Brutto-Grundfläche an.

Dieser Energieausweis entspricht den Vorgaben der OIB-Richtlinie 6 „Energieeinsparung und Wärmeschutz" des Österreichischen Instituts für Bautechnik in Umsetzung der Richtlinie 2010/31/EU über die Gesamtenergieeffizienz von Gebäuden und des Energieausweis-Vorlage-Gesetzes (EAVG). Der Berechnungszeitraum für die Konversionsfaktoren für Primärenergie und Kohlendioxidemissionen ist 2004 – 2008 (Strom: 2009 – 2013), und es wurden jährliche Mittelwerte verwendet.

1

Energieausweis für Wohngebäude

OIB Richtlinie 6
Ausgabe: März 2015

Logo

GEBÄUDEKENNDATEN

Brutto-Grundfläche		charakteristische Länge	
Bezugsfläche		Heiztage	
Brutto-Volumen		Heizgradtage	
Gebäude-Hüllfläche		Klimaregion	
Kompaktheit (A/V)		Norm-Außentemperatur	

	mittlerer U-Wert		
	LEK-Wert		
	Art der Lüftung		
	Bauweise		
	Soll-Innentemperatur		

ANFORDERUNGEN (Referenzklima)

Referenz-Heizwärmebedarf	$HWB_{Ref,Rk}$ erfüllt / nicht erfüllt (obligatorisch) / k.A.	$HWB_{Ref,BK}$ ###,# kWh/m²a
Heizwärmebedarf		HWB_{BK} ###,# kWh/m²a
End-/Lieferenergiebedarf	EEB_{BK} erfüllt / nicht erfüllt (alternativ zu f_{GEE}) / k.A.	E/LEB_{BK} ###,# kWh/m²a
Gesamtenergieeffizienz-Faktor	f_{GEE} erfüllt / nicht erfüllt (alternativ zu EEB_{BK}) / k.A.	f_{GEE} #,##
Erneuerbarer Anteil	Erneuerbarer Anteil erfüllt / nicht erfüllt / k.A.	

WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	### ### kWh/a	$HWB_{Ref,SK}$	###,# kWh/m²a
Heizwärmebedarf	###,### kWh/a	HWB_{SK}	###,# kWh/m²a
Warmwasserwärmebedarf	###,### kWh/a	WWWB	###,# kWh/m²a
Heizenergiebedarf	###,### kWh/a	HEB_{SK}	###,# kWh/m²a
Energieaufwandszahl Heizen		$e_{AWZ,H}$	#,##
Haushaltsstrombedarf	###,### kWh/a	HHSB	###,# kWh/m²a
Endenergiebedarf	###,### kWh/a	EEB_{SK}	###,# kWh/m²a
Primärenergiebedarf	###,### kWh/a	PEB_{SK}	###,# kWh/m²a
Primärenergiebedarf nicht erneuerbar	###,### kWh/a	$PEB_{n.ern.,SK}$	###,# kWh/m²a
Primärenergiebedarf erneuerbar	###,### kWh/a	$PEB_{ern.,SK}$	###,# kWh/m²a
Kohlendioxidemissionen (optional)	###,### kg/a	$CO2_{SK}$	###,# kg/m²a
Gesamtenergieeffizienz-Faktor		f_{GEE}	#,##
Photovoltaik-Export	###,### kWh/a	$PV_{Export,SK}$	###,# kWh/m²a

ERSTELLT

GWR-Zahl		Erstellerin	
Ausstellungsdatum		Unterschrift	
Gültigkeitsdatum			

Die Energiekennzahlen dieses Energieausweises dienen ausschließlich der Information. Aufgrund der idealisierten Eingangsparameter können bei tatsächlicher Nutzung erhebliche Abweichungen auftreten. Insbesondere Nutzungszeiten und -intensitäten unterschiedlicher Lage können aus Gründen der Geometrie und der Lage hinsichtlich Ihrer Energiekennzahlen von den hier angegebenen abweichen.

2

Figure 3.1: Layout of the two mandatory pages of an Austrian Energieausweis

Article 13 – Display of energy performance certificates

§ 118 (4) BO requires the display of an Energieausweis in a clearly visible place for any building with a total useful floor space of more than 500 m² that is visited frequently by the public; since July 9 2015 the threshold for buildings used by public authorities that are visited frequently was lowered to 250 m².

Article 14 - Inspection of heating systems, Article 15 – Inspection of air-conditioning systems, and Article 16 - Reports on the inspection of heating and air-conditioning systems

The inspection of heating and air conditioning systems is regulated with a law on fire authority, air monitoring and air conditioning inspections (WFLKG, 2013). § 14a requires any air conditioning system with an effective rated output more than 12 kW to be inspected every three years with details on the inspection outlined in (2), and a more thorough inspection every 12 years explained in (3). Likewise, § 15g requires the inspection of heating systems with an effective rated output of more than 15 kW every two years, and heating systems with an effective rated output of more than 50 kW every year. Both inspections require a review on the proper dimensioning of the system under inspection.

The expert conducting the inspection of either heating or air conditioning systems is required to make a report on the results of the inspection and has to submit those results to the competent authorities. Authorities are required to randomly sample those inspection results and verify their validity.

4. Renovating Austria's Building Stock

4.1 Austria's Building Stock

Statistics on the Austrian building stock are maintained in the building and apartment register which is administered by Statistik Austria (GWR-G, 2004). The latest housing census was conducted in 2011 as part of a general census on population, housing and enterprises, and if not otherwise indicated will be used for figures presented in the following chapter (ÖSTAT, 2014).

Stock numbers

As of 2011 the total count of buildings in Austria was at 2,191,280 buildings and 4,441,408 apartments (see **Table 4.1**). Compared to 1951, the first census after World War II, this represents an increase of 145 % in buildings, and a 108 % increase in apartments. Between 1951 and 1991 the focus of construction shifted towards single family homes, indicated by number of apartments per building which had dropped steadily between 1951 and 1991, from 2.39 % to 1.88 %. Since then however the focus has shifted back towards a bit, with numbers reaching 2.03 apartments per building in 2011.

Table 4.1: Building and apartment figures for Austria, 1951 – 2011

Austria	1951	1971	1991	2001	2011
Buildings	896.030	1.281.114	1.809.060	2.046.712	2.191.280
Apartments	2.138.001	2.666.048	3.393.271	3.863.262	4.441.408
App / Building	2,39	2,08	1,88	1,89	2,03

The large majority of the almost 2.2 million buildings are used as residential buildings, with single family homes, double family homes and apartment blocks accounting for 90.1 % of the building stock. The 9.9 % non-residential buildings are more diversified, with a breakdown given in **Figure 4.1.**

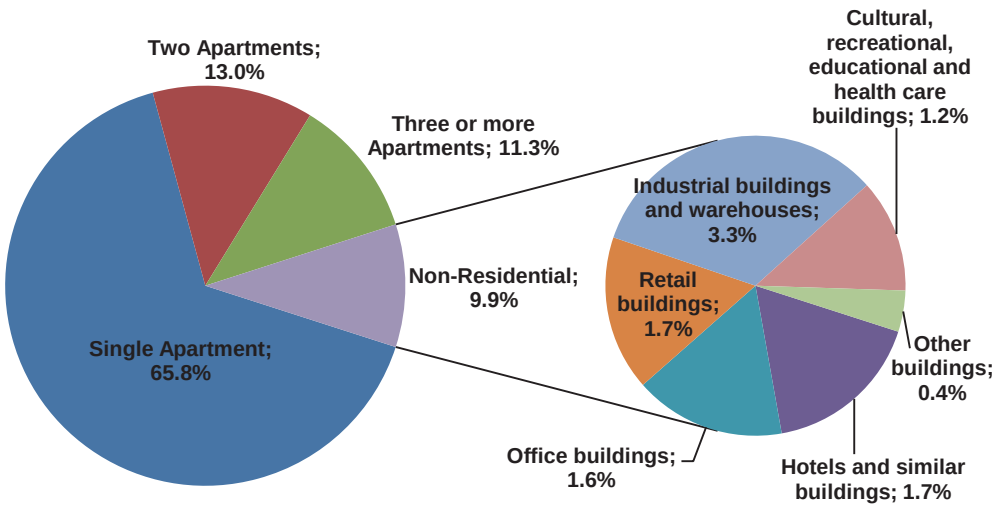


Figure 4.1: Austrian building stocks by classification, 2011

Even with the number of buildings more than doubling a large percentage of Austria's building stock is very old. As **Table 4.2** shows, the share of buildings constructed before 1961 is at 33 % as of 2011, and the share of buildings constructed before 1991 is at 75 %. It can be safely assumed that a large majority of the buildings constructed before 1961 have been renovated during their lifetime, but before the 1990s energy efficiency didn't have a major part in considerations for a renovation, and the improvements in quality of living often came with an increased energy demand. As a result most old buildings still have the potential for large improvements in their energy performance, and those improvements will have to play a major factor in reaching the national and European energy efficiency goals.

Table 4.2: Austrian building stock by construction date (in 1000 buildings)

Building type	Buildings total	Date of construction							
		before 1919	1919 to 1944	1945 to 1960	1961 to 1970	1971 to 1980	1981 to 1990	1991 to 2000	2001 and after
Total building stock Austria	2,191	327	165	243	283	325	305	264	276
Residential buildings (R.b.)	1,973	284	152	221	255	292	275	241	251
R.b. with one apartment	1,442	186	108	153	170	209	213	196	203
R.b. with two apartments	285	44	19	39	53	55	37	16	18
R.b. with 3 or more apartments	246	52	24	28	32	28	24	27	29
Non-Residential buildings	217	43	13	22	27	32	30	23	24
Share of R.b. %		14%	8%	11%	13%	15%	14%	12%	13%

Looking at the energy consumption the household and services sector together make up 36.3 % of the total consumption **(see Figure 4.2)**. Considering that, as previously illustrated, 90 % of the building stock belongs to the residential sector it is worth to take a closer look at the different energy uses in households, depicted in **Figure 4.3** (E-Control, 2015). Heating is by far the biggest contributor to household energy consumption, at 72 %, Appliances and lighting use 13 % of the total energy, while the heating of water consumes 12 % and cooking the final 3 %.

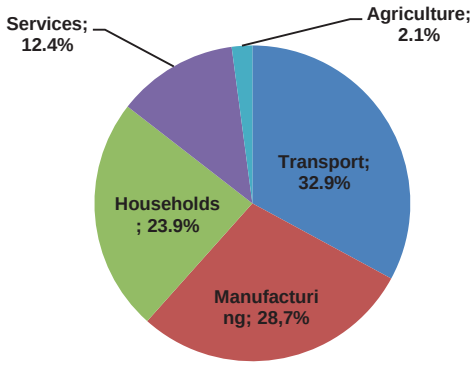


Figure 4.2: Energy consumption in Austria by sector, 2011

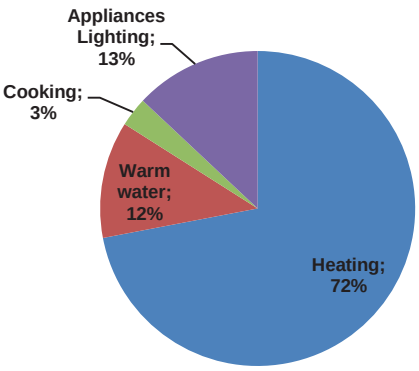


Figure 4.3: Energy consumption of households in Austria, 2011

Due to the effort required to calculate specific energetic values for existing buildings comprehensive figures by Statistik Austria are not available. Based on reference buildings equipped according to the references in the OIB handbook on energy-related properties of buildings, the heating energy demand values depicted in **Figure 4.4** were calculated for single and double family houses, apartment blocks and office buildings without renovations, or renovations taking place before 1970 (Kletzan-Slamanig et al, 2008). Of note are the significantly higher values for single and double family houses; significant improvements in heating energy demand came only after 1960, in the case of apartment blocks even later.

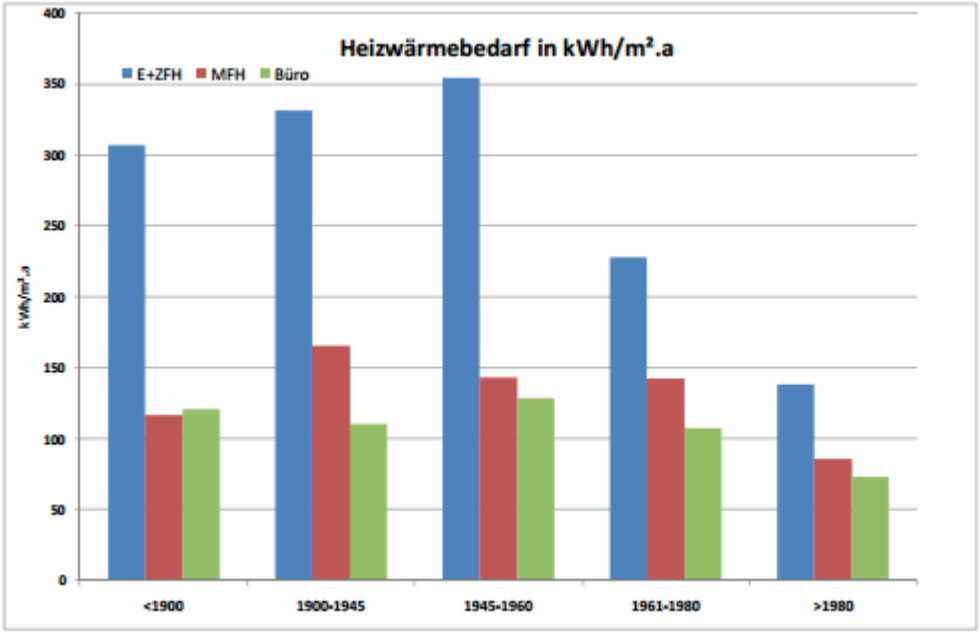


Figure 4.4: Heating energy demand for unrenovated buildings of different periods

Flow numbers for residential buildings

Renovation numbers for Austria differ based on the definition of a renovation. The following numbers are for residential buildings based on the definition of a thermal renovation by the Environment Agency Austria, who differs between five thermal renovation measures (5):

- Replacement of windows and doors,
- Renewal of heat supply system, such as boiler replacements,
- Thermal renovation of building fronts,
- Thermal renovation of roofs, and
- Thermal renovation of cellars;

Of those five measures three have to be implemented during a renovation to qualify as comprehensive. Between 2000 and 2012 the renovation rates for individual measures were between 1.5 % for thermal renovations of the roof and 2.3 % for replacement of windows; only 0.9 % of the renovations combined the renewal of part of the building envelope with a replacement or upgrade of the heat supply system, which combined can account for the biggest energy performance improvements.

The construction rate of residential buildings has gone down in recent years, falling off after the financial crisis of 2008. While it was at 1.08 for the years 2005-2008, in years 2009-2013 the construction rate dropped to 0.72 %.

The demolition rate of residential buildings differs based on the age of the buildings: While virtually no buildings constructed later than 2001 have been demolished, the demolition rate for buildings constructed between 1919 and 1980 is at an estimated 0.7 %. Interestingly the demolition rate for buildings constructed before 1919 is lower, at 0.6 %. A reason for the lower rate compared to later buildings may be the monument protection, which naturally is focused on older buildings. Applied to the 2011 building numbers of **Table 4.2** the overall estimated demolition rate is 0.46 %.

Outlook

Assuming that the current rates of construction and demolition will be stable until 2020, buildings constructed before 1991 still make up more than two thirds of the estimated total building stock with 69 % (see **Table 4.3**). This means that renovations of older buildings, using comparatively more energy anyway, are one of the most important factors for reaching the 2020 target numbers for energy efficiency.

Table 4.3: Austrian residential buildings prognosis for 2020

Residential Buildings (R.b.)	before 1919	1919 to 1980	1981 to 1990	1991 to 2000	2001 to 2011	2012 to 2020, est.	total buildings 2020, est.
R.b. 2011	284.112	922.138	275.034	241.140	251.555	-	-
Demolition rate R.b.	0,60%	0,70%	0,30%	0,05%	0,00%	-	-
R.b. 2020	269113	865645	267697	240057	251555	131660	2025727
R.b. 2020 in %	13%	43%	13%	12%	12%	6%	100%

Consequently the following subchapters will mainly deal with renovations of residential buildings. Focus will be on three main possibilities for renovations:

- Renovations involving the building envelope,
- Efficiency improvements of technical building systems, and
- Use of renewable energy sources;

To highlight the possibilities for new buildings a separate subchapter will present current examples of highly energy efficient buildings such as the Passivhaus, or the energy-plus-house.

4.2 Renovating the Building Envelope

4.2.1 The importance of the building envelope

The transfer of thermal energy from a place with a (relatively) high temperature to a place with a (again, relatively) low temperature is called heat transfer. Heat transfer can occur in three different ways (Glück, 1990):

1. **Conduction:** The transfer of thermal energy between atoms or molecules without transfer of mass.
2. **Convection:** The transfer of thermal energy of a fluid or gas in motion; the fluid or gas either takes up .or releases thermal energy from or to its environment.
3. **Radiation:** The transfer of thermal energy through electromagnetic radiation. Thermal radiation always happens both ways – no material has non-radiative surfaces – but the transfer from warm to cold is always dominant.

All three modes of heat transfer are responsible for transporting heat from the inside of a building to the outside – the walls conduct heat, the glass of windows is permeable for thermal radiation, and any leaks in the building envelope create airflows that transport the building heat to the outside. For these reasons a building envelope that reduces the heat transfer to the outside as much as possible is paramount for an efficient energy performance, as it can reduce the total energy needed to have the floor area at a constant temperature by manifold.

The measure for heat transfer though a material is the thermal transmittance, measuring the rate of heat transfer (in watts) though one square meter of the material and divided by the temperature difference between the systems. It is expressed in Watts per meters squared Kelvin, W/m^2K.

OIB guideline 6 has a table with maximum U-values for walls, windows and doors, roofs and floors. **Table 4.4** shows a few selected values for different parts of the building envelope.

Table 4.4: U-values of building parts

Envelope Part	U-value [W/m²K]
Walls, to outdoor air	0,35
walls, between appartments	0,9
Windows, french doors	1,4
Doors, to outside	1,7
Roofs, regular	0,2
Roofs, above garage	0,3
floors, touching ground	0,4

In the case of renovated buildings the guideline requires regarding the U-values:

(a) A detailed renovation concept with the energy performance targets of the renovation are at least equivalent to the minimum energy performance requirements; any part or step of the renovation has to comply with those requirements.

(b) The U-values of parts of the building envelope have to be at least 6 % below the maximum U-values allowed in the guideline, with the requirements increasing to at least 12 % below the maximum values starting 2017.

Apart from low U-values of the various parts of building envelopes a sufficient airtightness is necessary for buildings to minimize heat losses. The method to measure the airtightness of buildings is called blower-door-test, and is specified in the standard ÖNORM EN 13829 (ÖNORM, 2001).

The test requires all indoor doors of a building to be open, all outdoor windows and doors to be closed, and technical systems such as air conditioners or exhaust devices to be turned off or closed. A blower-door fan is then installed into an exterior doorway and pressure gauges positioned both indoors and outdoors. The blower-door fan is then used to blow air either into or out of the building, creating a pressure differential that forces air through leaks and holes of the building envelope. The amount of air needed to create a pressure differential reflects the airtightness of a building, with airtightness rising as less air is needed.

4.2.2 Insulation of walls, roofs and floors

The first proven case of building insulation is around 3,500 years old: In 2003 a German team of archaeologists found remains of a Bronze Age house with a double wattle and daub wall, filled with dried grass (Staeves, 2010). With a 10 cm thick and sufficiently dense grass layer an estimated U-value of 0.5 – 1.0 W/m²K could have been reached – not sufficient for today's regulations, but still astonishingly efficient. **Figure 4.5** shows the reconstruction of such a wall.

Figure 4.5: Reconstruction of a bronze age building wall

Different forms of Insulation – Roof

In general three different forms of roof insulation do exist, with a fourth one available if the space below the roof is not used as living space (Energieheld, 2015). The most efficient but also most expensive possibility is to fix insulation plates above the rafters. The reason this is the most expensive option is that the plates have to be fixed between the rafters and the roof tiles, meaning that the roof usually has to be retiled. The biggest advantage of an above-rafter-insulation is that it covers the whole roof which prevents thermal bridges that reduce the effectiveness of insulations.

Insulation pads or rolls can also be placed between the rafters. They require the removal of an eventually present cover and the rafters are thermal bridges, but the installation of such insulations is relatively easy and cheap. To improve the overall effectiveness often a below-roof-insulation is added, most of the time in the form of insulation plates. Combined those two insulations can provide an adequate effect, but they reduce the floor space below the roof by a bit.

If the space below the roof doesn't need to be heated it is also sufficient to simply insulate the top ceiling. This is generally cheaper as the area that needs to be insulated is almost always smaller than the roof surface. Various forms of insulation can be used – usually preferred are plates, with an additional flooring on top if the truss still needs to be walkable.

Different forms of Insulation – Walls

A relatively widespread form of wall insulation is the exterior insulation and finishing system, short EIFS. EIFS consists of insulation plates, a layer of basecoat mortar with incorporated glass fiber fabric to prevent cracks when cooling down by distributing the strain caused by the temperature drop, and the new exterior façade. The efficiency of an EFIS is relatively high, but it cannot be used for every building: Many old buildings are under monument protection, and regulations on the preservation of the townscape or on a minimum wideness of sidewalks can also prevent an EIFS. The thickness of the insulation layer can also require the replacement of windows, which is often not needed and thus just an additional financial burden. In recent years EIFS have come under criticism for the predominant use of polystyrene as insulation material (Stukenberg, 2013); apart from its low biodegradability it is treated with the fire retardant Hexabromocyclododecane (HBCD), an environmental toxin under suspicion of harming fertility.

An alternative system to EIFS is insulation through a back-ventilated curtain wall. This insulation system has a sub construction made of wood or aluminum-alloys that is fitted onto the outer wall. The spaces between the sub constructions are filled with insulation material, mostly mineral or rock wool. On the outside of the sub construction a layer to protect the insulation is fitted, followed by a second construction for the curtain wall; this offers a bigger scope for the design of the outer façade. Between the protective layer and the curtain wall is a layer of air, ventilating the whole system and giving the back-ventilated curtain wall its name. It is the most

expensive option to renovate the outer walls, but offers the widest range of possibilities in the design of it.

For buildings that have double-leaf walls a third possibility exists, the core insulation. If the cavity is thick enough it can be filled with insulation material – which one depends on the individual building, but it has to be both hydrophobic and fire-resistant. The problem with this form of insulation is that thermal bridges are usually not removed, and only a minority of buildings is built with double-leaf walls. For buildings that have them it is by far the cheapest form of wall insulation.

Insulations that are fitted on the inside are in theory possible, but the loss of useful space in the buildings generally prevents any closer considerations.

Different Forms of Insulation: Cellar

If a cellar is not heated it is more cost efficient to just insulate the ceiling of the cellar. This can be done from above, but requires the refitting of the floor. The cheaper method is to insulate from below, either using foam or plates to insulate the ceiling. If the space between floor and cellar ceiling is suitable the foam can also be sprayed into this space, though this leaves the danger of thermal bridges. If the space between floor and cellar ceiling cannot be used the lowering of the ceiling height is a factor that needs to be included in calculations.

If the cellar is heated, the walls and floor need to be insulated. The cheaper method is the insulation with vapor retarder and insulation plates on the inside of the cellar walls, which keep the cellar dry and reduce the thermal transmittance. This has two disadvantages though: the floor space is reduced, and the space between the cellar walls and the insulation can get moist and moldy. Newer capillary insulations can uptake moisture and emit it into the room air, thus keeping the walls dry; their price is significantly higher though.

The other possibility would be to fit the insulation on the outer walls of the cellar. The additional cost of this is significant though if not done during the construction of the building, as otherwise the earth around the cellar walls needs to be excavated and the walls need to be maintained before the insulation can be installed. The U-values for exterior insulations are usually superior to an interior insulation, but especially in urban environments it is almost impossible to reach the outer cellar walls of a building.

Insulation Materials

The materials used for insulation purposes are generally classified into three major groups (Amtmann et al, 2014):

1. Material made of synthetic resources
2. Material made of mineral resources
3. Material made of renewable resources

The main synthetic material for insulations is the previously mentioned polystyrene, a cheap material with good thermal transmittance, but low UV tolerance and low capability of respiration, as well as the aforementioned low biodegradability. Polystyrene is mainly used for plates but can also be used in granular form. The use of HBCD as fire retardant is not admitted anymore as of 2013. Other synthetic materials include phenol resin and polyurethane, also mainly used for the production of insulation plates.

The main mineral - and really general – resource for insulation material is glass- and stone wool, which combined have a 57.3 % market share on the European insulation market (IAL Consultants, 2013). Glass wool is one third sand and two thirds recycled glass, which are molten and converted into fiberglass and spun into a texture similar to wool; for stone wool the same mechanics apply, using half specific minerals, half debris. The intertwined fibers have an overall very low density and the air pockets that are a result of the texture make the wool a good thermal insulator and sound absorber, though it is very susceptible to moisture. Glass- and stone wool are usually used as rolls or plates, but can also be loose or used as padding material. Other mineral insulation resources include calcium silicate, pumice or expanded clay.

The renewable material group has the smallest market share of the three groups, but its ecofriendly production and use has led to a renewed interest in them. Wood has traditionally been one of the main renewable insulation materials. Wood fibers, Wood wool or cork can be used as insulation plates, the latter two can also be used as loose material for paddings or fillings. Wood wool and cork both have a good U-value, and cork as well as wood fibers have an exceptional thermal storage capability.

The fibers of the hemp and the flax plants are also well suited for insulations. Hemp especially, processed with up to 15 % support material, can be used for most forms of insulation described earlier; it is very sturdy, has a good U-value and can store moisture up to a third of its self-weight and release it without losing its thermal capabilities. Hemp can be used in the form of plates, pads or loose fibers for paddings.

Other renewable materials include sheep wool, hay, and cellulose, made out of old sorted newsprint.

Conclusion

Controversies about fire safety, damage caused by moisture, health risks and the economic feasibility have given insulations a worse reputation than they deserve. The industry is still evolving and learning from its mistakes, and policymakers have also taken steps to phase out greenhouse gases and other harmful substances in the production and usage of building insulations. The effects of a thoroughly planned and well-made insulation are still substantial; unfortunately for a long time the main focus was on the insulation of building walls, to detriment of the insulation of roofs and cellars.

For many buildings wall insulation is not a feasible option. Monument protections and townscape preservation restrictions can make insulations on the outer façade impossible, and thorough indoor insulations would strip buildings of a significant part of their floor space. For many small, older single family homes outdoor wall insulations are also too expensive, as the insulations get relatively cheaper with economies of scale. Still, insulation of the roof and the cellar – at least the cellar ceiling – are technically and economically feasible while offering long-term benefits on living quality and heating costs. The rediscovery of natural substances such as hemp have given engineers a renewable, ecofriendly and versatile alternative to existing insulation materials, it remains to be seen if the surge in demand for them will continue in the future.

4.2.3 Windows

Even though windows get renovated or replaced more frequently than other parts of the building envelope they are still one of the main culprits for a bad energy performance of a building. An old or wrongly installed window can pull down the energy performance of a building even with the other parts of the building envelope thermally renovated.

Until the late 1970s 2 types of windows were prevalent: Simple one-piece windows with a single glazing, which were mostly installed in buildings constructed during the construction booms after the two World Wars and had a very high thermal transmittance, and double or coupled windows, which offered a substantially better insulation by placing two sets of windows in the same frame. In the end of the 1970s the usage of single insulating glazing became common, providing a substantial upgrade to the old single glazed windows; still those windows offered just the same insulation quality that traditional coupled windows had.

The next generation of windows debuted in the 1990s with the spread of double-glazed windows. The two panes of a double-glazed window are separated by around 1cm, the space in between is either filled with dry air or an inert gas. Together with the coating of the two panes with a metal-oxide layer to further improve the thermal resistance a double-glazed window offers insulation comparable to the current minimum requirements in Austria. In the last years a third pane was added to make triple-glazed windows, although double-glazed windows are still commonly used. Table Q shows average U-values of the different window types as well as their main usage in construction (Verband Fenster + Fassade, 2014).

Table 4.5: U-values of different window types

Window Type	Main use	Average U-value [W/m²K]
Single window	until 1978	4,70
Double- and coupled window	until 1978	2,40
Window with uncoated insulation glass	1978 - 1995	2,70
Double-glazed window with coating	1995 - 2000s	1,50
Triple-glazed window with coating	since 2000s	1,10

The metal-oxide coating can have an additional role, depending on its attributes and its placement:

- Heat protection glasses have a high solar transmittance in addition to the low thermal transmittance. This maximizes the solar energy gains and helps reducing the heating expenses. Because the placement of the coating is important for the solar transmittance (better facing the sun) but doesn't matter in terms of thermal transmittance, the coating for heat protection glasses is best situated on the outside-looking side of the inner pane. In the summer the high solar transmittance can be a detriment though as it helps heating up the rooms.
- Sun protection glasses have a low solar transmittance and a low thermal transmittance. They have an additional reflective coating on the outer pane, mostly on the inside-looking side as this lengthens the lifetime of the coating, in addition to the heat protection coating. The sun protection glasses have their disadvantage in the winter, when the energy needed to keep the rooms at a constant temperature is higher due to the low thermal transmittance.

Smart glass

A newer, not yet often used development is the use of smart glass for adjustable sun protection. There are different technologies using electrical current or temperature differences to change the light transmission properties of glasses, for the purpose of insulations the use of electrochromic glass is the most widespread.

The basic structure of a double-glazed window with electrochromic glass is similar, with two panes and the space in between filled with an inert gas. The outer pane however has a much more sophisticated layout (Dittrich, 2004): The metal-oxide coating is made up of five thin layers: A separator is sandwiched by two electrodes on either side, with two transparent conductors on either side of the electrodes. This metal-oxide layer can be either on the inside of the outer pane or incorporated between two glass panes. In the basic configuration, the glass clear, lithium ions reside on the innermost electrode; applying a small voltage causes the ions to migrate to the outermost electrode containing tungsten oxide, forming $LiWO_3$ which absorbs or scatters up to 98 % of the incoming light (Verrengia, 2010). Reversing the current causes the $LoWO_3$-molecules to dissolve and the lithium ions return to the innermost electrode. The smart glass does not need any energy to be functional, only for switching between the modes energy is needed.

Apart from the higher price compared to regular double- or triple-glazed windows the biggest disadvantage of smart glasses is the increased heat generation through the absorbed sun rays – also a reason why the electrochromic part of the window has to be part of the outer window. The additional complexity of the outer pane and the increased heat generation also require more regular maintenance, and the current generation smart windows start to degrade in performance after roughly 10 years. The technology behind electrochromic windows is still evolving, as are long-term studies on it; to make them really viable an increase of their lifespan to 20-25 years (which is also the average lifespan of a window) will be needed.

Conclusion

While the main focus of windows lies with the glass used, it is important to note that the frame of a window is equally important. Just as old or leaky windows can ruin much of the insulation an otherwise well insulated building envelope would provide, a frame that does not fit with the glass or isn't soundly fitted to a wall insulation acts as a thermal bridge that can singlehandedly take the energy performance of a building down.

Overall the installation of new and energy efficient windows can be a relatively cheap and easy energy saving measure. The U-value requirements shown in Table AA indicate that even in buildings that are in accordance with the minimum energy performance requirements windows are the main reason for heat leaks. Especially in buildings that are restricted in the use of wall insulations due to various reasons a window renewal is often one of the few viable measures to reduce heat emissions.

4.3 Improving the Efficiency of Technical Building Systems

No matter the quality of a building envelope's insulation energy is needed to regulate the temperature of the living space. Improving the efficiency of the technical building systems used to achieve that – heating systems, air conditioning systems and others – is therefore crucial for a good energy performance. The measures that can be taken are generally divided in two main categories:

(a) Recycling heat already used to reduce the energy output needed
(b) Adjusting the output more closely to the individual demand

The following chapter isn't meant to be a complete list; it provides an overview of possible measures that can be implemented to achieve efficiency improvements. It is also tailored to the residential demands in Austria, putting the focus on the improvement of heating systems. Obviously most of the improvements have to be adjusted for the individual demands to reach the highest improvements.

4.3.1 Heat recovery

The concept of recovering heat produced by oneself to decrease the energy demand has been incorporated by mother nature millions of years before the first technical heat recovery system was conceived. Anatidae – the biological bird family including ducks, geese and swans – use a form of heat recovery in their feet to keep the heat losses minimal while swimming in cold water (Ederstrom & Brumleve, 1964). The arteries of a duck's foot are enveloped by an extensive venous network that transfers the warmth of the arterial blood to the veins, causing a steep temperature gradient between the feet and the rest of the body. This naturally low temperature of the extremities exposed to cold water minimizes the heat loss and enables anatidae to swim even in ice-cold water without danger of freezing.

Plate heat exchangers

The amount of heat exchange is not only dependent on the thermal transmittance of a substance but also the surface area that can be used for the transfer of heat. Plate heat exchangers follow that concept by using a series of metal plates – usually around 0.4 – 0.8 mm thick - through which both a high-temperature and a low-

temperature fluid flow (Techno System, 2011). **Figure 4.6** shows the structure of a plate heat exchanger.

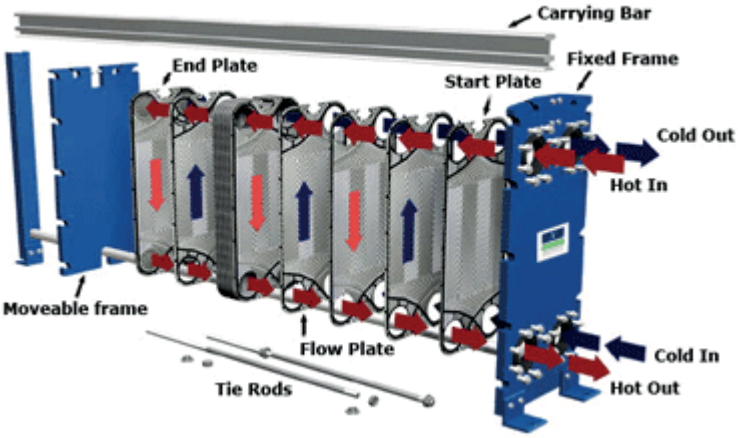


Figure 4.6: Structure of a plate heat exchanger

The heat flows of the high- and low-temperature fluids can be aligned in different ways, with their own advantages and disadvantages. Flows in the same direction minimize the temperature of the hull of plate heat exchangers, but require larger surface areas and limit the temperature exchange between the fluids (Wagner, 2009). Conversely, flows in opposite directions can cause high hull temperatures, but require smaller exchange plates and make it possible for the lower-temperature fluid to actually have a higher temperature than the high-temperature fluid when coming out of the plate heat exchanger. It is also possible to have the fluids flows crossing; this has the disadvantage that the plate heat exchanger will have areas of (comparatively) great warmth and cold, which can be a danger to the material used.

Heat plate exchangers have various applications: They can be used as parts of heat pumps, which will be described in the next part; as part of water heat exchangers to recycle the thermal energy of waste water, which are also talked about later; in ventilation systems to adjust air taken from outdoors to the indoor temperature, thereby reducing the need to heat or cool; and basically any application where highly efficient heat exchange is needed.

Heat pumps

Heat pumps use electrical energy to transfer thermal energy from a reservoir of low temperature into a system with higher temperature, in the case of buildings the heating system. Heat pumps use the same concept as refrigerators - using the thermal energy of a room to cool the inside of the refrigerator – but the thermal energy is moved opposite the direction of natural heat flow.

For a liquid to evaporate it needs to uptake energy equal to the liquids vaporization enthalpy. This energy is released when the vapor condenses again, and this cycle is the base on which heat pumps work. **Figure 4.7** shows a more detailed model of a heat pump (Fawcett, 2011). The thermal energy of a low-temperature environment is taken up by a low-pressure, low-temperature liquid, which turns into vapor thereby. A compressor turns the low-pressure liquid into a high-pressure liquid, which causes a temperature increase. This high-pressure, high temperature vapor then moves into the condenser, and the vaporization enthalpy released by the transformation into a liquid gets released into the (relatively) low-temperature heating system. The liquid flows into the expansion valve, where the transformation into low-pressure reduces the temperature again.

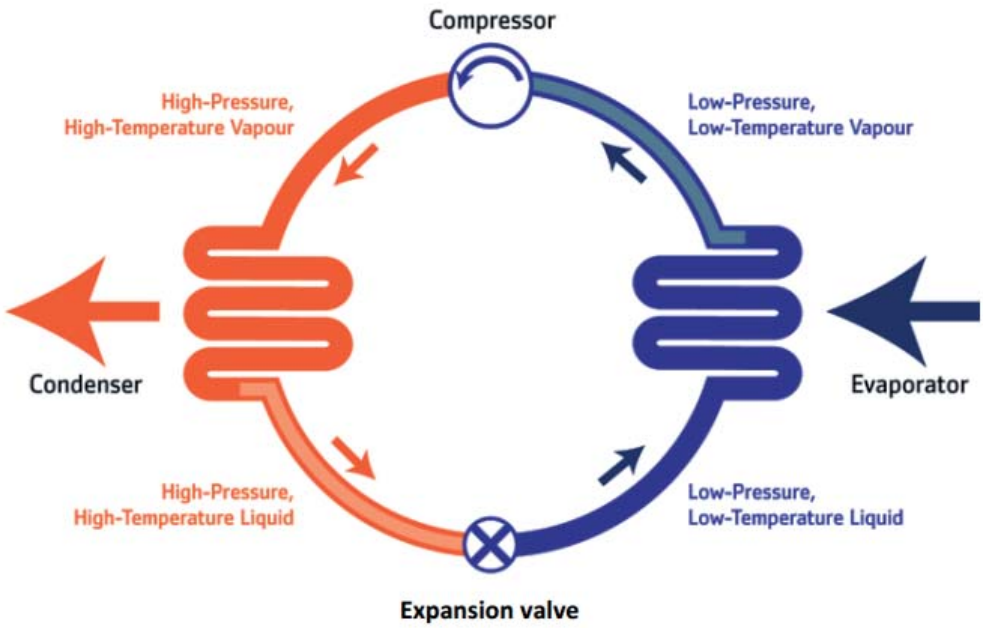


Figure 4.7: Representation of a heat pump

Heat pumps can generally be classified into two categories: Air source heat pumps and ground source heat pumps. Ground source heat pumps profit from the fact that the temperature of the ground a few meters below surface is 10° C for the whole year. This enables a higher coefficient of performance (COP), which depends on the temperature difference between the condenser (T_1) and the evaporator (T_2):

$$COP_{max} = T_1 / (T_1 - T_2)$$

The use of a ground source heat pump requires a borehole or trenches, which makes them unsuitable for many urban buildings. Conversely air source heat pumps have no specific land requirements, and thus are both cheaper overall and an option for a wider range of buildings. The fact that outside temperatures are usually lower than the 10° C found in the ground makes the COP worse than that of a ground source heat pump though, and it gets progressively worse the lower the temperature gets. **Table 4.6** shows the COPs of air source heat pumps with various inlet and delivery temperatures.

Table 4.6: Coefficients of performance for different temperature differences

Temperature		Heat pump COP	
Inlet	**Delivery**	**7 kW**	**9.5 kW**
-7° C	35° C	2,3	2,5
2° C	35° C	3	3,3
7° C	35° C	3,4	3,8
7° C	45° C	2,8	3

With the delivery temperature being an important factor for the COP the use of a heat pump is more suited for heating systems using a relatively lower temperature. At very low air temperatures parts of the air source heat pumps exposed to the outside have the additional possibility of freezing, further reducing the COP. For usage during extremely cold weather and to reach higher water temperatures a supplementary electrical heating system is often used.

In general heat pumps have higher initial and maintenance costs due to their complex nature and require heating equipment adjusted to their strengths and weaknesses. Heat pumps also require on-peak electricity, which in larger numbers can present difficulties for the current electricity network (Speirs et al, 2010), and somewhat relativizes the classification of a heat pump as ‘renewable’. Those

concerns, combined with the somewhat limited scope of application, makes it necessary to decide on a case-by-case basis if a heat pump can be used to improve the energy performance of a building.

Heat recovery of waste water

The heat of hot waste water can be captured by heat exchangers to reduce the energy needed for hot water supply. The heat exchanger can be installed in the waste water sewer pipes of buildings or building complexes, or on a smaller scale directly in the pipes connected to drainages. Current technologies in use have an overall effectiveness of 30 – 50 %, with the numbers rising to around 70 % for newer systems currently in development (Brumec & Krammer, 2011).

The representation of a simple waste water heat recovery system is shown in **Figure 4.8** (Energy Saver, 2015); newer systems mostly use a plate heat exchanger. The supplied cold water is heated through a heat exchanger between the drain water pipe and the incoming cold water, and is then either stored in a hot water tank or directly used thereafter. To maximize the efficiency of the heat exchange it is important that the flows rate of the two pipes is the same.

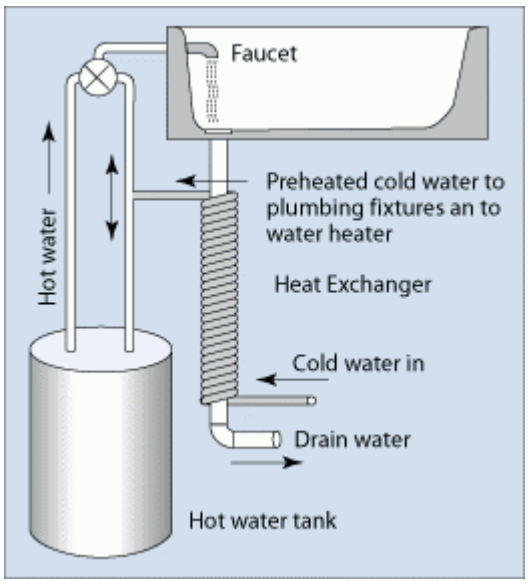


Figure 4.8: Diagram of a drain water heat recovery system

A disadvantage of such a configuration is that the heat exchanger works all the time – as a consequence the water is also (somehow) heated at first when cold water is running, and it takes longer (and produces more waste water) to get water of sufficiently low temperature out of faucets. And as with heat pumps the installation costs of systems with a high effectiveness are relatively expensive, as they need to be adapted to the individual building and hot water supply system. This also means that older buildings often don't have the technical feasibility of waste water heat exchangers, reducing the range of application for such an apparatus.

4.3.2 Adaptation and monitoring of existing technical building systems

Improvement of Existing Heating Systems

Most building heating systems are fueled with boilers that warm water or other fluids powered by combustion of fuels. As with other parts of the building boiler technology has evolved and many of the boilers used in older buildings are very inefficient by modern standards. Those regular boilers can only be run on a very limited temperature range and thereby run at maximum capacity most of the time. Even in the best cases this limits the yearly utilization ratio to at most 60 – 70 % of net combustion heat (Dehli, 2010).

Newer boilers, so called low-temperature boilers, can be run continuously with lower infeed temperatures; as around 85 – 90 % of the yearly heat supply is provided with a boiler workload of less than 50 % the installation of a low-temperature boiler can increase the yearly utilization ratio to 90 – 93 %. Condensing boilers have an even higher ratio: They use the latent heat of the boiler by separating and condensing the water vapor produced during combustion. The energy set free through the condensation (see heat pumps) is then too used to heat the water, giving condensing boilers a yearly utilization ratio of up to 100 % and even more; these numbers can be reached because declarations of utilization ratio are based on net, and not gross, combustion heat.

Another culprit for unnecessarily high energy demand of heating systems is the heating pump (which is not to be confused with the heat pump). Heating pumps are responsible for sustaining the flow of hot water in the heating system, so that each radiator gets the required thermal energy. Similar to boilers, older generation heating pumps run at full capacity all the time irrespectively of the actual demand, with an average power of 85 Watt (Mainova, n.d.). Newer pumps have sensors

pressure to gauge the flow speed needed to efficiently run the heating system and can adjust the output automatically, which cuts the required average power almost in half, to 45 Watt. Since the early 2000s highly efficient heating pumps are on the market using electronically commuted motors that exhibit a superior efficiency compared to motors of previous generations. Modern high efficiency heating pumps have an average power output of 5-15 Watt, which translates to energy savings of up to 90 % compared to older, inefficient pumps (Wilo, 2009).

Compared to the measures discussed so far in the fourth part of this paper it is relatively uncomplicated to change the boiler or heating pump, and offers a relatively fast amortization for its initial costs. To maximize the effectiveness of changes to a heating system it is essential to first gauge the insulation quality of the building envelope, and if necessary – and possible – to minimize any heat leaks. This allows determining the best boiler sizing, and hydraulic balancing to optimize the distribution of water in the system. During a renovation it is also recommended to check the insulation of heating pipes in non-heated parts of the buildings, and if necessary to upgrade the insulation.

Monitoring- and Controlling Systems

The easiest way to control the temperature of a heating system is through a thermostat, which measures the actual room temperature, compares it with the desired room temperature which can be configured by the occupant, and when needed corrects the output to reach the scheduled temperature. Regular thermostats are usually mounted on every single radiator and can be adjusted individually.

Most thermostats can be regulated via a numerical scale, e.g. 0-6, leading to the common misconception that the numbers represent the intensity of heat radiated, and using the maximum setting will result in a faster heated room; actually each of those numbers is correlated to a specific temperature, and the heat supply is regulated with a temperature sensor located in the head of the thermostat (CO_2Online, 2015). As the valve that regulates the heat supply can only be fully closed or open the thermostat cannot provide ‘more’ or ‘less’ heat. Therefore turning the radiator up to the maximum setting never decreases the heating time but will most likely cause unnecessary energy consumption before the desired room temperature is reached.

More sophisticated thermostats can be programmed to have specific heating schedules, to optimize the heating output based on the inhabitants sleeping and working habits. Thermostats can also be controlled with a mobile phone application; the thermostat is configured to recognize the proximity of one or multiple mobile phones and ensures that the living space is only fully heated when someone is at home (Tado, 2015).

Depending on the temperature preferences of its inhabitants a modern thermostat can provide a significant reduction in energy consumption at low costs and effort, even for buildings with perfect insulation and highly efficient technical building systems.

4.4 Using Renewable Energy Sources

Note: Figures used have been collected by Statistik Austria and released in the 2014 Census unless otherwise indicated.

4.4.1 Current Situation in Austria for Households

In 2011 / 2012 the total energy consumption of the 3.6 million households in Austria that were registered as a primary residence amounted to over 272 million Gigajoule, or around a quarter of the total energy consumption of Austria, at 24.8 %. The biggest share of energy sources are wood products with 24.9 %, and electricity with 21.9 %. Solar energy and heat pumps made up 4 % of the consumption, more than doubling its 2003/2004 share of 1.6 %. Detailed figures for the total consumption are shown in **Table 4.7**.

Table 4.7: Energy consumption in Austria by fuel type, 2011-2012

Energy source	Consumption in Gigajoule (GJ)	% of Consumption
Coal, coke, coal briquets	1,433,404	0.5%
Wood, pellets, briquettes	67,830,759	24.9%
Oil, liquid gas	49,316,475	18.1%
Gas	54,068,240	19.8%
District heating	29,142,090	10.7%
Electricity	59,784,103	21.9%
Solar, heat pumps	10,843,980	4.0%
Total	**272,419,051**	

More than two thirds of the total residential energy consumption, 71.2 %, is used by heating systems. Here, electricity only has a 6.5 % share; the majority of the electricity consumed by households is needed for lighting, hot water and appliances. Wood products again have the biggest share, followed by gas, and oil products. Together they account for almost 80 % of the total consumption used for heating, while only being installed in around 65 % of Austria's households. Conversely district heating is the energy source for 25 % of the households but makes up only 12.5 % of total heating consumption. Detailed figures that present the energy share of fuels for buildings of different age categories are not available, but it is standing to reason that oil and wood products (as well as coal products, but they are almost

extinct and will hopefully be in the next years) are used in buildings that are (a) built before 1990 and (b) haven't been renovated during the last decades. The figures for household and consumption shares of different fuel types are also shown in **Table 4.8**.

Table 4.8: Heating energy consumption of households in Austria by fuel type, 2011-2012

Energy source	Households	% of Households	Consumption in Gigajoule (GJ)	% of Consumption
Coal, coke, coal briquets	17,940	0.5%	1,368,673.9	0.7%
Wood, Pellets,	739,989	20.3%	63,602,241.7	32.8%
Oil, liquid gas	700,848	19.2%	44,670,966.0	23.0%
Gas	930,922	25.5%	45,959,273.3	23.7%
District heating	912,727	25.0%	24,158,052.3	12.5%
Electricity	237,541	6.5%	7,628,630.8	3.9%
Solar, heat pumps	106,863	2.9%	6,651,257.5	3.4%
Total	**3,646,830**		**194,039,095.4**	

As wood is a renewable resource the use of wood products to fuel heating systems isn't a bad thing by itself, as the use of ecologically produced pellets causes less environmental burdens than other traditional fuel sources (Hassler & Nussbaumer, 2001). Unfortunately pellets only have a 7.6 % share of the total wood consumption; unprocessed wood dominates the market for wooden fuels with 79.8 %. Additionally the fuel wood imports of Austria have risen dramatically in the last 15 years, as shown in **Figure 4.9** (Strimirzer & Höher, 2015). Interestingly the export of fuel wood products, mainly in the form of pellets, also increased over the same time span.

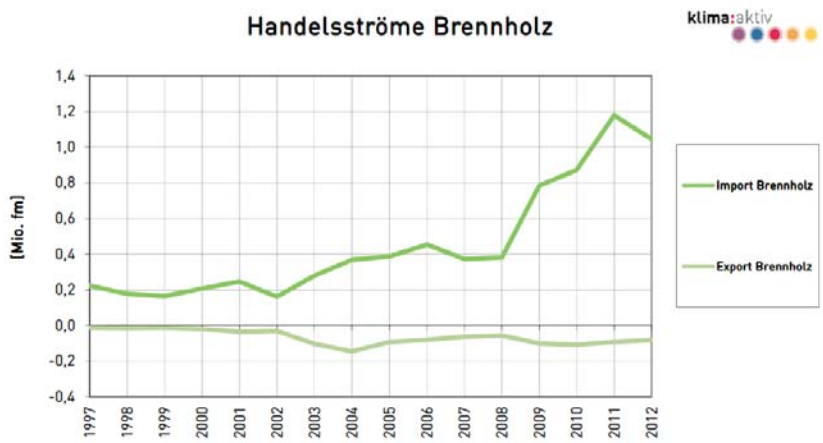


Figure 4.9: Wood Imports and Exports in Austria, 1997 - 2012

4.4.2 Cogeneration and District Heating

The energy production in Austria has traditionally been dominated by water power, with a share of around 66 % in 2012 (PROGNOS, 2014). The majority of the fossil-fuel power stations – 83 % as of 2012 - are equipped with cogeneration installations, giving cogeneration plants a 25 % share of total energy production in addition to the 12.5 % share of heating energy consumption. Many bigger cities in Austria have formulated concepts to expand the use of cogeneration, in the case of Vienna even trigeneration.

However over the last years the profitability of cogeneration plants has dropped. This has a multitude of reasons: Caused by the financial crisis of 2008 the demand and thus the price of energy has dropped; as an additional consequence the prices for CO_2-certificates have collapsed, further reducing the financial advantages of efficient cogeneration plants; and the energy market liberalization, coupled with Germany's increased production of renewable energy, further drove down energy prices.

Since 2011 the overall profitability of Austria's gas-powered cogeneration plants has been negative, and with energy- and CO_2-certificate prices expected to remain low over the next few years a reversal of this trend is unlikely. The Kraft-Wärme-Kopplungs Gesetz, a law on provisions for cogeneration plants, was amended in 2014 to re-introduce subsidies for efficient cogeneration plants in addition to current tax advantages (KWK-G, 2014); the total volume of 12 million Euros per year that is assigned by the law will not be nearly enough for cogeneration plants to become profitable, endangering a vital part of Austria's energy production.

This negative trend naturally has an effect on the development district heating networks. While district heating providers plan with a yearly expansion rate of around 2 % of the existing network length, the estimated yearly growth rate for thermal energy supply was lowered to 0.8 % (FGW, 2013). With the dire financial conditions of many cogeneration plants it is unrealistic to expect a substantial growth without substantial investments of state and federal states.

More than any other measures to increase the energy performance of buildings access to district heating is dependent on measures and investments of government and suppliers. The cost of the development of district heating networks and the efficiency losses on longer distances make district heating inefficient for rural regions, reducing its scope mainly to urban environments. The share of district heating in selected Austrian cities as of 2011 is shown in **Table 4.9** (FGW, 2015).

Table 4.9: District heating share in selected Austrian Cities, 2011

City	District heating share
Graz	44%
Klagenfurt	30%
Linz	60%
Salzburg	23%
Vienna	36%

4.4.3 Photovoltaics and Solar Thermal Collectors

Photovoltaics

The modern history of photovoltaics, the conversion of solar energy into electricity, started on 25 April 1954 when Bell Laboratories demonstrated the first practical silicon solar cell (American Physical Society, 2015); the efficiency of the cell was at 6 %, back then a huge improvement over previous experiments with photovoltaic cells. Four years later Vanguard-1 was the first satellite to use photovoltaic cells as optional power supply, and the cells supplied the satellite with energy until 1965 (McLaughlin Green and Lomask, 1970).

The market in Austria for photovoltaics began its rise in the early 2000s as a consequence of the Ökostromgesetz, a law designed to promote the energy production with renewable energy sources (Biermayr et al, 2015). Since 2009 the power output of photovoltaic installations has increased dramatically, reaching a peak output of almost 800 MW by 2014 (see also **Figure 4.10**).

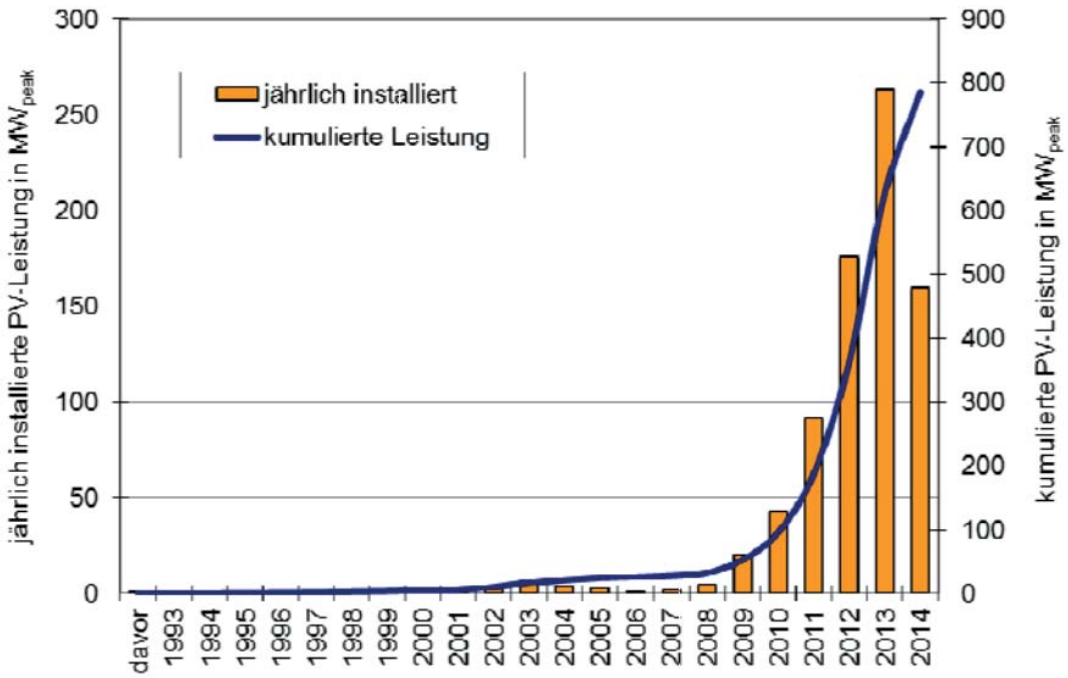


Figure 4.10: yearly installed and cumulative photovoltaic energy output, 1993 - 2014

Today the efficiency of photovoltaic cells is at around 10-20 %, with a yearly degradation rate of around 0.1 % (Pfister, 2011). The production of the cells has also been refined and optimized over the years so that it takes between 2 and 5 years for a photovoltaic cell to produce the power needed for its production (Bauer, 2008). The statutory feed-in compensation established with the mentioned Ökostromgesetz guarantees a minimum price for excess energy fed into the grid, giving photovoltaic installations an expected amortization rate of 10 – 15 years (Märtel, 2015).

Solar Thermal Collectors

The use of solar thermal energy goes back to the antiquity; the best known example is the Olympic fire, which is traditionally ignited with sun rays reflected by a parabolic mirror (The Olympic Museum, 2013). A few millennia later, in 1891, the first solar water heater was patented in the USA. After the world wars seemingly ubiquitous fossil fuels, the introduction of nuclear energy, and the resulting drops in energy costs made the development of solar energy an afterthought in the western hemisphere; during that time Asia became the leading force in solar technologies, with over 4,000,000 solar collector units installed in Japan by 1969 (Hastings, 2013). It was only after the oil shock of 1973 that alternative and renewable energy sources started to attract public interest again.

Three years later the first solar thermal collectors were introduced in the Austrian energy market, mainly used for the heating of tap water and swimming pools. Until the early 1990s the development of a solar thermal collector market was volatile, with demand rising and falling based on the oil price (Faninger, 2010). The lack of standards and technical problems with first generation collectors also stunted the growth of the solar thermal market until the 1990s, when the next, more reliable generation of solar thermal collectors was introduced. These improved collectors were the first to be used for renovation of buildings to reduce the required output of boilers.

Until 2009 the solar thermal collector market grew significantly as a consequence of rising oil prices and new improvements enabling the application of solar thermal collectors to assist district heating and industrial process heat. The financial crisis, falling energy prices and the emergence of photovoltaics as direct competition for space on building roofs have since led to a decline of new solar thermal energy

installations. A graphical representation of the market development of solar thermal collectors is shown in **Figure 4.11**.

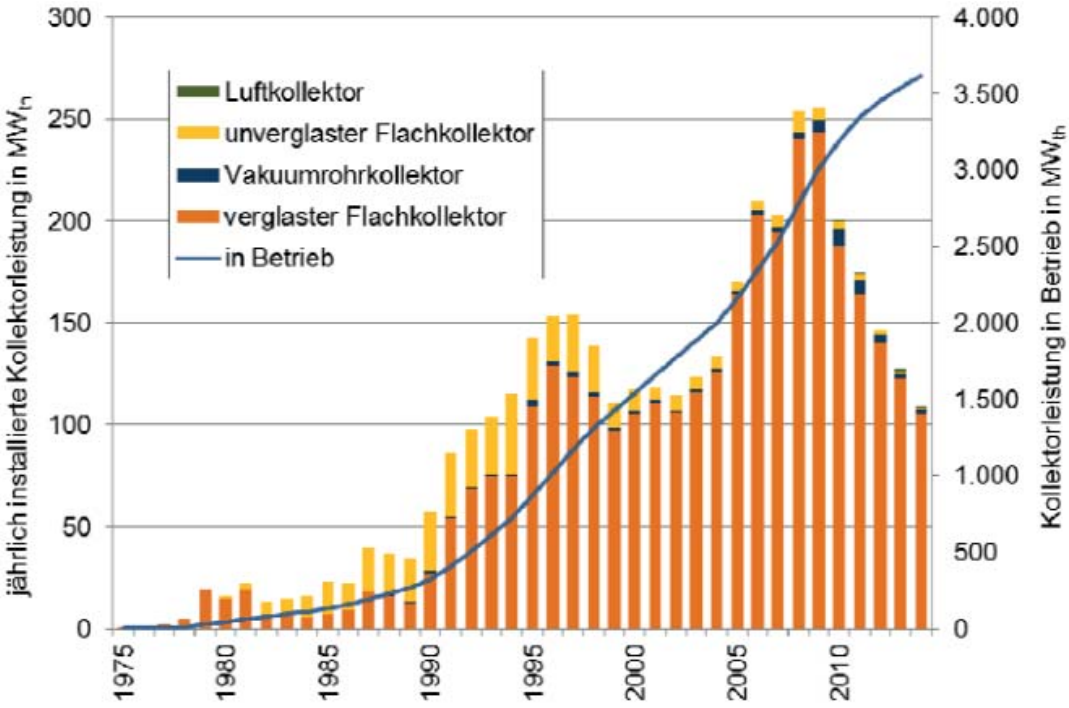


Figure 4.11: Yearly installed and cumulative solar thermal collector output, 1975 – 2014

The thermal efficiency of current solar thermal collectors depends, like a heat pump, on the temperature difference - a collector used to heat water has a higher efficiency than one used to supplement heating; the efficiency different collectors is usually between 30 and 60 %. The energetic amortization of a solar collector is usually around 2 years, but other than photovoltaics a heat collector does not have the possibility to sell excess heat, increasing the amortization rate of solar thermal collectors to 20 years and more.

Application of Solar Energy Technologies

Both photovoltaics and solar thermal collectors use the sun to produce energy; combining the two technologies to reduce the space needed and increase the overall efficiency of a unit would seem natural. Unfortunately a photovoltaic cell requires low cell temperatures for ideal efficiency, while the efficiency of a solar thermal collector increases with rising temperatures. Although hybrid modules incorporating both technologies are on the market, their efficiency is not yet on par with the efficiency of single systems. As thermal collectors also require far less

space than photovoltaic installations of comparable output hybrid modules are only feasible for buildings requiring a disproportionate amount of thermal energy (10).

With the roofs of many buildings being unsuitable for solar energy installations, unreliable energy production, high initial costs and in the case of thermal collectors a long amortization rate make other technologies that improve the energy efficiency of buildings more attractive at first glance. If feasible however the autonomous energy production lessens both the dependence on the national grid and the load of the grid itself. In well insulated and calibrated buildings it is possible to reduce the external energy consumption to an absolute minimum or even zero. Solar energy units also synergize well with heat pumps, as the combined output of the two devices provides a year-round supply – heat pumps working best during cold seasons, solar energy units during warm seasons.

The biggest advantage photovoltaics have over thermal collectors is the better use of excess energy. To prevent the loss of excess thermal energy collected through thermal energy system it is necessary to install thermal storages, which use space and also have a limited capacity. The thermal efficiency of a photovoltaic unit in combination with a heat pump is comparable to the efficiency of a solar collector; also, as mentioned, excess energy produced by photovoltaics can be fed into the grid, which (a) generates revenue and (b) makes use of the energy.

5. Prospects and Conclusion

5.1 Current State of the Art

While renovations are often restricted by the layout of buildings, by their environment, or legal provisions, many of those restrictions do not apply to the construction of new buildings. Looking beyond the minimum energy performance requirements, this chapter takes a cursory look at what is possible today by presenting the Passivhaus standard and the new TU-Plusenergiehaus, which opened in 2014 with the claim of being the first office building in the world to produce more energy than it consumes.

5.1.1 The Passivhaus

According to the official homepage of the Passivhaus Institute Darmstadt (PID), a Passivhaus is *"[…] not a brand name, but a tried and true construction concept that can be applied by anyone, anywhere"* (Passivhaus Institut, 2015a). The first Passivhaus was constructed in 1991 under the supervision of Dr. Wolfgang Feist, who also founded the PID in 1996. The Passivhaus standards were developed as a set of quality requirements for buildings that need to be met for official certification.

The key numbers that need to be met by a building to achieve Passivhaus certification are laid down in **Table 5.1**. The target for airtightness means that, during a blower door test, at a 50 Pascal pressure difference between building and outdoor air not more than 60 % of the volume of the building is exchanged in an hour.

In 2015 new Passivhaus-classifications have been released, with slight modifications to the indicator targets (Passivhaus Institut, 2015b); requirements for primary energy demand have been replaced with requirements for primary renewable energy demand, and the better classes have minimum requirements for their renewable energy production. A Passivhaus can now be classified as 'classic', 'plus', and 'premium', with increasing requirements for the better classes. The new figures are shown in **Table 5.2**.

Table 5.1: Passivhaus Indicators

Indicator	Target
Heating Demand	≤ 15 kWh/m²a
or Heating Load	≤ 10 W/m²
Cooling Demand	≤ 15 kWh/m²a
Primary Energy Demand	≤ 120 kWh/m²a*
Airtightness	n50 max. 0.6 h^{-1}
* replaced as of 2015, see **Table 5.1**	

Table 5.2: New 2015 requirements for Passivhaus classes

Indicator	Passivhaus 'Classic'	Passivhaus 'Plus'	Passivhaus 'Premium'
Primary renewable energy demand [kWh/m²a]	≤ 60	≤ 45	≤ 30
Renewable energy production [kWh/m²a]	-	≥ 60	≥ 120

To meet those standards additional guideline targets have been released:

- Recommended opaque fabric U-values of ≤ 0.15 W/m²,
- Window and door U-values of ≤ 0.8 W/m²,
- If possible elimination of thermal bridges, and
- Whole house mechanical ventilation with heat recovery, with a minimum 75 % efficiency;

The first Passivhaus in Austria finished construction in 1996, and by the end of 2008 12.5 % of newly constructed buildings were planned according to the Passivhaus standards (Lang, 2010). As of 2009 a total of 6,850 buildings with around 12,000 housing units were designed as Passivhäuser, giving Austria a Passivhaus-ratio five times higher than Germany or Switzerland, other pioneers of Passivhaus implementations.

The PDI has also developed guidelines on building renovations with Passivhaus components called EnerPHit (Passivhaus Institut, 2013). The requirements for certification have been adapted: While most of the indicators specified in **Table W** have stayed the same, the target figure for specific heating demand of renovated buildings is at most 25 kWh/m².yr, or alternatively evidence that all energy-relevant building components have been renovated according to Passivhaus criteria. As of 2009 180 buildings in Austria have been renovated based on EnerPHit standards.

The European requirements for NEZBs suggest a comparison to the new Passivhaus standards, and the results aren't flattering for the European legislation (Lang, 2015). The NZEB requirements for primary energy demand are almost everywhere significantly less stringent than those for even the 'classic' Passivhaus. The requirements for Austria especially are alarmingly high considering its leading role on the field of building energy performance in previous years, with only Romania having worse NZEB requirements (see also **Figure 5.1**).

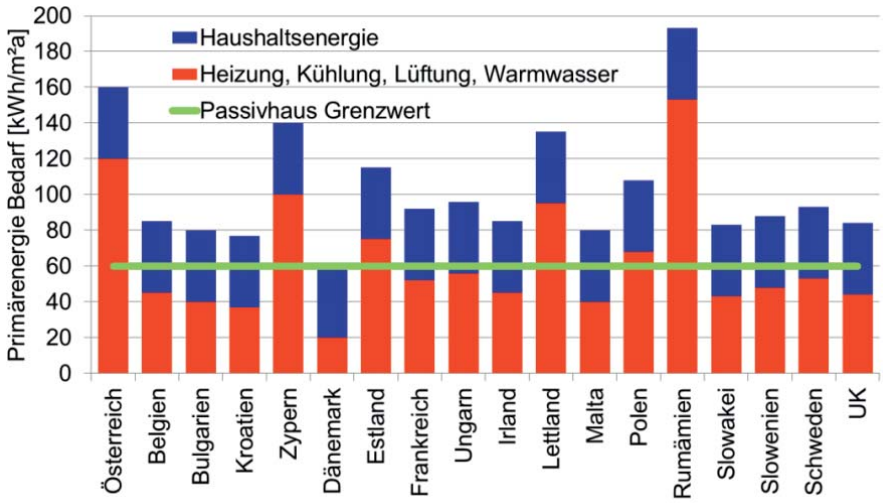


Figure 5.1: Primary energy demand of NZEB regulations, Passivhaus classic

5.1.2 The TU-Plusenergiehaus

Energy-plus-houses are buildings that on average produce more energy from renewable sources than they need from external sources; 'needed energy' in this context usually means energy needed for basic building functions (e.g. lighting, technical building systems). The TU-Plusenergiehaus, finished in 2014, wants to go one step further and be the first office building to produce on average more energy than is needed for both basic functions and specific appliances (e.g. Computers, telephones), calling this type of buildings 'energy-plus-plus-houses' (Univercity, 2015).

The biggest challenge for such a building is the relatively low surface area available for solar installations compared to a single-storied house, as depicted in **Figure 5.2**. As the surface area of a roof stays the same no matter how many floors a building has it gets progressively harder to provide the necessary energy with the available surface area.

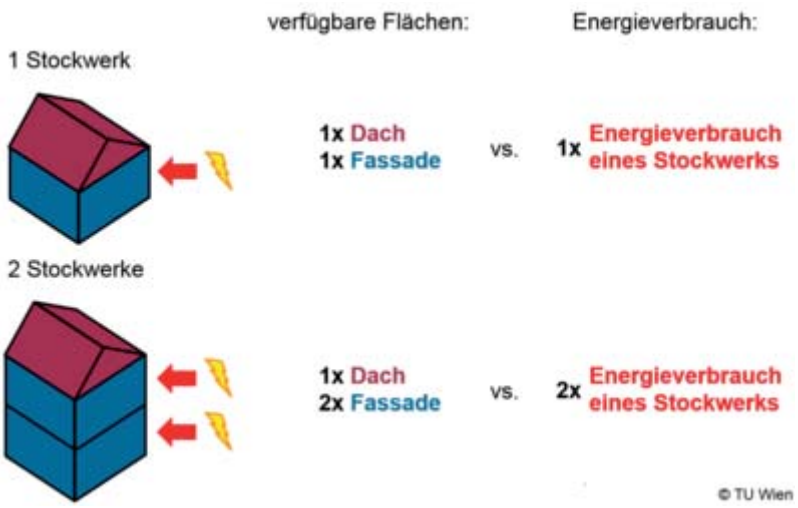


Figure 5.2: Surface Areas of buildings with one and two floors for solar energy

To maximize the energy output of the building photovoltaic installations were integrated into both roof and façade, and energy recovery systems for elevators also provide a smaller amount of energy. If the energy produced is not sufficient to supply the needs of the offices additional energy is taken from the grid, while excess energy is transferred to other buildings of the Technical University.

The waste heat of the server room in the basement is used for heating systems during colder seasons; to meet additional demands when the waste heat is not sufficient the heating system is connected to Vienna's district heating network. In warmer months two hybrid-cooling towers supply cooling energy to temperate both the server room and the offices.

Even with the optimization of integrated energy sources the total energy production is limited. To reduce the energy demand apart from traditional renovation measures components using energy – 9,300 overall - were catalogued and optimized, and intelligent automated systems designed and integrated.

As a result of this package of measures the primary energy demand for both building and use, around 800 kWh/m²a before the renovation, was reduced to 56 kWh/m²a for the office part, which equals a 93 % reduction. The combination of photovoltaics and energy recovery systems produce 5 kWh/m²a more than needed, confirming the set target. The high-performance computers of the university – usually not found in regular office buildings - located in the TU-Plusenergiehaus require an additional 52 kWh/m²a; with this classified as energy needed for the use of the building the TU-Plusenergiehaus is still considered as energy-plus-house of classical definition.

An example of the optimized performance of energy-consuming systems is the IT-infrastructure. The personal computers in offices are specifically designed for office purposes, and applications requiring more performance are outsourced via cloud computing to the building server. This allows focusing the heat production of personal computers as much as possible to a single room, which enables highly efficient cooling of the produced heat in warmer months, and utilizes it for heating purposes during colder months.

What makes the TU-Plusenergiehaus especially impressive is the fact that it is not a newly constructed but a renovated building. It combines maximal use of local energy sources with meticulously planned energy efficiency measures, providing a template for future renovations of office buildings.

5.2 Conclusion

The development of the energy market in the EU over the last 20 years shows that Europe is becoming more and more dependent on energy imports. With more than 50 % of the energy consumed in the EU being imported since 2004 security of supply can become a big issue in the future. To solve this two possible solutions exist: Substantially more domestic energy production, or less energy consumption. With the endeavor of politics to slowly phase out fossil energy sources and many countries turning away from nuclear energy for now (no one knows what nuclear fission may bring, and when that may be) the development of renewable energy sources alone makes it highly unlikely that Europe's energy production will rise substantially in the near future. This is one of the reasons why a 20 % reduction in energy consumption based on 1990 levels is one of the main targets of Europe's 2020 strategy.

The Energy Efficiency Directive and the Energy Performance of Buildings Directive are hailed as vital parts of this strategy. One of the main objectives of the former and the sole objective of the other, the energy performance of buildings is the single most important part of the European energy market that needs to be improved on. While they set binding targets for the renovation of public buildings or yearly energy savings targets for distributors, they also offer loopholes: The 3 % renovation rate of public buildings is only mandatory for the buildings owned or used by the national government – buildings owned by federal states, communities or other public authorities *can* be included by the governments in the law, by they don't have to; likewise additional provisions essentially reduce the energy saving requirements for distributors by up to 25 %, which in the case of Austria is fully used.

The European Union and its member states often use figures from 1990 as reference values for different energy-related policies. This is quite unambitious for a few reasons:

- The dissolution of the Soviet Union was followed by a large contraction of the industry in most of Eastern Europe,
- The heavy industries in general have been on the decline for the last few decades, and
- The financial crisis of 2008 again caused a large reduction in energy consumption.
- Both European and national legislation on energy-efficiency-related matters became a lot stricter after 1990

While it made sense to base numbers on 1990 levels when UNFCCC was signed in 1992 and the Kyoto protocol in 1997, to still use those numbers as reference levels 25 years later more seems like a gimmick to make reduction numbers artificially bigger.

As for Austria, the – compared to other EU countries – very unambitious definition of an NZEB is not the only signal that it is in danger of losing its pioneering role in building energy performance and environmental protection: In June 2015 the European Commission noted that Austria still had not implemented all EBPD directives in a satisfactory manner (European Commission, 2015b); in its report *Trends and Projections in Europe 2015* the European Energy Agency singled Austria out as one of only four countries who are not on track to meet its 2020 greenhouse gas emission targets (European Energy Agency, 2015); and the Austrian national budget numbers for 2016 show that a significant reduction in subsidies for thermal renovations (Austria Presse Agentur; 2015)

The last part is especially alarming as renovation rates differ drastically between different forms of ownership: While buildings owned by public authorities and non-profit-organizations have a renovation rate of approximately 3 %, privately owned buildings lag behind significantly. This has various reasons (IIBW, 2012): The initial costs and complexity of comprehensive efficiency measures discourage many apartment and home owners, and the structure of financial support instruments is often too restrictive to cater to the needs of individual buildings. Privately owned rental apartments also are afflicted by the user-investor-dilemma: The party that needs to invest in thermal renovations – the owner – is not the party profiting from

those renovations – the tenant. With those factors in mind a reduction of subsidies for thermal renovations will further lessen the chances that the targeted growth of renovation rate will be achieved.

And yet the potential for improvement is immense: Depending on the targeted energy performance requirements theoretical savings of 60 to more than 90 % of the previous energy demand can be achieved for residential buildings before 1980; even residential buildings constructed after 1980 have improvement potential of 50 to 70 %. It is important to note though that the actual heating energy consumption differs from the theoretical heating energy demand for buildings with either a very high or a very low heating energy demand (Bauer, 2013): In buildings with a very high heating energy demand the actual energy consumption is significantly lower, mostly because of fuel poverty. Conversely buildings with a very low heating energy demand have an on average substantially higher heating energy consumption; this is in part a result of the rebound effect described in part one of this thesis, in part a result of non-optimal habits of inhabitants – the figures for buildings are calculated for ideal circumstances, and buildings with very low energy demand are especially susceptible to energy-inefficient habits.

This discrepancy between demand and consumption shows the probably most important fact when it comes to energy efficiency: It is not enough to implement laws and use state-of-the-art to achieve the goals the EU set for the future; the change needs to start in everyone’s mind, and with everyone’s habits, if true change is to be achieved.

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