UNIVERSIDADE DE COIMBRA

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Improvement of energy efficiency in Finnish offices and commercial buildings

Dissertação de Mestrado Integrado em Engenharia Eletrotécnica e de Computadores

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UNIVERSIDADE DE COIMBRA

Faculdade de Ciência e Tecnologias da Universidade de Coimbra
Departamento de Engenharia Eletrotécnica e de Computadores

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Preface

First of all, I would like to thank my coordinators, Prof. António Martins and Prof. Matti Lehtonen for helping me throughout the writing process of this dissertation. However, this would not have been possible without the precious help of Prof. Paulo Coimbra opening an agreement with the University of Aalto so I could undergo a period of 1 year of exchange studies in Finland. For the unconditional support and professionalism always shown by Ms. Sofia de Jesus, Ms. Maria da Conceição Pereira and Ms. Niina Huovinen throughout the whole exchange process, I am very thankful. To my friend Katri Vaittinen, thank you for the support and encouraging words whenever the motivation was low. To my friends Jennifer Sofia and Andrew Hilditch, thank you for the spell check and grammar revision.

It has been a long journey of 7 years that is now coming to an end, and I want to thank all my friends and those who have been part of this incredible experience for the friendship demonstrated. Finally and most important of all, to my family and my parents in special, thank you very much for always backing me up. The last 7 years would have never been possible without your support.

Abstract:

The improvement of energy efficiency in the buildings sector is one of the fields being targeted worldwide, including in the European Union, to reduce the energy consumption and greenhouse gas emissions.

It is of great importance the awareness of the population in general (mainly employees, employers or building managers) about measures that help achieving improvements of energy consumption of the current building stock, also including available efficient technologies.

The benefits are extended when the information is complemented with the knowledge of current energy policies or information regarding financial supports from governmental institutions.

As a member of European Union, Finland has been proceeding with changes to its ”Energy and Climate Strategy” and, despite the fact that the country is on its way to achieve the renewables target imposed by EU, there is still possibility to increase the energy efficiency in various sectors, including the buildings sectors.

The national energy indicator target for 2020 is to have a final energy consumption of 310 TWh.

One of the biggest energy demand end-uses in the country is space heating which is responsible for 25% of the final energy consumption. Even though Finland is characterized by a cold climate and long winters, the need for cooling energy is now increasing due to the global warming, and efficiency measures to be applied for cooling purposes are also becoming increasingly relevant.

Despite the advanced and efficient district heating network of the country, there are still buildings which are not yet covered by the system, and possibilities to replace the traditional heating by oil and gas include the use of heat pumps.

Regarding the need for air conditioning and ventilation, commissioning of the HVAC systems is of major importance to find opportunities to increase the overall efficiency. However, the complexity of the HVAC system varies according to the type, design and floor area of the building, which means that Building Automation System (BAS) plays a crucial role in the management of the loads. When this control is extended to include the lighting system, the overall efficiency benefits are very relevant.

Keywords: Finland, offices, commercial buildings, energy efficiency, energy policies, building automation systems

Resumo

A melhoria da eficiência energética no sector dos edifícios é um dos campos focados em todo o mundo para reduzir o consumo energético e emissões de gases com efeito de estufa.

É da maior importância o conhecimento da população em geral (principalmente trabalhadores, entidades patronais ou gestores de edificios) acerca de medidas que visam a melhoraria do consumo energético em edificios, inclusivé tecnologias eficientes atuais disponiveis.

Os beneficios são maiores quando a informação é complementada com o conhecimento de politicas energéticas em curso, ou informação relativa a incentivos económicos por parte de instituições governamentais.

Como membro da UE, a Finlândia tem procedido a alterações na sua "Estratégia de Energia e Clima" e, apesar do país estar no caminho certo para atingir os objetivos relacionados com as energias renováveis imposto pela UE, há possibilidade de aumentar a eficiência energética em vários setores, como é o caso do setor dos edifícios.

O indicador energético alvo para 2020 está estabelecido como um consumo final de energia de 310 TWh.

Uma das maiores demandas energéticas do país é o aquecimento dos espaços, responsável por 25% do consumo final de energia. A Finlândia, apesar de caracterizar-se por um clima frio e longos invernos, tem vindo a necessitar de mais energia para arrefecimento devido ao aquecimento global, e medidas que visam um aumento da eficiência energética neste tipo de demanda tornam-se agora mais relevantes.

Apesar da eficiente e avançada rede de distribuição de aquecimento urbano do país, existem edifícios que ainda não estão cobertos pela mesma, e possibilidades para substituir o aquecimento tradicional a óleo e gás nestas exceções inclui o uso de bombas de calor.

No que à climatização e ventilação dos espaços diz respeito, auditorias efetuadas aos sistemas HVAC são da maior importância for forma a descobrir oportunidades de aumento da eficiência energética. No entanto, a complexidade dos sistemas HVAC varia de acordo com o tipo, design, e área dos edifícios, significando que o Sistema de Automação (BAS) tem um papel fundamental na gestão de cargas. Quando o controlo é estendido ao sistema de iluminação, os benefícios para a eficiência no geral são bastante relevantes.

Palavras-chave: Finlândia, escritórios, espaços comerciais, eficiência energética, políticas energéticas, building automation systems

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Abbreviations

ASHRAE - American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BAS – Building Automation System
CFL – Compact Fluorescent Lamp
CHP – Combined Heat and Power
CRI – Colour Rendering Index
EED – Energy Efficiency Directive
ELA – European Lift Agency
EPBD – Energy Performance of Buildings Directive
ETP – Energy Technology Perspectives
EU – European Union
GLS – General Lighting Service
HEPA – High-Efficiency Particulate Arrestance
HVAC – Heating, Ventilation & Air-Conditioning
IEA – International Energy Agency
LED – Light-Emitting Diode
LMS – Light Management System
MEE – Ministry of Employment and the Economy
NEEAP – National Energy Efficiency Action Plan
OECD – Organisation for Economic Cooperation and Development
SULPU – Finnish Heat Pump Association
ZEB – Zero-Energy Building

1 Introduction

The buildings sector has reached over one third of the total final energy consumption in the world and with the population number also increasing worldwide, the improvement of the energy use has been of major importance and concern over the past years.

Many countries around the world have been adopting energy measures and policies aiming to sustainable low-carbon economies and, have set short, medium, and long term targets with focus on the increase of energy efficiency and the penetration of renewable energies in their markets.

There are several possibilities to reduce the energy demand in the buildings sector. In fact, adding the best technology available to the knowledge of efficient architectural concepts in the design of buildings, it is possible to construct nearly zero energy buildings (ZEBs) which are characterized by their low energy demand, and consume most of that energy from renewable sources.

The architecture of the building itself plays then a fundamental role, as in a well-designed building project the demand for thermal loads is reduced and the use of natural light minimizes the demand for artificial light. Such efficient design also takes into account passive ventilation concepts, meaning that the air renovation indoors is done naturally without the use of mechanical ventilation equipment.

However, such energy performance is more easily and economically viable to be achieved in new constructions where every detail and concept are taken into account during the project phase.

Adding to this fact, most of the present building stock will still be standing for the next decades, therefore it is of major importance to explore all the possibilities which can turn them into more energy efficient and environmentally friendlier buildings.

1.1 Objectives of the dissertation

The improvement of energy efficiency is an extremely wide topic that can be covered from several points of view such as economical, governmental, environmental, institutional, technological, cultural or sectorial for example.

The available information is countless and relatively easy to be accessed by the public in general. However, the enormous amount of available data can sometimes be difficult and confusing to understand by the population, either by the use of technical terms, by the generalization of a certain topic, or simply because the information being researched has to be crossed over different references in order to obtain a clear answer.

Given the exchange period fulfilled by the author at the University of Aalto as an Erasmus student, this dissertation aims to give a clear picture about the energy demand by Finnish offices and commercial buildings, and discuss what can be done in order to achieve better levels of energy efficiency within the Finnish reality.

It also aims to give a simple briefing of the most relevant policies and strategies followed by Finland regarding energy efficiency in the buildings sub-sector, including some relevant energy indicators.

1.2 Structure of the dissertation

This dissertation is structured in the following way:

Section 2 places the sector of buildings on a frame of global energy demand, complemented with the identification of the essential energy policies and strategies adopted by the European Union and by the Finnish Government which are directed to the building sector.

Section 3 characterizes the energy use within the Finnish services sub-sector, whereas the most common sources of energy demand are put into frame.

Section 4 identifies the possibilities to increase the energy efficiency in the Finnish services sub-sector based in the economically viable replacement of technologies.

Section 5 introduces the role of automation in the improvement of electrical efficiency of buildings (building automation systems).

Section 6 offers a systematization of conclusions which might help define appropriate policies to reduce energy consumption/increase energy efficiency in buildings.

1.3 Scope of the dissertation

This dissertation is directed to the energy use by offices and commercial buildings in Finland, and it targets the efficiency improvements that are possible to undergo given the current building stock. The Finnish buildings sector is also placed in a frame of national energy consumption and some of the most important measures followed by the government in order to, directly and indirectly, improve the efficiency in the sector are also covered.

This dissertation is not meant to assess new constructions nor explores the design and working principle of efficient technologies which can be implemented in buildings.

2 The building sector and energy efficiency policies

2.1 World energy demand by buildings

Energy consumption can be seen as a distribution of demand between sectors, the major ones being transport, industry, and buildings. The buildings sector [1], which includes the residential and services sub-sectors is responsible for about 35% of the final energy consumption[1] in the world, and is therefore the most energy demanding sector as depicted in *Figure 1*. The buildings sector is responsible for about 17% of total direct energy-related CO_2 emissions from final energy consumers and, adding that percentage to the emissions related to electricity and heat consumption, the sector contributes overall with one-third of global CO_2 emissions.

Buildings require energy for different purposes such as heating, cooling, ventilation, lighting, and other applications. The type of energy required varies and if some applications require electricity to run, others require heating energy. Both electricity and heating energy can be provided by the grid (in case of heating energy from the grid we are talking about district heating networks which will be explained in a later section), but they can also be obtained from the transformation on-site of other types of energy such as fossil fuels or renewable energy. The mix of energy sources which represent the energy demand of buildings worldwide is depicted in *Figure 2*.

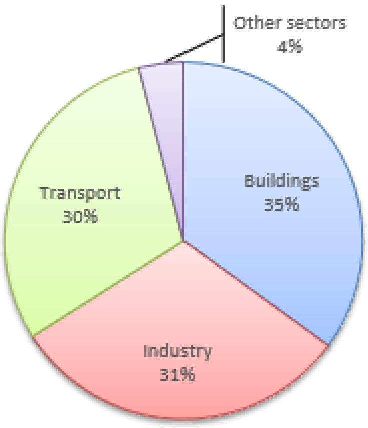

Figure 1 - Global final energy consumption by sector, 2010 *[1]*

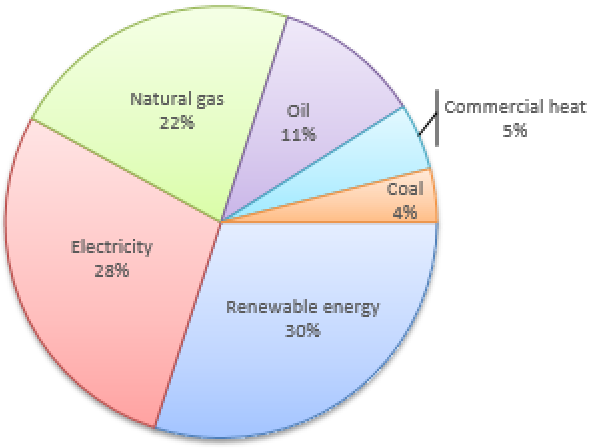

Figure 2 – Global energy mix of buildings sector, 2010 *[1]*

In a business-as-usual scenario[2], the energy demand by buildings worldwide is predicted to rise almost 50% between 2010 and 2050 [1]. This trend, however, can be reversed to a more positive reality by following an energy efficient and low-carbon pathways, which are estimated to lead to a 25% reduction in the total energy use for the same period of time. This environmentally friendlier

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[1] Final energy consumption is the energy that is provided for all final energy applications such as cooling and lighting for example.

[2] Business-as-usual scenario represents a scenario for future patterns of activity which assumes that current circumstances are expected to continue unchanged.

pathway represents energy savings of more than 40 Exajoules (EJ), which is equivalent to the levels of primary energy consumption achieved by India and Russia combined in 2010[3].

In 1971, buildings were responsible for 37% of the final electricity consumption in the world and reached 50% in 2010 [1]. During this period, the services sub-sector registered the biggest growth in the final electricity consumption in OECD countries in contrast with the small growth registered by the residential sub-sector. Nevertheless, the electricity consumption by the services sub-sector increased in both OECD and Non-OECD countries as shown in *Figure 3*.

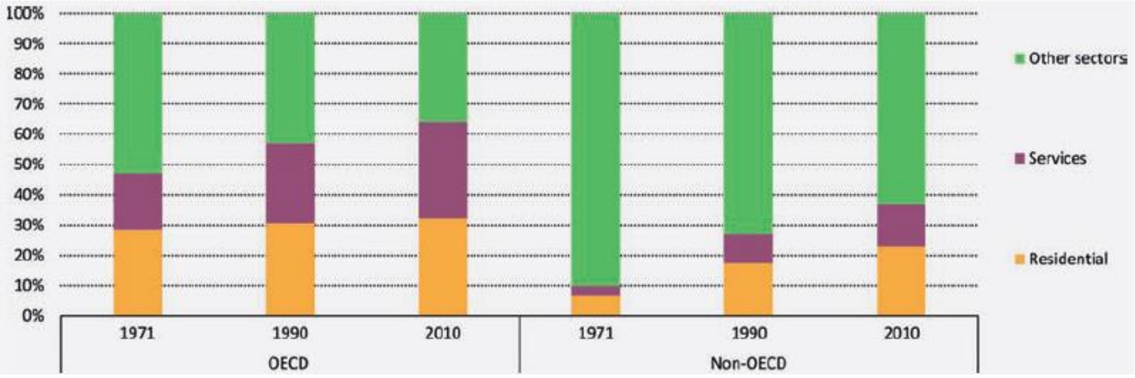

Figure 3 – Electricity consumption in the buildings sub-sector. *[1]*

As already mentioned, there are different types of end-use applications responsible for energy consumption in buildings, and they vary according to the type of building, building purpose, or geographical location. In moderate and warm climates, about 38% of the energy consumption in buildings goes for cooking whereas water heating comes as the second biggest demand of energy as depicted in *Figure 5*. In contrast, space heating is responsible for 45% of the final energy consumption in cold climate countries, and the value increases to 60% if we include water heating as shown in *Figure 4*.

The energy consumption trends in the buildings sector are mostly related to factors such as the age of buildings, building type, climatic conditions or improvements done in the energy efficiency. Regarding the services sub-sector specifically, the energy consumption trends are also related to the sector's level of activity and growth in floor area. For example, commercial buildings have different sources of energy demand than those found in office buildings.

Buildings are structures that often last for decades and some can last for centuries. More than half of the current global building stock will be standing in 2050 [1]. Looking at the actual building stock in OECD countries, this value will be closer to three-quarters, and the main reason is because

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[3] According to IEA, the total primary energy consumption in Russia and India in 2010 was about 55.79 EJ.

buildings in OECD countries are more frequently renovated than demolished and built from scratch. Given this fact, the improvement of energy efficiency in the actual building stock is crucial in order to reduce the total energy consumption of countries, therefore curbing the increase in greenhouse gas emissions that has been recorded worldwide.

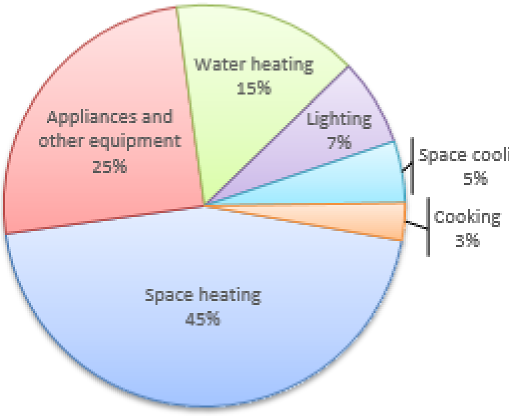

Figure 4 - End-use energy of buildings in cold climate countries, 2010 *[1]*
Note: Cold climate countries comprise OECD countries excluding Australia, Mexico, New Zealand and Israel, and non-OECD Europe and Eurasia

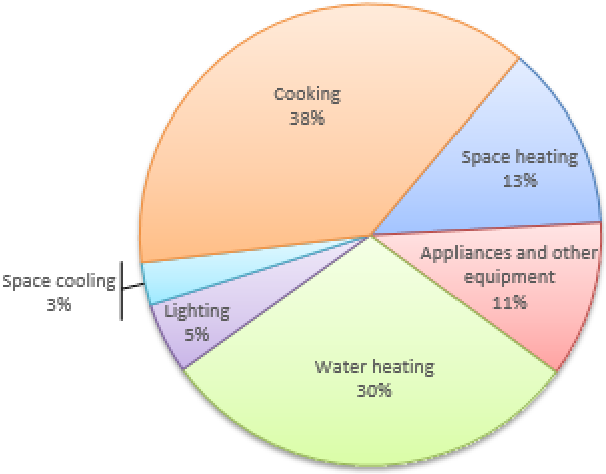

Figure 5 - End-use energy of buildings in moderate and warm climates, 2010 *[1]*

2.1.1 Predicting the future of the buildings sector worldwide

The ETP (Energy Technology Perspectives) Buildings model [2] by IEA, is a model that considers all energy uses that are traditionally associated with buildings and based on that information analyses possible global scenarios or trends regarding the energy use in the future, allowing different strategies to be taken in order to improve energy efficiency.

Simply put, the model analyses factors such as the type of building, floor area, or building age among other indicators, and determines the useful energy demands for the buildings. Based on each individual type of energy end-use, the model then offers different technology and fuel options including their current techno-economic features such as efficiencies for example, as well as their future improvement potential.

Every year IEA releases a publication on Energy Technology Perspectives, however such publications are not free of charge and, thus, this dissertation will cover the publication released in 2012.

ETP 2012 has analysed and modelled possible scenarios of global energy demand in the future, and it has projected two possible scenarios, 2DS and 6DS respectively.[4]

The 2DS scenario reflects a projection where certain targets are met in order to restrict the global average temperature increase to a maximum of 2ºC by 2050, as well as to cut global greenhouse gas emissions to least half by the same date.

The 6DS scenario shows a projection where the actual circumstances are expected to remain unchanged, meaning specifically that there is no effort on the part of the governments, industry or the general public to curb emissions, and the results are disturbing. According with the 6DS scenario, by 2050, the global energy use will almost double (when compared to 2010), and the total greenhouse gas emissions will rise even more, resulting in an average increase of at least 6ºC of the global temperature.

Under this projection, the global direct CO_2 emissions from all buildings will be about 25% higher in 2050 than in 2010, reaching a value of 3.5 Gigatonnes of CO_2 ($GtCO_2$) released into the atmosphere.

Under the 6DS scenario, the total energy demand in the buildings sector will increase from 117 EJ in 2010 to 173 EJ in 2050.

On the other hand, the results shown in the 2DS projection are more optimistic. Under this scenario, the energy consumption by the buildings sector will reach 130 EJ by 2050, which is 25% lower than the 6DS forecast, and only 11% higher than the 2010 levels.

Regarding the global annual direct emissions from buildings, the value will be 1.9 $GtCO_2$ in 2050, which is about 35% less than 2010 levels.

It is also important to notice that the energy indicators forecasted by the 2DS model can be achieved, despite the inevitable prediction of an increase of 68% in the number of households, 74% increase in the residential floor area, and a 66% increase in the services sub-sector floor area over the same period.

Achieving such goals will not only require a change in the current technology being used, but it will also be depending on the successful implementation of strong policies by countries to ensure that the full potential of energy efficiency is reached. [1]

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[4] In fact, an intermedium scenario (4DS) was also projected by IEA, where the temperature is set to increase by at least 4ºC in the long term. However, the author has preferred to keep the focus onto the two limiting forecasts (2DS and 6DS) so the reader can better perceive the impact that chosen policies and measures (regarding energy consumption and efficiency) will have in its whole extension.

2.1.2 Predicting the future of the services sub-sector worldwide

Since 1990, the consumption of energy has grown by 39% in OECD countries and 122% in non-OECD countries. Despite the slower increase in OECD countries when compared to the rest of the world, and considering the impact of the economic struggle felt in those countries over the last years, OECD countries still accounted for 68% of global energy consumption in the services sub-sector. [1]

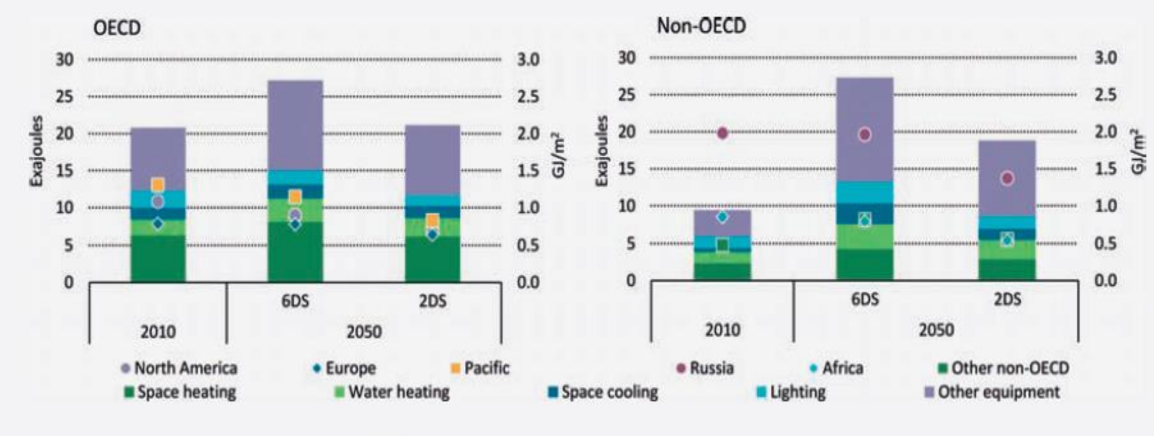
Looking into this sub-sector and considering the 6DS scenario, a growth in energy consumption of 1.5% per year between 2010 and 2050 is predicted, while the residential sub-sector is expected to grow by 0.8% per year.

As already mentioned, the floor area of the services sub-sector is expected to increase by 66% between 2010 and 2050 regardless of the path of energy use followed in the future.

Under the 2DS scenario, 57% of total energy consumption in the services sub-sector by 2050 will be due to electricity demand, which is 8% higher than the 2010 level. This trend is a consequence of the much greater consumption of energy by electrical end-uses, especially space cooling, lighting, office equipment and other electrical equipment.

Space heating will be responsible for 23% of the energy consumption, whereas water heating will be responsible for 13%. The final energy consumption trends in the services sub-sector according to the 2DS and 6DS models is depicted in *Figure 6*.

It is important to refer that the strong increase in floor area will be the main responsible for the doubling in energy consumption levels between 2010 and 2050 in the 2DS scenario in non-OECD countries. [1]



Notes: GJ = gigajoule, m² = square metre. Symbols for the different regions represent energy intensity in GJ/m².

Figure 6 - Services sub-sector energy consumption by end use and intensity for selected countries. *[1]*

2.2 European Union (27)[5] energy demand by buildings

The European Union is the largest regional energy market and the biggest energy importer in the world.

Buildings in the EU represent the sector that is responsible for the largest share of energy consumption having reached about 40% of total final energy use in 2010.

The overall energy use in EU buildings has increased at a rate of 0.9% per year between 1990 - 2010, whereas renewable energies grew at more than 3.0% per year. [1]

In the buildings sector, the electricity use increased by 62% whereas the use of energy from renewable sources increased by 81% during the same period, especially in the services sub-sector. During this period, the renewables penetration more than tripled in this sub-sector.

By 2010, renewables accounted for nearly 10% of total final energy consumption in buildings.

The European climate differs geographically, and the energy mix of the buildings sector also varies across Europe according to these geographical differences. Nordic and Eastern European member states have colder climates, and the need for space heating is higher in these countries than that in the warmer Mediterranean regions.

Space heating in the EU (27) is the end-use responsible for the largest demand in terms of final energy consumption, representing about 70% of the final energy consumption in the buildings sector. It is responsible for 66% of residential energy use, (*Figure 8*), and for about 39% of energy consumption in the services sub-sector as depicted in *Figure 7*.

In the colder Nordic countries and some Eastern European member states, space heating accounts for as much as 65% of total final energy demand in buildings.

In warmer climates, including many Mediterranean member countries, space heating demand is often less than half of building energy consumption.

However, space cooling is the fastest-growing end-use in both the residential and services sub-sectors across EU member countries, with an increase of 69% and 63% between 2000 and 2010, respectively. [1]

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[5] EU 27 without Croatia as it has joined the Union in 2013

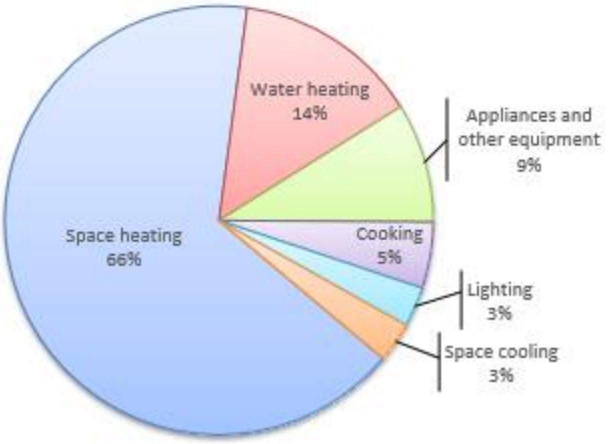

Figure 8 - Residential sub-sector energy consumption by end-use for EU (27), 2010. Total 12.8 EJ *[1]*

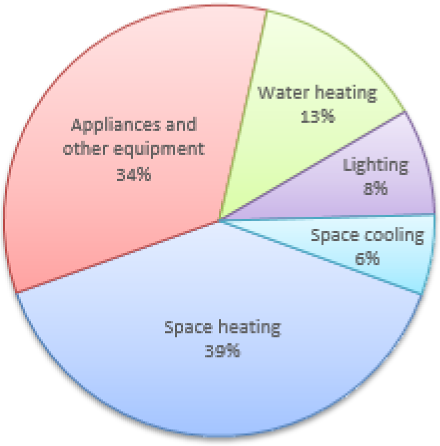

Figure 7 - Services sub-sector energy consumption by end-use for EU (27), 2010. Total 6.5 EJ *[1]*

2.2.1 Predicting the future of the buildings sector in the European Union (27)

The number of buildings in the EU is growing, and the building floor area also follows the trend as depicted in *Figure 9*. The floor area of both the residential and services sub-sectors is expected to rise between 2010 and 2050, but the growth in the services sub-sector itself is estimated to be 35% in 2050. As a result, it is essential to explore the possibilities to increase the efficiency of the energy use in this type of buildings.

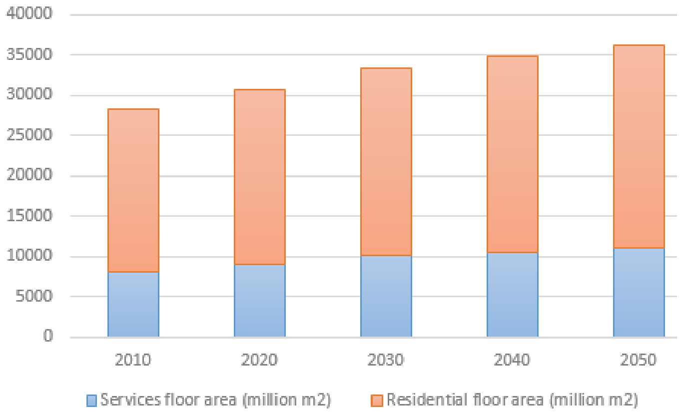

Figure 9 - Floor area growth forecast for the buildings sector in EU 27 members. *[1]*

The EU is continuing the path towards a de-carbonised economy with the reduction of the use of oil and coal in buildings under present commitments, through the release of energy related directives which are adjusted and implemented by every member country according to their own energy strategy.

Both 6DS and 2DS scenarios show that coal and oil use will decrease significantly by 2050 (in different proportions though), while the penetration of renewables will increase considerably in order to meet energy and emissions targets established for 2050.

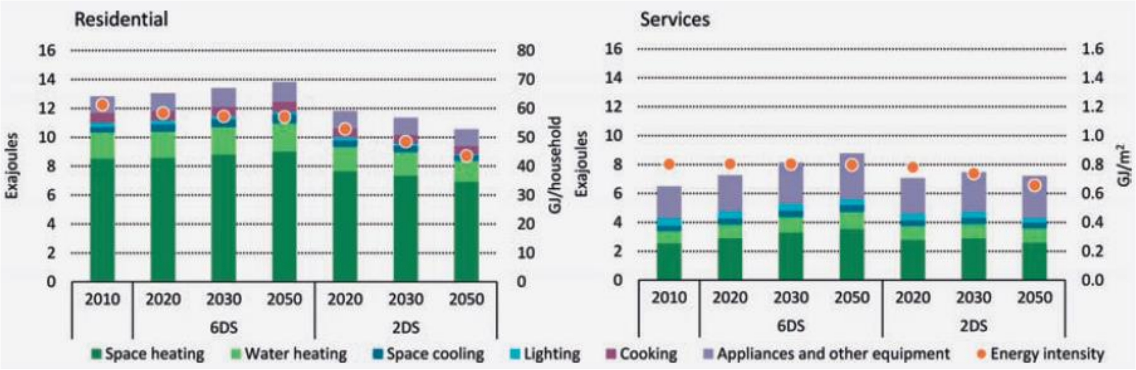

Figure 10 - EU (27) residential and services sub-sectors energy consumption by end-use and intensities. *[1]*

Notes: GJ = gigajoule. m2 = square metre. For the services sub-sector, cooking is reported under the category “Appliances and other equipment”.

Figure 10 depicts the energy consumption by source and energy intensities in the residential and services sub-sectors according to the 2DS and 6DS projections. It is possible to observe that in the services sub-sector the growing pattern of energy consumption by appliances and other equipment, represented by 6DS, have margin to be stabilized as shown by the 2DS model. The same goes for space heating, being the second type of demand which offers more potential to reduce energy consumption.

Under the 6DS, electricity and heat use in commercial buildings are expected to increase by nearly one-third in 2050, and the renewable energy sources, excluding biomass and energy from waste, more than double its value for the same period.

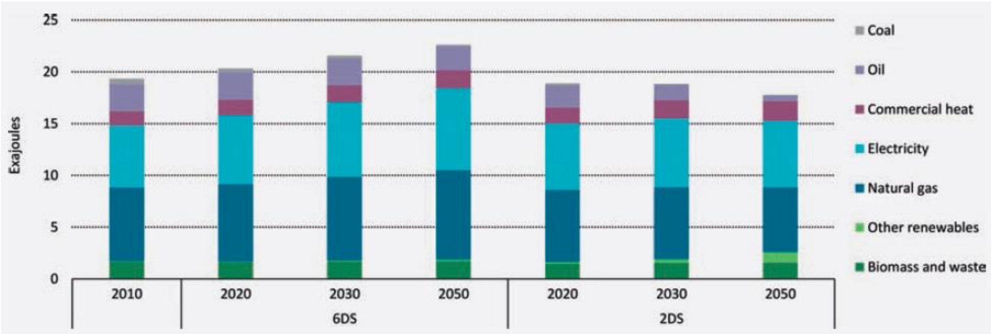

Figure 11 – Energy consumption by the buildings sector in EU (27) by energy source. *[1]*

Figure 11 shows the prediction of energy consumption by energy source of the buildings sector in EU (27) according to the forecasts obtained for the 2DS and 6DS models. The highest growth in the 6DS model happens in the consumption of electricity, value that increases only marginally in the 2DS model. In the 2DS, it is important to notice the drastic reduction in the oil dependence and the significant growth in the energy provided by renewable sources (wind, geothermal and solar). Regarding the energy intensities, in the 2DS model, the value of this indicator will decrease by 29% between 2010 and 2050 in the average household, whereas in services buildings the reduction will be about 18% for the same period. However, the energy intensities will remain more or less constant if no efforts to increase energy efficiency are done as shown by the 6DS model.

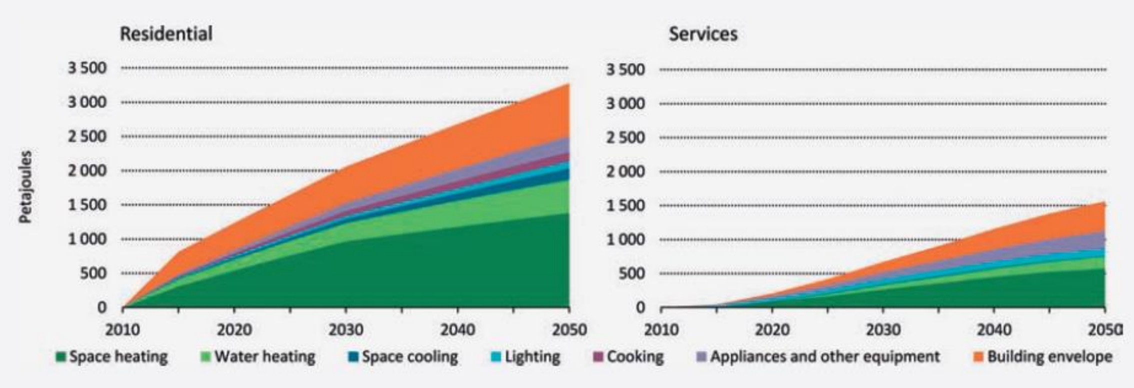

Figure 12 – Energy savings from 6DS to 2DS in EU (27) in the residential and services sub-sectors. *[1]*

Figure 12 depicts the overall energy savings that can be achieved in both residential and services buildings following the trends reflected by the 2DS and 6DS projections. Overall energy savings in the 2DS model account for roughly 4.8 EJ (about 1.6 EJ of energy savings only from services buildings) of reduced annual energy consumption by 2050 when compared to the 6DS.

This decrease in the energy consumption will give rise to a decrease in the annual emissions from the building sector to less than 500 $MtCO_2$ by 2050, or nearly 60% less than the levels projected by 6DS in 2050. [1]

Total improvements in the services sub-sector will account for roughly one-third of overall buildings energy savings by 2050.

It is important to notice that, in this sub-sector, the highest potential for energy savings is found in space heating. Naturally, improvements in the building envelope also offer big reduction possibilities.

Overall, space heating improvements can significantly reduce building energy intensities, where space heating accounts for about half of total buildings energy savings by 2050 in the 2DS model.

2.3 The Finnish energy sector

The total energy consumption in Finland comes from an even distribution of energy sources respectively fossil fuels, renewable energy and nuclear energy as shown in *Figure 13*.

Total energy consumption has seen ups and downs over the last 15 years, but it has been decreasing since 2010, and has stabilized at a value of 381 TWh in 2013, from which 303 TWh has been consumed as final use energy.

However, preliminary data for 2014 released by Statistics Finland [3] has estimated that these indicators were 372 TWh of total energy consumption from which 300 TWh were consumed by end use demands, meaning that the downward consumption trend continued in 2014.

By 2013, the total energy consumption from fossil fuels was 42%, renewable energy accounted for 31%, and nuclear energy for 18%. However, the use of fossil fuels has been decreasing, contrasting with the growth of energy produced by renewable energy sources.

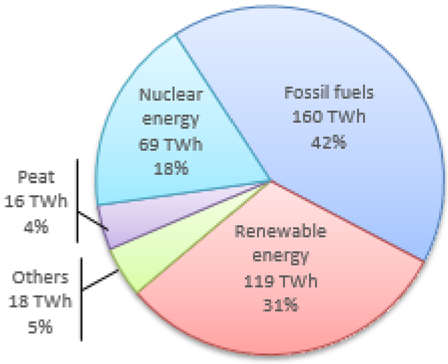

Figure 13 - Total energy consumption by source in Finland, 2013. Total 381 TWh *[3]*

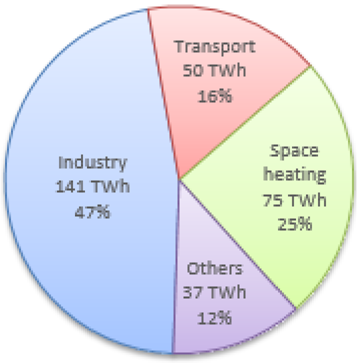

Figure 14 - Final energy consumption by sector in Finland, 2013. Total 303 TWh *[3]*

An inevitable characteristic of Finland's energy consumption structure is the high share of energy-intensive industry, as well as a long lighting and heating season. This can be observed in the final energy consumption of 2013, (*Figure 14*), where industry accounted for 47%, space heating for 25%, and transport for 16% of total demand.

Overall, both total and final energy consumption have decreased between 2010-2013 (preliminary data for 2014 maintains the decreasing tendency), reflecting the warmer temperatures felt in the country that reduced the consumption of energy for heating purposes. The increase in the imports of electricity within the Nordic Electricity Market also contributed for the decrease of the total electricity production.

Finland has a long term energy strategy [4], where two energy sources have been prioritised, nuclear energy and renewable energy.

In fact, Finland is on track to meet its share of the ambitious targets set by EU to reduce the greenhouse gas emissions of 20% below 1990 levels for the 2013-2020 period.

Finland is also running a renewables programme in order to increase the share of renewable energy to 38% of final energy consumption by 2020. [5]

In order to achieve this objective, the implemented measures include promoting the use of forest chips and other wood-based energy, the penetration of wind power as alternative energy source, the use of biofuels in transport, and the greater utilisation of heat pumps[6].

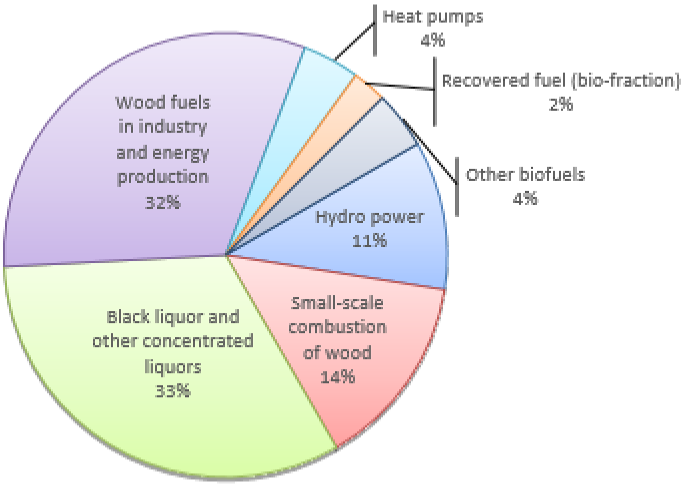

Figure 15 - Consumption of renewable energy sources in Finland, 2013.
Total 119 TWh *[3]*

In 2013, (*Figure 16*), about 68.3 TWh of electricity was produced in Finland of a total of 84.04 TWh, and nuclear energy itself was responsible for providing 26.9% of the total amount, whereas the net imports from the Nordic electricity market contributed with 18.7% of the total share.

The country has developed one of the World's most extensive and efficient combined heat and power (CHP) industries and district heating networks.

CHP accounts for about 27.8% of the electricity production and district heating provides almost half of the country's space heating.

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[6] The definition of "heat pump" as a source of renewable energy is far from being consensual. In fact heat pumps are mechanisms which transfer heat between two locations, and an external source of energy to run the whole system is required. However, the Finnish Heat Pump Association [58] (SULPU) claims heat pumps as a much cheaper way of generating heat when compared to traditional sources such as electricity, oil, pellets or even district heating.

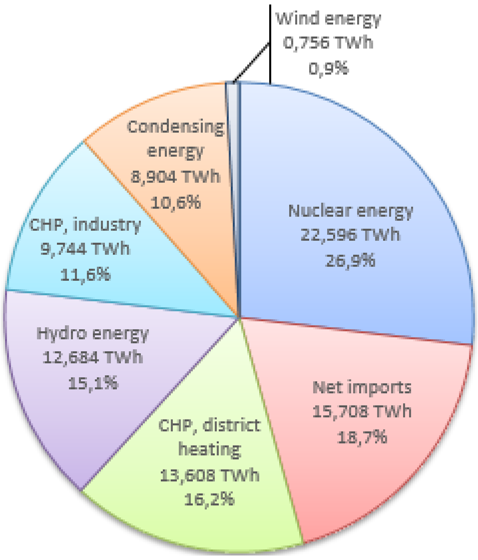

Figure 16 - Electricity supply/production in Finland, 2013.
Total 84.04 TWh *[3]*

2.4 The Finnish building sector

According to Statistics Finland [3], preliminary data shows that the total energy consumption in 2014 accounted with approximately 372 TWh (about 2% less than 2013 values). Under this data, the total electricity consumption was 83,3TWh. The services and buildings sector were responsible for 27% of the final consumption of electricity as depicted in the *Figure 18*.

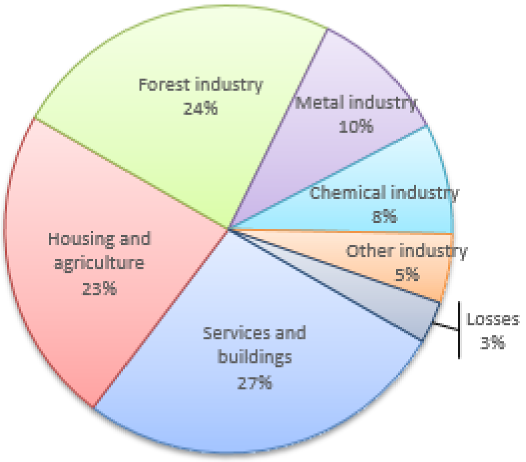

Figure 18 - Electricity consumption in Finland, 2014. Total 83.3 TWh *[3]*

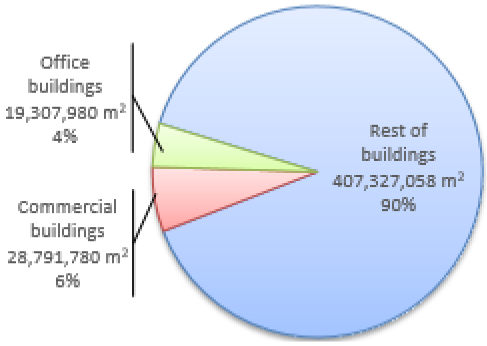

Figure 17 - Distribution of buildings by floor area, 2013. Total 455,426,818 m^2. *[3]*

Back in 2012 [6], Finland had a population of 5,398,300 inhabitants and, in 2013, the total building area in the country was 455,426,818 m^2 (*Figure 17*). From this whole, residential buildings accounted with 285,417,151 m^2, commercial buildings 28,791,780 m^2 and office buildings 19,307,980 m^2.

Over the last decades, the population of Finland and commercial activity have been concentrated in large urban areas, especially in Southern Finland. Regarding the floor area, the whole country's distribution of commercial and office buildings can be split into 3 areas: Helsinki sub-region, other growing sub-regions, and other sub-regions (*Figure 19*). Each of these 3 areas have nearly one-third of the total floor area of the country.

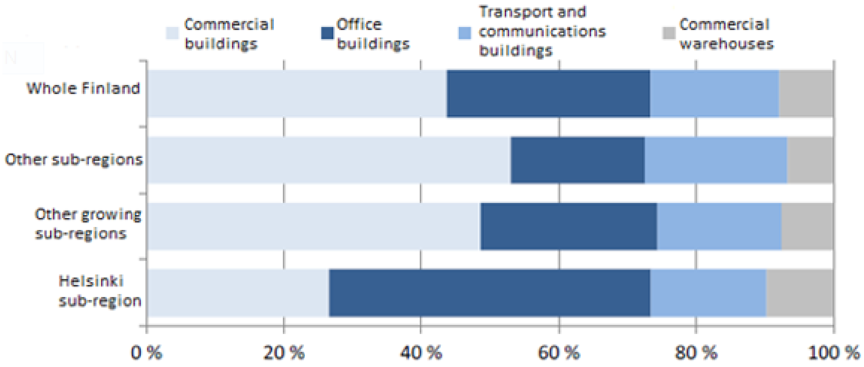

Figure 19 - Distribution of floor area of Finnish commercial and office buildings by location. *[6]*

Regarding the energy consumption of offices and commercial buildings, heating and hot water are responsible for the greatest energy consumption rates, whereas electricity demand accounts for a much smaller percentage as can be seen in *Figure 20*.

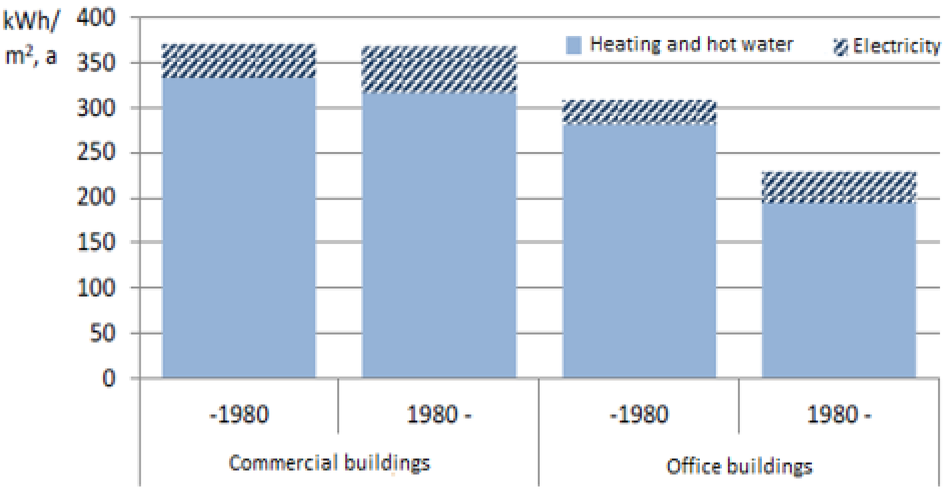

Figure 20 - Energy consumption of Finnish commercial and office buildings. *[6]*

Finland released a "*Long-term Climate and Energy Strategy*" in 2008 [4], and the Finnish government predicted that if no further action was taken the total primary energy consumption in

Finland would rise from 421 TWh (36.2 Mtoe) in 2006 to 479 TWh (41.2 Mtoe) by 2020 and to 523 TWh (45 Mtoe) by 2050.

The objectives of the country regarding the increase of energy efficiency and decrease of energy consumption aim for a final energy consumption of 310 TWh (26.66 Mtoe) by 2020 which corresponds to a level of primary energy consumption of 417 TWh (35.86 Mtoe) by 2020. [7]

Finland’s updated “*Climate and Energy Strategy”* released in 2013 [8], indicated that primary energy consumption could not increase as much as previously expected, mainly because of the economic recession faced by the country and also as a consequence of overall increases in energy efficiency across the economy.

Although the energy efficiency in the Finnish buildings sector has already been increasing for some time, it is the sector where the energy efficiency measures carried out by the government are expected to achieve the greatest energy savings.

Measures carried in the past such as the adjustment of building regulations or financial support for the acquisition of efficient heating systems and other residential improvements, are estimated to generate savings of 12% in the energy consumption by 2016, reaching more than 15% in 2020 when savings are expected to reach 18.6 TWh (1.6 Mtoe). [5]

2.5 Policies and measures

2.5.1 EU directives for energy efficiency in buildings

When it comes to reducing the energy consumption of buildings, the “Energy Performance of Buildings Directive” and the “Energy Efficiency Directive” are the EU’s main legislation and they are described as follows. [2]

2.5.1.1 Energy Performance of Buildings Directive 2010 (2010/31/EU)

The EU introduced the Energy Performance of Buildings Directive (EPBD) in 2002 as a measure to improve the energy efficiency in the buildings sector. The EPBD is a directive that requires all EU countries to improve their building regulations by establishing minimum energy performance requirements, an energy performance calculation method, and energy certification and inspection schemes for boilers and air-conditioning systems.

However, in 2010, the EPBD was revised with tougher requirements for buildings, also including a requirement which called for all member states to ensure that all new buildings be nearly zero-energy buildings (ZEBs) in the forthcoming years. [1]

A zero-energy building is a building with very low energy demand, where the required energy is primarily supplied by renewable sources, being therefore an environmentally friendly energy end-use. [9]

Under the EPBD [10]:

- Energy performance certificates must be included in all advertisements for the sale or rental of buildings.
- EU countries must establish inspection schemes for heating and air conditioning systems or put in place measures with equivalent effect.
- All new buildings must be nearly zero energy buildings by 31 December 2020 (public buildings by 31 December 2018).
- EU countries must set minimum energy performance requirements for new buildings, for the major renovation of buildings, and for the replacement or retrofit of building elements (heating and cooling systems, roofs, walls, etc.).
- EU countries have to draw up lists of national financial measures to improve the energy efficiency of buildings.

2.5.1.2 Energy Efficiency Directive 2012 (2012/27/EU)

The EU introduced the Energy Efficiency Directive (EED) in 2012 with the objective of reducing the total energy consumption and greenhouse gas emissions of all member states through the improvement of energy efficiency.

The Energy Efficiency Directive requires that all member states establish goals at national level regarding energy efficiency by 2020. These goals to be achieved are based on either the indicators of total energy consumption or final energy consumption.

This directive also establishes standards to energy suppliers and end-use consumers.

Under the EED [10]:

- EU countries should make energy efficient renovations to at least 3% of buildings owned and occupied by central government.
- EU governments should only purchase buildings which are highly energy efficient.

- EU countries must draw-up long term national building renovation strategies which can be included in their "National Energy Efficiency Action Plans" (NEEAPs). NEEAPs are plans where energy related indicators and measures regarding the improvement of energy efficiency are set according to each individual country. Examples of contents that form such plans are an estimation of energy consumption, planned energy efficiency measures, and the improvements that individual EU countries expect to achieve. Under the EED, the member countries must draw up these plans every three years, and also provide annual reports. [11]

2.5.2 EU 2020 Energy Strategy

Europe 2020 [12] is a strategy promoted by the EU that has the promotion of growth and employment as a key objective. Accordingly, five main targets were set to be accomplished by the end of 2020. The targets are related to employment, research and development, climate change and energy sustainability, education, and poverty reduction.

These targets are translated into national targets in each EU member country separately, reflecting different situations and circumstances.

The "Climate change and energy sustainability" target, also known as the "20/20/20" target is defined by:

- Reduction of greenhouse gas emissions to a level 20% lower than 1990 (or even 30%).
- Achievement of 20% of energy consumption from renewable sources.
- Increase the energy efficiency by 20%.

2.5.3 Energy strategies and policies adopted by Finland

As a member of the EU, Finland has to ensure compliance with the European Union's directives. The European Union's directives [13] that have significant influence in the national energy and climate policies of Finland are:

- Energy Performance of Buildings Directive (2010/31/EU) [14]
- Energy Efficiency Directive (2012/27/EU) [15]
- Renewable Energy Sources Directive (2009/28/EC) [16]
- Eco-design Directive (2005/32/EC) [17]
- Emissions Trading Directive (2003/87/EC) [18]

In order to reduce the overall energy consumption of buildings, building codes have been updated and subsidies to enhance the efficiency of the existing building stock have been introduced.

As already seen, heating accounts for the highest energy demand by buildings, and the Finnish Government has various measures in place to encourage switching from oil-heating systems to district heating, wood-based boilers, heat-pumps, or renewable energy sources such as biofuel oils and solar-powered heating. The switch is promoted through the energy advice system and the Höylä III Energy Efficiency Agreement, and encouraged by a 2011 subsidy scheme, whereby the government covers up to 20% of the cost of installing efficient or wood-fuelled heating systems. [5]

Energy efficiency audits have also been supported by the Ministry of Trade and Industry since 1992, and continued now by the Ministry of Employment and Economy. Energy audits are studies of energy consumption in buildings which, in turn, offer opportunities that increase the efficiency in the use of energy. [19]

The most important events regarding the placement of Finland in the way toward a de-carbonized economy and also as a response to the energy measures imposed by the European Union are as follows.

2.5.3.1 Long-term Climate and Energy Strategy (2008)

On November 6th 2008 [20], as a response to the goals set by the European Commission for Finland regarding the energy sector, the Finnish Government approved an ambitious "*Long-Term Climate and Energy Strategy*" where the principal objectives and means of Finland's climate and energy policy for the next decades were presented.

Having forecasted a primary energy consumption of 479 TWh, final energy consumption of 347 TWh and electricity consumption of 103 TWh by 2020, the Government proposed key measures to reach the objectives set by the EU regarding the promotion of renewable energy, the enhancement of efficiency in energy consumption, and the decrease of greenhouse gas emissions. According to the Strategy [4] the main goals to be achieved are:

- Final energy consumption of 310 TWh (same as 2008 level) and electricity consumption of 98 TWh (around 8 TWh higher than 2008 levels) in 2020.

  In order to achieve this objective, the efficiency of energy consumption had to be improved, particularly in housing, construction and transport. As the range of measures required was broad, some measures were completed later as part of the work of the Energy Efficiency Committee which was underway back then.

- A share of renewable energy sources in the final energy consumption of 38% by 2020 through intensified support and steering systems.

  The key points to meet this obligation were based on a strong increase in the use of wood-based energy, waste fuels, heat pumps, biogas and wind energy.

  The use of forest chips would increase, and also 6 TWh of wind energy is set to be part of the total share of energy provided by renewable sources by 2020. This means that a minimum of 700 new 3 MW wind power plants in Finland are going to be constructed by that date.

  As a new method for promoting renewable energy, a cost-effective feed-in tariff system, operating on market terms, was introduced.

2.5.3.2 Government decision on energy efficient measures (2010)

On February 4th 2010 [21], after the approval of the *“Long-Term Climate and Energy Strategy 2008”* for Finland, the Government issued its statement on the strategy.

The objectives of the long-term strategy, already mentioned above, meant an improvement in the final energy consumption of 37 TWh (about 11% of the forecasted consumption), and an increase of the efficiency in the electricity consumption of 5 TWh (about 5% of the forecasted consumption) by 2020. In the long term, the objective set was to decrease the final energy consumption by 2050 of at least one third of the 2020 levels.

Regarding the building sector the government decided the following policies and measures, most of which were implemented in 2011:

- Stricter energy regulations for new building projects.
- Support and encouragement for renovation, construction and improvement of energy efficiency of buildings through targeted economic steering and support measures.
- Promotion of life-cycle based tools for building planning, use and maintenance.
- The development and implementation of operating models for the planning and customer-oriented realisation of renovation construction, in co-operation with the actors in the construction and real estate sector.

2.5.3.3 Long-term Climate and Energy Strategy update (2013)

On March 20th 2013 [8], the Government proceeded to update the *"Long-term Climate and energy Strategy"* released in 2008 in order to ensure that the national targets for 2020 will be achieved and also to prepare a pathway toward meeting the long-term energy and climate objectives. The new goals and measures put in place to increase the efficiency of buildings were the following:

- Overall improvement (in all sectors) of energy efficiency to ensure that the final energy consumption targets set in the "*Long-term Climate and Energy Strategy 2008*" will be met (maximum of 310 TWh by 2020).
- Design of a National Energy Efficiency Action Plan (NEEAP) in accordance with the Energy Efficiency Directive 2012/27/EU.
- Preparation of a long-term strategy to improve the energy efficiency of buildings, concerning the time limit set in the Energy Efficiency Directive 2012/27/EU.

Additional measures were also included [8] in order to achieve the objective set by the EU regarding the emissions reduction of at least 80%, outlined in the low-carbon and energy road maps to 2050. These additional measures related to the building sector are:

- Systematic property management and the improvement of energy efficiency whenever buildings undergo renovation (for example, the building envelope, ventilation, domestic hot water), which enables more cost efficient implementation of energy-efficiency measures in comparison to those carried out separately.
- Establishment of a working group to investigate the opportunities for promoting small-scale generation. The working group will be tasked with evaluating the role of small-scale generation in the promotion of renewable energy and the energy efficiency of buildings in particular, including zero or nearly zero-energy construction. In addition, the working group will consider measures to promote the viability of small-scale generation.

2.5.4 Finnish energy entities

There are several entities in Finland which are directly related to the establishment and management of the energy measures and policies adopted by the country, or simply carry major responsibilities within the energy sector. Some of the most relevant entities are as follows:

Ministry of Employment and the Economy [22]

The Ministry of Employment and the Economy (MEE) is the supreme entity which co-ordinates and plans the energy policy of the country, including the transposition of EU energy directives into national law.

In the electricity sector, for example, the MEE determines the policies related to the security of energy supply and the functioning of the market. However, climate policy, housing, building and planning are the responsibility of Ministry of the Environment.

Motiva Oy [23]

Motiva Oy is a company owned by the State and its main tasks are related with the promotion of energy efficiency and sustainable use of energy. Motiva carries responsibilities in marketing energy efficiency agreements; management of energy audits and training of auditing personnel; and promotes the use of renewable energy. Naturally, Motiva Oy receives most of its funding from the MEE.

Tekes [24]

Tekes is the “Finnish Funding Agency for Technology and Innovation”, which is part of the Ministry of Employment and the Economy, and it funds research and development of projects carried out by companies, research centres and universities. As a public entity, the funds are granted from the State budget.

Tukes [25]

The “Finnish Safety and Chemicals Agency” (Tukes) is a product surveillance centre, and is the entity in charge of the market surveillance of both “Ecodesign Directive” and “Energy Labelling Directive”.

VTT [26]

The “Technical Research Centre of Finland” (VTT) is another state-owned organisation, and is the biggest multi-technological applied research organisation in Northern Europe.

Its focus areas are new energy technologies, fuels and combustion, nuclear energy, engine technology and energy in transportation, pulp and paper industry, and energy systems.

3 The energy use in offices and commercial buildings

3.1 Lighting

Lighting [27] is a large and rapidly growing source of energy demand in the world, and almost one fifth of the total amount of electricity generated is consumed in lighting.

Back in 2005 grid-based electricity consumption for lighting was 2650 TWh worldwide, representing 19% of the total electricity consumption at that time.

However the use of artificial lighting is not uniform across the globe. The developed countries are equipped with the greatest share of artificial lighting, whereas fuel-based lighting is still widespread in developing countries. Yet, nowadays the picture is changing, and the demand for electricity-based lighting is growing in such countries.

Almost half of the global electricity use for lighting (48%) is consumed by the service sector. The rest is distributed between the residential sector (28%), industrial sector (16%), and street and other lighting (8%). More than 50% of the electricity used by lighting is consumed in IEA member countries.

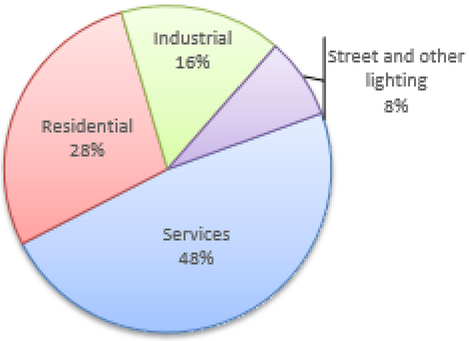

Figure 21 – Worldwide electricity use for lighting by sector, 2005. *[27]*

The use of artificial light is also translated in environmental impacts, and such impacts are derived from the energy consumption of lighting itself, the materials used to produce lighting equipment, and the disposal of used equipment. Yet, lighting is one important cause of energy-related greenhouse gas emissions.

Back in 2005, the total lighting-related CO_2 emissions was estimated to be 1900 Mtons, representing 7% of the global CO_2 emissions from the use of fossil fuels.

However, despite the growing demand for artificial lighting, a number of studies [27] have proven that increasing the energy efficiency of lighting used in buildings is a cost-effective way to reduce CO_2 emissions. The biggest potential to reduce CO_2 emissions and improve the energy efficiency of lighting can be made in developing countries, where the lighting systems are the least developed (efficient), followed by countries with economies in transition, and the smallest gains can be made in already industrialised countries, where the lighting systems are the most developed (efficient).

3.1.1 Lighting in buildings

In 2005 [27], global lighting electricity consumption of commercial buildings was equivalent to 48% of the total lighting electricity consumption.

The amount of electricity used for lighting in buildings varies according to the type of building, and in some cases, it is one of the single largest electricity users like in most of the commercial buildings.

Currently, fluorescent lamps dominate the lighting preferences in both office and commercial buildings.

Back in 2005, in OECD commercial buildings, linear fluorescent luminaires provided 76.5% of the light output and the rest of the light output was provided by a mixture of incandescent, compact and HID lamps (high-intensity discharge lamps).

The high purchase price of CFLs (compact fluorescent lamps) compared to incandescent lamps has been a major barrier to their market penetration even though they last much longer, save energy, and have short payback periods.

The important factors concerning lighting are energy efficiency, daylight use, individual control of light, quality of light, emissions during the lifecycle, and total costs.

3.1.2 Energy regulations and policies in lighting

In order to increase energy efficiency and to reduce greenhouse emissions, the use of energy for lighting is part of many directives, regulations and other pieces of legislation within the European Union.

The most important directives and other pieces of legislation at the European level regarding the lighting sector are [27]:

- Eco-design Directive (2009/125/EC) [17]
- Ballast Directive (2000/55/EC) [28]
- Energy Performance of Buildings Directive (2010/31/EU)
- Energy Efficiency Directive (2012/27/EU)
- Energy Efficiency Label Directive (98/11/EC) [29]

The regulation 244/2009 [30] from the European Commission which concerns eco-design requirements for non-directional household lamps has determined the phase out of inefficient lamps from the European market since 2009 as can be seen in Table 1.

Stage	Date	Lamps to be banned (i.e. cannot be “placed on the market” anymore)
1	1 Sept 2009	All non-clear lamps not equivalent-class A (any power)
		Clear lamps equivalent-class D, E, F, G with luminous flux ≥ 950 lm (e.g. power ≥ 100 W incandescent lamps, 230 V > 60 W halogen lamps)
		Clear lamps with luminous flux < 950 lm equivalent-class F,G
2	1 Sept 2010	Clear lamps equivalent-class D, E, F, G with luminous flux ≥ 725 lm (e.g. power ≥ 75 W incandescent lamps, 230 V = 60 W halogen lamps)
		Clear lamps with luminous flux < 725 lm equivalent-class F,G
3	1 Sept 2011	Clear lamps equivalent-class D, E, F, G with luminous flux ≥ 450 lm (e.g. power ≥ 60 W incandescent lamps, 230 V ≥ 40 W halogen lamps)
		Clear lamps with luminous flux < 450 lm equivalent-class F,G
4	1 Sept 2012	Clear lamps equivalent-class D, E, F, G any power
5	1 Sept 2013	Enhanced functionality requirements
6	1 Sept 2016	Poor efficiency halogens (C)

Table 1 – Lamps to be banned according to the EC regulation 244/2009 *[27]*

3.1.3 Lamp types and their typical characteristics

Several lamp types are currently available on the market, offering different features which are most useful for each individual type of application. *Table 2* depicts the characteristic of the most common lamps.

Lamp type	Characteristics							
	Luminous efficacy (lm/W)	Lamp life h	Dimming control	Re-strike time	CRI[7]	Cost of installation	Cost of operation	Applications
GLS[8]	5-15	1000	Excellent	Prompt	Very good	low	Very high	General lighting
Tungsten halogen	12-35	2000-4000	Excellent	Prompt	Very good	Low	High	General lighting
Mercury vapour	40-60	12000	not possible	2-5 mins	Poor to good	Moderate	Moderate	Outdoor lighting
CFL	40-65	6000-12000	with special lamps	Prompt	Good	Low	Low	General lighting
Fluorescent lamp	50-100	1000-16000	good	Prompt	Good	Low	Low	General lighting
Induction lamp	60-80	6000-100000	not possible	Prompt	Good	High	Low	Places where access for maintenance is difficult
Metal halide	50-100	6000-12000	possible but not practical	5-10 mins	Good	high	Low	Shopping malls, commercial buildings
High pressure sodium (standard)	80-100	12000-16000	possible but not practical	2-5 mins	Fair	High	Low	Outdoor, streets lighting, warehouse
High pressure sodium (colour improved)	40-60	6000-10000	possible but not practical	2-6 mins	Good	High	Low	Outdoor, commercial interior lighting
LEDs	20-120	20000-100000	excellent	prompt	Good	High	Low	All in near future

Table 2 – Lamp types and characteristics. *[27]*

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[7] CRI, also known as “Colour Rendering Index” is a measure that represents the ability that a certain light source has to reveal the “natural” colour of an object. “Natural” colour in this context is the colour perceived when the object is exposed to daylight for example.

[8] GLS, also known as “General Service Lighting lamps”, represent in this table the “Incandescent Lamps”.

3.2 Elevators and Escalators

If the buildings sector is responsible for about 35% of the final energy consumption worldwide, elevators and escalators account for 2-10% of the energy consumption of a building. [31]

However, the most known monitoring campaign in Europe, called the Energy-Efficient Elevator and Escalators (E4) Project, suggests that the energy consumption of elevators can account for 3% to 8% of the total electricity consumption of a building. [32]

According to E4project, about 4.8 million elevators and 75,000 escalators and moving walks were operating in the European Union (27) in 2010.

Only in the services sector, there were about 1.6 million elevator units and about 56,000 escalators and moving walks.

It is also estimated that every year 125,000 elevators and 5,000 new escalators and moving walks are installed.

In terms of electricity consumption, elevators and escalators accounted for 1% of the total electricity consumption in the services sector of the European Union (27) in 2010, and the consumption trend was set to be increasing.

A cooperation between E4project and the national member associations of the European Lift Association (ELA) has concluded that the total electricity consumed by elevators in EU (27) plus Norway and Switzerland in 2010 was estimated at 18.4 TWh. For this value contributes the residential sector with 6.7 TWh, the services sector with 10.9 TWh and the industrial sector with 810 GWh. [33]

The same cooperation has depicted the amount of elevators in Finland. The numbers referent to the offices and commercial buildings are shown in Table 3. It is possible to observe that in Finland, gearless traction elevators are the most common in the offices whereas geared traction elevators have a greater share in commercial buildings. These two types of elevators are explained in 3.2.2.

Use	Number of units	Age	Technology		Nominal load	Speed	Rise	Number of trips per year
		Decade of installation	Electro mechanic or Electronic	Geared Traction, Gearless Traction, drum or Hydro	Kg	m/s	m	
Office	1500	-1980’s	Electro mechanic	Geared traction	630	1,0	20,00	100000
	3000	1990’s-2000’s	electronic	Gearless traction	630	1,0	22,50	120000
Commercial	1000	2000’s	Electronic	Gearless traction	1600	1,00	13,00	250000
	2000	-1990’s	Electronic	Geared traction	900	1,00	13,00	300000

Table 3 – Lifts in Finnish offices and commercial buildings. *[34]*

3.2.1 Elevator consumption

The electricity consumption of elevators happens in both running and standby modes. Running mode refers to the periods of time where the elevator is moving between floors, whereas standby mode refers to the periods when the elevator is not being used or is idle.

In fact, the measurements carried by E4project have shown that the overall electricity consumption of elevators is greatly affected by the consumption during the standby mode as presented in Figure 22.

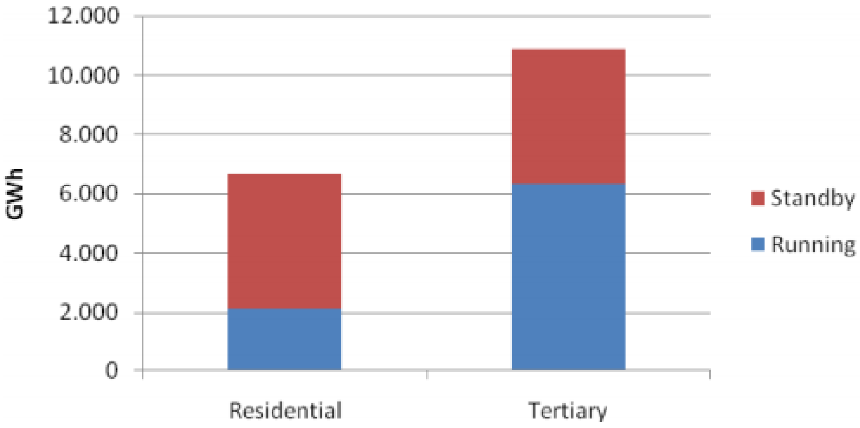

Figure 22 – Annual electricity consumption of elevators in the residential and services sectors in Europe (27) plus Norway and Switzerland. *[33]*

The factors affecting the energy consumption of lifts include the number of floors, floor height, population inside the building, traffic pattern, total running time, number of start-ups, cabin lighting, and the design of the mechanical and control systems. [35]

3.2.2 Elevator types

Elevators can be divided into two different types: hydraulic and traction elevators. [36]

In hydraulic elevators, the cart is pushed upward by means of a hydraulic cylinder installed at the bottom of the shaft. An electric motor drives a pump which forces a fluid (usually oil) into the cylinder starting the upward movement. Then, for the descents, a valve controls the fluid to flow back into the tank.

However, this type of lift is slow (speed less than 1m/s) and the maximum travel distance is 20m.

In traction lifts, the car is suspended by wire ropes (or belts) which are driven by an electric motor. A counterweight is also used and generally equals the mass of the car plus 45 to 50% of the rated load. This counterweight keeps the whole system balanced, which reduces significantly the energy consumption.

The traction lifts can also be geared or gearless lifts. In geared lifts a reduction gear is used to reduce the speed of the car and are typically used in buildings which range from 7-20 floors. Its speed varies between 0.1 to 2.5m/s.

Today, gearless lifts are the most common type of lift, and their speed ranges from 0.63 to 10 m/s. In this type of lift, the roller is driven directly from the motor.

3.3 Heating

3.3.1 The heating system in Finland

Space heating is naturally responsible for a large share of energy consumption in Finland.

According to Statistics Finland [3], space heating of buildings accounted for one-quarter of the final energy consumption in 2014.

The heating systems of buildings in Finland are driven by wood, geothermal energy, district heating, electricity and oil. Over the years, electricity based heating systems have been replacing the wood and oil based systems, however, the majority of the buildings in Finland are heated by means of district heating. Recently, old buildings have been connected to the district heating network and the district heating has got considerably widespread [6]. The distribution of sources for heating in Finnish offices and commercial buildings is depicted in Figure 23.

District heating consumption accounted for 31.700 GWh in 2013. The consumption was shared between residential buildings (55%), industrial sector (10%), and other customers such as offices and public buildings (35%). [37]

District heating is then a natural and reliable heating method in densely built areas, and it is available in almost all towns and population centres over Finland. Almost 50% of the heating market is taken by district heating, and about 95% of apartment buildings and most public and commercial buildings are connected to the district heating network.

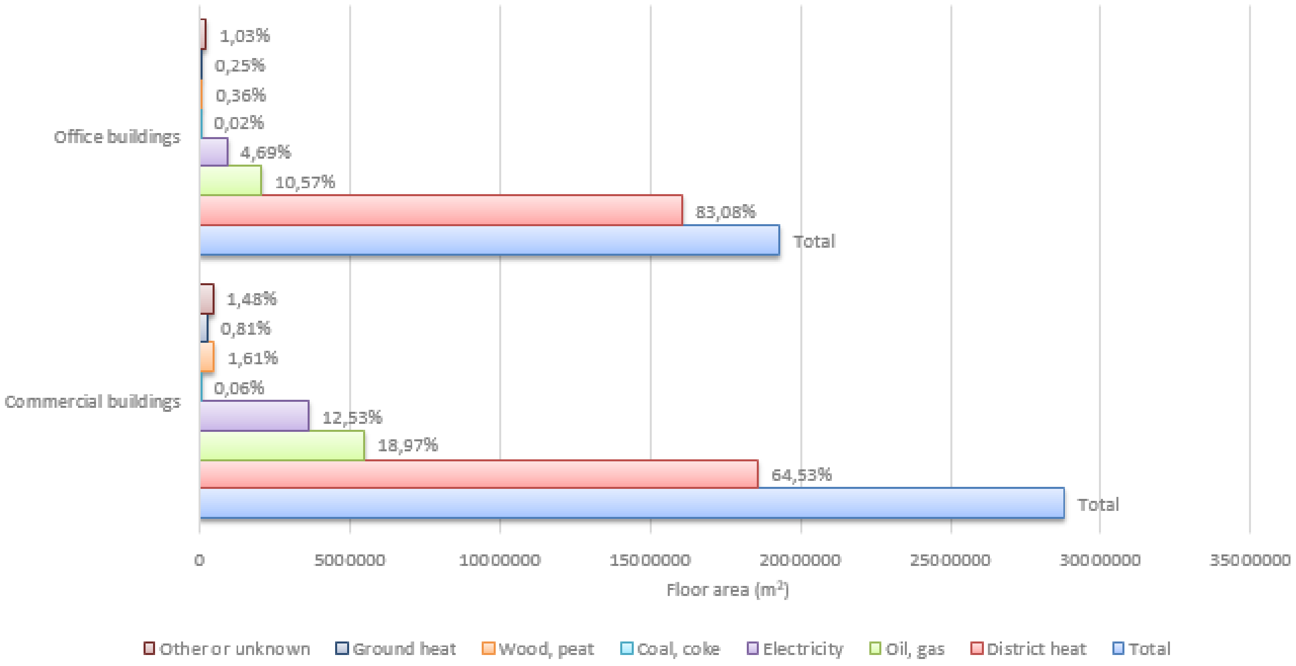

Figure 23 - Distribution of heating sources in Finnish offices and commercial buildings, 2013. *[3]*

District heating utilises heat energy generated in electricity production (combined heat and power generation CHP) and as waste heat from industrial and other processes which would otherwise be wasted, this being the main reason why district heating is considered as an efficient system. [38]

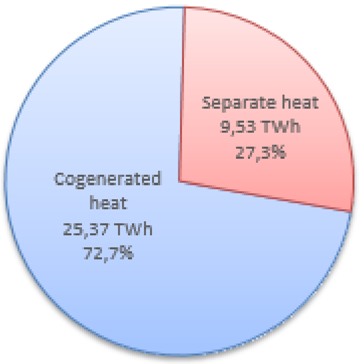

Figure 24 - District heat production in Finland, 2013. Total 34.9 TWh. *[3]*

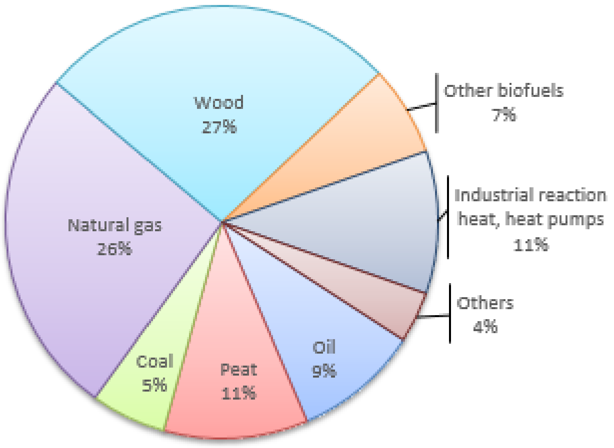

Figure 25 - Fuels for separate district heat production in Finland, 2013. Total 11 TWh. *[3]*

In Finland, the district heat production comes from cogenerated heat and separate heat as shown in Figure 24 and Figure 25. In general, three quarters of district heating comes from cogeneration (CHP) plants. It is mostly produced by means of natural gas (32%), coal (23%) and biofuels (22%) whose percentage is forecast to grow. Despite the fact that district heating and CHP usually rely on conventional energy production that involves a great amount of fossil fuel combustion, studies have shown that there is no advantage from replacing district heating by property-specific renewable energy systems. [6]

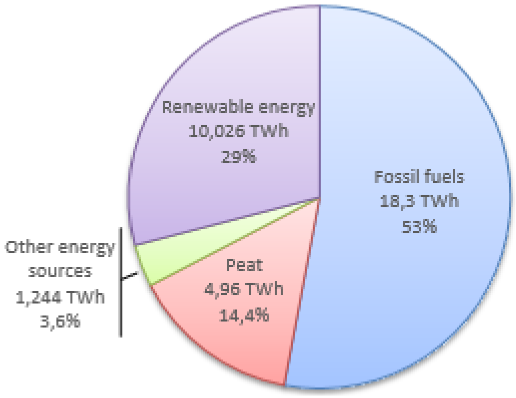

Figure 26 - District heat production in Finland, 2013.
Total 34.9 TWh. *[3]*

3.3.2 District heating working principle

A district heating network is a set of facilities with a heat generation unit or boiler, a network of pre-insulated pipes, and a group of buildings that need to be heated.

At first, the boiler from the heat generation unit heats water. The boiler room can be powered by fossil fuels (gas, oil or coal), recuperation fuels produced by household garbage for example, and renewable energy such as wood or geothermal energy in case of biomass and or heat from earth respectively. [39]

The heated water is channelled by the network of pre-insulated pipes to the various places of consumption, in this case buildings.

Within every building, substations are equipped with an exchanger. The purpose of the exchanger is to help transfer the heat from the network of pre-insulated pipes to the internal network of the buildings. The exchanger also makes it possible to adjust the flow and the temperature according to user needs, and to monitor the heat consumption.

The network is specifically adapted for the use of alternative energies such as recuperation and renewable energies.

The district heat system requires very little maintenance from the end user and it is easy to join the network in some countries such as Finland. [40]

The most effective way to generate district heat is in a combined heat and power production (CHP). The CHP facilities generate electricity at the point of end use instead of a high-voltage transmission system. Most importantly, CHP gathers leftover, or otherwise wasted heat from the generation process and converts it into energy to be further utilized in heating, cooling or other energy needs. A CHP system provides often substantial financial savings on energy cost especially in cases where high demand for the recovered heat exists.

The benefits of district heating are the energy costs, which are more stable for district heating customers, as well as improved energy security, reduced air emissions by centralizing boiler operations, and the high efficiency obtained. [39]

3.4 Cooling

The mechanical cooling of buildings, such as retrofitted air conditioning systems have become very common in Finnish buildings such as in offices [41]. Due to climate changes, the Finnish climate has become warmer, decreasing the need for heating and increasing the need for cooling. It has been estimated that, in the worst possible scenario in the future, as much as 20% of a building’s electricity may be used for cooling in Helsinki.

The Helsinki’s main energy company (HELEN) is already on its way to expand the district cooling network, where 80% of energy need is covered with renewable waste energy. District cooling is covered below.

3.4.1 District cooling

District cooling is the process of distributing chilled water from a central generation source for cooling and air-conditioning. This chilled water can be produced from different sources, including electric chillers, absorption chillers (using combined heat and power or industrial waste energy), or cold sea or lake water.

The chilled water service replaces stand-alone chillers and cooling towers by providing reliable cooling. District cooling significantly reduces the use of ozone-depleting refrigerants, lowers potable water usage at the building, and uses energy more efficiently. [42]

3.4.2 District cooling in Finland

The 80-90% energy efficiency for district heating, electricity and cooling production in Helsinki is one of the highest in the world. [41]

During November to May, when the water temperature is below 8ºC, water from the Baltic Sea is pumped to a heat exchanger, where the cold is extracted for the city's district cooling network. During the summer period, when the sea water is too warm, excess heat from co-generation plants is used to run absorption chillers and provide the required cold to the cooling network. [43] Currently, district heating suppliers also offer district cooling in Helsinki, Turku, Lahti, Vierumäki, Tampere, Pori and Espoo, which are mostly located in the southern part of the country.

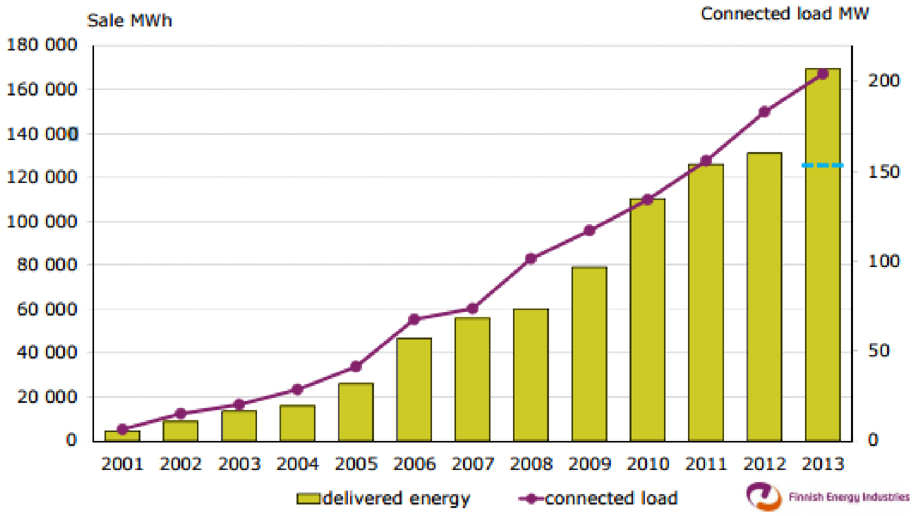

Figure 27 – Delivered district cooling energy and connected load. *[44]*

Data from 2013, as depicted in Figure 27, shows that the district cooling production reached 169 GWh in Finland. For this value, heat pumps accounted with 48.8% of the production, free cooling from the Baltic Sea accounted with 26.3%, absorption chilling accounted with 17.1% and compression chilling 7.8%. [44]

4 Increasing the energy efficiency

4.1 The building façade

A key action to improve energy efficiency in buildings and to reduce greenhouse gas emissions is to improve the building envelope, which effectively reduces the thermal load of the building [1]. The Finnish climate is characterized by long cold winters and mild summers which usually stand in an average temperature of 17ºC at Helsinki latitude and 12ºC in the Northern regions [45]. However, an assessment of energy demand for heating and cooling in Finland [46] has shown that due to global warming the temperatures are also rising in the country. The average air temperature is expected to be 1.2-1.5ºC higher by 2030.

The same assessment also predicted that a typical office building would have a decrease of 13% in the demand for heating and an increase of 13% to 15% of cooling energy demand by 2030.

The Finnish building stock is already naturally prepared for the cold winters, and major improvements in the façade would not be economically viable for such purpose. However, due to the increasing temperatures which are already being noticed in the summer, small improvements in the building façade would allow a decrease in the demand for cooling. Filtered glass windows and window shades are a solution.

4.2 Lighting

4.2.1 Considerations in lighting installation

The aim of an optimum lighting design varies with the purpose of the lighting system. For example, the type of lighting required in offices can be different than that required in shops or restaurants. However, despite the type of building or lighting purpose, the light has to achieve certain appearances and to fulfil the fundamental physiological and psychological visual requirements, being adequate for visual tasks without causing discomfort. An optimum lighting design allows such features to be achieved as an energy efficient manner. [27]

Good lighting quality is obtained when the lighting system offers adequate lighting levels in the building according to the light distribution of spaces, limiting or eliminating glare, and considering the light colour characteristics.

Variations of luminance and colours may have an impact on people. It can strengthen attractiveness, trigger emotions, or affect people's mood. As a conclusion, good lighting quality can increase visual and task performance in offices leading to better productivity, or it can affect people psychology when used in commercial buildings.

From an energy point of view [27] there are three groups of features which transform electrical energy into light: the lamp, the luminaire, and the room. The electrical power is transformed by the lamp into luminous flux, the luminaire distributes the flux in the room, and the room transforms the flux into visible luminance by means of surface reflections.

From an efficiency point of view, [27] a good lighting system loses its advantages when the best lamp is used with a bad/incompatible luminaire or ballast. The combination of a good lamp, ballast and luminaire in a wrong installation may not meet the user needs or provide the lighting service in an inefficient way.

Concluding, the first key point to obtain an efficient lighting design is to choose efficient lamps, which produce the proper spectrum and offer the required operating features, and couple them as high-quality luminaires. In order to increase the energy efficiency even more, efficient room lighting concepts and controls should be considered.

4.2.2 The role of LED in offices and commercial buildings

Fluorescent lamps dominate a great part of the lighting system in office and commercial buildings. Compared to a conventional uniform office lighting installation with fluorescent lamps, LEDs allow concentrating light on working areas and to have light where it is actually needed. In the case of commercial buildings, the energy used in lighting for architectural purposes could be improved with the application of LEDs, which would provide different colours and light intensities in exchange of very low consumption levels. This is a crucial point, as the lighting systems used for architectural purposes are a continuous source of energy demand in buildings.

One of the main advantages of LEDs, is that due to the fact that LEDs are small point sources with high intensities, and they can form luminaires with different shapes and sizes just by combining different arrays. [27]

The biggest barrier to the penetration of LED technology for lighting applications is its price, however the trend in LED light output and light cost is continuing to follow Haitz’s law, according to which the evolution of LEDs in terms of light output increases by a factor of 20 per decade, while the costs decrease by a factor of 10. [27]

This means that LED technology should be considered as a great option in the improvement of the energy efficiency in offices and commercial buildings.

Table 4 presents the most important advantages and disadvantages of the use of LED for lighting.

Characteristics of LEDs	
Advantages	Disadvantages
Small size (heat sink can be big)	Lack of standardization
Robustness	High price
Long lifecycle	CRI can be low
Switching On/Off has no effect on lifecycle	Risk of glare as a result of small lamp size
No mercury	Need for thermal management
High luminous efficacy	
Availability of different colours	
Easy to dim	

Table 4 – Characteristics of LEDs. *[27]*

4.2.3 Lighting control systems

Another possibility to optimize the energy efficiency of lighting systems is to adopt a good lighting control system. The main purpose of these systems is to reduce energy consumption while ensuring good lighting quality at the same time.

The need for light control is dependent on the lighting needs of the considered zone, the characteristics of the zone, and the user's needs.

For example, in some situations the basic On/Off method used with daylight dimming may be adequate, but at other times such control system may be ineffective for several reasons, which means that other techniques for lighting control must be adopted.

Apart from reaching good energy efficiency, an optimal light control system also needs to be accepted and understood by the user, which in some situations is even more important than the efficiency of lighting system by itself. [27]

At first, it should be given the occupants the possibility to control the system**.** The occupant's needs and priorities vary for each individual, and they also vary with time for the same occupant. Therefore it is important that the occupants have the possibility to control the system according to their will/needs.

Then, it is of great importance that the system is understood by the occupants**.** If the lighting system and its working principle is familiar to the user, such knowledge will help improving the energy consumption as the user will know exactly how to adjust the light or notice if some defect is occurring within the system.

Finally, the system must be easy to use and address everyone (building operators, occupants, facility managers, maintenance teams, installers, etc).

Some of the most important strategies of lighting control are presented as follows: [27]

Predicted Occupancy Control

The predicted occupancy control strategy (POCS) helps reducing the operating hours of the lighting installation.

Schedules usually vary on a daily basis, according to the occupancy of the building. A daily time schedule is then set, and lighting is automatically switched On/Off allowing for energy savings.

Different schedules can also be programmed for different areas of the building.

Real Occupancy Control

The real occupancy control strategy (ROCS) also helps reducing the operating hours of the lighting installation but on the basis of the occupancy time of a space, which is detected by sensors.

The system detects whether the room is occupied/un-occupied and switches the lights On/Off accordingly. This type of control strategy is therefore more suitable for zones where occupancy is not predictable or does not follow a daily pattern. The potential of savings can vary from 20% to 50%.

Constant Illuminance Control

The constant illuminance control strategy (CICS) prevents lighting energy use from exceeding its requirements, maintaining constant and uniform lighting levels.

In this strategy, a photocell is either used to measure the lighting level within a space or to determine the ageing of the lighting level. When the light level goes too high/too low, the controller of the system reduces/increases the lumen output of the light sources accordingly.

Daylight Harvesting Control

The daylight harvesting control strategy (DHCS) allows the building to support the use of daylight with extra artificial lighting in order to maintain good lighting levels.

Similar to CICS, a photocell is used to measure the lighting level of a space, on a surface or at a specific point allowing the controller to increase/decrease the lumen output of the light sources according to the lighting needs. Sensors are often used in large areas, where each monitors and controls a separate group of luminaires in order to maintain a uniform lighting level throughout the whole area.

This type of strategy is generally used in spaces that have relatively wide areas of windows or skylights, making it ideal for certain offices and commercial buildings.

The potential for savings can vary from 20% (daylight harvesting alone) up to more than 50% (daylight harvesting plus real occupancy).

4.2.4 Conclusion on lighting efficiency

There is a significant potential to improve the energy efficiency of old and new lighting installations in offices and commercial buildings. The use of natural light as much as possible is naturally the best solution to decrease the energy consumption of the lighting system. However, other improvement possibilities vary between the whole replacement of the current lighting system for a more efficient one, or by adapting lighting control strategies within the building. People awareness about how the lighting control system works also plays a crucial role, especially if there is a personal awareness concerning energy savings.

As a resume, the energy efficiency of lighting installations can be improved with the following measures: [27]

- Using natural light as much as possible.
- Using an efficient combination of lamp-luminaire according with each type of situation. Incandescent lamps should be replaced by CFLs or LEDs; mercury lamps should be replaced by high pressure sodium lamps, metal halide lamps or LEDs; ferromagnetic ballasts should be replaced by electronic ballasts.
- Using controllable electronic ballasts with low losses.
- Considering lighting control strategies according to the area, occupancy and user’s needs.
- Providing the users of the building with an understanding about the lighting control system and raising awareness about the importance of energy savings.
- Maximizing the use of daylight.
- Considering the benefits of using of high-efficiency LED-based lighting systems.

4.3 HVAC

4.3.1 Overview

In offices and commercial buildings, high concentrations of people and equipment generate high concentrations of heat, making air conditioning and air circulation very important.

These types of buildings have then mechanical systems known as HVAC systems, which stands for heat, ventilation and air-conditioning. Given the fact that these systems contribute for the greatest share of energy consumption in buildings, it is useful to have a general idea of what these systems are and how do they operate.

The air that is inside a building comes from the outside, and the purpose of the HVAC system is to modify the outdoor air conditions to make it suitable for indoors use. In a simple way, the HVAC system moves a column of air around in a loop that passes through ducts to the spaces, mixes the air in the spaces, and then is withdrawn back again to a machine called an air handler where there are cooling coils, heating coils, humidifiers and dehumidifiers. All of these components are energy consuming devices and sustainability issues should be considered. Having a good ventilation and comfortable temperature without consuming unnecessary energy.

The productivity, comfort and health of the occupants of a building can also be related with the air quality, which means that the HVAC system plays an important role in this matter.

In certain air-conditioned environments, the conditioned air that is recirculated can carry contaminants, and the HVAC system is also responsible for filtering such contaminants and dust.

With the spiral costs of fuel, HVAC systems must also be efficient and economical. Energy efficient HVAC systems [47] can adopt variable air volume designs, or include some energy efficiency parts such as digital control systems, mechanisms to obtain heating/cooling benefits from recirculating air, and high efficiency ECM (electronically commutated motor) fan motors.

The key components of an HVAC system are: chiller/air conditioner, air handler, air filters, distribution ducts, dampers, terminal units, and air diffusion devices. [48]

The chiller transfers heat from one medium to another, using heat exchangers and circulated fluid (or gas) to cool the air that passes through it.

The air handler is a fan or a blower that moves air through the building distribution ducts

The air filters being used depend generally on the requirements of the occupants and the activities in the building. They can have different filtering levels, and can be included in the air handler unit itself whereas more sophisticated filters such as “High Efficiency Particulate Arrestance” (HEPA) filters may be used in the distribution ducts. [49]

Distribution ducts provide a circulation path for the conditioned air between the air handling unit and the indoor environment, and their cross-section can be round, square or rectangular shaped.

The dampers are units that consist individually of one or more blades which can be used to control the amount of air that flows through a duct. Dampers allow different parts of the building receive ventilation according to the room area and user needs. Automated dampers might work as firewalls which close in case of a fire, or as part of the building automation system (BAS) which automatically controls the airflow to different spaces according to the control type. [49]

The terminal unit is a device that controls the airflow delivered to a room and it consists of an automated damper. The damper is generally controlled by an actuator (electric, pneumatic or digital) which is regulated by a thermostat.

The air that comes from the distribution ducts enters the occupied space through air diffusion devices which can be diffusers, registers or grilles. The new air is then mixed with the existent air within the zone, returning back to the air handler unit through the return ducts.

Once having returned to the air handling unit, a portion of the returned air is exhausted and replaced with fresh exterior air, and the cycle starts again.

4.3.2 Improvement of the HVAC system

By understanding the general working principle of an HVAC system and its main components, it is possible to understand what can be done in order to minimize the energy consumption of such systems. The improvement of energy consumption of an HVAC system can be achieve by:

- Optimizing the size of the distribution ducts. The distribution ducts have different sizes and shapes, and the cross section area of a distribution duct will influence the volume of air which flows through it. The air flows faster in ducts that have lower than higher volumes, and by minimizing the size of the ducts it is possible to reduce air losses.
- Selecting appropriate diffusers. By selecting the diffusers according to the configuration and needs of the space to be acclimatized/ventilated, the air that comes from the distribution ducts can be distributed evenly and become a homogeneous mixture.
- Installing air inlet and outlets according to the room characteristics following ASHRAE[9] recommendations. The fresh air and the air that was previously inside the building space gets mixed more efficiently if the air inlets and outlets of the distribution ducts are to be found in places within the room area which maximizes the whole process.
- Segregating different zones with dampers. This allows different zones either to obtain ventilation and air conditioning at the same time, or to be isolated individually from the whole system when there is no need it.
- Implementing the control of the HVAC system in the building automation system. The benefits of building automation systems are described in a further section but, in shorthand, this implementation allows to a more efficient management of the ventilation and air conditioning needed to different zones. This is obtained for example, by shifting loads away from peak demand periods, providing ventilation and air conditioning only when needed or, in more

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[9] AHSRAE stands for “American Society of Heating, Refrigerating, and Air-Conditioning” and it develops standards and guidelines regarding energy efficiency of HVAC systems.

advanced systems, to integrate the use of passive ventilation and free cooling within the HVAC system.

- Commissioning of the HVAC system. The commissioning of the HVAC system is of crucial importance, as energy savings can be achieved if the system is designed, monitored and maintained in an exemplar way.
- Considering the benefits between displacement and traditional mixing ventilation for each room according with the demand needs.
- Considering the use of free cooling. Free cooling is the concept of using outdoor air for cooling indoor environments. In regions where humidity does not represent a problem such as the case of Finland, and when the outdoor temperature is lower than the indoor temperature, the system can turn off the chiller (chiller being bypassed) and switch for cooling provided by outside air.
- Considering variable air volume diffusers. [50] VAVs are self-modulated, which means they monitor individual space conditions and adjust air flow to satisfy the occupants selected level of room temperature. The VAV diffuser moves an integral damper to barrier airflow.
- Considering variable frequency drives. VFDs can optimize the power consumed by HVAC fans, speeding up or slowing down the fan based on the climate demands of the space under control. A reduction of the fan speed (and air flow) by 20% results in 49% decrease in electrical consumption. [51]
- Selecting equipment which works efficiently at partial-load regime. Examples of such equipment are variable volume fan systems and variable capacity pump systems. [47]

4.3.3 Passive ventilation

Passive ventilation is a ventilation strategy that can improve the energy consumption of the building by contributing with natural ventilation of the spaces and, during summer, to reduce the cooling loads.

However, in the existent building stock, such strategy may be difficult to implement, as it requires proper architectural configuration of the building in order to allow (or maximize) the natural airflow throughout the building spaces without the need of energy consuming equipment such as fans.

Passive ventilation strategies can be based either in wind force or in stack ventilation. [52]

Given the example of a balloon filled up with air, the pressure that the air exerts in the inner surface of the balloon is higher than the pressure exerted by the outdoor air if we consider a normal outdoor pressure of 1 Atm.

As soon as the balloon is open the air instantly flows out of it, showing therefore that air flows from higher to lower pressures.

In buildings, the same principle happens when the ventilation is done naturally by wind force. The windward side of the building (the side of the building where the wind is blowing at a certain period of time) has higher pressure than the leeward side (the side(s) of the building which is (are) protected from the wind). This difference in pressure is the key condition for the air to move freely, and the volume of the air that moves is proportional to the difference between pressures or pressure amplitude. The bigger the difference between lower and higher pressure, the higher is the volume of air that can be moved per unit time.

Several types of openings around the building envelope allow the air to freely move inside (or to the outside). Such openings can be windows, ventilation louvers or rooftop vents, and control systems can be implemented in order to allow the natural ventilation of spaces without affecting negatively the indoor temperature of the building.

Stack ventilation works differently than the previous, and its main working principle relies on the fact that hot air is lighter than cold air and therefore rises.

In this type of passive ventilation, the difference in air temperature inside the building space maximizes the ventilation process. The air stratification due to heating creates a low pressure at the lower level zones compared to the atmospheric pressure outside the building. Due to the difference between those pressures, the external air penetrates the building through ducts located in the lower areas of the building. Once inside, the air gets warmer and rises, being then exhausted through ducts located in the ceiling or in the upper side of the walls.

This method of passive ventilation is less efficient than the previous, however it works well in areas where wind speed is low or non-existent.

4.3.4 Possibilities for cooling improvement

As previously discussed in above sub-sections, district cooling is an efficient solution for cooling the spaces in Finland but the actual district cooling network is far from reaching the dimension of the district heating network. Thus, mechanical cooling could also be improved by using heat pumps, integrating free cooling techniques in the cooling system (cold water from the sea or borehole wells), or by reducing the thermal load of the building.

4.3.4.1 Absorption heat pumps

The use of absorption heat pumps [53] can be a solution for cooling Finnish offices and commercial buildings.

One of the features of this kind of pumps is that the pumps are driven by a heat source and not by electricity, contributing for a decrease in the consumption.

This kind of heat pumps are based on an ammonia-water absorption cycle to provide heating and cooling. There are two coils in opposite sides of the system. One of them condenses the refrigerant (which in this case is ammonia) releasing its heat, whereas in the second coil the refrigerant (which is now mixed with water) is evaporated absorbing heat.

This absorption of heat cools the temperature of the space as the heat is being removed.

During the cycle, the ammonia is absorbed into water before the evaporation stage starts, and the task of the external heat source in this type of pumps is to boil the ammonia out of the water after that stage so the cycle can be repeated again.

The heat source can be, for example, solar-heated water from the abundant solar energy available in the long summer days, or district heat if the building is connected to the network.

4.3.5 Possibilities for heating improvement

In the search for possibilities that have potential to increase energy savings for heating, heat recovery from ventilation and better building insulation must be taken into account.

In places where the district heating network is not available, ground-source heat pumps or air-source heat pumps could be used to achieve better energy savings over traditional electrical heating. However, the type of heat pump should be considered. For example, air-source heat pumps work more efficiently under warmer than freezing temperatures, as it requires more energy to transfer heat from colder zones.

4.3.6 Ground-source heat pumps

The ground-source heat pump [54] consists of a loop of pipes called geothermal heat collectors[10] filled with a refrigerant (water), that are buried in topsoil, bedrock or water.

During the winter months the outside air is usually cooler than the temperature below ground. The refrigerant circulates in a loop underground and absorbs the earth's heat. This heat is brought to the surface and transferred to the heat pump. The heat pump then distributes such heat to the different areas of the building through low-temperature heat distribution systems, such as water-circulated underfloor heating, or through a radiator network.

During the summer time, the system works in reverse. The temperature below the surface is cooler than the air. The fluid absorbs the heat inside the building and the heat pump sends it to the pipes under the ground. The ground's temperature cools the refrigerant and it circulates again.

4.3.7 Reduction of the building thermal load

By reducing the building thermal load, less electricity is required to operate air conditioning units during summer and heating energy to heat the spaces during the winter.

The most viable possibility to decrease the thermal loads in the current building stock is by proceeding to changes in the windows.

Most of the windows in the Finnish buildings are dual-glazed, but it is still possible to improve the insulation by applying low-emissivity (low-E) coatings to the glass and eventually to adopt triple-glazed windows. Low-E coatings can reduce the heat loss through the window's glass by up to 70% [55] in comparison with clear glass units.

Low-E coatings reduces the heat loss in winter and also the amount of solar heat gain in summer.

Window frames are also a factor for heat losses/gains, and aluminium frames are usually less efficient in thermal isolation than fibreglass, wood or vinyl frames. [55]

The use of tinted glass can also be used to block solar transmission and minimize heat gains. This blockage of solar transmission could not make sense in some climates where the sun is an important source of heat during the winter. However, the Finnish winters are dark with long nights, and the contribution of solar heating to assist the heating system in this season would be perhaps lower, than the contribution that tinted glass gives during summer to reduce the need for cooling energy.

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[10] Geothermal heat collectors are basically heat exchangers.

4.4 Elevators and Escalators

4.4.1 Improvement possibilities

According to a study carried by the “Swiss Agency for Efficient Energy Use” [56], stand-by consumption of lifts is very high, and it offers potential to reduce energy costs.

The same study also characterizes, from an energy efficiency point of view, the two major factors that may be responsible for high stand-by consumption in elevators: the cabin lights (in situations where they are permanently on) and the door locking devices which require constant power.

Therefore some of the potential measures which can reduce this stand-by consumption in both lifts and escalators include: [56]

- Switching off the frequency converter control device and other control functions when the lift/escalator in not in motion. Whenever the lift or escalator is not in motion (off-peak periods), a stand-by mode (something similar to the sleep mode used in computers for example) requiring lower power supply can be used.
- Using efficient power supply units (switched units, toroidal transformers).
- Using efficient display options such as LED technology for example, and promote the use of LEDs in the lighting system of the cabin in elevators.
- In elevators, because the mass moved up also tends to come down, regenerative drives can use the energy generated in braking modes. Such energy can be stored or transformed to another form of energy used inside of the building by another appliance demanding power at the same time [35].

5 Building Automation Systems

5.1 A background on Building Automation Systems (BAS)

A building automation system (BAS) is a centralized control system, which monitors and controls different types of loads in the building. These loads can be the lighting, HVAC, security, and mechanical (lifts and escalators for example) systems of the building. Through the continuous monitoring and control of different systems within the building, the operational performance of the facility is ensured as well as the comfort and safety of the users. [57]

Such control systems can be adopted in both new and existing buildings.

A BAS is a very important tool regarding energy efficiency. The constant monitoring of energy consumption allows the system to automatically proceed with energy efficient or cost saving actions such as shifting loads away from peak hours. Some of the advantages offered by BAS and some common control strategies are presented below.

5.2 Types of system control

5.2.1 Lighting

All lighting control strategies described in Section 4 can be used either as an isolated system or be part of a lighting management system (LMS) that runs continuously. [27] Light management systems are a solution to increase the general efficiency of the lighting system, as it is possible to monitor and schedule the light operations within the building.

Lighting management systems can also be associated with the building automation system, contributing for an integration at a larger scale of the lighting control systems with other technical equipment (e.g. heating, ventilation, cooling, security, etc.)

Some of the advantages of lighting management systems are: [27]

- Possibility for monitoring and scheduling light operations in any area within the building.
- Possibility for remotely control energy consumption of lighting.
- Ability to perform load-shedding strategies whenever the electricity demand in the building is high. [51]
- Possibility to record lighting scenes or predefine scenarios.
- Provides an efficient way to control lamps as it is possible to manage lamps in different zones independently.

- Availability of information regarding the lighting system operation and consumption, such as the number of operating hours in a certain area, the number of times the lights are switched on, timeline of the energy consumption, etc.

5.2.2 HVAC

As already mentioned above, when the HVAC system is integrated in the building management system, not only there is potential for energy savings, but the management and monitoring of the system becomes centralized and easily performed.

Some important control techniques used in HVAC systems are described below: [51]

Zone Scheduling

This type of control defines a schedule which serves as a basis for the BAS to reduce or shutdown the energy consumption of the HVAC system.

An improvement to this type of control is possible by setting the schedule for the whole year, reducing therefore the consumption whenever the occupancy might be lower such as night periods, weekends or holidays for example.

When adapted with occupancy sensors, this strategy works well in areas of unpredicted occupied hours.

Optimum Start

In this type of control, the system determines the minimum length of time required to bring the current temperature (measured when the area is unoccupied) to the occupied set-point temperature in an optimal way, warming up/cooling down the area so the temperature will be at comfortable levels when first occupied.

Optimum Stop

In this type of control, the earliest possible time to shut down the HVAC system before the unoccupied period starts is measured. The heating/cooling is then switched off, still allowing for the indoors temperature to remain within acceptable levels during the end of the occupancy period.

Ventilation on Demand

In this type of control, CO_2 levels are measured and used to estimate the number of occupants in a room. Calculations are then performed and the control system decides whether fresh air is needed, triggering then the ventilation. CO_2 levels can also assist heating and cooling anticipation in thermostatic control, optimizing the comfort and air circulation within the space.

Chiller Optimization

Whenever the cooling needs of the building are reduced, the temperature of the water that is circulating in the chiller is increased, leading to an increase of the chiller efficiency. A technique known as “load reset” raises the chilled water temperature set-point until one of the chilled water valves is 100% open. From this moment, once one of the valves is 100% open, the chilled water temperature has to decrease back again if the need for cooling increases.

6 Systematization of Conclusions

Finland, with its cold weather during most of the year and the lack of sun during nearly half of it, presents a challenge when it comes to the improvement of energy efficiency in offices and commercial buildings.

Due to the fact that the district heating network covers most of the buildings, there is no significant advantage in acquiring renewable energy systems to provide heat in the buildings covered by the network. Instead, and given the fact that the district heating networks are mostly supplied from combined heat and power (CHP) plants and from the combustion of biomass, the government could promote the use of more renewable energy sources to provide heat to the district heating network.

On the other hand, the lack of sun when heating is most needed would be a barrier to the adoption of renewable energy systems based in solar energy, and the acquisition of geothermal heat pumps would be suitable for buildings which are not covered by a district heating network.

Regarding the need for cooling, Finland is not a country that requires large amounts of energy to keep a comfortable temperature indoors. With most of the offices and commercial buildings located within the Helsinki sub-region and given the current expansion of the district cooling network, such cooling method will be, in a near future, a solution for the desired cooling during the summer months. For the buildings which are not covered yet (or will not be in the near future) by the district cooling network, passive cooling concepts, proper shading systems, better thermal insulated windows, integration of free cooling from water sources such as lakes or borehole wells in the HVAC system, or absorption heat pumps which are driven by the heat provided by the already expanded district heating networks offer good improvements for reducing cooling needs.

When it comes to lighting and other applications such as elevators, conveyors, lifts and electronic equipment, there are three key aspects which would help increasing energy efficiency.

The first, regards the replacement of old inefficient technologies for new efficient and environmentally friendlier solutions.

The second takes into account the spread of information and raise of awareness of people regarding the efficient use of energy in the work place.

The third concerns the implementation of building automation systems which effectively help reducing the energy consumption of buildings, allow a decrease in the energy bill by shifting loads away from energy peak demand periods, efficiently control the lighting and HVAC systems, and help monitoring the energy consumption in a very detailed way, which helps tracking uncommon energy demands and fix such situations more effectively.

The questionnaire done by the E4project to all member countries has shown that Finland doesn't have national and regional regulations or standards in place asking for energy consumption of lifts, escalators and moving walks. This leads to a lack of knowledge about the current energy demand from these moving systems and therefore does not offer the chance to implement measures which could, otherwise, maximize the energy consumption efficiency. [34]

7 References

[1] IEA, Transition to Sustainable Buildings, 2013.

[2] IEA, “IEA - Buildings,” 2015. [Online]. Available: http://www.iea.org/etp/etpmodel/buildings/.

[3] Satistics Finland, 2014. [Online]. Available: http://www.stat.fi.

[4] Finnish Ministry of Emplyment and the Economy, “Long-term Climate and Energy Strategy - Government Report to Parliament 6 November 2008,” 2008.

[5] IEA, Energy Policies of IEA Countries - Finland 2013 Review, 2013.

[6] Finnish Ministry of the Environmnet, “Long-term strategy for mobilising investment in the renovation of the national stock of residential and commercial buildings,” 2014.

[7] Finnish Government, “Finland EED Anual Report 2014, Report pursuant to Article 24(1) of the Energy Efficiency Directive (2012/27/EU) to the European Commission,” 2014.

[8] Finnish Ministry Of Employment And The Economy, “"National Energy and Climate Strategy - Government Report to Parliament on 20 March 2013",” 2013.

[9] IEA, “Energy Efficiency FAQ,” [Online]. Available: http://www.iea.org/aboutus/faqs/energyefficiency/.

[10] “Buildings,” 2015. [Online]. Available: http://ec.europa.eu/energy/en/topics/energy-efficiency/buildings.

[11] European Commission, “National Energy Efficiency Action Plans,” 2015. [Online]. Available: http://ec.europa.eu/energy/node/84.

[12] “Europe 2020 in a nutshell,” 2015. [Online]. Available: http://ec.europa.eu/europe2020/europe-2020-in-a-nutshell/targets/index_en.htm.

[13] Motiva, “Energy in Finland - Key Policies,” 2013. [Online]. Available: http://www.motiva.fi/en/energy_in_finland/key_policies/eu_directives.

[14] EU Directives, “Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings,” [Online]. Available: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010L0031&from=EN.

[15] EU Directives, “Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC,” [Online]. Available:

http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0027&from=EN.

[16] EU Directives, “Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC,” [Online]. Available: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&from=en.

[17] EU Directives, “Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products,” [Online]. Available: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0125&from=EN.

[18] EU Directives, “Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC,” [Online]. Available: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32003L0087&from=EN.

[19] Finnish Ministry of the Employment and the Economy, “Energy Efficiency Agreements and Audits,” [Online]. Available: http://www.tem.fi/en/energy/energy_efficiency/energy_efficiency_agreements_and_audits.

[20] Finnish Ministry Of Employment And The Economy, “"The Government aims at decreased energy consumption and intense growth in the share of renewable energy sources",” 2008. [Online]. Available: http://www.tem.fi/en/current_issues/press_releases/press_release_archive/year_2008?105043_m=93164.

[21] Finnish Ministry Of Employment And The Economy, “Government Decision on Energy Efficiency Measures,” 2010. [Online]. Available: https://www.tem.fi/files/26317/Government_Decision_on_Energy_Efficiency_Measures.pdf.

[22] Ministry of Emplyment and the Economy, “https://www.tem.fi/en,” [Online].

[23] Motiva Oy, “http://www.motiva.fi/,” [Online].

[24] Tekes, “http://www.tekes.fi/,” [Online].

[25] Tukes, [Online]. Available: http://www.tukes.fi/.

[26] VTT, “http://www.vtt.fi/,” [Online].

[27] IEA ECBS, “Guidebook on Energy Efficient Electric Lighting for Buildings - Summary Report,” 2010.

[28] EU Directives, “Directive 2000/55/EC of the European Parliament and of the Council of 18 September 2000 on energy efficiency requirements for ballasts for fluorescent lighting,” [Online]. Available: http://eur-lex.europa.eu/resource.html?uri=cellar:8f82cf9e-53fd-49ac-ae1f-efd1866784dd.0005.02/DOC_1&format=PDF.

[29] EU Directives, “Comission Directive 98/11/EC of 27 January 1998 implementing Council Directive 92/75/EEC with regard to energy labelling of household lamps,” [Online]. Available: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31998L0011&from=EN.

[30] EU Regulations, “Comission Regulation (EC) No 244/2009 of 18 March 2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for non-directional household lamps,” [Online]. Available: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:076:0003:0016:en:PDF.

[31] Ministry for Foreign Affairs of Finland, “"Company Profile: KONE Builds Eco-Efficient Elevators and Escalators in the U.S.",” 2015.

[32] Anibal de Almeida et al., “E4Project Paper - Elevators and escalators: Energy performance and Strategies to promote energy efficiency,” [Online]. Available: http://www.e4project.eu/Documenti/WP6/IEECB'10_No27_FinalVersion.pdf.

[33] Aníbal de Almeida et al., “E4Project, WP4, Estimation of savings,” 2010. [Online]. Available: http://www.e4project.eu/documenti/WP4/E4-WP4-Estimation%20of%20Savings.pdf.

[34] E4Project, “WP2 - Characterization of the existing situation in terms of electricity consumption and installed capacity,” 2009. [Online]. Available: http://www.e4project.eu/Documenti/WP2/E4-WP2-D2.1-2-3-AssessmentReportEU.pdf.

[35] T. Tutkia, *Master's Thesis on "Determining and modeling the energy consumption of elevators"*, 2014.

[36] E4Project, “WP6 - Options to improve lift energy efficiency,” 2010. [Online]. Available: http://www.e4project.eu/Documenti/WP6/E4-Brochure-finale.pdf.

[37] Finnish Energy Industries, “Kaukolämpötilasto 2013,” 2014.

[38] Finnish Energy Industries, “District Heat and District Cooling,” [Online]. Available: http://energia.fi/en/energy-and-environment/district-heat-and-district-cooling.

[39] “District Heating,” 2015. [Online]. Available: http://www.districtenergy.com/technologies/district-heating/.

[40] P. Pippuri, *Master's Thesis on "Heating mode choices of Finnish households and the Energy Paradox",* 2012.

[41] City of Helsinki, “"State of the Environment in the City of Helsinki: Theme Report 1/2008",” 2008.

[42] “District Cooling,” 2015. [Online]. Available: http://www.districtenergy.com/technologies/district-cooling/.

[43] IEA, Heating Without Global Warming - Market Developments and Policy Considerations for Renewable Heat, 2014.

[44] M. Riipinen, “HELEN - District cooling in Finland,” 2014. [Online]. Available: http://basrec.net/wp-content/uploads/2014/05/District%20Cooling%20in%20Finland.pdf.

[45] Finnish Meteorological Institute, “Ilmatieteen Laitos,” [Online]. Available: http://ilmatieteenlaitos.fi/.

[46] H. T. K. R. T. K. J. J. S. I. H. S. S. Kirsti Jylhä, “Assessment of energy demand for heating and cooling of buildings in the changing climate of Finland, World Sustainable Building Conference 18 - 21 October, 2011 Helsinki, Finland,” 2011. [Online]. Available: http://ilmatieteenlaitos.fi/c/document_library/get_file?uuid=805aec9a-b3f9-4f5b-bb0a-485ca69cdb58&groupId=30106.

[47] Whole Building Design Guide, “HVAC,” 2014. [Online]. Available: http://www.wbdg.org/resources/hvac.php.

[48] Energy Star, “Air Distribution Systems,” 2008. [Online]. Available: https://www.energystar.gov/ia/business/EPA_BUM_CH8_AirDistSystems.pdf.

[49] U.S. Mechanical Services, Inc., “Parts of an HVAC system,” [Online]. Available: http://www.usmechanicalservices.com/parts-of-an-hvac-system/.

[50] Price Industries, “VAV diffusers Engineering Guide,” [Online]. Available: http://www.priceindustries.com/content/uploads/assets/literature/engineering-guides/vav-diffusers-engineering-guide.pdf.

[51] Schneider-Electric, "Leading Techniques for Energy Savings in Commercial Office Buildings", 2006.

[52] Academia.edu, “AR6303 Climate and Built Environment - Ventilation, passive cooling, ventilation strategies, wind tower, venturi effect, stack effect,” [Online]. Available: http://www.academia.edu/8107322/Ventilation_passive_cooling_ventilation_strategies_wind_tower_venturi_effect_stack_effect.

[53] U.S Department of Energy, “Absorption Heat Pumps,” [Online]. Available: http://energy.gov/energysaver/articles/absorption-heat-pumps.

[54] Finnish Energy Industries, “Heat Pumps,” [Online]. Available: http://energia.fi/en/home-and-heating/electric-heating/heat-pumps.

[55] G. F. Marcus Dell, “Industry Focus Restoration & Renovation - Windows: replace, repair or renew?,” 2008. [Online]. Available: http://rdh.com/wp-content/uploads/2014/04/Windows___Replace_Repair_or_Renew24.pdf.

[56] J. Nipkow and M. Schalcher, Paper "Energy consumption and efficiency potentials of lifts".

[57] KMC Controls, “Understanding Building Automation and Control Systems,” 2015. [Online]. Available: http://www.kmccontrols.com/products/Understanding_Building_Automation_and_Control_Systems.aspx.

[58] Finnish Heat Pump Association, “sulpu.fi,” [Online]. Available: http://www.sulpu.fi/.