MECHATRONIC IN ENERGY EFFICIENCY AND ENVIRONMENTAL IMPACT

Sherif Hyseni

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MECHATRONIC IN ENERGY EFFICIENCY AND ENVIRONMENTAL IMPACT
MASTER DEGREE

Sherif Hyseni

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Sherif Hyseni

MECHATRONIC IN ENERGY EFFICIENCY AND ENVIRONMENTAL IMPACT

Supervisor: Dr. Bertan Karahoda

June, 2015

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Abstract

The content of this thesis is leaded by the big problems that the world faces today. One under some purposes of this thesis is to show the behavior of the world or humans towards the actual global problems that are global warming or climate changing. This is done by following a few steps. The first part aims to highlight the understanding of the risks, continuing with the second part that is focused on the cause of these problems and by ending with the third part that is concentrated in the actions needed to overcome these problems. The standpoint in this thesis is oriented in the direction of analyzing costs and risk problems in the field of: electricity, fossil fuel, high nuclear risk and even worst the global environmental impact regarding air pollution, clean water resources and global warming. Another purpose of this thesis is, seeking for solution provided by the mechatronic technology development, and its influence on electrical efficiency with a direct result in cost and environment. Also Kosovo’s duty and responsibility towards restrictions from the European Union standard “20-20-20” will be unfolded. This thesis refers to a new technology solution for heating that is available on the local market, called “DAIKIN”, it will be analyzed the functionality of this device and its promise to save a lot of heating costs. At the end for showing the impact of this device is done a case study of implementing the new mechatronic technology for heating and cooling solution offered by “DAIKIN” in the state buildings of Prishtina. In the outcome will be represented the results gathered by the data analyzed in this case study, the results will be related with the electrical efficiency, cost and environment, and finally emphasizing the benefits of implementing this new heating system.
ACKNOWLEDGMENT

Usually regarding the acknowledgement an undisputable merit goes to god, family, friends, obviously also the past life and education experiences must be considered because it influent the character and the personality and it contribute to the knowledge level of every person. Therefore in this regard I would like to express my sincere gratitude to my thesis advisor, Dr. Bertan Karahoda, who has consistently inspired me in this study and provided me precious suggestions and advice. This thesis would not been the same without his attentive guidance, and endless patience and encouragement through the past year. Besides that, I have also acquired valuable insights through his instructions, all this not only for the purpose of the academic studies but also for valuable life experience.

My sincere thanks also go to Mr. Dipl. Ing. Bahredin Osmani, the director of the company “Climasan” that is offering the technology of the “Daikin” company. He provided me with lots of constructive suggestions and comments not only on the structures and wordings but also the content of the thesis with his professional experience and extensive knowledge in research conducting. He assured me all the necessary literature to achieve my goals of this thesis.

In additionally a grateful thanks goes to the representative of the municipality of Prishtina because they provided the necessary information needed to make this thesis more realistic.

Last but not least, a special and heartfelt gratitude goes to my colleague and my friend Mr. Kushtrim Dragusha, with whom I have a friendship that started at the beginning of my bachelor studies, in one way or another hi is responsible for my decision to study in the field of Mechatronic, a decision that I never will regret about it. Beside that his contribute in this thesis is also worthy to mention, he was patient enough to listen to my opinion, to my ideas, to my analyses. He also has contributed through his professional criticizing in some points. And how can you not thank him for offering such an contribute.
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GLOSSARY OF TERMS

IEA – International Energy Agency

EPA – Environmental Protection Agency

GDP – Gross Domestic Product

EES – Electrical Energy Storage

GHG – Greenhouse gas

GWP – Global warming potential

ODP – Ozone depletion potential

A2L – Lower flammability
1. Introduction

The topic that I have chosen for my thesis is a hot ongoing research field all over the world and a lot of effort and investment are spent in this field. Starting from different government around the world that have applied different restriction and invented new laws, the Governments are also the biggest investors by financing huge research in the field of alternative, renewable and efficiency energy systems for a more secured and cleaner future for the coming generation, and for the best of our wonderful planet Earth. Not to forget the contribution of scientist that warned the politicians of the potential risk of the dramatic climatic changes in the past years. Also they foreseen how our future will be if we do not consider the risk and continue harming the planet earth, all this is known with the terms “Global Warming”. In one or another way the merits for our survival will go to the scientists for two reasons: first they make us clear that we have to change, and second they will find a solution how to do this.

To have a better impression and a bigger overview about all this that is mention above in the following paragraphs or in the upcoming chapters you will find more detailed information, by presenting some of the ongoing research all over the world.

Starting with the world impact of actual energy and transport system, climatic and environmental impact, alternative and renewable energy systems, the European Union (EU) and their target for the year 2020, about the Mechatronic collaboration to solve energy problem, the influence of Nanotechnology regarding new materials for improving storage capacities of electricity and creating new materials that are used as renewable alternative materials for energy systems or improve the current alternative system by getting more electrical power in the output, unfortunately I have to mention also some conspiring theory about the presence of different solution that have not been published, following with Kosovo capacity to be proactive in help finding solution for global problems, and finally the aim and focus of this thesis based on the contribution that this thesis can give to suggest a solution that Kosovo can implement and do its duty.
1.1 Actual energy and transport system

78% of the actual energy consumption comes from non-renewable energy sources and is used mostly for transportation and electricity. This is illustrated in the picture 1 Energy consumption.

All over the world we have over 50,000 coal power plants, over 450 nuclear power plants, around 122 natural gas power plants, over 1.015 billion motor vehicles are in use in the world, around 450,000 airplanes and helicopters for civilian and military exist in the world.

1.2 Environmental world impact

The biggest energy source in the world until now for creating electrical power is coal but the waste and the pollution that is created during that process for one (1) GW a year is equal to 8 million ton CO$_2$ emission in the atmosphere. [1]

A proved example tells us that 1 car emits 4 tons CO$_2$/year. And calculating all cars of the world gives a result that cars represent 40% of the world’s CO$_2$ emissions. This tow parts together are responsible for the global warming and are the starting points where we have to make big changes.

1.3 Alternative and renewable energy systems

Mention renewable energy sources we have to talk about that every day the sun provides approximately 170,000 terawatt hours of energy about 2,850 times the energy required by people around the world. In 40 minutes of daylight the sun releases upon the earth the amount of energy that is consumed by the entire population of the planet in one year. All the energy stored in Earth’s reserves of coal, oil, and natural gas is matched by the energy from just 20 days of sunshine. But the technology is still not good enough to convert this energy to electrical power. Also wind and hydro power are astonishing from their possible capacity to contribute for generating electricity, some of the most popular alternative and renewable energy systems are [2]:
1.4 European Union target for the year 2020

Since they have been warned of the possible risks that the planet earth may have in the near future, and considering the huge opportunity that offers the renewable energy systems, the European Union has defined its targets and their member states for 2020. These targets, known as the "20-20-20" targets, they set three key objectives for 2020 [3]

- 20% more renewables in the final consumption of electricity,
- 20% more energy efficiency and
- 20% reduction in EU greenhouse gas emissions from the level of 1990

And an astonishing fact is that the most states in the EU already achieved this target but they do not stop and be satisfied with their achievements they continue investing in this growing industry because of the economic benefits and the new job opportunity and the moral issue regarding to the health of our planet and of course for the living creatures that live on this planet.

1.5 Mechatronic contribute in solving energy problems

With a high and fast evolution of the technology spatially computer power, hardware, software sensors, and by integrating different engineering study fields like: Computer, Mechanic, Electronic and Control engineering and combing them to create a new study field called Mechatronic was e very good decision, it found application in different industries like: automotive, aerospace, medical, defense systems, costumer products, manufacturing, material processing etc.
Mechatronics in our days has the main role in providing solutions that are required to overcome the situation created in the past years, and it was also one of the key points that make us clear that the change is possible. It starts in the industry by modernized the machinery therefore getting a high accuracy. With involving a large number of different sensors a better control is provided. The control of these systems by computers makes the decision command and feedback faster than ever. All this advantages implicate directly the efficiency impact of the machinery by working hours per day, week ore year. By energy consumption, in increasing the efficiency use less electrical power. And many other benefits that are worth to mention, but because it has a huge application in our daily life it would be a subject for another thesis.

1.6 Nanotechnology

Above is mention that mechatronic offers us a very high accuracy that makes possible to work in the nanoscale and this is equal with 1 nanometer = $10^{-9}$ meter. This kind of technology will be the next key point to the global warming solution. In this small scale we have the possibilities to configure and rearrange the chemical components to new structure getting new form, new functionality also creating new materials for different purposes.

Why and how could nanotechnology be the next key to success? Because the actual alternative and renewable energy souses like solar and wind are not so much reliably because for solar we need sun that is not possible to have 24 hours and also wind is not something that can be controlled, so the need of storing the energy that is created when we had sunshine and wind and use that energy later is the biggest challenge for this kind of energy source. And with the actual storing capacities of the batteries is just impossible to have good results. For this task nanotechnology is near to provide new battery systems that will solve that problem, and not just regarding the battery issue nanotechnology is finding better ways to use more efficiency the existing systems like solar by getting more energy output that known materials used until now.
All this mention until now should make us believe that we will have a happy end regarding the risk of global warming.

1.7 Conspiring theory

Believe it or not but is nearly impossible to do a research in the field of free energy system or zero emission or green environment and public health without being confronted with so called institutions that pretend, a solution and research about free energy has been done in past as well but results was not promising. Even in most of the cases, researchers have been punished with death. That’s the start of conspiracy theory shows up. A good example to believe this is the work of Nikola Tesla when he supposed that he has found a solution for wireless energy transmission and that result with the burning of the laboratory where he worked and with the stop of financing his research. I do not know but imagine the impact of free energy for everyone and everywhere.

1.8 Kosovo capacity and duty towards global problems

Kosovo is one of the newest countries in the world recognized by 106 states. Coming after a war in the year 1998-1999 and until wining the independence on February 17, 2008 Kosovo goes through many different problems. Also the actual political and economical potential of Kosovo is not very stable and in this condition we cannot do much to help on global problems. But considering that energy efficiency is also a contribute and is part of the solutions needed to overcome the risk of global warming, and not to forget that during the war in Kosovo nearly everything was burned to the ground, therefore we need to invest with new technology that have already high efficiency solutions integrated. And updating old machinery or old technology with new technology can be very proactive in at least one of the EU targets that are to be achieved until 2020 we must increase the electrical efficiency by 20%.
1.9 Aim and focus of this thesis

This thesis has a special focus on topics like:

- Mechatronic technology development
- Influent on electrical efficiency
- Cost oriented results
- Environmental impact
- New technological solution “DAIKIN”
- Study of implementing “DAIKING” technology in state institutions in Prishtina
- Simulating efficiency on electricity, cost and environment
- Conclusion
2. Literature review

This part is focused in a historical human development that made big changes in the world by improving the living conditions for millions of people. Elaborating the impact of the industrial revolutions, that happened in the past and seeing forward for the next upcoming revolution that has to happen for the wellness of the planet earth. Reasoning the next industrial revolution by considering the actual energy and transport systems used all over the world, their high dependents on fossil fuel, and the potential production risk of nuclear power plants, analyzing for what the electricity is mostly used. Including the side effect that causes the use of such energy sources. A side effect that is known with the term “Global Warming”, representing the future risk of the planet earth. Getting informed with the actual state in the correlation with global warming, and the future prediction if we do not start to change now, continuing with a promising solution for the future of electricity. Considering alternative energy sources, renewable energy systems, electrical efficiency technology and new invention that interconnect the missing part of the storage capability of electricity or finding new materials to upgrade actual technology used for producing such energy, ending with thermodynamic behavior of buildings.

2.1 Historical review of human development regarding technology

I will refer shortly to the Stone Age time what happened with the human at that time way they evolved, where there no stones anymore or they found something better to use and evolved to a better live. This human instinct is continuing with improvement for better living condition that brought us where we are today. Going through different processes in gradual and slow steps, but the big changes and big steps are directly connected with the technology improvement. So starting from the early 18 century until beginning of the 20 century we had the fastest human development.

During the years, innovator discovered fast world changing new technologies and influent every aspect of life. Due to this contribute of such innovation we have today this living standard therefore some of innovation are worth to mention and they are:
• 1712 - The steam engine is invented
• 1764 - The spinning jenny is invented
• 1769 - James Watt improves the steam engine
• 1794 - Eli Whitney patents the cotton gin
• 1844 - Samuel Morse invents the telegraph
• 1853 - Elisha Otis invents the elevator safety break
• 1855 - The Bessemer Method for processing steel is invented
• 1866 - Alfred Nobel creates dynamite
• 1870 - Louis Pasteur develops vaccines for diseases
• 1876 - Alexander Graham Bell patents the telephone
• 1879 - Thomas Edison uses a light bulb to light a lamp
• 1883 - The Brooklyn Bridge opens
• 1903 - Orville Wright makes the first powered airplane flight
• 1908 - Henry Ford creates the Model T [4]

Of course there is more innovation, some before, some after and even some in between them from the above list. But this innovation has made big changes in the evolving process of society or even human itself. Therefore this period is called the “Industrial Revolution” and this period is separated in the first industrial revolution and the second industrial revolution.

While the First Industrial Revolution caused the growth of industries, such as coal, iron, railroads and textiles, the Second Industrial Revolution witnessed the expansion of electricity, petroleum and steel. Historians have labeled the years from 1870-1914 as the period of the Second Industrial Revolution. The Second Industrial Revolution was another great leap forward in technology and society. New innovations in steel production, petroleum and electricity led to the introduction of public automobiles and airplanes. [5]

Many of the changes that occurred during this period had to do with new products simply replacing old ones. For instance, during this time, steel began to replace iron. Steel was being utilized for construction projects, industrial machines, railroads, ships
and many other items. Steel production made it possible for rail lines to be built at competitive costs, which further spread transportation. It is hard to imagine a time when electricity was not a common luxury. However, the beginning of the Second Industrial Revolution was just such a time. Before the introduction of public electricity, candles and gas lamps were used to light homes and factories.

Many activities were simply done in the daytime. The use of electricity fundamentally changed the way people worked and lived. The first efficient commercial electrical generators were used in the 1870s. In 1881, Great Britain was the very first country to install a public power station. Beginning in 1910, it was possible to power a residential area from one single station.

Imagine now a life without electricity what would this mean: not just that we would have any lightning but we won’t have also no TV, no radio, no internet, and none of the electronic devices would work. Also other related products that use electricity to be created cannot be use anymore, like getting petroleum for our transportation needs, so also the transportation known today would be a big problem. Thinking of such things looks like seeing a horrible dream.

But! Some statistics make us clear that around 1.3 billion people around the world are without access to electricity. And the death rate under this people is very high. [6]

Besides that! What are the side effects of human dependents on electricity? The using of electricity is not such a big problem considering the way of producing electricity by burning fossil fuel that first create a high pollution of the environment and second it is responsible for the high risk of (health and quality of life) Global Warming.

Therefore the third industrial revolution is more than ever needed and is directly connected with electricity. Not to find something to replace electricity but to find a solution of producing electricity in a clean way and that as soon as possible. For good luck the transition has already began and a lot of investments are being made in this direction.
2.2 World actual energy systems

Approximately 78\% of the actual energy consumption comes from non-renewable energy sources and is used mostly for transportation and electricity. Around \(\frac{3}{4}\) of the electricity production goes to buildings and only \(\frac{1}{4}\) goes to production factories. This is the same also for fuel production \(\frac{3}{4}\) of the overall production is used for transportation purposes and only \(\frac{1}{4}\) is used for production factories.

Around the world we have different electrical power plants for producing electricity the total number of such power plant is approximately:

- 50000 coal power plants
- 2724 gas power plant
- 1000 oil power plants
- 450 nuclear power plant

These electricity sources represent the total electricity production for the year 2012 with 78 \% the other part of electricity sources 22 \% comes from renewable sources, which will be covered later.

The total electricity production for the year 2012 was 21’016 TW/h. The production of electricity by different sources will be represented in table 2.2.1. [7]

Table 2.1 World electricity production from all energy sources in 2012

<table>
<thead>
<tr>
<th>Energy source</th>
<th>Percentage</th>
<th>TW/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal power plants</td>
<td>40 %</td>
<td>8390</td>
</tr>
<tr>
<td>Gas power plant</td>
<td>23 %</td>
<td>4744</td>
</tr>
<tr>
<td>Oil power plants</td>
<td>4 %</td>
<td>879</td>
</tr>
<tr>
<td>Nuclear power plant</td>
<td>11 %</td>
<td>2342</td>
</tr>
<tr>
<td>Other</td>
<td>22 %</td>
<td>4661</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100 %</strong></td>
<td><strong>21016</strong></td>
</tr>
</tbody>
</table>
According what’s mentioned above the biggest energy source in the world until now for creating electrical power is coming from fossil fuel and that mostly from coal. But the waste and the pollution that is created by using coal for creating electricity is that one (1) GW a year is equal to 8 million ton CO2 emission in the atmosphere. In the paragraph 2.5 we will mention the overall pollution of the process of creation electricity.

Another source for creating electricity is Nuclear power, and in the environmental aspect this source is with a lower pollution and has less waste but this waste is radioactive and dangerous. And the security aspect of such nuclear power plants is not very popular, and it speaks against the utility of such power generator, because of the high risk of exploding. And in our days unfortunately the nuclear power plants are or may be a target of terrorism.

2.3 Electricity use in everyday life

It is mention that ¾ of the electricity production goes to buildings. But for what is it used, 60 % of the electricity in our homes and buildings is used for heating and cooling purpose, another 12 % is used for hot water and the rest 28 % is used for other household devices. There are different methods and solution offer for heating, cooling and in our days it includes also the solution for hot water that’s equal to the 72 % of the electricity use in our homes and buildings.

The most known and used solutions regarding this issue in Kosovo for heating purposes is using:

- Wood
- Wood Pellets
- Coal
- Oil
- Geothermal
- Solar
- Air
What have this solution in common and which one is the best and most environmental friendly to use. All of them uses in one way or another electricity, mostly for water pump. But they can be divided in two groups, first group is consisting of the solution that use fossil fuel like: wood, wood pellets, col, oil and the second group that use renewable energy sources like: geothermal, solar and air. The aim is to minimize the use of fossil fuel because of the pollution that they create. For this reason there are only three remaining alternative left form the second group.

Heating using geothermal method is a good solution for small houses with garden, not a very good solution for high buildings without garden. Solar, is also a very good solution but the usual problem in this field is the sun and the availability during 24 hours. Air, sounds promising, it is everywhere and has a heating capacity also in temperature of –25°C. Also there is no need to drill the earth like for the geothermal method. And air is available during 24 hours, not like the sun, that is needed for the solar method. And it is a solution for both homes and buildings.

2.4 World transportation systems

1.015 billion Motor vehicles are in use in the world, around 450’000 airplanes and helicopters for civilian and military exist in the world. A proved example tells us that 1 car emits 4 tons CO₂/yare. Calculating all cars of the world gives a result that cars represent 40% of the world’s CO₂ emissions. And the dependents of cars on petroleum have another world impact and that in the financial and economic stability of the countries around the world.

Electricity and transportation together are responsible for the global warming and are the starting points where we have to make big changes.

Like in the electricity field also the transportation systems is looking forward for big changes and that by using renewable sources, but the most promising solution for the transportation system is to use electrical cars. Therefore solving the electricity problem is like solving both problems.
2.5 Actual state of global warming

Global warming is mention more than ones until now, and that for the reason because it’s a high risk that the planet earth is facing in a near future. The consumption of fossil fuels in last few decades had a huge contribution to the degradation of our environment. Global warming, climate change, extinction of wildlife species, depletion of ozone layer, and increase in air pollution are few of the problems from which our environment is suffering. Global warming is increasing the Earth's average surface temperature due to greenhouse gases, such as carbon dioxide emissions from burning fossil fuels or from deforestation, which trap heat that would otherwise escape from Earth to the space.

“According to Environmental Protection Agency (EPA) reports, the earth’s temperature has increased by 0.8 degrees Celsius over the past century. More than half of this increase has happened in the last 25 years”. [8] It seems that the temperature is rising at a rate faster than ever before. Greenhouse gases keep heat close to the earth’s surface making it livable for humans and animals.

However, global warming is happening largely due to an over-emittance of these gases and fossil fuels by the human activities like burning of fossil fuels, deforestation, industrialization and pollution. This are considered a few of the factors responsible for global warming. [8]

Some other facts are that by the start of industrial revolution in the 1700's, humans began emitting more fossil fuels from coal, oil, and gas to run our cars, trucks, and factories and this causes that there is more carbon dioxide in the atmosphere today than at any point in the last 800,000 years. This has a domino effect so since 1870, global sea levels have risen by around 20 centimeter also the water is heating and this have some consequences like: drought, severe hurricanes, massive fires and melting of the polar caps. [9]

The heat waves caused by global warming present greater risk of heat-related illness and death, most frequently among patients of diabetes who are elderly or very young. And what about nature, global warming puts coral reefs in danger as warmer water increases the possibility of coral diseases and the rising sea levels makes it more
difficult for coral to receive adequate sunlight, and that has a huge impact on the food chain of millions of creature, including on the end the humans to.

Imagine the Montana Glacier National Park known for high mountains has only 25 glaciers instead of 150 that were there in the year 1910.

In the following you will find listed some of the evidence for understanding that the rapid climate change is closely related to:

- Sea level rise
- Global temperature rise
- Warming oceans
- Shrinking ice sheets
- Declining Arctic sea ice
- Glacial retreat
- Extreme nature events
- Ocean acidification
- Decreased snow cover [10]

If this continues it is foreseen that there will be an ice-free Arctic summer maybe in 2020 or 2030, but for sure in 2040. And it is almost unavoidable due to the global warming trend. So be aware that we have to change, and we have to do it now. [11]

2.6 Promising energy solution

Most of the scientists agree that our planet is facing big and fast changes. But not all of them agree with the term “Global Warming” that is used to explain this changes and the effect that this changes will have, is the right term to use. Because the warming or the rising of the temperature will be only the start of the changes and that will have a global impact on the weather. Therefore most of the scientists nearly 100 % of them agree to the term “Climate Change”.

Another questionable thing is that not all of the scientists approve the theory that the human activity is directly connected to this climate changes. But facts that speak against them are directly connected with the technological improvements of super computers
that allowed us to handle more data, and to create simulations of the possible future that will happen if we continue with this trend of emitting harmful gases like: carbon dioxide, methane, and nitrous oxide etc. in our atmosphere. This simulation and the weather that we have just the last few years approve the risk and the theory that the climate is changing rapidly due to human activities and their dependents on burning fossil fuel for their purpose.

The mankind thought and invented different scenarios for possible risk that may destroy our planet.

Some of them are:

- Gamma Ray Burst, coming from a dying star from the space
- Black hole, coming from a dying star near our solar system
- Asteroid, from a chaotic university
- Super volcano, risk from inside the earth
- Nuclear war, there are 80’000 bombs with an equality of Hiroshima
- Plague, biochemical viruses
- Climate Change. [12]

The above list started with the risk coming from the space that represents a kind of risk that we cannot do anything to stop or to influent it, continuing with natural events of our planet that may occur without human interaction or with human intervention, following with the most actual risk that is caused by the worst enemy of the humanity that is the human itself.

Although some of them are controlled by the human like the nuclear war and the deathly viruses. But the climate change may run out of our control. If we continue living this life with this lifestyle, in a near future we will see and witness a climate that the planet earth didn’t had for more than 800,000 years.

So what could be done to stop or at least to slow down the climate change in such a fast scale.

There are some promising possibilities like: renewable energy sources, electrical storage capacity and electrical efficiency
2.6.1 Renewable energy sources

Renewable energy sources are sources from which could be created energy without harming the environment. The total amount of electricity created in the world from these sources is 22 %. There are many sources of energy that are renewable and considered to be environmentally friendly and harness natural processes. These sources of energy provide an alternate ‘cleaner’ source of energy, helping to negate the effects of certain forms of pollution. All of these power generation techniques can be described as renewable since they are not depleting any resource to create the energy. While there are many large-scale renewable energy projects and production, renewable technologies are also suited to small off-grid applications, sometimes in rural and remote areas, where energy is often crucial in human development. [13]

The most known renewable energy sources are:

- Solar
- Wind
- Hydro energy,

The sources mentions above are not the only renewable energy sources also other renewable energy sources are in the developing phase like:

- Tidal
- Wave
- Geothermal
- Biomass and waste

2.6.1.1 Solar energy

This form of energy relies on the nuclear fusion power from the core of the Sun. This energy can be collected and converted in a few different ways. The range is from solar water heating with solar collectors or attic cooling with solar attic fans for domestic use to the complex technologies of direct conversion of sunlight to electrical energy using mirrors and boilers or photovoltaic cells. Unfortunately these are currently insufficient
to fully power our modern society. The Earth receives an incredible supply of solar energy. The sun, an average star, is a fusion reactor that has been burning over 4 billion years. It provides enough energy in one minute to supply the world's energy needs for one year. In one day, it provides more energy than our current population would consume in 27 years. In fact, "The amount of solar radiation striking the earth over a three-day period is equivalent to the energy stored in all fossil energy sources." Therefore this power source is considered to be the best one to us, but unfortunately until now the efficiency of such installation is not very promising regarding the actual efficiency of son light the can be converted to electricity that is approximately equal to 20%, if you including also the thermal energy that is created from such solar plans systems that it increases the efficiency very much.

The outcome of these two energies electricity and thermal energy created using the solar energy is strongly connected with each other. Because during the process of converting sun light to electricity the solar panels will have a very high temperature that have a bad side effect on the process of creating electricity because it makes a higher resistance. Therefore by observing this heat through water tubes that are under the solar panel we can transfer that heat to other heating bodies and cool down the solar panel.

We have different solar energy system that can be used by people. There are three primary technologies by which solar energy is commonly harnessed is:

- Photovoltaics (PV), which directly convert light to electricity
- Concentrating Solar Power (CSP), which uses heat from the sun (thermal energy) to drive utility-scale, electric turbines, and
- Heating and Cooling Systems, which collect thermal energy to provide hot water and air conditioning.

In 2010, the International Energy Agency (IEA) predicted that global solar Photovoltaics capacity could reach 3,000 GW or 11% of projected global electricity generation by 2050, enough to generate 4,500 TW/h of electricity. Last year, in 2014, the agency reassessed their long-term predictions, raising the estimations for solar power to 27% of global electricity generation by 2050 where 16% will come from Photovoltaics solar energy and 11% from Concentrated Solar Power.
Even this prediction could be changed very fast because of the rapid technology improvement especially in the field of Nanotechnology by creating new materials that will increase the efficiency of the solar energy systems. [14]

2.6.1.2 Wind energy

We have been harnessing the wind's energy for hundreds of years. From old Holland to farms in the United States, windmills have been used for pumping water or grinding grain. Today, the windmills are equivalent to modern wind turbine that can use the wind's energy to generate electricity. Wind turbines, like windmills, are mounted on a tower to capture the most energy. At 30 meters or more above ground, they can take advantage of the faster and less turbulent wind. Turbines catch the wind's energy with their propeller-like blades. Usually, two or three blades are mounted on a shaft to form a rotor. A blade acts much like an airplane wing. When the wind blows, a pocket of low-pressure air is formed on the downwind side of the blade. The low-pressure air pocket then pulls the blade toward it, causing the rotor to turn. This is called lift. The force of the lift is actually much stronger than the wind's force against the front side of the blade, which is called drag. The combination of lift and drag causes the rotor to spin like a propeller, and the turning shaft spins a generator to make electricity.

Wind turbines can be used as stand-alone applications, or they can be connected to a utility power grid or even combined with a photovoltaic (solar cell) system. For utility-scale sources of wind energy, a large number of wind turbines are usually built close together to form a wind plant. Several electricity providers today use wind plants to supply power to their customers. Stand-alone wind turbines are typically used for water pumping or communications. However, homeowners, farmers, and ranchers in windy areas can also use wind turbines as a way to cut their electric bills.

Small wind systems also have potential as distributed energy resources. Distributed energy resources refer to a variety of small, modular power-generating technologies that can be combined to improve the operation of the electricity delivery system. [15]

While we’ve been harvesting energy from wind for several decades, it is only in the last few years as the world has become more concerned about global climate change that
we’ve increased installation of wind turbines to the point where wind has become a noticeable contributor to our energy mix. In 2010, installed wind capacity reached 197 gigawatts (GW) and produced about 2.5% of the world’s electricity. In 2010, China surpassed the US in the total amount of installed wind capacity to grab the number one ranking. But number one is perhaps not as impressive when one takes into account the population size and GDP of China as well as the US. More impressive, when one accounts for country size, are: Denmark, which gets 28.1% of its power from wind compared to China’s 1-2% and the US 3-4%. [16]

The prediction of using wind energy to create electricity is also incredible and especially by studying new ways of using wind power. In our days the wind power system is upgraded to a new level and that just by improving the old normal wind turbines with some additional components that uses increases the effect of the airflow towards the wind turbine to make them rotate faster so they automatically generate more energy, or you can reduce the cost of creating big wind turbines by creating smaller ones and more efficient ones. In Japan a project is going one in the field of wind energy and they used a method to create eddies that doubled the speed of rotating the wind turbine.

2.6.1.3 Hydro energy

Hydroelectricity is the term referring to electricity generated by hydropower. The production of electricity is through the use of the gravitational force of falling or flowing water. It is the most widely used form of renewable energy, accounting for 16 percent of global electricity generation with a value of 3427 TW/h of electricity production in 2010 and it is expected to increase about 3.1% each year for the next 25 years. Hydropower has become "the leading source of renewable energy. It provides up to 95% of all electricity generated by renewable sources worldwide. Other sources like: solar, geothermal, wind and biomass account for around 5% of renewable electricity production." In the US, 81% of the electricity produced by renewable sources comes from hydropower. Worldwide around 17% of all electricity is generated by hydropower. Some regions depend on it more than others. For example, 75% of the electricity produced in New Zealand and over 99% of the electricity produced in Norway come from hydropower. [17]
Hydropower is electricity generated using the energy of moving water. Rain or melted snow, usually originating in hills and mountains, create streams and rivers that eventually run to the ocean. This energy has been exploited for centuries. Farmers since the ancient Greeks have used water wheels to grind wheat into flour. Placed in a river, a water wheel picks up flowing water in buckets located around the wheel. The kinetic energy of the flowing river turns the wheel and is converted into mechanical energy that runs the mill. In the late 19th century, hydropower became a source for generating electricity. The first hydroelectric power plant was built at Niagara Falls in 1879. In 1881, street lamps in the city of Niagara Falls were powered by hydropower. In 1882 the world’s first hydroelectric power plant began operating in the United States in Appleton, Wisconsin. [18]

A typical hydro plant is a system with three parts:

- An electric plant where the electricity is produced
- A dam that can be opened or closed to control water flow and
- A reservoir where water can be stored.

The water behind the dam flows through an intake and pushes against blades in a turbine, causing them to turn. The turbine spins a generator to produce electricity. The amount of electricity that can be generated depends on how far the water drops and how much water moves through the system. The electricity can be transported over long-distance electric lines to homes, factories, and businesses.

Hydroelectric power provides almost one-fifth of the world's electricity. China, Canada, Brazil, the United States, and Russia were the five largest producers of hydropower in 2004. One of the world's largest hydro plants is at Three Gorges on China's Yangtze River.

Hydropower is the cheapest way to generate electricity today. That's because once a dam has been built and the equipment installed, the energy source in this case flowing water is for free. It's a clean fuel source that is renewable yearly by snow and rainfall. Hydropower is also readily available; engineers can control the flow of water through the turbines to produce electricity on demand. In addition, the reservoirs may offer recreational opportunities, such as swimming and boating.
But damming rivers may destroy or disrupt wildlife and other natural resources. Hydropower plants can also cause low dissolved oxygen levels in the water, which is harmful to river habitats.

Advantages and disadvantages of using hydroelectricity are:

Advantages:

- Flexibility
- Low power costs
- Suitability for industrial applications
- Reduced CO2 emissions
- Other uses of the reservoir

Disadvantages:

- Ecosystem damage and loss of land
- Siltation and flow shortage
- Methane emissions
- Relocation
- Failure risk
2.6.2 Electricity storage capacity

Definitely electrical energy storage represents the most important part of the solution needed to overcome continuously damage of our environment. This part is connected with some disadvantages of renewable energy sources in relation to continuous supply of electricity demand, there must be found a solution to make them more applicable and competitive compared with other known sources of energy that are poisoning our environment. Beside the disadvantages of the efficiency of such renewable energy sources we have also other weaknesses. It is known that wind power only produces electricity when there is strong wind flow present, and solar power only in the day time when the sun is shining, the output of these sources is strongly connected to the wind speeds and sunshine intensity. Because of that and also since operators of the electrical grid must constantly match electricity supply and demand, this makes variable renewable resources more challenging to incorporate into the electrical grid than traditional known sources like coal and nuclear generation technologies, which can be scheduled to produce power in a specific amount and in a specific times. Electrical grid operators have several options for managing the variability of electricity supply introduced by large amounts of renewable generation, one of which is electrical energy storage (EES).

Electrical energy storage (EES) technology represents the key point or the bridge between renewable energy sources and their successful integration in the electricity system. EES has the potential to facilitate the large-scale deployment of variable renewable electricity generation, such as wind and solar power, which is an important option for reducing greenhouse gas (GHG) emissions from the electric power sector and also prevents the emitting of carbon dioxide (CO₂) during electricity generation. [19]

2.6.2.1 Benefits of electrical energy storage

Some benefits of energy storage are that with storage there can be provided several functions such as providing regulation services, load following, ramping, storage can responds instantly, it adds no energy to the grid while it is in standby, important is that it has zero emissions, uses zero water resources and it is quiet, etc.
2.6.2.2 Electrical energy storage technologies

There are different EES technologies and they are categorized by the method of storage, by the amount of energy they can store, how quickly they can store energy and for how long they can release the stored energy. Some EES technologies are more useful for providing short bursts of electricity for power quality applications, other EES technologies are useful for storing and releasing large amounts of electricity over longer time periods this is referred to us as peak-shaving, load-leveling, or energy arbitrage. These EES technologies could be used to store renewable energy outputs during periods of low demand and release this stored power during periods of higher demand. For example, wind farms usually generates more power at night when winds speeds is high, but in that period the demand for electricity is lower therefore EES could be used to shift this output to other periods when there is a high demand of electricity.

Some of the major technology options for EES will be shown in the following table 2.2 by including the advantages and disadvantages of the usage of that specific system. [20]

Table 2.2 EES Technologies – Advantages/Disadvantages

<table>
<thead>
<tr>
<th>Storage technology</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium Sulphur (NaS)</td>
<td>High energy density</td>
<td>Heating may be required</td>
</tr>
<tr>
<td>Batteries</td>
<td>Long life cycle</td>
<td>Potential safety issues with the molten sodium</td>
</tr>
<tr>
<td></td>
<td>Quick response</td>
<td>Fire issue at a Japan installation</td>
</tr>
<tr>
<td></td>
<td>Efficient in charge-discharge cycles</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Able to tolerate a high number of charge/discharge cycles</td>
<td></td>
</tr>
<tr>
<td>Flow Batteries</td>
<td>Less sensitive to higher depths of discharge</td>
<td>Low energy density</td>
</tr>
<tr>
<td></td>
<td>Able to tolerate a large number of charge/discharge cycles</td>
<td>Not commercially mature</td>
</tr>
<tr>
<td></td>
<td>Reduced likelihood of the cells output being reduced to that of the lowest performing cell.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Virtually unlimited capacity</td>
<td></td>
</tr>
<tr>
<td>Storage technology</td>
<td>Advantages</td>
<td>Disadvantages</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>----------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Lead Acid Batteries</strong></td>
<td>Lead-acid batteries are an established technology, with existing infrastructure for end of life.</td>
<td>Susceptible to high depths of discharge (unless deep cycle variant)</td>
</tr>
<tr>
<td></td>
<td>Relatively efficient</td>
<td>Low energy density</td>
</tr>
<tr>
<td></td>
<td>Low self-discharge rates</td>
<td>Potentially hazardous materials</td>
</tr>
<tr>
<td><strong>Lithium ion (Li-ion) Batteries</strong></td>
<td>Li-ion batteries have an extremely high energy density, in the order of 400 Wh/l</td>
<td>Li-ion batteries have a higher cost than other technologies</td>
</tr>
<tr>
<td></td>
<td>Li-ion batteries are able to tolerate more discharge cycles than other technologies</td>
<td>Negative effects of overcharging/over discharging</td>
</tr>
<tr>
<td></td>
<td>High efficiency</td>
<td>Potential for issues associated with overheating</td>
</tr>
<tr>
<td><strong>Sodium Nickel Chloride Batteries</strong></td>
<td>High energy density</td>
<td>Heating may be required</td>
</tr>
<tr>
<td></td>
<td>Long life (20 years)</td>
<td>Potential safety issues with the molten sodium</td>
</tr>
<tr>
<td></td>
<td>Little / no self-discharge</td>
<td>Unsuitable for short cycling</td>
</tr>
<tr>
<td></td>
<td>No cooling requirement</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fully recyclable</td>
<td></td>
</tr>
<tr>
<td><strong>Liquid Air Energy Storage</strong></td>
<td>Not geographically constrained</td>
<td>Lower efficiency unless waste heat used</td>
</tr>
<tr>
<td></td>
<td>Existing global supply chain for components</td>
<td>Technology currently not demonstrated in the MW scale</td>
</tr>
<tr>
<td></td>
<td>Unlimited feedstock for the energy vector</td>
<td></td>
</tr>
<tr>
<td><strong>Compressed Air Energy Storage (CAES)</strong></td>
<td>CAES has rapid start up times</td>
<td>Conventional plant still requires fuel (gas)</td>
</tr>
<tr>
<td></td>
<td>Longer asset life than technologies such as batteries</td>
<td>Current technology has a low round trip efficiency</td>
</tr>
<tr>
<td></td>
<td>The mechanical system is extremely simple</td>
<td>Can only be constructed where suitable geological features exist or requires additional infrastructure</td>
</tr>
<tr>
<td><strong>Pumped Hydro Energy Storage (PHES)</strong></td>
<td>Mature large scale technology</td>
<td>Geographically constrained</td>
</tr>
<tr>
<td></td>
<td>Large power</td>
<td>Limited potential</td>
</tr>
<tr>
<td></td>
<td>Fast response times</td>
<td>Away from demand centers</td>
</tr>
<tr>
<td>Storage technology</td>
<td>Advantages</td>
<td>Disadvantages</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>----------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Pumped Heat Electricity Storage</td>
<td>Thermal - mechanical system with long life</td>
<td>Not commercially mature: first commercial plant was in 2014</td>
</tr>
<tr>
<td></td>
<td>No external emissions or hazardous materials</td>
<td>Potentially large footprint</td>
</tr>
<tr>
<td></td>
<td>Virtually unlimited number of charge/discharge cycles</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low cost</td>
<td></td>
</tr>
<tr>
<td>Flywheels</td>
<td>Rapid response times</td>
<td>Must be housed in robust containers, in order to contain fragments if the flywheel fails</td>
</tr>
<tr>
<td></td>
<td>Low maintenance requirements</td>
<td>Variable speed rotation as energy is extracted</td>
</tr>
<tr>
<td></td>
<td>Effective way of maintaining power quality</td>
<td>Requirement for precision engineered components</td>
</tr>
<tr>
<td></td>
<td>Virtually unlimited number of charge/discharge cycles</td>
<td>High price</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>Only emissions for using hydrogen are water vapors</td>
<td>Low round trip efficiencies (in the region of 40%)</td>
</tr>
<tr>
<td></td>
<td>Can be transported from the point of production to the point of demand if required</td>
<td>Low volumetric energy density</td>
</tr>
<tr>
<td></td>
<td>Can be used to power vehicles in addition to grid storage</td>
<td>There are potential safety concerns over the storage of hydrogen</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stored hydrogen can be used any time without self-discharge as with other storage technologies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fuel cell technologies are currently expensive</td>
</tr>
<tr>
<td>Superconducting Magnet Energy Storage (SMES)</td>
<td>Ability to rapidly release stored energy</td>
<td>Low energy density</td>
</tr>
<tr>
<td></td>
<td>Quick to recharge</td>
<td>Large parasitic losses associated with the cooling of the superconducting magnet</td>
</tr>
<tr>
<td></td>
<td>Almost infinite cycle life</td>
<td>High cost of superconducting materials</td>
</tr>
</tbody>
</table>
Table 2. 5 EES Technologies – Advantages/Disadvantages (Continue)

<table>
<thead>
<tr>
<th>Storage technology</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Super Capacitors</td>
<td>Capacitors demonstrate a virtually unlimited number of charge/discharge cycles</td>
<td>A higher rate of self-discharge makes super capacitors not suitable for longer term energy storage</td>
</tr>
<tr>
<td></td>
<td>Suitable for high current loads</td>
<td>Currently expensive</td>
</tr>
<tr>
<td></td>
<td>Not susceptible to overcharging</td>
<td>Low specific energy density</td>
</tr>
<tr>
<td></td>
<td>Extremely rapid cycle times</td>
<td></td>
</tr>
</tbody>
</table>

2.6.3 Electrical efficiency

Finally the third but not less important aspect of the solution to global warming or climate change, is working on the improvement of the electrical efficiency, in the aspect of using electricity in all electrical devices. The ideal case would be to use less electricity and provide more output than actual electrical technology devices. If not possible, than at least provide the same output, by using less electricity for a specific task.

Lately in this direction were discovered many inventions in the technology aspect. Today not only that every production process is modernized with new electrical efficient equipment offering higher precision, fewer waste, and running nearly fully environmental friendly, beside the dependents on electricity and the production process of it. There are also new household technology with a high increase on electrical efficiency, that makes a huge different in the overall consumption of electricity in the world. Around ¾ of the world electricity production goes to buildings and homes. Those are one of the most responsible factors of the greenhouse emissions effect, that’s strongly connected to the global warming or climate change.

Efficiency is also part of the EU standard “20-20-20”, where the EU state members have to increase the efficiency of using electricity by 20% until the year 2020. Kosovo is still not an EU member but that don’t mean that we cannot contribute in one way or another, to be part of the proactive states that wants to take part of the responsibility towards global problems.
The capacity and the status of a new and young state is known, also the currently instability in the field of politics and economics don’t allow us to do much. The investments in renewable energy sources and electricity storage are too much and required a high bugged for research. Because of these facts Kosovo is planning to contribute in the field of Efficiency. Kosovo has already a law that is for the importation of cars, no car older than 13 years can be imported and registered in Kosovo. Also in cooperation with the EU bank and banks in Kosovo, people who want to increase the efficiency of their homes can get a loan from the bank with a special payback offer.

After analyzing the usage of the electricity in our homes or buildings, it is discovered that around 60% of the electricity in our homes and buildings is used for heating and cooling purpose, another 12% is used for hot water and the rest 28% is used for other household devices. Space heating and hot water have an integrated solution therefore it refers to 72% of the overall electricity use in our homes or buildings.

When talking about space heating, water heating, cooling, refreshing, we have to refer to what they actually have in common, that would be that, everything is related to temperature and that mostly in the temperature difference created and influenced from the surrounding environment, and the common temperature inside our homes or buildings that would be of course for winter time heating and for summer time cooling.

All this behavior has to do with thermodynamic that will be explained shortly in the following.
2.7 Thermodynamic transformation system in buildings

Thermodynamic is one of the basic physical expressions that give an essential meaning to the modern concept of physics. It deals with energy and the form of the transformation of energy and it covers the differential behavior of temperature between different bodies, it analyses the possibility of the absolute zero, also as a fundamental it studies the thermal equilibrium between first, second and third body.

Under the definition of thermodynamic that says that: “thermodynamic is a branch of physics concerned about heat and temperature and their relation to energy and work” [21], it defines macroscopic variables, such as internal energy, entropy, and pressure, which partly describe a body of matter or radiation there are three main laws plus another fundamental law that is now added as the forth law of thermodynamic.

The law explaining thermodynamic are as follow:

- First law: “Energy can be changed from one form to another, but it cannot be created or destroyed.”
- Second law: “heat energy cannot be transferred from a body at a lower temperature to a body with a higher one without the addition of energy.”
- Third law: “The third law states that the entropy of a pure crystal at absolute zero is zero. Since there can be no physical system with lower entropy, all entropy thus has a positive value by definition.”
- Zeroth law: “if two bodies are in thermal equilibrium with a third body, then they are also in equilibrium with each other.” [21]

The second law of thermodynamic is the most interesting one for this thesis. Because of this physical behavior of the temperature we spend a lot of energy in form of electricity in winter time to heat the space in our homes and in our buildings also to get warm water, and in summer time to cool and refresh our homes or buildings and also to have more cold water or create ice for cooling our drinks. Therefore to reduce as much as possible the effect of the temperature exchange between the outside environment and the inside of our homes and buildings we have to make very good isolation. That of course increases the efficiency.
But this thesis doesn’t focuses on that part of savings and efficiency increase. The focus of this thesis is a new efficient technology that solves the problem of heating and cooling in a high economical and environmental friendly way by using the thermodynamic behavior of different bodies, under different circumstances. That technology is called “DAIKIN” a device that uses mostly normal air and a special fluid to generate heat or cold. Important to mention is that it dose the work without releasing any harmful element in the environment.

From the first law of thermodynamic we know that energy can only change or it can transform between different forms, during this process sometimes energy will be absorbed or released like in the molecular transformation where the chemical elements forms by releasing electrons or obtaining them and also other elements not just electrons but even if the corresponding elements do not interact with each other during their collision they create a force called friction. Therefore with every interaction between different bodies, is created a friction force that creates a specific amount of energy in form of heat. Where the second law of thermodynamic comes in consideration, that heat generated by the friction force, will loss the energy or temperature by warming up the bodies beside them. Because it confronts this time with the third law of thermodynamic, trying to keep the thermal equilibrium between different bodies. The most efficient use of these forces until now at least in the theoretical part is the Carnot cycle, which seems to be the most efficient engine it is not realistic because of the fact that there is no ideal gas or any ideal reversible process, everything known until now is irreversible. “All real physical processes are irreversible. Just as the ideal gas approximates the behavior of all gases, but no real gas is truly ideal there are only processes which are close to being reversible, but never quite get there.” [22]

These new technology uses in one or another form the Carnot cycle, but by using external forces to help the process of transferring a fluid from one state to another state and then back to the original state and during this process is obtained heat or cold.
3. Problem declaration

The problem is obviously known or can be simple explained in global terms with “Global Warming” or “Climate Change” that is currently mobilizing all scientist and governments around the world. The role of the governments is to plan and secure investments in different researches in this field. And the role of the scientists is to try to find possible solutions.

This thesis is focused only locally, and that in the possibility to give any contribute towards global problems. The actual state of Kosovo let no other choice besides working in the electrical efficiency and in different efficiency systems that can be used to reduce the emission of harmful chemical element in the environment.

The main problem in Kosovo is the production and usage of electricity. In the most cases the usage of electricity has a doubled negative effect especially when the electricity is used for heating systems that rune under other harmful elements for the environment like: wood, wood pellets, coal and oil.

A solution to this would be to use a device that has high electrical efficiency and dose not poison the environment, to offer heating for our homes and buildings. The system that is analyzed in this thesis besides providing solution for heating at the winter time, it also provides solution for the summer time when we have to cool our homes or buildings. The company providing this technology is called “DAIKIN”.

The main focus of this thesis is in the field of Electrical efficiency, environment and the influent in economy. The research questions are closely related to the product offered by “DAIKIN” and the questions are:

- How the new technology for heating and cooling influent the electrical efficiency
- How much effect has the new technology for heating and cooling in the environment
- The influent of the new technology for heating and cooling in the field of economy
4. Methodology

The methodology used in this thesis is a case study that analyzes the actual electricity use from the state buildings in Prishtina the capital city of Kosovo, including the heating system used from these buildings, showing the rate of the environment damage causes from these buildings only from using electricity and heating systems. Calculating the triple benefits of using the new technology for heating and cooling in the state buildings of Prishtina and that only for heating purposes, the triple benefits are in the field of: electrical efficiency, cost and environment.

To have a better overview about the results of this thesis, first will be explained the actual use of Kosovo’s resources for creating electricity and the effect caused to the environment by using this resources with the actual electrical production technology available. By explaining this we will know how much electricity is generated in Kosovo during the year, and comparing how much dose the state buildings of Prishtina contribute the consumption of this electrical energy, also we will get a result that tells us how much dose the use of electricity from the state buildings of Prishtina influent the environment. In this part will be included also the resources used for heating in this buildings in the aspect of costs and release of harmful elements in the environment.

Before analyzing the benefits of using the new technology for heating and cooling in these buildings, there will be explained in details the functionality of this technology, how does it offer high electrical efficiency, how this technology is used to creating heat, the advantages using this kind of system for heating.

After understanding the full functionality and the benefits of using the new technology for heating and cooling, there will be analyzed as a case study the implementation of this technology in the state buildings in Kosovo, in the aspect of efficiency increase of this buildings, what would lead directly to cost benefits and beside that is also analyzed the environmental impact of using this technology.

All the information’s are in accordance with the company offering the new heating and cooling solution called “DAIKIN”
5. Kosovo’s electrical resource and the environmental impact

Kosovo is a very small country located in the Southeast of Europe in the central part of Balkan Peninsula. With a total area of not more than 10,887 km² and a population of approximately 1.824 million regarding the World bank report of 2013. But still Kosovo is a rich country regarding the natural and mineral resources.

Since it is the surface upon which most economic activities happen, land is one of the most important natural resources contributing towards economic development. Kosovo has a total surface area of 10,887 square kilometers which is classified as: 53 to 54.23% agricultural land, 40.92% forest land and 4.85% infertile land. Kosovo possesses a wide variety of soils. It is assessed that 15% of the soil in Kosovo is high quality soil, followed by 29% of medium quality, so 56% of all soil is poor quality soil, while the high and medium quality make up 44% of the soil in Kosovo. The high and medium quality soil is composed 11% by humus soil, 8.4% grey carbonate land, 7.8% alluvial soil, and other dark and serpentine soils. The poor quality soil is composed of diluvia lands, swamps, acidic grey soils and other infertile soils, and it mainly lies on hilly areas and mountains.

Beside that the natural resources are abundant in Kosovo. Kosovo is mainly rich in lignite and mineral resources such as: coal, zinc, lead, silver and chromium but also productive agricultural land. Kosovo is also rich in forests, rivers, mountains and soil; it is among the richest countries regarding natural resources in Europe, based on surface. Kosovo is especially rich in coal, being aligned among European countries as the third with the largest coal reserves. Kosovo possesses around 14,700 billion tons of lignite in reserves, which aligns Kosovo as the country with the fifth largest lignite reserves in the world. It also has reserves of other minerals at an approximated value of 1 trillion dollars, reserves such as: aluminum, gold, lead, zinc, copper, bauxite, magnesium, etc. Kosovo also possesses rich reserves of asbestos, chromium, limestone, marble and quartz. While the majority of Kosovo’s natural resources remain unused, its large reserves are a great potential for future development, as assessed by the World Bank. [23]
Only the reserves of lignite coal in Kosovo are calculated to be worth around 300 billion dollars in the 2010 market. Kosovo is calculated to have the world's fifth largest reserve of lignite. But the usage of this source for creating electricity comes with a huge environmental cost. Unfortunately lignite is the lowest grade of coal, has low energy content and is expensive to transport.

And this source is actually used for the production of electricity in Kosovo, and that in the amount of 97% of the total electricity production in Kosovo, the other three percent comes from hydropower. And this is making a huge impact on the environment of Kosovo.

Since most of Kosovo's coal is processed in outdated and highly polluting power plants, it is plagued to have an annually impact in coal-related health problems, with 835 early deaths, 310 new cases of chronic bronchitis, 22,900 new cases of respiratory diseases among children most often asthma and 11,600 emergency visits to country's hospitals.

To improve the actual state of the negative impact on the environment of Kosovo regarding the use of the electricity production, Kosovo is planning to build a new electricity power plant and to close the old outdated power plants actually running, but still it will only be an improvement on the efficiency by using new technology, nothing more because the basic concept will be the same also the new power plant will run on coal. Believing that coal is the answer to Kosovo's economic problems and energy security is wrong. Yes, Kosovo is struggling economically, with an unemployment rate of about 45 percent and average salary, for those employed, of less than $6,000 per year. But the answer is not coal.

The answer, instead, is in energy efficiency, which is a hardly tentative from an industry perspective but absolutely necessary for Kosovo. Considering that today, Kosovo is wasting 30 percent of its electrical energy, according to official data, because sufficient energy efficiency programs have not been instituted. Add to that number another 37 percent from electricity losses where 17 percent results from outdated grids and technical deficiencies, the rest is coming from commercial losses. In this direction
Kosovo should make the first steps to win the war against coal dependence. Also beyond energy efficiency, the World Bank suggests that Kosovo's renewable energy sector could provide 34 percent of the country's energy demand by 2025, by providing 60 percent more jobs and provide savings between 5 and 50 percent including a scenario that even involves a new coal-fired power plant. But in sum, there is no need for a new coal-fired power plant. The answer for electricity stability and a clean environment is likely the same us for the rest of the world, in energy efficiency and renewable energy. [24]

In the following section of this thesis are presented the important information to know about the actual energy system of Kosovo.

5.1 Kosovo's electricity generating system – demand and production

Nearly 100% of electricity generated in Kosovo is coming from Coal power plants. Energy generation division is separated in two power plants “Kosova A" and "Kosova B" and chemical separations that are lied in the around area of Kastriot that is about 8 km far from Prishtina capital city of Republic of Kosovo. The total electricity production capacity of these two power plants is 5150GWh.

5.1.1 Power plant “Kosova A”

Power Plant “Kosova A” is composed from five generation units known as A1, A2, A3, A4 and A5. Unit A1 of this power plant is set in operation by the year 1962 with generation capacity of 65MW; A2 by 1965 with generation capacity 125MW; A3 by 1970 by generation capacity of 200MW; A4 by 1971 with generation capacity of 200MW and A5 by 1975 with generation capacity of 210MW. Units A3, A4 and A5 are still in function. According actual plan there are in use two units while third one is the “hot” reserve because of their low readiness that is because of its seniority. Units A1 and A2 are out of operation without defined status and according actual plans this will stay like that till the end when is planned to be done its decommissioning together with other units. Quantity of generated energy from PP “Kosova A” per year is 1500GWh. [25]
5.1.2 Power plant “Kosova B”

Power Plant "Kosova B" is composed by two generation units as there are B1 and B2. First unit B1 was set in operation by the year 1983 with generation capacity of 340MW, while second unit (B2) by 1984 with generation capacity of 339 MW. Both units are in generation and are in good condition. Based on finished investment and following investments there was improved evidently units situation that even these ate old about 25 years abovementioned units ate in high technical readiness. 2008 and 2009 are years when was achieved maximum generation in both units during its history since units were set in operation by the year 1984. Quantity of generated energy from PP “Kosova B” per year is 3650 GWh. [25]

5.2 Kosovo’s electricity generating system – environmental impact

The environmental degradation in Kosovo is mostly connected to air pollution. Air pollution is a critical environmental problem spatially in urban areas, as well as the whole country. Ambient air quality is particularly bad in Pristina, the Obiliq area, the Drenas area, and Mitrovica. The principal sources of contaminants are sulfur dioxide (SO2), nitrogen oxides NO and NO2, ozone (O3), lead (Pb), carbon dioxide (CO2), particulate matter (PM or dust), and dioxin.

The main sources of this pollution are in the field of energy and mining, including the two coal-fired power plants of the Kosovo Energy Corporation (KEK) and its coal-mining area. Also a huge impact has the household heating system that uses mostly wood and lignite. A high influent has also the industrial complexes, such as Mitrovica Industrial Park (Trepca), nickel mining and production in Drenas/Gllogovc (Ferronikeli), and the cement factory in Hani Elezi (Sharrcem), including public companies offering household heating in Pristina, Gjakova and Mitrovica, not to forget the impact of transport and Landfills of urban and industrial waste with varying local impacts.
The power plants Kosova A and Kosova B located in Obiliq are the main source of air pollutants, though NOx emissions are more equally divided among the power plants, transport, and other industries. Air emissions from the plants are particularly relevant for Pristina’s air pollution and the municipalities surrounding them.

Further, the decentralized burning of lignite and wood for household heating has a high effect in substantial PM emissions. Air emissions from the power plants are much higher than the European Commission (EC) Directive for Large Combustion Plants allow, the Particulate Matter emissions for Kosovo B are a factor 3-6 times lower than those of Kosovo A.

In the table 5.1 we can see the sectors that are responsible for the greenhouse gas emissions for the year 2009.

**Table 5.1 Greenhouse gas emission by sector**

<table>
<thead>
<tr>
<th>Source</th>
<th>Overall CO₂ %</th>
<th>Measure Gg (Giga gram) 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CO₂</td>
</tr>
<tr>
<td>Electricity</td>
<td>99.82</td>
<td>7,040,831.31 (7,040,831,310.00 ton)</td>
</tr>
<tr>
<td>Industry</td>
<td>0.16</td>
<td>11,474.52</td>
</tr>
<tr>
<td>Transport</td>
<td>0.02</td>
<td>1,110.44</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>7,053,416.27</td>
</tr>
</tbody>
</table>

Regarding the table 5.1 we can see that electricity generation has the highest impact on the environment. In the table 5.2 will be shown the emission of the electricity production power plants Kosova A and Kosova B and compared with the limitation of the EU standards.
Table 5.2 Estimates of air emissions for key pollutants for 2010 (mg per Nm$^3$ flue gas)

<table>
<thead>
<tr>
<th>Greenhouse gas</th>
<th>Power plant</th>
<th>Kosova A</th>
<th>Kosova B</th>
<th>EU limitation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Unit A3</td>
<td>Unit A4</td>
<td>Unit A5</td>
</tr>
<tr>
<td>SO$_2$</td>
<td></td>
<td>685</td>
<td>652</td>
<td>892</td>
</tr>
<tr>
<td>NO$_x$</td>
<td></td>
<td>694</td>
<td>700</td>
<td>692</td>
</tr>
<tr>
<td>Dust/PM</td>
<td></td>
<td>1,535</td>
<td>1,850</td>
<td>1,401</td>
</tr>
</tbody>
</table>

Note: Nm$^3$ is normal cubic meter and is a common unit used in industry to refer to gas emissions

Beside the huge environmental impact and the health impact related to the air pollution, there is also another perspective of view and that is the economical aspect of the environmental degradation and health related illness.

In the table 5.3 will be presented the annual cost of the environment degradation of Kosovo calculated for the year 2010. And in the table 5.4 will be presented the cost of the health impact of the air pollution also calculated for the year 2010.

Table 5.3 Estimated annual cost of environmental degradation in Kosovo, 2010

<table>
<thead>
<tr>
<th>Pollution or contamination estimate</th>
<th>Annual cost (€ million)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>Outdoor air</td>
<td>37.2</td>
</tr>
<tr>
<td>Lead</td>
<td>41.7</td>
</tr>
<tr>
<td>Solid waste</td>
<td>19.0</td>
</tr>
<tr>
<td>Forests</td>
<td>16.7</td>
</tr>
<tr>
<td>Water, sanitation, and hygiene</td>
<td>8.0</td>
</tr>
<tr>
<td>Water from heavy metals</td>
<td>0.4</td>
</tr>
<tr>
<td>Total</td>
<td>123.0</td>
</tr>
</tbody>
</table>
With annual costs of environmental degradation of €221 million, Kosovo faces serious social and economic impacts from poorly managed polluting activities and could make huge gains from remedial actions to protect and restore the quality of the environment.

Table 5.4 Costs of health impacts of air pollution, 2010 (€)

<table>
<thead>
<tr>
<th>Category\estimate</th>
<th>Low</th>
<th>Mid</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality: adults</td>
<td>29,973,823</td>
<td>84,442,006</td>
<td>142,453,784</td>
</tr>
<tr>
<td>Mortality: children</td>
<td>232,258</td>
<td>267,514</td>
<td>304,572</td>
</tr>
<tr>
<td>Chronic bronchitis</td>
<td>821,763</td>
<td>1,276,667</td>
<td>1,760,920</td>
</tr>
<tr>
<td>Hospital admissions</td>
<td>233,932</td>
<td>362,999</td>
<td>500,131</td>
</tr>
<tr>
<td>Emergency room visits</td>
<td>455,463</td>
<td>707,595</td>
<td>975,993</td>
</tr>
<tr>
<td>Restricted activity days</td>
<td>2,552,296</td>
<td>3,966,004</td>
<td>5,468,837</td>
</tr>
<tr>
<td>Lower respiratory illness in children</td>
<td>931,027</td>
<td>1,439,229</td>
<td>1,992,154</td>
</tr>
<tr>
<td>Respiratory symptoms</td>
<td>2,031,439</td>
<td>3,156,141</td>
<td>4,353,499</td>
</tr>
<tr>
<td><strong>Total cost (€)</strong></td>
<td><strong>37,232,002</strong></td>
<td><strong>95,618,156</strong></td>
<td><strong>157,809,890</strong></td>
</tr>
</tbody>
</table>

Regarding the table 5.4 we can see that the annual cost of the health impact due to air pollution ranges from around 37 million euro to 158 million euro with a middle point of approximately 96 million euro, and if we include also the environmental degradation represented in table 5.2.3 with a middle point of approximately 221 million euro. If we sum up these results we can calculate the total economic losses of Kosovo regarding the benefit of using electricity in the form we are used to use it. That total losses are represented in the table 5.5.
Table 5.5 Total economic losses in the environmental aspect of Kosovo for 2010

<table>
<thead>
<tr>
<th>Economic losses</th>
<th>Annual cost (€ million)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>Cost of environmental degradation</td>
<td>123</td>
</tr>
<tr>
<td>Costs of health impacts</td>
<td>37,232,002</td>
</tr>
<tr>
<td>Total costs (€)</td>
<td>37,232,125</td>
</tr>
</tbody>
</table>

All the information above starting from the chapter 5.2 are based on an electronic source in a PDF format, information regarding this source you will find in the references under, [26]

5.3 Kosova’s heating system

Kosovo has only tree public companies offering heating for the winter time and they are operating only in three cities like Prishtina, Gjakova and Mitrovica. “Termokos” is the company offering heating for the city of Prishtina and that only partially for the urban area of Prishtina that represent less than one present of the total area of Prishtina, but it offers services to 12,000 costumers mostly for household user. Until this year the heating system used from the company “Termokos” was based on burning fossil fuel like Mazut by being responsible for a high environmental degradation of the area of Prishtina. But in the last winter season for the first time Prishtina had realized a new heating system that is more environmental friendly using a cogeneration system that uses the steam created from the electricity power plant to heat the city.

And still because the heating system in not covering the entire city area it is making only a small positive difference. Because the rest of the city uses traditional methods for heating their homes or buildings like: wood, coal, wood pellet, mazut and oil and that has a huge impact on the environment. Representing the second largest factor of the environmental degradation after the electricity production of the coal fired power plants, so it is calculated that it has a higher impact than transport and industry in the city area. Also the economic aspect of view, only the heating of the state buildings costs the
municipality of Prishtina over 500,000 Euro that are calculated only for base material used by different heating systems like: mazut, wood, wood pellet, oil etc. this cost are only for the winter season.

Therefore the new heating technology analyzed in this thesis will have a great impact by improving the electrical efficiency, that would led to less energy requirements, so less environmental degradation related to electricity production, this will have a direct influent on health related illness coming from air pollution, and not to forget the economic benefits by lowering the degradation factor of the environment, less illness means less costs, and effective use of the electricity implies less electricity costs.
6. Heating and cooling solution offered by “DAIKIN” technology

Daikin is the world's largest manufacturer of energy-efficient heating, cooling and ventilation products and systems that provide outstanding indoor comfort control for homes, businesses and industrial customers. Daikin offers several products with different capacities depending on the volume and the capacity required for heating a specific area. Mostly Daikin offers two units for heating and cooling one outside unit and one inside unit that of course have different function.

Daikin leads the air conditioning market in the three cutting-edge core technologies and that in: Heat pump, investors and refrigerant control. These are the tree main part way Daikin technology is the leading company in the world regarding offering products for heating and cooling systems also other products. In these tree technologies Daikin has included the main solution toward the global problems of “Global Warming” or “Climate Change” by using renewable energy sources for heating purpose, using new technology to increase the electrical efficiency and for increasing heating properties using new environmental friendly materials. This company found the best way to interconnect the technology to offer to the society a new heating system. They oriented all their capacity in three fields by becoming the world’s leading company that dose different implementation and researches in:

- Heat pump
- Inverter
- Refrigerant control

The heat pump is used for absorbing and moving heat from the outside air that represent the renewable energy source, the inverter is used to contribute to energy savings and for offering higher comfort, the refrigerant control represents the high efficiency transfer of heat.

Daikin technology incorporate these technologies in two unit the outside unit and the inside unit.
6.1 Daikin technology – outside unit

The outside unit consists of several parts: ventilator, evaporator, compressor, inverter, heat pump between the units. This part is responsible for combining the tree main technologies that make this product so successful, by using the power of renewable energy sources, the high efficiency technology and the environmental friendly components or materials.

The first role of this part is to extract the heat from the outside air and before explaining this process first will be represented some properties of the air, to understand how we can extract heat from air and that in wintertime when the air is so cold.

Air has a high heating capacity even in temperature up to –25 °C. The air has also some specific physical capacities like for example pressure (P), and the normal pressure of the air is measured with Pascal and that is equal to $P = 1.01 \times 10^5$ Pa.

The air has also an approximately normal temperature behavior of around 295 Kelvin that would be represented with $T = 295$ K. Also the molecular properties of the air are about 0.0029 kilogram divided by mole so we get $M = 0.0029$ kg/mol, that represent the average between nitrogen and oxygen because the air consist almost of nitrogen and oxygen. From this information above we can calculate what’s the volume (V) for a mol, that would be around $V = 1/40$ m$^3$, also the density ($\rho$) of the air can be calculated and that is equal to $\rho = 1$ kg/m$^3$, and to the most important one for our use is the calculation of how many molecules are in one centimeter square of air and that is about $2 \times 10^{19}$.

The last calculation is very important for this kind of technology, because the large number of molecules in only one centimeter square is responsible for the temperature of the air by moving around and colliding with each other they release temperature. The air is also a very god absorber of the temperature coming from the sun and as higher this temperature is the molecules moves faster, due to this fact they can release more energy.
6.1.1 Daikin technology – ventilator

Daikin uses this characteristic of the air by using a ventilator to orient and to increase the air flow towards an evaporator in which flows a fluid that will be warmed up due to the collision of its surface with the air that leads to heat exchange between the air and the evaporator. This is shown in the figure 6.1 below.

![Figure 6.1 Air, ventilator and evaporator system](image)

The system described above is created to use the outside air as one of the biggest renewable source available in our planet. The physical properties of the air are already described above. In this case the air has a double positive effect first it is used as a clean source and without changing his properties it will be released on the other site again as a clean air source, second it is used as a heat exchanger between the evaporator and the inside flowing fluid, that eliminates the use of electricity to heat the fluid used for creating heat. Until now we have only a ventilator that is using electricity. And in the table below table 6.1 are shown the properties of the ventilator and in table 6.2 the fan motor properties. [27]

### Table 6.1 Ventilator properties

<table>
<thead>
<tr>
<th>Fan</th>
<th>Type</th>
<th>Discharge direction</th>
<th>Air flow rate</th>
<th>Nom.</th>
<th>m³/min</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Propeller fan</td>
<td>Horizonta</td>
<td>Cooling Nom.</td>
<td>m³/min</td>
<td>106</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Heating Nom.</td>
<td>m³/min</td>
<td>102-105</td>
</tr>
</tbody>
</table>
6.1.2 Daikin technology – compressor

This unit consists also of other parts like a heat pump that is used to circulate the fluid between the two units and through different phases. First phase was the evaporator the second one is the compressor. Daikin uses one of the most efficient compressors technologies available today and that is a hermetically sealed scroll compressor. That compared with other similar technologies has a lot of advantages. In the diagram represented by the figure 6.2 below are presented various types of compressors. Where is shown that the scroll compressor is a rotary – positive – displacement compressor type.

---

**Table 6.2 Fan motor properties**

<table>
<thead>
<tr>
<th>Fan motor properties</th>
<th>Brushless DC motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td></td>
</tr>
<tr>
<td>Output</td>
<td>W 70.00</td>
</tr>
<tr>
<td>Drive</td>
<td>Direct drive</td>
</tr>
<tr>
<td>Speed Cooling Nom. rpm</td>
<td>850</td>
</tr>
<tr>
<td>Speed Heating Nom. rpm</td>
<td>820-840</td>
</tr>
</tbody>
</table>

---

**Figure 6.2 Compressor types [28]**
Compared with other compressor technologies the scroll compressor required approximately 70% fewer moving parts, also 20% more efficient, and has approximately half the weight compared to other compressor technologies. The specific design of the compressor used by Daikin that uses a digital scroll compressor system offers in additionally 30% more efficiency by using a specific method to control the desired temperature, by controlling the rotation of the scroll compressor and that in two direction horizontally and vertically the vertical movement specifies when the compressor is compressing the fluid and when he is in an idle state. In the figure 6.3 below is represented the vertical and horizontal cut of the scroll compressor. [29]

Figure 6.3 Scroll compressor [30]

6.1.3 Daikin technology – inverter

Until now the use of electricity in Daikin technology was for the ventilator and for the compressor but even in this direction Daikin products are trying to use the electricity in the most efficient way, in the following comes the third part of ensuring higher efficiency and this is done by using invertors. Daikin’s inverter technology used for controlling the electricity use and to ensure the use of electricity is the most efficient possible is a true innovation in the field of climate control. The principle work flow of the inverter is simple the inverters adjust the power used to suit the actual requirement - no more and no less! This technology provides clear benefits in two aspects: comfort and energy efficiency.
**Comfort** because the inverter pays back its investment very fast. An air conditioning system with an inverter continuously adjusts its cooling and heating output to suit the temperature in the room, this improves the comfort level. The inverter reduces system start-up time, so the required room temperature is reached more quickly. As soon as the correct temperature is reached, the inverter ensures that it is constantly maintained.

**Energy efficiency** because an inverter monitors and adjusts the ambient temperature every time when needed, energy consumption drops by 30% compared with a traditional on/off system. [31]

An inverter is a control device that ensures higher electrical efficiency is also environmental friendly and works or operates with low noise. In the figure 6.4 below is shown the application us of the inverter technology.

![Figure 6. 4 Inverter use](image)

The operating method or the work flow of an inverter is shown or is described by the figure 6.5. Where we can see that the inverter reaches faster the desired temperature and due to the control effect and the feedback it controls continuously the temperature to hold it comfortable so that the room temperature don’t get over heated than wait until it
gets colder to be activated again like in the case where is no inverter used. This typical attributes of the inverter makes is so successful in the electrical efficiency and it offers savings up to 30% of electricity use compared with other systems or technologies that do not use inverters.

![Diagram of inverter model vs conventional model](image)

**Figure 6. 5 Inverter technology vs non-inverter technology**

Some advantages of using technologies that uses inverter’s vs other conventional models are: [32]

- You reach much faster the comfort temperature you want
- The start-up time is reduced by 1/3
- You save a lot of energy and also money: 30% less power consumption
- Avoids cycling of the compressor meaning that there are no voltage peaks
- The energy consumption cost is reduced by 1/3 (compared to normal on/off units)
- No temperature fluctuations

### 6.1.4 Daikin technology – heat pump

Often the complete outside unit is called heat pump but in these theses it refers to a pump that is used to circulate a specific fluid that runs through different phases, where first it gets heated up in the outside unit and then in the inside unit it releases his heat to get cool down again and in this form it repeats se same process over and over again.
Before mentioning the fluid that is used by Daikin, his physical and chemical properties, will be explained also the inside unit, the important parts and function of this unit.

6.2 Daikin technology – indoor unit

The inside unit consists of four main parts: condenser, water pump – to heating body (floor heating etc.), digital control unit and an expansion wave. The first role of this unit is to release the heat of the fluid to a condenser that is a tank full with water and called hydro tank, there the water will be heated and send through a water pump to the heating bodies like: floor heating, radiators or fan coil units and in additional it can be used also for creating domestic hot water for the household needs by adding a specific hot water tank what would increase the efficiency of the total system. The next role is to set and to control the desired room temperature and of course to ensure that every time we can have access to domestic hot water. And at the end the expansion wave that has an important function in the fluid circulation between the indoor unit and the outdoor unit, because here the fluid gets prepared to restart his cycle again, more detailed explanations related to the fluid will be found in the next section. The indoor unit consists also of several other parts that will be shown in the figure 6.6.

![Figure 6.6 Indoor unit](image)

1. Heat exchanger
2. Expansion tank (2.64 gal.)
3. Circulator
4. Tank with back-up heating
5. Air purge valve
6. Refrigerant fluid connection
7. Refrigerant gas connection
8. Water inlet connection
9. Water outlet connection
10. Pressure gauge (water circuit)
11. Water filter
12. Pressure relief valve
13. User interface
14. Switch box
15. Flow switch
6.3 Refrigerant control – fluid R-32 (HFC32)

Until now several times is mention that for the heating purpose Daikin technology uses a fluid to transfer the heat from the outdoor unit to the indoor unit. This fluid is a refrigerant material called R32. R32 goes through different phases to realize his duty, before explaining the heating process by using R32, first there will be some explanation, properties and other related information regarding to the fluid R32.

First what’s an R-32 refrigerant? R-32 is the next generation refrigerant that efficiently carries heat and has lower environmental impact and for the first time wildly used in the Daikin products. The term refrigerant expresses a medium that is used for conveying heat. Air conditioners and other products transfer heat while circulating refrigerant between the indoor and outdoor units this is usually done for to purposes for heating and cooling. Although there are various types of refrigerants used in the world, R-32 is a new refrigerant currently getting the most attention. Because R-32 efficiently conveys heat, it reduces electricity consumption up to approximately 10% compared to that of air conditioners using refrigerant R-22. Furthermore, compared to the refrigerants widely used today such as R-22 and R-410A. But the most important part of using this new refrigerant R-32 is because of its global warming potential (GWP) that is one-third lower and is remarkable for its low environmental impact. To have a better overview about this refer to the figure 6.7 where is shown a comparison between different refrigerants and the environmental impact of their use, by considering that the CO₂ has an indication factor in the environment of one (1). [33]

![Figure 6.7 Global warming potential of different refrigerants][33]
From the figure 6.7 we can see that the developing trend of refrigerants goes in a good direction. The use of refrigerants have some restrictions: refrigerants must not harm the Ozone layer or contribute to Global Warming. And therefore there is growing worldwide interest in finding a next-generation refrigerant that does not harm the ozone layer or contribute to global warming. At one time, chlorofluorocarbons (CFC) were used as air conditioner refrigerants, but the 1987 Montreal Protocol designated CFCs as substances that seriously deplete the ozone layer and therefore called for their total phasing out. Hydro-chlorofluorocarbons (HCFC) became substitutes for replacing CFCs; however, even they were later added to the list of banned substances under the Montreal Protocol since HCFCs also deplete the ozone layer.

For this reason all HCFCs production must be completely phased out in industrialized countries by 2020 and in developing countries by 2030. Industrialized countries are in the process of replacing HCFCs with hydrofluorocarbons (HFC), which do not harm the ozone layer and has a low contribute to global warming. The Kyoto Protocol, adopted in 1997, called for a reduction in HFC emissions.

Because of these regulation not only the global warming potential is an important factor that has to be considered in this kind of application but in this type of application it is important to consider also the ozone depletion potential (ODP) of the refrigerants, these values are represented in the picture 6.8.
The most used and the mainstream refrigerant R-410A, has an ozone depletion potential (ODP) of 0, its global warming potential (GWP) still remains a problem and in this part improvements have to be done. Also R-32 has an ozone depletion potential of 0, but the refrigerant has only approximately 1/3 of the GWP of R-410A. Consequently, investigation of this promising next generation refrigerant has increased. However, because R-32 had been an extremely difficult refrigerant to handle, its use was not practical until now. Daikin became the world’s first company to succeed in applying R-32 to their technology by leveraging its expertise as the only manufacturer that develops and manufactures both air conditioners and refrigerants.

Of course also the Daikin Company used the most common known refrigerant for air conditioners and heating systems that is the R-410A refrigerant. But from since November 2012, Daikin became the first company in the world to use R-32 (HFC) [33]. The first use was in residential air conditioners for the Japanese market. Some of the advantages of the new refrigerant R-32 compared to the old refrigerant R-410A are:

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>Ozone Depletion Potential (ODP)</th>
<th>100 Year Global Warming Potential of Different Refrigerants*</th>
</tr>
</thead>
<tbody>
<tr>
<td>R12 (CFC)</td>
<td>1.0</td>
<td>10,900</td>
</tr>
<tr>
<td>R22 (HCFC)</td>
<td>0.055</td>
<td>1,810</td>
</tr>
<tr>
<td>R410A (HFC)</td>
<td>0</td>
<td>2,090</td>
</tr>
<tr>
<td>R32 (HFC)</td>
<td>0</td>
<td>675</td>
</tr>
</tbody>
</table>

Figure 6. 8 Environmental impact of different refrigerants [33]
- Considerably lower refrigerant cost than R410A and potentially better affordability
- Available now in high volumes globally since it is 50% of R410A composition
- 8% higher critical temperature, better performance at higher ambient conditions similar pressure and pressure ratio,
- A close drop-in replacement for R410A without major system redesign
- 9% lower liquid density, lower system charge requirement
- 28% lower vapor density and lower system mass flow rate, about 50% lower pressure drop expected,
- Higher volumetric capacity despite the 28% lower mass flow due to 43-50% higher latent heat
- 41% higher liquid thermal conductivity, higher heat transfer coefficient at same mass flux
- No glide and potential to optimize heat exchanger with smaller tube volume for further charge reduction [34]

From the facts mention until now and from the picture 6.9 below is easy to understand why to use the R32 refrigerant. But the use of this refrigerant has also some other benefits because the R32 is one of the most balanced solution currently available.

Figure 6. 9 R32 comparison and advantages
The other benefits are:

- R32 does not depleting the ozone layer
- It has a smaller Global Warming Impact compared to R410A & R22
- Higher Energy Efficiency compared to R410A & R22
- Reduced refrigerant charge possible
- More compact design possible
- Acceptably safe because only slightly Flammable (Class A2L)
- Refrigerant Production capacity is available (R32 is a component of R410A)
- Easy to recycle and reuse (single component refrigerant)
- Affordable for developing countries

The refrigerant R32 fulfills the requirements to be the next generation refrigerant. Because of its strong connection to the required standards that are shown in the picture 6.10 below. [35]

![Figure 6. 10 Required standard for the next generation of refrigerants [35]](image)

The only disadvantages of the refrigerant R-32 are that: [34]

- Mild flammability rating (difficult to find a Low-GWP A1 non-flammable fluid)
- Higher compressor discharge temperature from higher vapor specific heat
- New oil likely required since existing polyolester (POE) oil is not miscible with R32

But in overall, R32 offers more advantages than disadvantages. Its lower cost provides incentive for investing development time for mitigating its disadvantages through compressor and system design optimization.
6.4 The heating process of Daikin technology

For realizing the heating or the cooling Daikin uses a refrigerator fluid called R32 that flows between the units and due some processes it goes from the liquid form to a gas form, where it changes also the parameters of the heating capacity. In the following figure 6.11 is described the heating system used from Daikin

![Figure 6.11 Heating process using Daikin solution](image)

In the figure above is described the process of heating. Starting by the outside unit where the ventilator is mounted. His role is to get us much air as possible in the evaporator. In this part the air is used to prepare the R32 refrigerant that is in a liquid form to a common temperature, before it flows to the next part that would be the compressor. Not to forget that the outside air has a heating capacity in up to – 25°C. Therefore in the 1st step the fluid has approximately a temperature up to 10°C. Than it goes to the compressor where the fluid will be compressed and by compressing this fluid we have in the 2nd step a temperature up to 70°C with a pressure up to 28 bars, this brings the fluid to another form from liquid to gas. And through the heat pump it flows to the inside unit.
In the inside unit the fluid flows through the condenser that is full with water and it releases his temperature to the water that gets a temperature up to 55°C. Through another water pump the water will go to the heating bodies inside the building that can be for example floor heating. So by releasing his temperature the fluid become colder and in the 3rd step the temperature is again up to 10°C. For completing the flow cycle the fluid has to go through an expansion wave. So that in the 4th step the fluid has to become colder than the outside temperature and due to this it also again changes his form, now from gas to liquid. In this step the temperature difference between the fluid and the outside temperature should be as higher as possible to have a greater heating effect.

This process continues after and after again and the good side of this is that in summer time it can be used for cooling the building by inversing the steps.

One of the mayor benefits of this technology is that it uses the outside air in the most efficient way and this makes the huge different in the overall efficiency system compared with other heating systems, especially when compared with electricity heating systems.

The electricity heating system uses one (1) kW electrical power, and it produces one (1) kW thermal energy, see figure 6.4.2. Compared to the Daikin air heating solution that extract form the air approximately 75 – 80 % of the thermal heat, by reducing the electrical requirements and in this case for producing 1 kW thermal energy we have to use only 20 – 25 % electricity compared to the electrical heating system se figure 6.4.3. [36]
Daikin air heating technology offers different models and depending on the type and model that is chosen we can get up to 4/5 of the thermal energy for free from the outside air and for realizing this purpose is only 1/5 of electricity needed, and that only for the ventilator, the compressor, and the circulating pumps. [37]

This comparison is also nearly equal compared to other heating systems that uses or consumes first more electricity to be able to run and uses a nonrenewable energy source like oil or coal or even wood, the only difference is in the price of the energy source used for heating.

For arguing this in the following you can find some energy conversion to kilowatt/hour:
• 1 kilocalorie = 4190 joules
• 1 kilowatt hour (kwh) = 3600 kilojoules = 859 kilocalories
• 1 m3 natural gas = 10 kwh
• 1 barrel of oil = 1700 kwh
• 1 calorie = 4.184 J

In the table 6.3 are represented some energy content of some fuels. [38]

Table 6.3 Energy content of different sources

<table>
<thead>
<tr>
<th>Description</th>
<th>Energy in kwh</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 kilogram of dry wood</td>
<td>5.3 kwh</td>
</tr>
<tr>
<td>1 kilogram of coal</td>
<td>8.1 kwh</td>
</tr>
<tr>
<td>1 cubic meter of natural gas</td>
<td>8.8 kwh</td>
</tr>
<tr>
<td>1 liter of petrol</td>
<td>9.1 kwh</td>
</tr>
<tr>
<td>1 liter of diesel-oil</td>
<td>10.0 kwh</td>
</tr>
<tr>
<td>1 kilogram of hydrogen</td>
<td>33.6 kwh</td>
</tr>
<tr>
<td>1 kilogram of Uranium 235</td>
<td>22.2 million kwh</td>
</tr>
</tbody>
</table>

Considering this another possible advantage of the air heating technology system of the Daikin company is to combine this system with a renewable electrical energy source like: solar, or wind power and we would get a nearly 100 % renewable and environmental friendly heating system.
6.5 Case study of implementing “Daikin” technology in state buildings in Prishtina

In this case study first is analyzed the energy consumption of the state buildings in Prishtina in the year 2013 also the heating system used from this buildings in case it isn’t electricity and that’s the most case. The analyze is done in more dimensions by calculating the electricity costs, the heating costs, the electricity production, the pollution related to that electricity production, and the health impact due to the environmental degradation of producing electricity for the Prishtina state buildings. The outcome of this case study will be represented by calculating the advantages of installing the Daikin heating technology in the state buildings of Prishtina.

Until now in this thesis is nearly everything mention that is needed for proceeding with the case study. The risk of global warming or climate change is emphasized, Kosovo’s electricity production system is explained, the health and environmental impact caused by the actual electricity production system is mentioned, the heating system used in Prishtina. So the basic data are available to start with the case study, but what else do we need to know to complete this case study, the missing information until now is the amount of money that the municipality of Prishtina pays for electricity, during the year or especially during the wintertime and by getting this information we can calculate the electricity power that is needed to fulfill the consumption requirements of the municipality of Prishtina, and the environmental and health impact of producing that electrical power in Kosovo.

Unfortunately this thesis is based only on local sources and due to the lack of information from the municipality of Prishtina the results are not based on the physical properties of the buildings that are necessary to be more exact with the calculation of the result. With physical properties is meaning that: the total square meters of this buildings is unknown, the isolation of this buildings is also unknown, the window technology is unknown, the temperature leak report is unknown.
And for this reason the calculations are only based on the electricity consumption and by eliminating the total extra costs for the old heating system used by the state buildings of Prishtina that is a large amount of many.

Only by calculating these factors we get a good result but if we could make a more detailed calculation the result would be only better.

The source for calculating the electricity requirements of the state buildings is partial offer from the municipality of Prishtina and partial from “KEDS”, Kosovo-s Electrical Distribution and Supply Company offering the electricity.

See appendix B to see an example of an electricity bill for a building that is in the responsibility of the municipality of Prishtina.

The total number of state buildings in Prishtina is 206 see more detail on table 6.4. [39]

<table>
<thead>
<tr>
<th>Description</th>
<th>Nr. of objects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific schools</td>
<td>1</td>
</tr>
<tr>
<td>Kindergarten</td>
<td>53</td>
</tr>
<tr>
<td>Primary school</td>
<td>66</td>
</tr>
<tr>
<td>High schools</td>
<td>17</td>
</tr>
<tr>
<td>Family medicine center</td>
<td>28</td>
</tr>
<tr>
<td>Other buildings</td>
<td>41</td>
</tr>
</tbody>
</table>

Considering that these thesis is talking about a new method or a new heating system of the state buildings of Prishtina, this new system would eliminate the older system that uses oil for heating and it is mention that the municipality of Prishtina pays 500,000.00 € for getting the oil for the heating system. [40] This large amount of many will not be needed anymore because the new system will work on the power of renewable energy that would be the wind power or better to say the outside air.
The total energy consumption of this buildings is equal to 768,402.49 €, and in such building systems is calculated that approximately 70% of the energy is used for heating and cooling purposes that would be that the municipality of Prishtina pays around 537,881.74 €. This is equal to an electricity power of 4,591,001.53 kWh, and by producing this electricity Kosovo emits to the environment approximately 36.728 ton CO2 all this for one year.

The second aim of this case study was calculating the difference that would be if the municipality of Prishtina decides to implement Daikin technology in their buildings for heating and cooling, and for such buildings using the newest heating technology offer by the “Daikin” company with the refrigerant R-32 the saving ratio would be equal to 9.4. Because in this case Daikin air heating system would use 1 kW electricity and gain or extract from the outside air another 9.4 kW thermal energy for the heating purpose. See figure 6.16.

![Daikin saving ratio using new refrigerant R-32](image)

In table 6.5 are shown the results that may be obtained after the implementation of Daikin technology, by including the replacement of the oil heating system, by calculating the benefits of the new energy efficiency Daikin system. Also in this table are included the average cost of the economic losses calculated in the table 5.5 that
represent the total cost of the environmental degradation and the total cost of the health impact, by referring with the same term like in table 5.5 with the term economical losses but this time is calculated only the contribute of the Prishtina state buildings that represent 0.09% of the total energy production in Kosovo.

Table 6. 5 Results of savings with Daikin Technology for heating and cooling.

<table>
<thead>
<tr>
<th>Description</th>
<th>Actual situation</th>
<th>Savings after implementation</th>
<th>Future situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity costs for heating and cooling purpose of Prishtinas state buildings</td>
<td>537,881.74 €</td>
<td>480,660.28 €</td>
<td>57,221.46 €</td>
</tr>
<tr>
<td>Electricity production requirement for heating and cooling purpose of Prishtinas state buildings</td>
<td>4,591,001.53 kW/h</td>
<td>4,102,597.12 kW/h</td>
<td>488,404.41 kW/h</td>
</tr>
<tr>
<td>Emitting of CO₂ considering the use of the electricity for heating and cooling purpose of Prishtinas state buildings</td>
<td>36.728 ton</td>
<td>32.821 ton</td>
<td>3.907 ton</td>
</tr>
<tr>
<td>Oil for heating system of the Prishtinas state buildings</td>
<td>500,000.00 €</td>
<td>500,000.00 €</td>
<td>0.00 €</td>
</tr>
<tr>
<td>Economical losses upon the electricity for heating and cooling purpose of Prishtinas state buildings</td>
<td>860,563.24 €</td>
<td>769,013.96 €</td>
<td>91,549.28 €</td>
</tr>
<tr>
<td>Total</td>
<td>1,898,444.98 €</td>
<td>1,749,674.24 €</td>
<td>148,770.74 €</td>
</tr>
</tbody>
</table>
6.5.1 Case study outcome

This case study shows an incredible outcome or a fascinating result, savings of an approximately value of 1,749,674.24 € and that only for one year without the need of further investments for the next 5 to 10 years. But unfortunately in this thesis is not calculated the payback time of the investments for changing the heating system to the air heating solution offered by the Daikin Company, because of the lack of information regarding the building infrastructure. And without these information it is impossible to foreseen the capacity and the model of the different Daikin heating units that are necessary to create a comfortable temperature either in winter or in summer time. For the calculation of the represented results in the table 7.2 is considered the theoretical approach and the overall practical experiments done with the Daikin devices.

Because of some missing information the result in the table 7.2 has to be considered with a mistake rate of up to minus twenty present (± 20 %). The overall result will not fade at all, even by adding the calculation of this mistake rate. Still the result remains worth enough to consider the change of the heating system, and by doing so, this will have another positive effect in creating a higher employment rate and this would be represented also with an economical growth. Another positive effect that the investing in the change of the heating system would have is that investing in the field of electrical efficiency and renewable energy sources is a requirement and a must, not only because of the European Union restrictions but also for the life of the future generation, and the wellness of our wonderful planet earth.
7 Conclusion

One of the purposes of this thesis is to show the behavior of the world or humans towards the actual global problems that are global warming or climate changing. This is done by following a few steps. The first part aims to highlight the understanding of the risks, continuing with the second part that is focused on the cause of these problems and by ending with the third part that is concentrated in the actions needed to overcome these problems.

To be able to face global problems a global mobility is required, where in one or another way the responsibility can be shared to the lowest level where it would affects every person. Fortunately the awareness in our days that we have to stop with emitting harmful gases in our atmosphere is spread out very much and beside that also a large number of different solutions are offered, where some are already applied and in use and some other solution are theoretical possible and many researches are trying to find ways how to make them for real application.

Kosovo for the moment has not enough capacity to make remarkable contribution to solution of such global problems, even for trying to reduce the pollution in Kosovo we have to rely on international help. Therefore the European Union and the European Bank together with the Norway government donated to Kosovo a value of 12 million euro. This donation has to be used for helping people to get a so-called green loan, where the only purpose of using this kind of loans would be in the increase of efficiency in private homes and this is calculated to have an outstanding result.

In this thesis is analyzed a device that can replace the actual heating system used in Kosovo that is fare away for being efficient and to find a solution that would have the power of providing same capacity but in an efficient way and by using renewable source that would have lower GWP and ODP. And the proposed solution is the use of new technology for heating and cooling on of them is provided by the “DAIKIN” company.

The case study realized in this thesis shows incredible results and a huge potential of providing first of all economical savings, than a cleaner environment, and less health related problems.
All this benefits and goods would not be possible without the impact of mechatronic. In this thesis is already mention the importance of mechatronic, the reason way it has to be mention also in the conclusion is that mechatronic and the technology development is becoming more and more essential for a normal life and for basic living conditions, technology is surrounding us in our daily activities. And mechatronic continues to evolve very fast in our days by providing not only solution to the problem mentioned in this thesis but also solution to other problems by offering new opportunity and go beyond the imagination of the humans.

An interesting future is waiting for us. We just need to start to change our behavior towards the environment in which we are living.
Reference


[34] R. R. Hung Pham, "R32 And HFOs As Low-GWP Refrigerants For Air Conditioning," in International Refrigeration and Air Conditioning Conference, Purdue, 2012.


Appendix A – Reason why I chose this topic

I started my bachelor studies with Computer Science, and by seeing the interdisciplinary and the possibility of the field of mechatronics I had chosen to continue Mechatronics for my major program. The subject of my bachelor thesis was Electro-pneumatic and PLC systems, where I could see how mechatronics systems improve our daily live in different ways.

Now near of the end of my master studies in mechatronic management I came to a conclusion for myself that mechatronics is a really good field and it helps us a lot in simplifying or modernizing nearly every production process, it modernized our entire life process with modern transportation systems, modern homes, improved the medical system by using precise machineries, improved all product with high accuracy, inventing household robots for helping the human in different task and so on.

But all these goods and benefits have their price, also because very few have many and many have few. I want to focus on the majority who have few and try to help them.

Death rate of hundreds of million people life are directly affected by the lack of access to clean water, even the absence of electrical power is a huge problem for ensuring medical care in the most places of the world where it’s needed. The rising temperature caused from the modern civilization for their transportation and the electrical dependents by burning fossil fuels is directly connected to the higher risk for different disease that could increase the death rate all over the world.

To have a robot in my home would be nice, but to have the opportunity to help millions of lives that would be wonderful. Therefore I will try to analyze the impact of mechatronics in electrical efficiency this would be directly connected with the environment of our planet earth and it would lead to the health impact of all living creatures in this until now unique known planet called Earth.
Appendix B – Electricity bill for the library “Hivzi Sylejmani”

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17.07.2014 2:59:43 PM  RB001 1 / 2
# Appendix B 2 Electricity bill for the library “Hivzi Sylejmani”

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**Total:** 37

- **Total:** 22,073.28
- **Balance:** 22,645.10
- **Balance:** 28.18

**Deri me - Up to - Do:** 17.07.2014

**Total:** 28.18