Saimaa University of Applied Sciences
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THE EFFECTS OF CLIMATE CHANGE ON FOREST INDUSTRY AND ENVIRONMENT: FINLAND AND MOROCCO

Thesis 2011

ABSTRACT

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The Effects of Climate Change on Forest Industry and Environment: Finland and Morocco, 81 pages
Saimaa University of Applied Sciences, Imatra, Finland
Faculty of Technology, Degree Program in Chemical Engineering
Bachelor‘s Thesis 2011
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The purpose of this thesis is to present the climate change problems and to describe how this affects the Finnish and Moroccan forest industry. This thesis also aims at explaining the scientific basis for climate change and the possible impacts of changing climate. The natural climate change, climate forcing, emission from forest industry, predicting climate change, and avoiding dangerous climate change are introduced and discussed to illustrate their potentials and impacts on the environmental and economic prospects domestically and internationally. As an application of the effect of climate change on forests, the experimental part in laboratory is about the effect of air humidity on hand sheet paper properties.

Two different research methods were used to complete this thesis work in different chapters and also for different evaluations. The information in this thesis has been collected by researching and studying the existing literature and other sources on the relevant subjects with the supervision and guidelines from instructor. The second method used was team interview of experts on the effect of climate change on forests. The respondents are mainly from Finland and Morocco. Among the respondents contacted were a researcher, three experts on environment, six pulp mill operators and random questionnaire respondents.

It was found out that pulp and paper industry is air emissions from recovery boiler and lime kiln as well as malodorous gases and chlorine compounds from bleaching chemical preparations are responsible for a big amount of greenhouse gas emissions which accelerate the climate change. It therefore becomes important that necessary corrective measures must be taken urgently.

Key words: Finland, Morocco, Forest, Industry, Climate, Change, Effects, Environmental

Contents

1 INTRODUCTION

1.1 Introduction of the work

Climate influences where we live, our growth, and our well- being. Each species of plant and animal has adapted to live within a specific climatic niche. Global warming has led to an average earth surface temperature increase of about 0.7 ^{0}C in the 20th century, according to the 2007 IPCC report. In Finland the annual mean temperature is predicted to increase by 2-6 degrees by the end 2100; increase in winter months of 3-9 degrees and summer months 1-5 degrees. The climate on the earth is changing because human activities are changing the chemical composition of the atmosphere, such that it translates into changes in the climate. This continuous change of the climate has very heavy effects on ecosystems that are not able to adapt themselves to these climate changes. In fact paper and pulp mill contributes big emissions of carbon dioxide that covers the earth, traps the heat and raises the global temperature. Lots of people confuse global warming with the ozone layer: these are two different phenomena; even though they share the similarity of been caused by humans.

The aim of this work is to create a deeper understanding of the scientific basis of climate change and its effects on forest industry and the environment. In other words, it attempts to answer the questions: “should we accept the reality of climate change and deal with it? “, and “why are scientists so alarmed about a few degrees of warming?”. In addition the purpose is to offer paper industries some clues to determine emissions and process towards indicators useful to set emissions-reducing targets. This thesis aims to improve or provide some remarks to the GHG pulp paper protocol.

This work is divided into seven chapters. The study begins with the introductory chapter which presents the background information. It also sought to clarify general issues of climate change on forests and environmental effects in Finland and Morocco. The first chapter also gives the motivation and general study approach and introduction of the Saimaa University. The second chapter is dedicated to review of literature which gives us knowledge about climate change, what is climate? How does it work? How our climate works and how different factors affect on our climate. How do we know that greenhouse gases are responsible for the climate change and prove that? The third chapter introduces climate forcing, natural and man-made induced climate change: What is natural variability and what is anthropogenic human induced climate change? Chapter four contains detailed description of emissions from forest industry. Prediction of climate change and avoiding measures of dangerous climate are introduced as well as how to address the changes. Chapter six (experimental part) is about the effect of air humidity on hand sheet paper and results obtained are discussed in the light of literature available. The last chapter includes the conclusions and discussion.

1.2 Introduction of the university

Finland is located in North Europe. It is bound by Russia to the east, the Gulf of Finland to the south, the Gulf of Bothnia and Sweden to the west and Norway to the north. The figure1.1 below indicates the location, and Finland ranked as one of the cleanest and most efficient nations around the world. Finland is an advanced industrial economy: the metal, engineering and electronics industries account for 50 % of export revenues, the forest products industry for 30 %. Finland is one of the leading countries in Internet use. Today, there are more mobile phone than fixed network subscriptions. Due to its global reputation and influences, Finland is an ideal destination of learning how the world's leading environment management system is working. Finland is also the leader for forest industry and its related education and research globally.

The Saimaa University of Applied Sciences is an institute of higher education in Southeastern Finland in the cities of Lappeenranta and Imatra and is located in the same place where the largest forest industry production centers in Europe: South-east Finland. Finnish forest industry enterprises, for example major production mills and research centers of UPM and Stora Enso are located in this area. The university is a terminal based on the cooperation with the Finnish advanced forest industry where students are able to be well educated and trained for the forest-based and environmental research and future career in the environmental engineering and forest sciences. The unit of technology offers the degree program in Chemical Engineuring at Saimaa University of Applied

Sciences, which provides the essential knowledge and necessary skills to the students who want to make contributions and efforts to forestry industry, environmental engineering institutions and chemical process industries.

Figure 1.1 Location of Finland in Europe

Saimaa University of Applied Sciences has strong international contacts with almost 100 partner Universities all over the world. Saimaa UAS has also several Double Degree agreements with its partner Universities. Saimaa University of Applied Sciences is focused in cooperation with university in Russia, Western Europe, the Nordic countries, and new EU Member States and also China and Malaysia in Asia. There is a lively teacher, student and trainee exchange between Saimaa UAS and its partner universities and other kind of cooperation and development projects are carried out together with partner universities. (1.)

2 UNDERSTANDING CLIMATE CHANGE

To be able to understand climate change, we need to understand climate. What is it? How does it work? What is the difference between weather and climate?

2.1 What exactly is the climate?

First of all, let's answer the question of what is the difference between weather and climate? Weather is elements which we see daily, such as temperature, rain, snow, hail and wind. These can change hour by hour, day by day. Climate on the other hand looks at how the weather changes over a long period of time, typically over a long period of time, typically over 30 years. It can be thought of as the average weather over a long period. Scientists have been able to define climate zones around the world. Here in Finland, we have temperate climate that is not especially hot or cold, wet or dry, when compared to other climates. It is a very different climate to that in the Sahara for example in Morocco, which is known as arid because throughout the year the weather is dry and hot. Scientists have to look at how the atmosphere interacts with the oceans, ice sheets, land masses and vegetation. These different interactions create a Climate System.

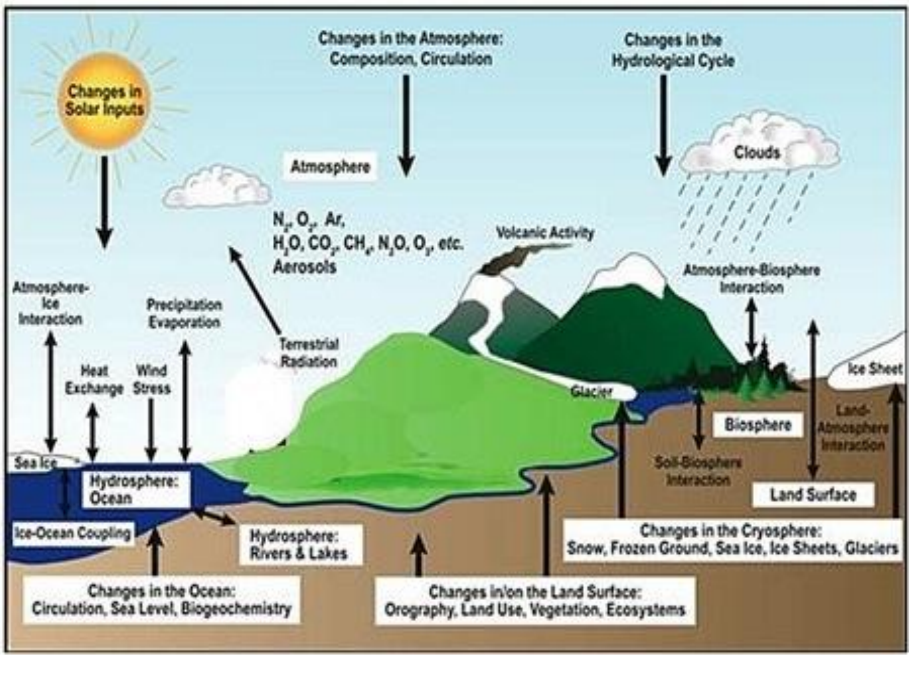

Figure 2.1 illustration of the climate

The distinction between weather and climate is an important one. For example, weather forecasts can be fairly specific ("it will be rainy tomorrow morning and cold in the afternoon, with temperature dipping close to freezing") but are little use more than a few days into the future. By contrast, climate predictions focus on expected changes in average conditions, while recognizing that individual days, weeks, months or years will always buck the longer-term trend. (2.)

The sun also drives our climate. Sunlight provides energy which heats the earth. Without the Earth's atmosphere and certain gases, the climate would be very different to what it is now. Our atmosphere stops the heat from escaping into space. If it did not do this, planet would be a very cold place indeed. Certain gases allow the suns energy through but stop it from escaping back into space, acting like a greenhouse. That is why it is called the greenhouse effect. The gases responsible for this effect, such as water vapour, carbon dioxide and methane, are called Greenhouse Gases. Scientists explained the heat-trapping effects of greenhouse gases more than 150 years ago. They discovered that, without the greenhouse effect, the Earth would be 30 ^{0}C cooler, making it uninhabitable to most forms of life. Greenhouse gases are so effective at keeping the earth warm that any changes will affect the Earth's temperature.(2.)

2.2 Climate change

According to the International Panel of Climate Change (IPCC), they describe climate change as any change in climate over time, whether as a result of human activity or because of the natural variability (3.). Greenhouse gases, such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) in the atmosphere have increased substantially through human actions. Greenhouse gases reduce heat radiation from getting back to space and hereby, causing climate warming. Before industrialization, prior to 1750, The concentration of carbon dioxide remained almost constant for thousands of years, according to the values determined from ice cores spanning.Carbon dioxide is the most important greenhouse gas produced by mankind. The global atmospheric concentration of carbon dioxide has increased from the value of about 280 ppm before industrialization to 397 ppm in year 2005 and the CO_2 concentration is increasing annually 1, 9 ppm (3.).

The changes of greenhouse gases in the atmosphere affect the balance of the climate system. The measure of radiative forcing can be expressed by the influence that a factor has in altering the balance of energy in the Earth-atmosphere or how much energy is incoming or outgoing from it. Since we emerged from the last ice age around 11.000 years ago , the Earth's climate has remained relatively stable, with global temperature averaging at about 14 ^{0}C. This has allowed complex ecosystems to thrive and support a wide range of life on Earth. (3.)

However, in the last century our climate has started to change rapidly. This isn't thought to be just a temporary blip in the system; the evidence points to a long term change in our climate which is happening at an unusual rate. But how can we tell if these changes are natural or wether they are down to us?

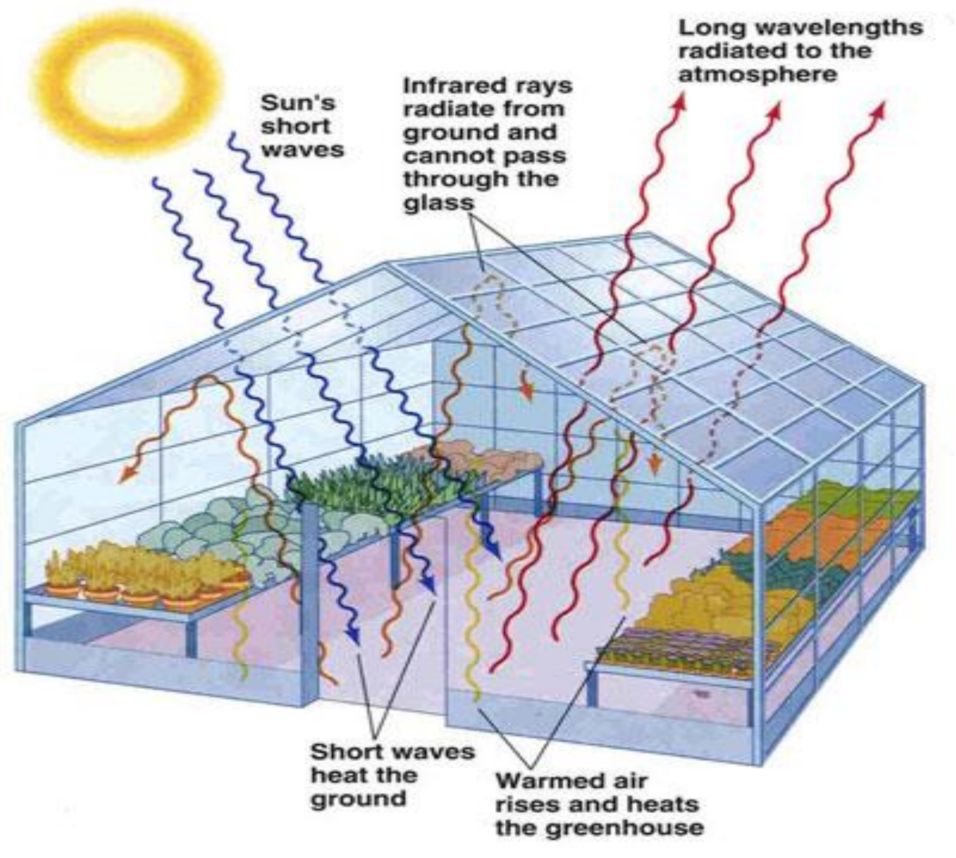

Figure 2.2 the greenhouse effect (2.)

There are many factors that can cause a warming of our climate; for example, more energy from the sun, large natural events such as El Nino or an increased greenhouse effect. Scientists have ruled out the sun and natural variation in our climate as the major causes of the recent warming. There is overwhelming evidence that most of this warming we have seen is due to increased amounts of greenhouse gases, such as water vapour, carbon dioxide and methane that occur naturally in the atmosphere. But human activities have directly increased the amount of carbon dioxide, methane and some other greenhouse gases. That mean if we do not change our behavior, greenhouse gases will heat up our planet by between 1.4 – 5.8 ^{0}C over the next 100 years. This is what panel of top international experts predicts. (1.)

2.3 How do we know that the climate is changing?

My question to the expert professor Julia Sling in Paris University was how we know that climate is changing. She said: although several aspects of climate are changing, temperatures provide the clearest evidence. For many decades, temperature near the surface has been carefully measured at thousands of locations on land at sea. There are a large number of measurements of temperature close to the Earth's surface which are global in extent, from which we can form a global average back to 1860. These all show temperatures higher in the past few years than at any time during the instrumental period, even allowing for measurement uncertainties and gaps in the data. Global average land and sea temperatures, shows considerable variability from year to year, but a clear underlying trend which shows rising temperatures until about 1940, a slight downward trend from about 1940-1975, and a rise of about 0.5 ^{0}C between 1975 and the present day.

Three independent types of temperature measurement -air temperature taken at land climate stations and on ships at night and the temperature of the sea surface- all show good agreement from 1900 until the last couple of decades, when land temperatures have been rising at a faster rate than sea temperature. Temperatures have also been measured in the atmosphere; over the last 50 years or so by weather balloons, and satellite remote sensing since 1979. In the mid-troposphere, about 5 km above the surface there has been a global- mean warming. Although data are sparse in tropical regions, according to sensors on weather balloons, there seems to have been a little change in temperature in the tropical mid- troposphere over the past 235 years, which is not what models predict. This discrepancy and its implications are the subject of ongoing research.

2.4 How has climate changed in Finland and Morocco?

Our weather is always changing and now scientists are discovering that our climate does not stay the same either. Climate, the average weather over a period of many years, differs in regions in Finland and Morocco that receive different amounts of sunlight and have different geographic factors, such as proximity to oceans and altitude. The earth has warmed, on average, by about 0.7 ^{0}C since 1910 with nine of the ten warmest years on record occurring in the past decade. There has been an increase in heatwaves, fewer frosts, and a warming of the lower atmosphere and Upper Ocean. (3.)

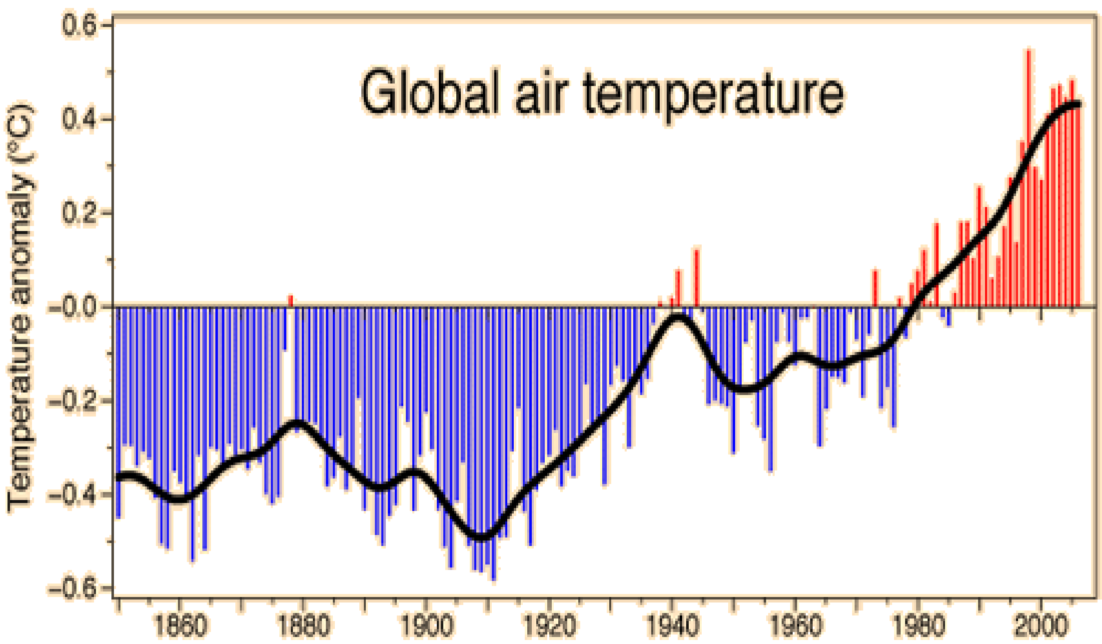

Figure 2.3 Global average temperature (2.)

In Finland temperatures have increased by almost 0.7^0C over the last hundred years, which is slightly more than the global average. Autumns are perhaps longer, winters shorter, warmer and wetter, summers hotter and drier. This winter has been very mild, grey and wet. We usually have cold and bright winter days and a lot of snow, sleet and even rain and the weather conditions have changed a lot. If winters are warm, we do not get enough snow for winter sports.(3.)

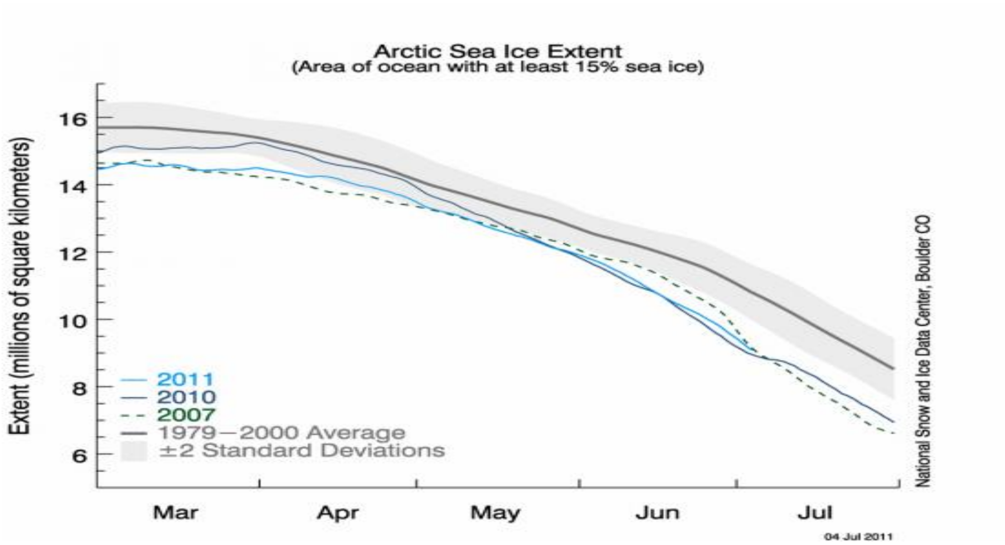

Figure 2.4 Global warming in terms of loss of snow coverand sea level (3)

According to the interview with Dr. Paula Pennanen about how climate has changed in Finland come out several facts: In summer we have had more heavy rains and thunderstor storms than before. Storms and strong winds have caused a lot of damage to forests and buildings when they make trees fall down and tear roofs loose. Storms have also caused problems with electricity. There are big changes in rainfalls. The summer 2002 was very hot and dry and the ground water level was very low. People who have wells of their own had big problems with getting water for their housholds. The summer 2003 was quite dry too and the level of ground water was still quite low. Luckily the situation is a bit better now and the level of ground water has risen. In forests trees grow faster.It is an advantage, of course. we get more timber for industry. Aproblem is what will happen to some species of trees their resting stage is too short? There will be more forests of deciduous trees and we can find coniferous trees in the north, for instance the spruce. On natural fauna (animals) we can see more southern species of birds and butterflies here.

3 THE CLIMATE FORCINGS IN FINLAND AND MOROCCO

Any changes to the Earth's climate system that affect how much energy enters or leaves the system alters Earth's radiative equilibrium and can force temperatures to rise or fall. These destabilizing influences are called climate forcing. Natural climate forcings include change in the Earth's orbit, large volcanic eruptions that inject light-reflecting particles as high as stratosphere and energy from the sun. Manmade forcings include particle pollution (aerosols), which absorb and reflect incoming sunlight; deforestation, which changes how the surface reflects and absorbs sunlight and the rising concentration of atmospheric carbon dioxide and other greenhouse gases, which decrease heat radiated to space. The main greenhouse gases are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). There is also so called indirect greenhouse which in atmosphere forms actual greenhouse gases. Those so called indirect greenhouse gases include hydrocarbons (HC), nitrogen oxides (NO_x) and carbon monoxide (CO).

3.1 Natural Forcing

Earth's climate has always been affected by a range of natural factors and is known to have changed significantly during recorded history, before gaseous emissions from human activity could have posed any significant threat to atmospheric or climatic conditions.

3.1.1 Changes in earth's orbit

The Orbital forcing is the effect on climate of slow changes in the tilt of the Earth's axis and shape of the orbit. These orbital changes change the total amount of sunlight reaching the Earth by up to 25% at mid-latitudes. It is well known that global temperature changes substantially over timescale of a hundred thousand years, as climate moves from ice ages to interglacial. The figure 3.1 shows measurements deduced from ice cores drilled from the Greenland ice sheet and analyzed by the British Antarctic survey and others as part of the European programme EPICA. The actual measurement is of the concentration of deuterium in air bubbles, and this can be related to local temperature rise of 9 ^{0}C between the depth of the last ice age 20,000 years ago and the current interglacial (Holocene). Swings between glacial and interglacial climate are likely to be initiated by subtle differences in the Earth's orbit and tilt of axis around the sun. (4.)

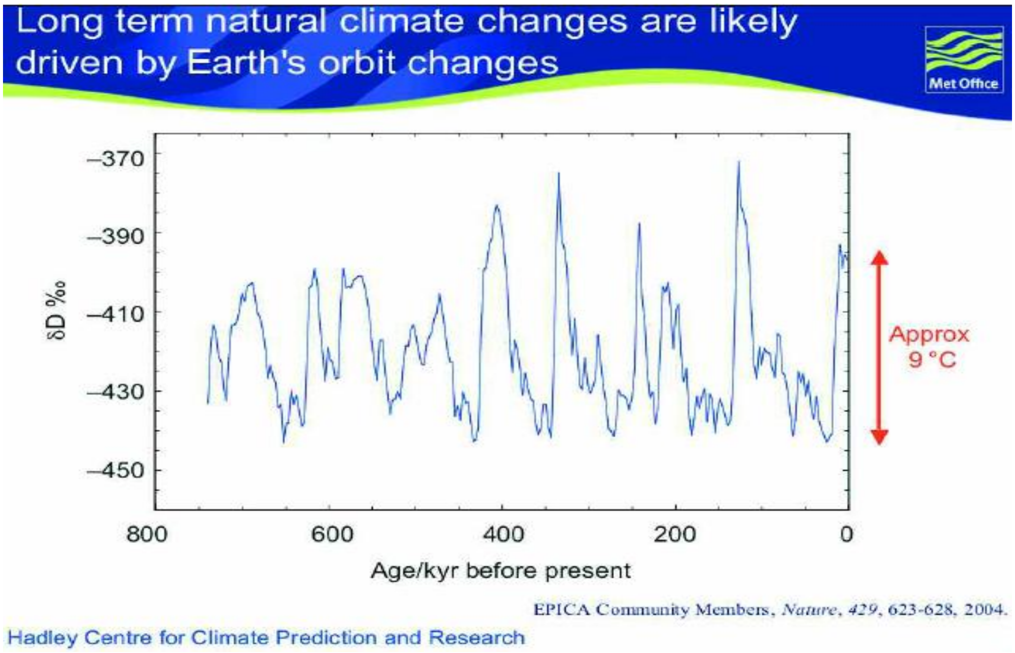

Figure 3.1 The long-term natural climate changes by Earth's orbit changes (4.)

Although these orbital changes dictate that the Earth will enter another ice age, this is unlikely to be for many thousands of years-quite a different timescale to that of man-made warming which may actually prevent the Earth from entering another ice age. (4.)

3.1.2 Energy from the Sun

In addition to long–term changes due to the Earth's orbit there are two main natural agents which can change global climate: changes in energy we receive from the Sun and the effect of volcanoes. The amount of energy received at the Earth from the Sun is shown here. There are several estimates of this quantity; the one shown here is due to lean, annual solar cycle is clearly seen, and so too is a rise between about 1900 and 1960, with little if any change after that. Solar irradiance before 1978 is estimated from proxy data and is less reliable than that measured since then by satellites. Based on the Hadley centre HadCM3 climate model, we can estimate the global temperature increase which the changing solar radiation may have caused; this is shown on the right-hand scale and amounts to one or two tenths of a degree so this may explain at least some of the global temperature rise observed in the early part of the 20th century. (4.)

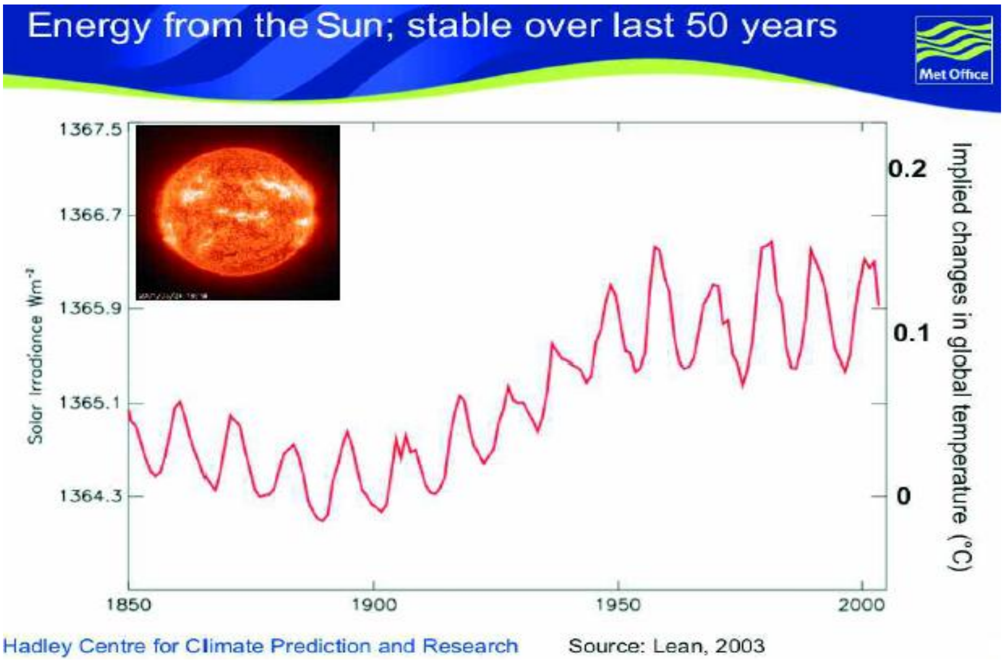

Figure 3.2 Energy from sun (4)

However, current climate models do include change in solar output, and attribution analyses that seek to understand the causes of past climate change by comparing model simulations with observed changes, do not find evidence for large solar influence. Instead, these analyses show that recent global warming has been dominated by greenhouse gas-induced warming, even when such analyses take into account a possible underestimate of the climatic response to solar changes by models.

3.1.3 Change in volcanic aerosol

When pressure in volcanoes from the molten rock beneath the earth's surface becomes too great, the rocks, usually accompanied by lava or gases, escape through a fissure or vent in the crust of the earth. "Volcano" is the term given to both the vent and the conical mountain left by the overflow of the erupted lava, rock and ash. Volcanoes inject gas into the atmosphere. If they are energetic enough, this gas will reach atmosphere and form small sulphate aerosol particles which can persist for a few years. They reflect back some of the solar radiation which otherwise would have heated the surface of the Earth, and hence act to cool the planet. The amount of volcanic aerosol in the atmosphere is very variable. Although energetic volcanoes were relatively common in the late 19th century and early 20th century, and there have been substantial numbers of energetic volcanoes since the 1960s, there was a period in the 1940s and 1950s when the atmosphere was relatively clear of volcanic aerosol. The amount of climate cooling due to volcanic aerosols would have been quite small in that period. This unusually low amount of volcanic cooling may have contributed to temperatures in the 1940s being relatively high compared to earlier decades. As with solar energy, optical depth due to volcanic aerosols has been estimated indirectly. As with solar energy, optical depth due to volcanic aerosols has been estimated indirectly before about 1983, and hence is less certain. (4.)

3.2 Man-made forcings

3.2.1 Emissions: Carbon Dioxide, CO_2

Carbon dioxide is considered as the most harmful of greenhouse gases. Its concentration in the atmosphere is the highest, and at the moment it is responsible for over a half of the enhanced greenhouse effect. Currently the annual emissions of CO_2 are over 23 billion tons, and the CO_2 concentration in the troposphere is higher than it has been in 420 000 years (5.) As shown in figure 3.3 the carbon dioxide is increasing from 1955 to 2005.

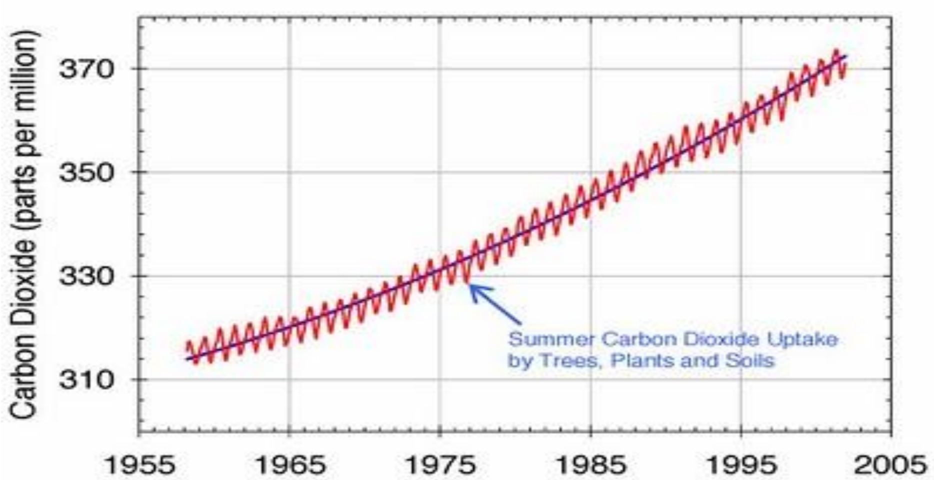

Figure 3.3 CO_2 in the atmosphere between 1955 and 2005 (5)

Carbon dioxide (CO_2) enters the atmosphere through the burning of fossil fuels (oil, natural gas, and coal), solid waste, trees and wood products, and also as a result of other chemical reactions. The concentration of CO_2 in the air is increasing rapidly of fossil fuels. Before 1960, the level of carbon dioxide was about 315 ppm (parts per million). Concentrations of carbon dioxide in the atmosphere are about 390 ppm (Figure 3.3).This increase in carbon dioxide in the atmosphere is mainly due to activities associated with the Industrial Revolution. Emissions from the combustion of fossil fuels 65% derived from deforestation and the conversion of prairie, woodland, and forested ecosystems primarily. (5.)

Climate change is caused by the emission of greenhouse gases. 63% of the totally emitted greenhouse gases is carbon dioxide (CO_2), 24% methane and 10% nitrous oxide (NO_x).Carbon dioxide emissions therefore are the most important cause of global warming. CO_2 is inevitably created by burning fuels like e.g. oil, natural gas, diesel, organic-diesel, petrol, organic-petrol, ethanol. The emissions of CO_2 have been dramatically increased within the last 50 years and are still increasing by almost 3 % per year, see graph 3.5 below:

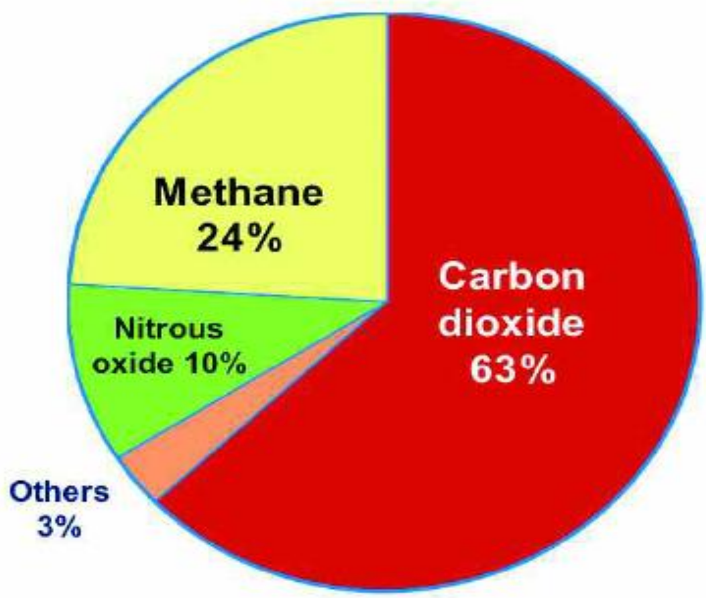

Figure 3.4 Global warming (5)

3.2.2 Emissions: Methane, CH_4

Many scientists consider methane released into the atmosphere to be one of the so called greenhouse gases that is leading to global warming. In fact, methane is considered to be the second most harmful greenhouse gas produced by human activity (after CO_2).Estimated to be responsible for one-fifth of all global –warming effects. Methane is released into the air from landfill sites, the combustion of fossil fuel and agriculture, particularly livestock and rice farming. According to Britain "Sunday Times" published in 2009 the negative effects of methane on global warming are far higher than earlier estimations. This is largely due to the unanticipated effects of methane interaction with airborne aerosols. (5.)

3.2.3 Emissions: Nitrogen Oxides, NO_x

Nitrogen oxides react with water vapor in the atmosphere to form nitric acid, a contributory element of acid rain .Nitrogen oxides lead to increase ozone levels in the lower atmosphere and contribute to the occurrences of smog in big city environments. The forest industry's contribution to total national NO_x emissions (in Finland) is less than five per cent. Nitrogen oxides react with hydroxyl radicals or with UV-radiation forming ozone in the lower part of the atmosphere which is poison and greenhouse gas. They also form aerosols which increase formation of the clouds. Probably the overall effect of the formation of the clouds is cooling. Nitrogen oxides can also react in the atmosphere to form nitric acid which can cause acidification in the lakes and in the forests. (6.)

3.2.4 Steam

Water has two important properties that influence the earth's radiation budget. Water vapour is one of the most important greenhouse gases (water vapour makes up for 60% of the Greenhouse gases). In addition, clouds (water droplets and ice crystals) are reflective, and increase the whiteness of the atmosphere, resulting in reflection of incoming solar radiation. Atmospheric water vapour presence increases substantially with rising temperatures due to evaporation. This produces a positive feedback as increasing greenhouse gases further add to the global temperature. However, this feedback is counteracted by the increased reflection by clouds. Most theories claim that the combination of both reflection and heat trapping leads to a net cooling effect. Through condensation and evaporation, water vapour is added or subtracted from the atmosphere. These processes account for most of the energy transfer between the atmosphere and land, and are called latent heat fluxes. These processes account for most of the energy transfer between the atmosphere and land, and are called latent heat fluxes. These fluxes do not directly influence temperature but are very important in driving the water cycle. (6.)

3.3 Natural and man-made carbon cycle

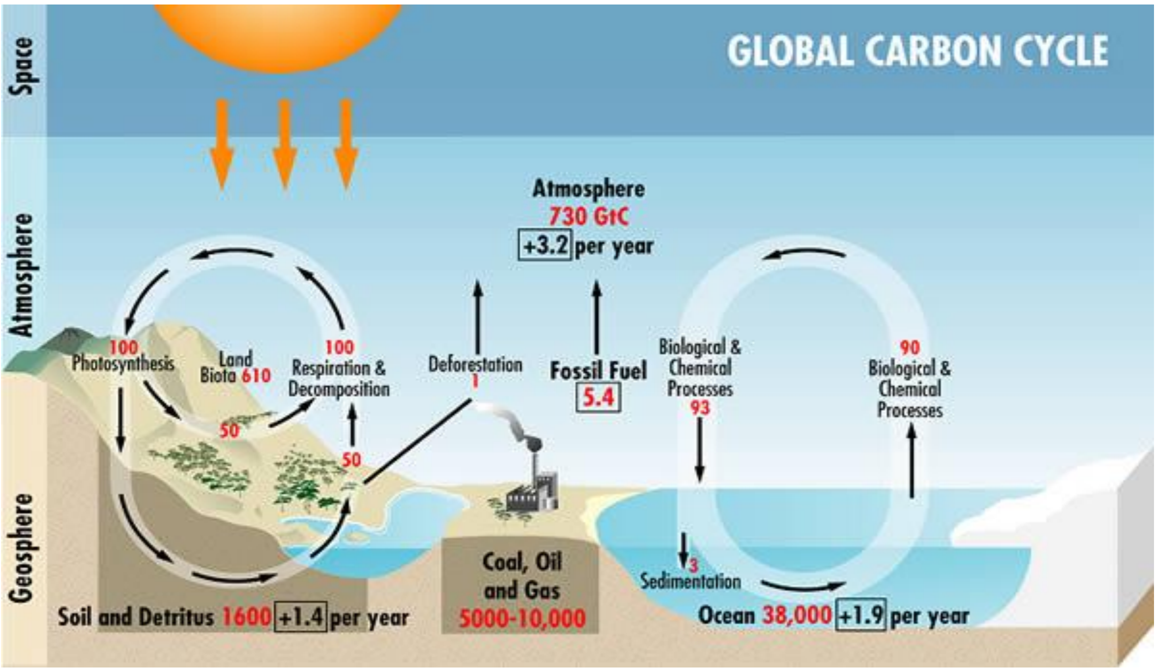

Figure 3.5 Natural and man-made carbon cycle (7)

The figure 3.5 shows that the carbon cycle is the process through which carbon is cycled through the air, ground, plants, animals, and fossil fuels. Large amounts of carbon exist in the atmosphere as carbon dioxide (CO_2). Carbon dioxide is cycled by green plants during the process known as photosynthesis to make organic molecules (glucose, which is food). This is where the nourishment of every heterotrophic organism comes from. Animals do the opposite of plants-they release carbon dioxide back into the air as a waste product from respiration to make food, but the majority of the carbon in the air comes from heterotrophic respiration (photosynthesis). Decomposers, when they break down dead organic matter, release carbon dioxide into the air also. Decomposers are essential because without them, all of the carbon on the planet would eventually get back into the food web. Carbon is also stored in fossil fuels, such as coal, petroleum, and natural gas. When these are burned, carbon dioxide is also released back into the air. Volcanoes and fires also release large amounts of CO_2 into the atmosphere. Carbon dioxide can dissolve in water, where some of it is later returned back into the atmosphere. The rest can be taken to form calcium carbonate, which builds up shells, rocks. (7.)

3.4 Drivers of CO_2 emissions: population and energy use

The main factors which have caused the rise in CO_2 emissions shown in the previous slide are twofold: (a) growth in population (shown in the left –hand panel) and (b) growth in energy-intensive standard of living, with increased ownership of goods, more services and greater travel. Of course, energy use per person is very different between Finland and Morocco.

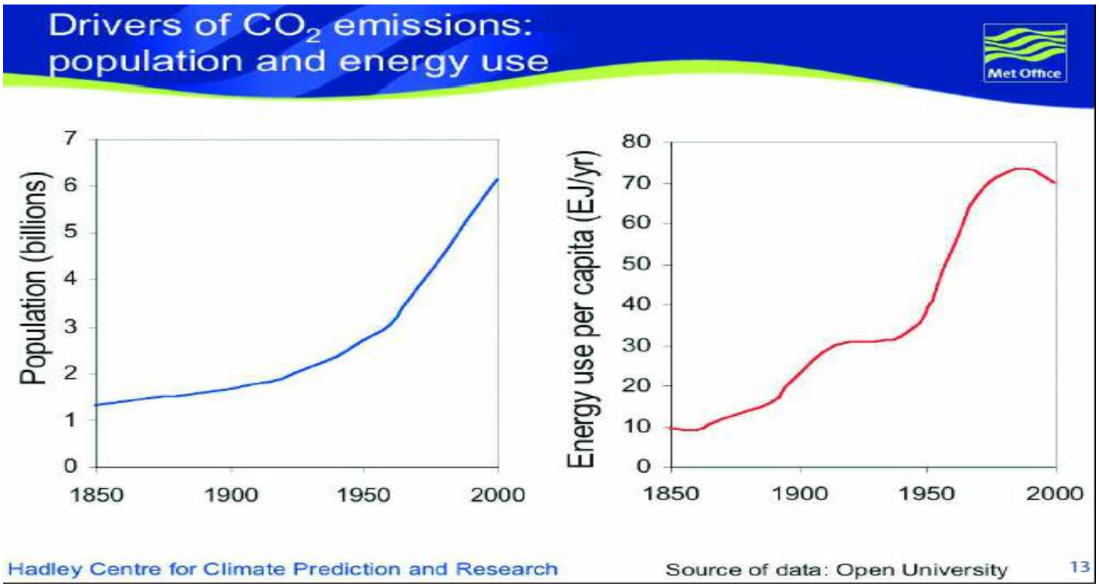

Figure 3.6 Drivers of CO_2 emissions: population and energy usage (4)

Direct carbon dioxide emissions. When we consume energy derived from fossil fuels, the generation of the energy (whether using gasoline in cars, heating our houses with natural gas, or lighting our houses with electricity) produces greenhouse gases. In 2000, the average household produced 12.4 tons of carbon dioxide from its household operations and approximately 11.7 tons from its automotive uses. Indirect carbon dioxide emissions: All remaining energy consumed in the economy, that is not directly due to the consumer, as above, results in indirect greenhouse gas emissions. When we buy a new product, that product has substantial embodied energy in it from its manufacture, packaging and delivery. Also when we visit an air-conditioned store, stay in a hotel on vacation, or work in a heated office building, these and other activities produce indirect carbon dioxide emissions. (4.)

3.5 Man –made greenhouse gases dominate the change in climate forcing

First three forms of natural forcing are discussed: a) orbital variations causing changes in amount and distribution of sunlight; large, but act on very long timescales b) variation in brightness of sun c) volcanic aerosols. And then manmade or anthropogenic forcing involves carbon dioxide, and other greenhouse gases. The figure shows that all man-made greenhouse gases dominate the change in climate: (LOSU= Level of Scientific understanding)

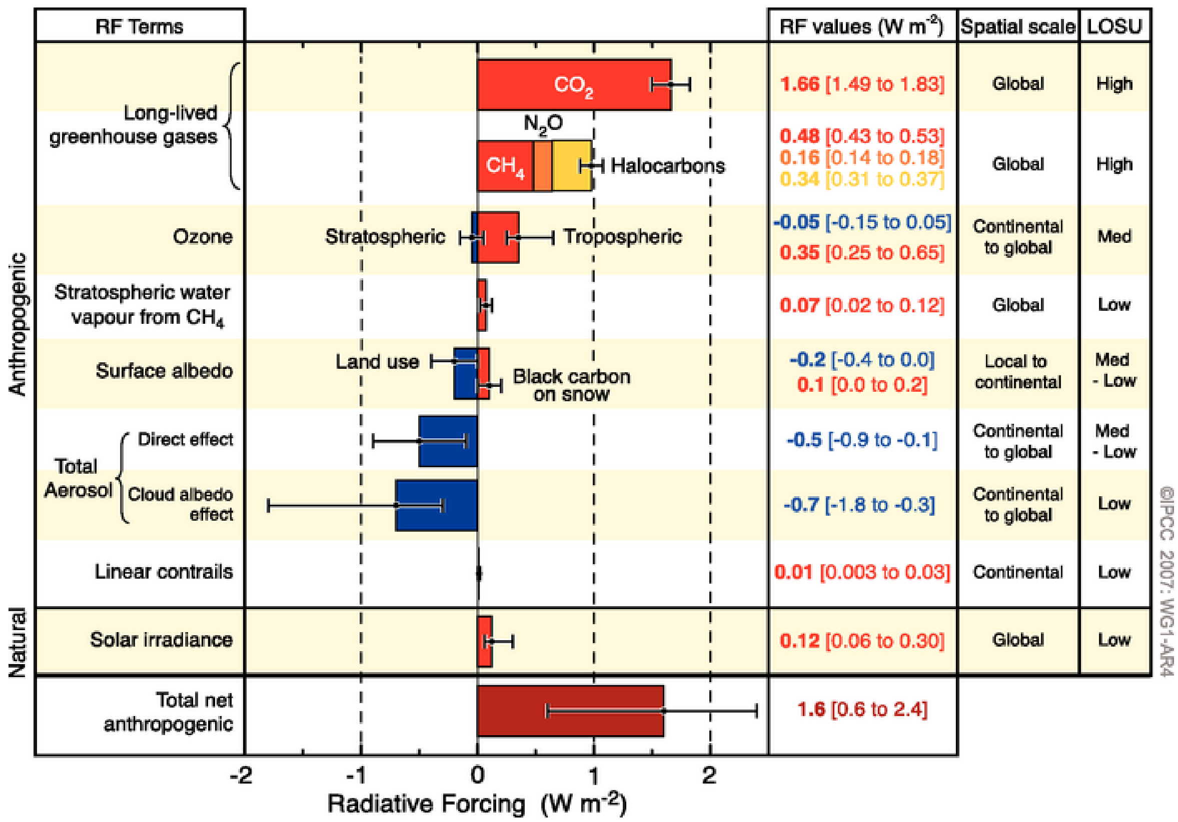

Figure 3.7 Radiative forcing components (4)

This figure , taken from IPCC TAR , shows the change in radiative forcing over the period 1750 to 2000, due to a number of forcing agents, each of which is linked to human activity (except for solar radiation). In some cases (for example, tropospheric ozone) a best estimate is shown, together with a vertical error bar showing the range of estimates. In other cases, such as mineral dust, only a range of uncertainty can be given. The level of scientific understanding of each of the factors is shown along the bottom of the diagram. Man-made changes in greenhouse gas concentrations represent the biggest and best-understood effect on climate over the period, as shown on the far left of the diagram, and carbon dioxide is the biggest contributor to this. (4.)

3.6 CO_2 emissions in Finland

Excessive carbon dioxide in the atmosphere accelerates the greenhouse effect. Carbon dioxide originating from renewable sources of energy (e.g. wood) does not increase the overall level of carbon dioxide in the atmosphere. This is because the carbon dioxide released is ultimately reincorporated into wood through forest re-growth. As can be seen from graph 3.8, the CO_2 emissions in Finland have been rising in the recent years. In the year 2008 the CO_2 emissions were 73 million tones. The increase in the CO_2 emissions was because the low production of hydropower in that year was compensated by energy produced in coal and peat power plants. (8.)

Figure 3.8 Emissions: carbon dioxides in Finland 1990-2006 (8)

Finland's target in reducing the CO_2 emissions is the 1990s level, 54 million tonnes. Although the energy production has become less CO_2 intensive since 1990, because the increased use of renewable energy and the increased capacity of nuclear power, Finland still has a lot to do to achieve the targets set up in the Kyoto protocol.

3.7 Comparing the CO_2 emissions of Finland with other countries

The carbon dioxide emissions produced by the human activities are not equally divided between countries. As can be seen from graph 3.9, in the year 2000 the United States was emitting the largest amounts of CO_2 when measured per country, having a huge share of 23.1% of the world´s CO_2 emissions. The second biggest emitter was China with a share of 11.5% mainly because of its huge economic growth in the recent years. The following five were Russia, Japan, India, Germany, and Great Britain. Finland is included in the others column having only 0.21% share of the carbon dioxide emissions per country. (9.)

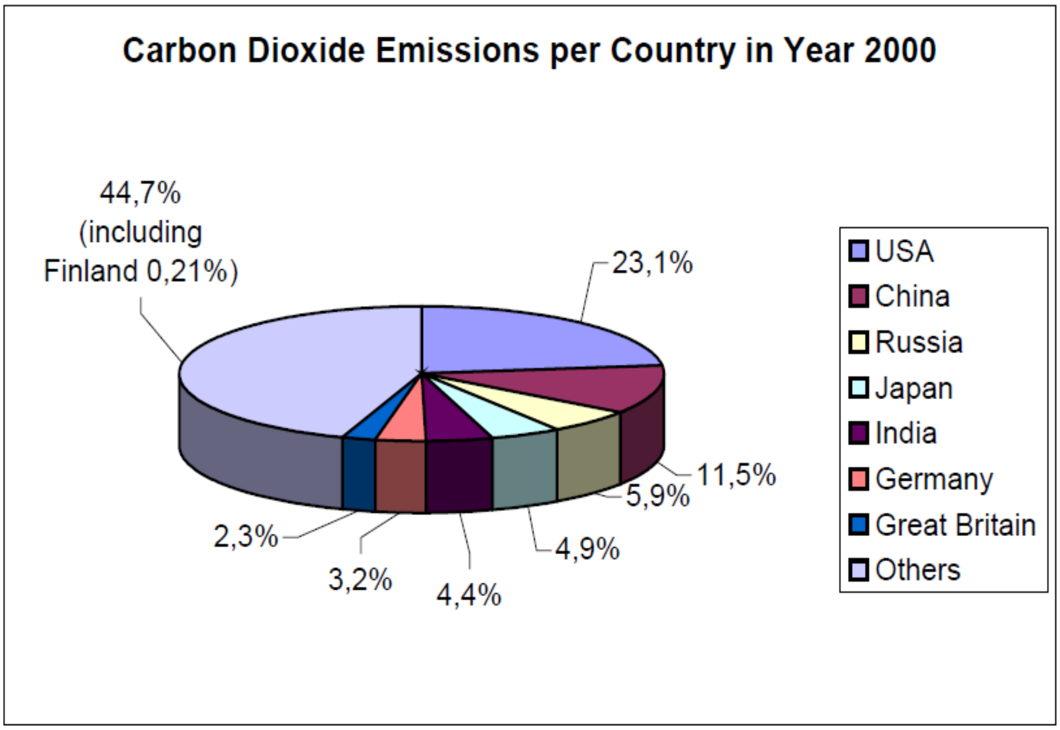

Figure 3.9 carbon dioxide emissions per century in 2000 (9)

3.8 CO_2 emissions in Morocco

According to the graph 3.10, the CO_2 emissions in Morocco have been rising rapidly in the recent years. In 1980 the carbon dioxide was 1,000 million tonnes and 8.000 million tonnes in 2009 (about one tenth of Finland). The increase in the CO_2 was mainly because the low production hydropower in that year was compensated by energy produced in coal and power plants. And also there are many too many cars in Morocco and most of them are the old Soviet cars. The great numbers of these cars use diesel and bad quality petrol.

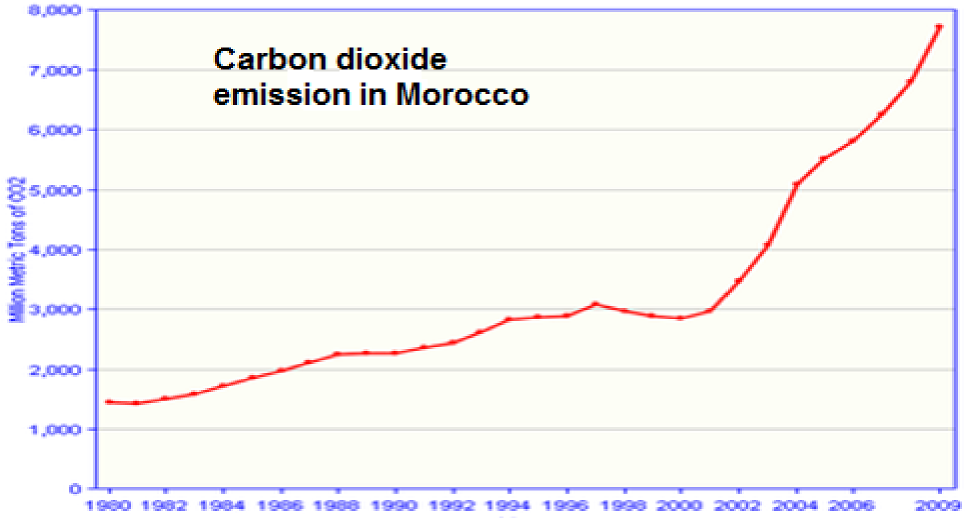

Figure 3.10 Carbon dioxide emissions from consumption in Morocco (10)

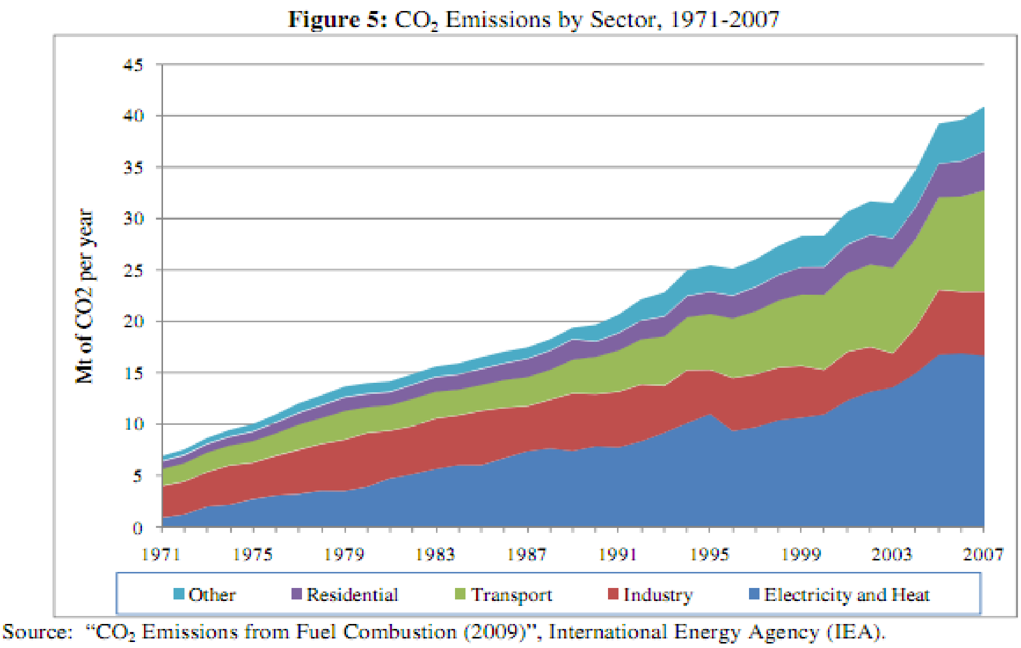

Figure 3.11 CO_2 emissions by sectors in Morocco from1971-2007 (10)

3.9 Comparing the CO_2 emissions of Morocco with other African countries

The graph shows CO_2 emissions from consumption of fossil fuels and land use change and forestry in top fifteen African countries between 2000 and 2005. As can be seen in the graph, South Africa was the highest emitter in Africa with an average of 110.1 Tg cy^{-1} for the period 2000-2005 followed by Egypt (38,2 Tg Cy^{-1}, Algeria (22,4 Tg Cy^{-1}) and Libya (12,2 Tg Cy^{-1}) and Morocco (9.2 Tg Cy^{-1}). Morocco compared with other African countries, because Morocco increased use of renewable energy and the increased capacity of nuclear power and trams are often used in morocco city nowadays. But still Morocco is actually doing quite badly compared to modern countries.

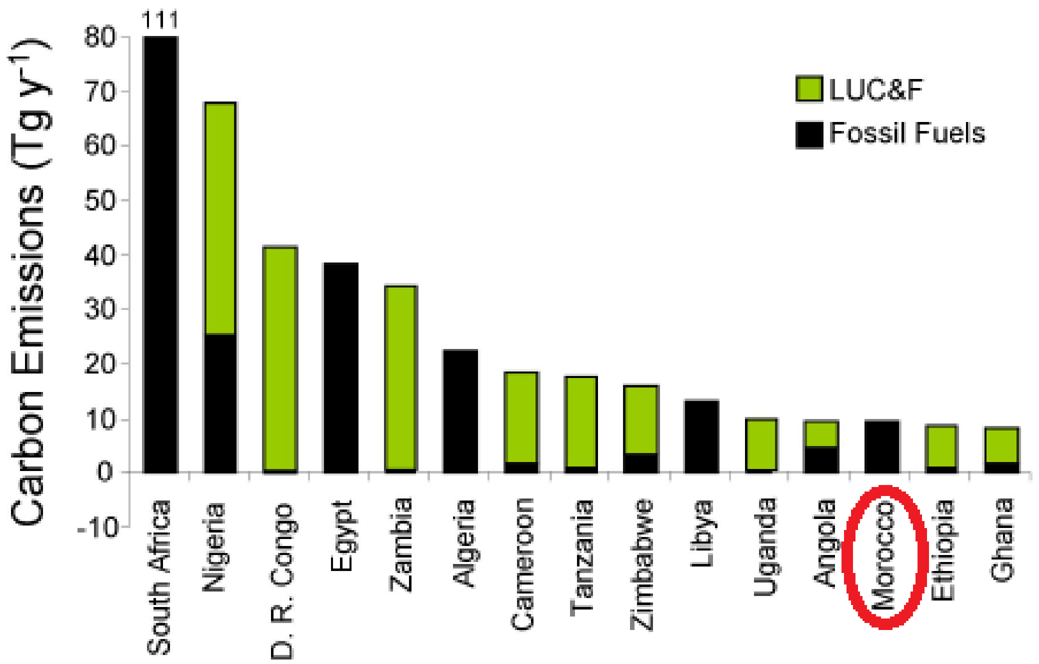

Figure 3.12 Annual emissions of carbon (Tg Cy^{-1}) (10)

4. EMISSIONS FROM FORESTS AND ENVIRONMENTAL ISSUE

4.1 Finnish forest industries background

As shown in figure 4.1 Finland owns the greatest forest coverage in Europe.

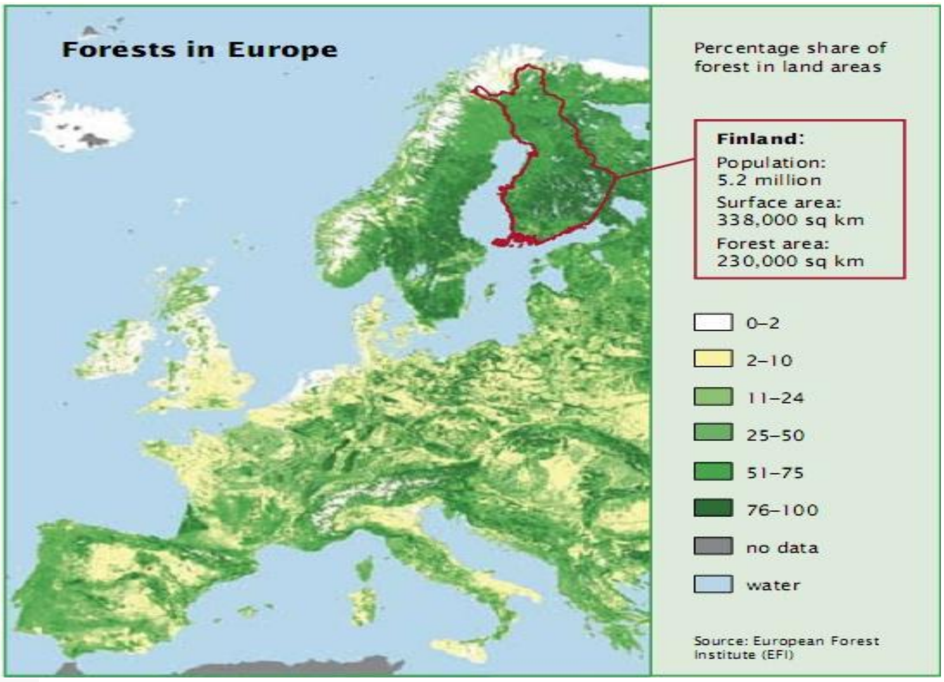

Figure 4.1 Forest coverage rate in Europe (8)

Finland is Europe's most heavily forested country, with over ¾ of the land area representing 23 million hectares, under forest cover. There is an additional 3 million hectares of sparsely wooded forest areas and treeless open mires and rocky forest land. Altogether land accounts for 80% of the land area. Nearly all of Finland belongs to the boreal coniferous forest zone, which is characterized by a short growing season and a limited number of tree species. Due to the Gulf Stream, however, conditions in Finland are more favorable than in other places on the same latitude. (8.)

Industrial use of forest as sawn goods and paper began in Finland in the late 19th century. A century ago, forest industry products made up 80% of Finnish exports. Today forestry and the forest industry make up about 5, 1% of Finland's gross domestic product, and approximately 18% of Finnish exports. High-quality printing and writing paper make up over 40% of the total export value of forest industry products, while sawn goods and wood-based panels account for some 20% of export value. Finland is among the major supplier of forest related products to the world markets, particularly in printing and writing paper. It is also one of the biggest importers of round wood. The European Union is the most important customer region for Finnish forest-industries products. Some 60% of Finnish exports go to EU countries, mainly to Germany, Great Britain, France and Spain. Other European countries account for 10% of forest industry exports, and the rest of the world 30%. (8.)

4.2 Moroccan forest industry's

Factory Cellulose du Maroc pulp and paper mill

Cellulose du Maroc is a company that produces pulp from Eucalyptus wood. The factory Cellulose du Maroc located 4 km from the capital Rabat, Cellulose plant in Morocco was founded in 1952 with an initial capacity of 12 000 tones. With over 250 employees, Cellulose du Maroc has reached a production record of 158 000 tons in 2010. Cellulose du Maroc remains the only pulp production company in North Africa for more than 50 years, with Government as major shareholder (62%).The Arab Investment company has 27, 32% of the capital. In 2010, Cellulose du Maroc turnover went beyond 1 billion euro where 85% was achieved from exports, with a record production of 158 000 tons. The main customers are western European and Mediterranean countries. Cellulose du Maroc is positioned as high quality pulp producer for tissue and printing paper. Cellulose du Maroc have witnessed several expansion and modernization phases:

- ✓ Founded in 1952 with a production capacity of 12 000 tones,
- ✓ 1976: Production capacity extended from 60 000 T to 100 000 T
- ✓ 1995: Production capacity reached 125 000 T
- ✓ 1995: Creation of Eucaforest Company to insure local wood supply
- ✓ 2007: Production reaches 145 500 T
- ✓ 2010: Production reaches a new record of 158 000 tons

Because of the high quality of its products, which meet international standards, La Cellulose du Maroc has earned its customers trust. During last decades, Cellulose du Maroc has developed and enhanced its know-how in order to offer its customers reputable pulp, known for its whiteness, softness and cleanliness. In order to meet its customer’s requirement, Cellulose du Maroc produces two pulp grades:

- ECF (element chemical free) Free Eucalyptus Kraft bleached Strong pulp-Certified FSC mixed: Made on the basis wood in order to obtain high mechanical characteristics (FSC=forest stewardship council).
- ECF Free Eucalyptus Kraft bleached Strong pulp-Certified FSC mixed: Made on the basis wood in order to obtain high optical feature. (10.)

Figure 4.2 Factory Celuluse du Maroc of pulp and paper in Morocco (10.)

Second factory is international paper: Morocco “ CMCP”

For over 60 years, CMCP (Compagnie Marocaine des Cartons et des Papiers) has been known as a reliable supplier for paper-based packaging products and as a leader in its sector. Nowadays, CMCP operates 3 facilities in Morocco, located in Casablanca, Kenitra and Agadir, and employs about 1200 people. CMCP concentrates on two main business sectors: corrugated boxes and recycled paper and board for various packaging applications. Besides, the company manufactures paper-based corner protection, cores and tubes. (10.)

CMCP is the largest integrated supplier of corrugated boxes in Morocco and we use our own recycled paper to manufacture our products. For segments requiring virgin fiber paper, we can rely on International Paper, the world's largest Kraft liner supplier. This assures our customers of a reliable supply of quality products made of quality raw materials. Our products range is large and our capabilities allow us to provide our customers with various packaging solutions, created by team of enthusiastic professionals constantly working to exceed our customers' expectations. Our modern and efficient plants help us in the process. This has been recognized by many customers over the years as we supply corrugated boxes to all of the multinational brand leaders in Morocco in segments like food and beverage, automotive, electronics, ceramics, chemicals and textiles. We are a leader in the fresh Fruit & Vegetables packaging business and supply corrugated boxes and services to all types of players in the Fruits & Vegetables supply chain (producers, wholesalers and exporters operating both within the country and internationally. (10.)

In paper mill in Kenitra, one paper machine is dedicated of making recycled packaging board, both coated and uncoated the product range offers customers a wide choice of product constructions and grammages, available in both roll and sheet form. CMCP is ISO 9001 certified since 2000 which is another assurance for our customers that they receive the products they have specified. Environmental considerations are an integral part of the Casablanca mill activity. The mills forest management systems on leased forest land have been highly recognized in Morocco: in 2007, the mill CMCP in Casablanca mill was the first Morocco pulp and paper mill to achieve ISO 14001 certifications in the field of forestry management and harvesting practices. (10.)

4.3 Emissions to atmosphere from forest industry

The most significant air emission components of forest industry from a kraft pulp mill are shown in figure 4.3.

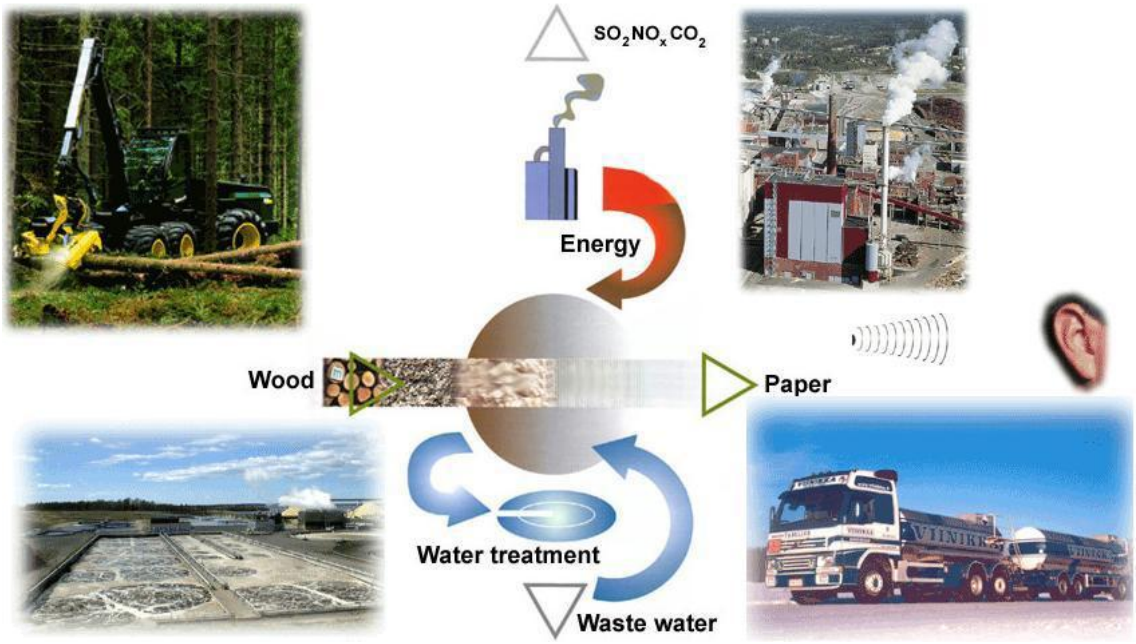

Figure 4.3 Emissions to the atmosphere from forest industry

Emissions to the atmosphere from a Kraft pulp mill originate from chip storage, cooking digester, pulp washing, bleaching chemical preparation, chemicals recovery, evaporation, bark furnace, recovery boiler, white liquor preparation, lime kiln, tanks and pulp drying (only for market pulp).They consist mainly of sulphur-containing compounds such as sulphur dioxide and malodorous reduced sulphur compounds like methyl mercapatan, dimethyl sulphide, and hydrogen sulphide. The latter compounds are commonly referred to as total reduced sulphur (TRS). From furnaces nitrogen oxides are also emitted and furthermore small amounts of dust (solid particles) as fly ash. From bleach plants and from bleaching chemical preparation chlorine compounds may leak to the atmosphere. Volatile organic compounds (VOCs) mainly turpenes and methane, are emitted to the atmosphere from wood chips stored in heaps outdoors the process. The VOC emission from chip piles vary among other things with the time chips are stored, temperature and the wood species, In the following the major sources of air emissions are discussed in more detail.

4.3.1 Air emissions from recovery boiler

The recovery boiler is a major source of atmospheric emissions in a Kraft pulp mill. Emissions are mainly represented by sulphur dioxide as shown in figure 4.4. In addition there are emissions of particles (primarily sodium sulphate and sodium carbonate), nitrogen oxides and malodorous compounds (hydrogen sulphide) after recovery boiler is fed with the evaporated black liquor, approximately one third of the dry substance in the evaporated liquor consists of inorganic chemicals and two thirds are dissolved organic substance. After a convention the black liquor (strong liquor) has a dry solids content of about 65%. The aim of evaporation is to achieve high dry solids (DS) content in the thick black liquor fed to the recovery boiler in order to generate more steam. By installing further equipment a dry solids content of 75-80+% can be achieved. The sulphur emissions from the boiler will typically be reduced by about 80% when DS content is increased from 65-67 to 74-76% due to higher temperature in the recovery boiler and the more favorable incineration conditions. Some examples exist however where emissions of S have not reduced beyond DS of 72-73%. A drawback to the higher temperature is that emission of NO_x can increase. The recovery boiler is equipped with an electrostatic precipitator in order to remove the larger amount of particulates (mainly Na_2SO_4) from the flue gases. Additionally, recovery boilers are often equipped with a scrubber in order to decrease the emission of SO_2. In recent years, pulp mills have caused serious emissions of sulphur (acidification) but during the last years especially the sulphur emissions have been reduced considerably by large progresses of process technology. (11.)

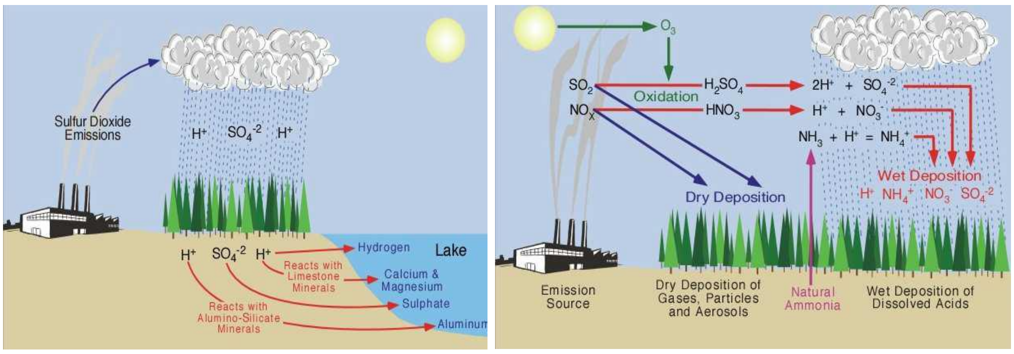

Figure 4.4 Emissions of sulphur (acidification) from pulp mill industry

As can be seen from figure 4.5, in the cooking process wood fibers are separated from each for further processing by dissolving the lignin between fibers. The dissolved lignin and other dissolved organic and inorganic matter from cooking chemicals (black liquor) are separated from the pulp during washing. The dry solids content of separated black liquor is increased by removing water from the black liquor in the evaporation process. Sodium and sulfur are recovered from the black liquor by burning the black liquor in recovery boiler. This chemical reaction and burning of organic materials releases a considerable amount of heat energy. The heat is recovered by transferring it through water-filled tubes in walls of the recovery boiler. The water vaporizes into steam and electricity is produced from steam with a turbine. In addition, some of the steam can be used in different stages of the process in heating the cooking process and soot blowing in the recovery boiler itself. (12.)

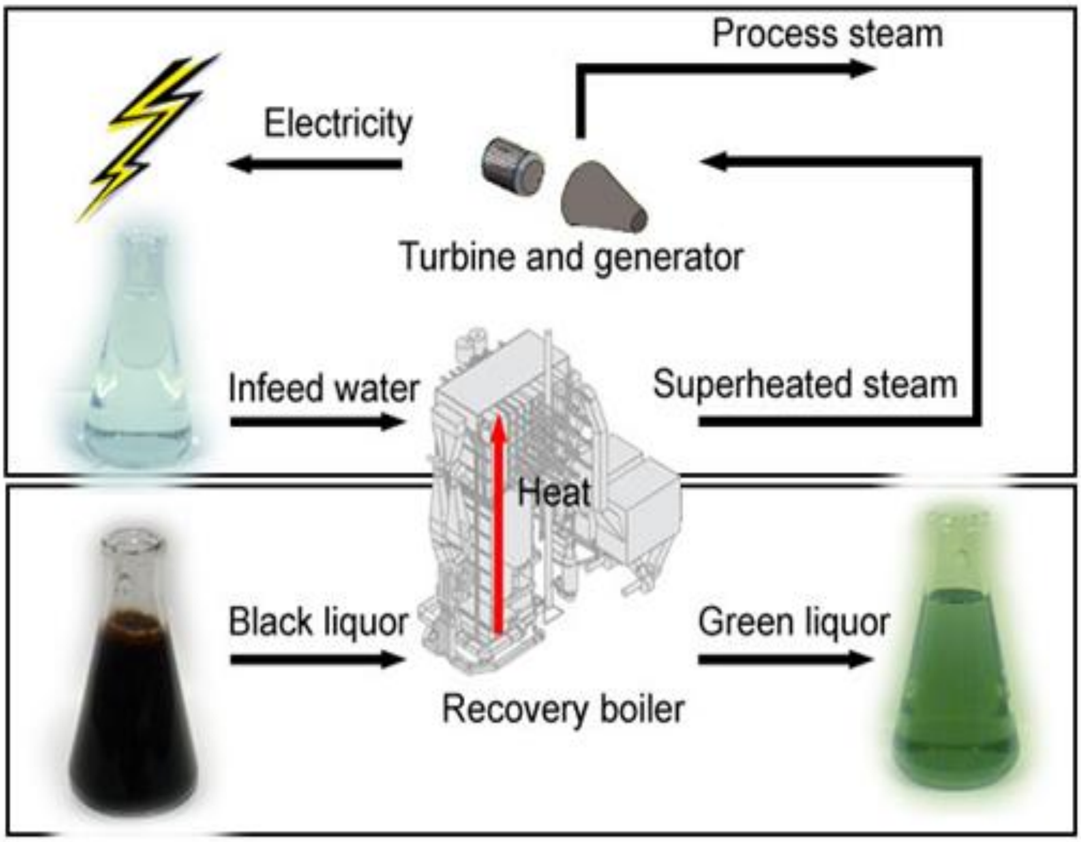

Figure 4.5 Generation of steam in recovery boiler

Figure 4.6 below shows some principal inorganic reactions in a recovery boiler and also where in the furnace the reactions take place. In a conventional recovery boiler there is an oxidizing zone in the upper part and a reducing zone in the lower part. The strong liquor is introduced through one or several nozzles into the reducing zone. Combustion air is mostly supplied at three different levels as primary, secondary and tertiary air (from the bottom up). (11.)

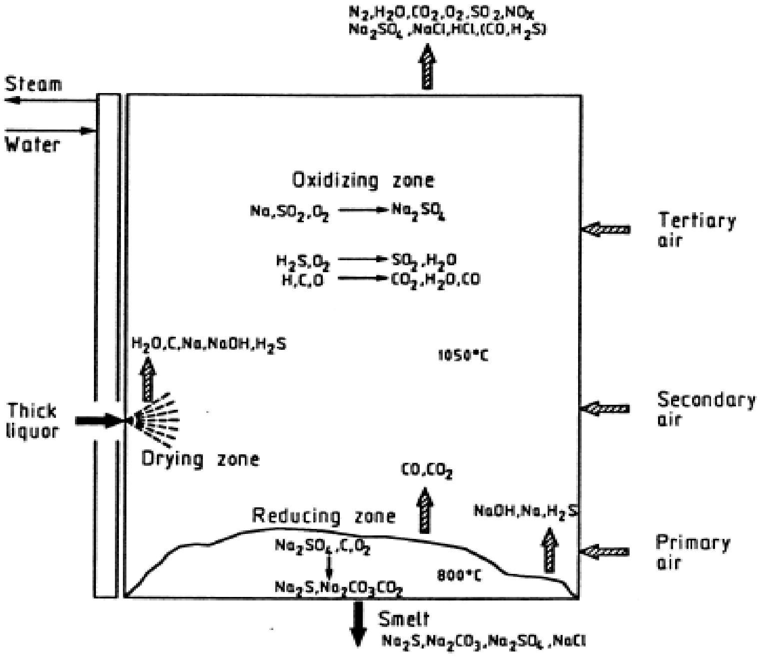

Figure 4.6 Principal inorganic reactions in a recovery boiler

A smelt consisting mainly of sodium sulphide (Na_2S) and sodium carbonate (Na_2CO_3) is formed at the bottom of the furnace. When the sulphur is reduced to sulphide in the smelt also some hydrogen sulphide is formed. Small amounts of hydrogen sulphide may leave with the flue gases if the air supply is not sufficient or if the mixing of air into the furnace is incomplete. Temporary high emissions of hydrogen sulphide from the smelt may occur as a consequence of disturbances caused by deposits of dry substances on the furnace walls falling into the smelt. In the oxidizing part of the furnace, the sulphur is oxidized to sulphur dioxide and sodium in the gas phase reacts with the sulphur dioxide to form sodium sulphate. Higher dry solids content leads to a high temperature in the furnace and thus a lower emission of hydrogen sulphide and a higher emission of sodium. The higher sodium emission means that more sulphur is bound as sodium sulphate and thus the emission of sulphur dioxide is decreased. (11.)

In general, the emission of sulphur from the recovery boiler is influenced by the following operation variables:

- Temperature in the different zones which on the other hand is influenced by the heating value and dry solids content of the strong black liquor and the amount of combustion air.
- The sulphur- to- sodium ratio (S/Na_2) in the liquor (sulphidity). A high S/Na_2 ratio means that the release of sodium in the furnace in relation to the sulphur amount is not sufficient to bind the sulphur and thus a larger share of the sulphur leaves the furnace as sulphur dioxide instead of sodium sulphate. High dry solid contents of the black liquor may compensate this effect.
- Distribution of the black liquor across the boiler area.
- Supply (amount of air excess and primary air temperature) and distribution of combustion air.
- The load on the furnace. Operating a recovery boiler in an overloaded mode has an adverse effect on the emissions characteristics, especially on the quantity of hydrogen sulphide produced.

4.3.2 Lime kiln emissions

To be able to understand emissions from lime kiln, we need to understand the chemical recovery cycles. The principal operations of the chemical recovery cycle according to Wikipedia (6.) are as follows (see figure 4.9)

- Concentration of the residual liquor from the brown stock washers, i.e. weak black liquor, in multiple-effect, stream heated evaporators to form concentrated black liquor
- Incineration of concentrated black liquor at 65%-80% dry solids in a reductive recovery furnace to generate high pressure steam and to recover chemicals in the form of sodium sulfide (Na_2S) and sodium carbonate (Na_2CO_3).

- ❖ dissolving inorganic smelt flowing off the bottom of the recovery furnace in water or weak white liquor to form green liquor
- ❖ causticizing clarified green liquor with lime to form white liquor containing a minimum amount of uncreated chemicals for the cooking process

$$CaO\ (s) + H_2O \rightarrow Ca(OH)_2\ (s) \quad (1)$$

$$Ca(OH)_2\ (s) + Na_3CO_3\ (aq) \rightarrow 2\ NaOH(aq) + CaCO_3\ (s) \quad (2)$$

- ❖ Lime mud ($CaCO_3$) washing and filtering, and reburning in a lime kiln to recover lime

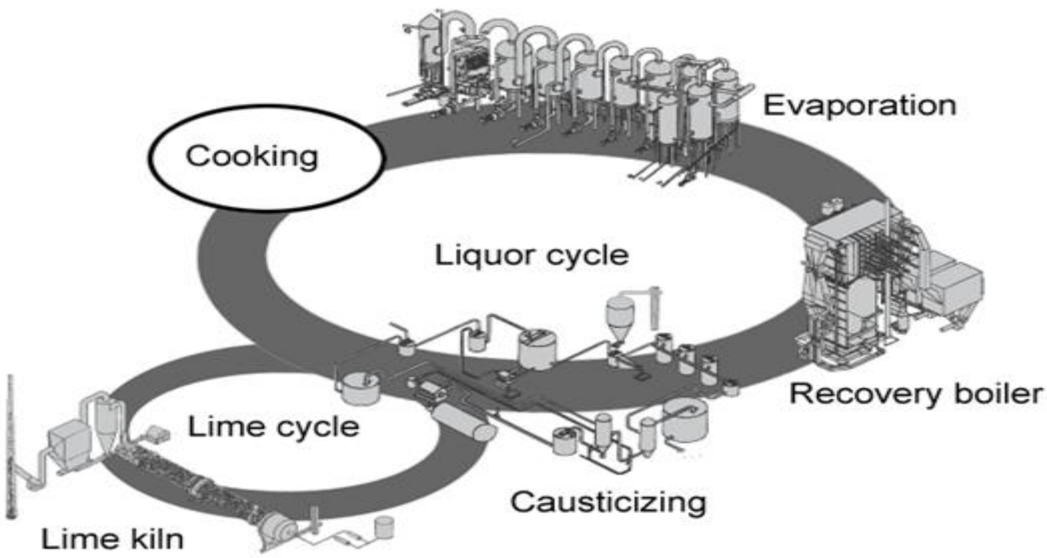

Figure 4.7 The chemical recovery cycle (12)

The major air emissions from the lime kiln are sulphur dioxide, nitrogen oxides; reduced sulphur compounds (TRS) and particulate matter.

Sulphur dioxide: SO_2 emissions

Sulphur emissions from the lime kiln are due to sulphur in the fuel and malodorous gases if such are burnt. The role of sulphur entering the sulphur with lime mud is in this respect marginal. A limited amount of sulphur can be absorbed in the lime kiln gaseous Na forming sodium sulphate according to the reaction equations:

$$Na_2CO_3\ (l) + \quad 2\ Na\ (g) + CO_2 + 1/2\ O_2 \qquad (3)$$

$$SO_2\ (g) + 2\ Na\ (g)\ O_2 \rightarrow Na_2\ SO_4\ (l) \rightarrow Na_2\ SO_4\ (S) \qquad (4)$$

The main sulphur absorbing compound is thus the sodium carbonate (Na_2CO_3) in the lime mud. When this capacity is exhausted, SO_2 is released. This effect is enhanced when malodorous non-condensable gases are incinerated in a kiln. Therefore, SO_2 emissions are usually a clear function of the amount of malodorous gas flow. To minimize the formation of SO_2 either the sulphur content in the fuel can be reduced or if malodorous non-condensable gases (NCG_s) are to be burnt in the lime kiln, sulphur compounds can be scrubbed out of these gases prior to burning in the lime kiln. A small internal NaOH scrubber for the malodorous gas flow (i.e. not for the total flue gas flow) will reduce H_2S almost completely while the methyl sulphides are reduced by about 50-70% and methylmercaptane by less than 20%. Typical total S emission from lime kilns is ten up to several hundred mg/m^3 if NCGs are burnt and 10-30 if they are not. The figure 4.8 shows that sulphur emissions have decreased in Finland by 80% per produced tonne between1992 to 2007. (12.)

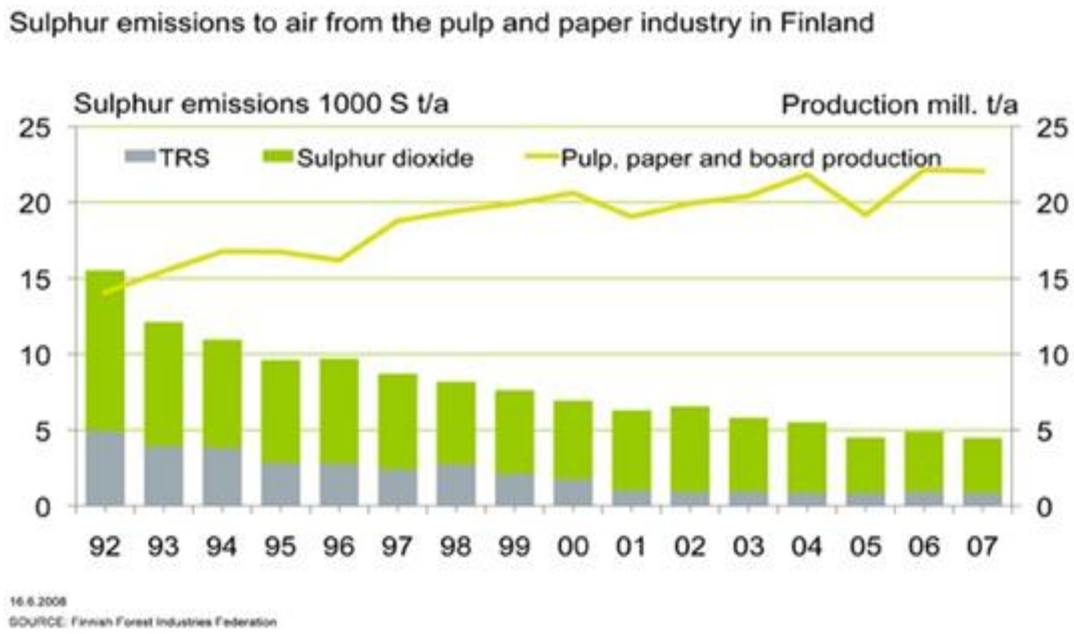

Figure 4.8 Sulphur emissions in forest industry between 1992 and 2000

Total reduced sulphur emissions (TRS)

The TRS emissions from a lime kiln consist mainly of hydrogen sulphide. Observed H_2S concentrations are normally less than 50 mg/m^3 (90 percentile) resulting in a total emission of small ≤ 0.03 kg/t. H_2S formation in the lime kiln depends on oxygen levels and the amount of sodium sulphide in the mud burnt in the kiln. The presence of sufficient excess air can be ensured by a residual oxygen control system. The sodium sulphide content can be controlled by properly operated lime mud washing and filtering so that sodium sulphide (Na_2S) is prevented from entering lime kiln. If Na_2S enters the cold drying and heating section of the lime kiln in the presence of CO_2 and water H_2S is formed according the reaction equation

$$Na_2S + CO_2 + H_2O \rightarrow H_2S + Na_2CO_3 \qquad (5)$$

With a proper capacity of the lime mud filter a small amount of air is sucked through the lime mud cake and the residual Na_2S left on the surface of lime mud particles is then oxidized to sodium thiosulphate that does not cause any H_2S formation in the kiln. If H_2S problems arise, the reason is in many cases poor lime mud quality in terms of lime mud dry solids content and purity. Technical options are improvement of green liquor clarification and the lime mud washing or replacing a part of the lime with make-up lime. (11.)

4.3.3 Malodorous gases

Malodorous gases in Kraft pulping are normally H_2S, methyl mercaptane, dimethyl-sulphide and dimethyl-disulphide. Sometimes malodorous gases are referred to as Total reduced sulphur, TRS. The malodorous gas streams are generally divided into strong (concentrated) and weak (diluted) gases. The latter normally refers to a concentration of < 0.5 g of S/m^3, while the more concentrated or strong gases are normally above 5 g/m^3. Concentrated gases come from digester, evaporation plant and condensate stripper. In total they add up to about 25 m^3/t of pulp. The non-condensable gases from the cooking plant and the stripper gases from the steam stripping of foul condensates from the evaporation plant usually contain 1-2.5 kg S/Adt. (12.)

and normally higher at hardwood pulping than at softwood due to different lignin structure. Concentrated gases are collected and burnt either in the lime kiln, the recovery boiler or in a separate burner. If a dedicated burner is used a scrubber is normally added to control emission of the SO_2 formed. The heat energy can be used but NO_x formation is high, up to 1 g/MJ of fuel. This level can be reduced by about 70% by optimizing combustion conditions. (12.)

The advantage of burning the malodorous gases in the lime kiln is that no extra furnace is needed. In addition, the sulphur in the gas can be absorbed which reduces the emission of sulphur dioxide. However, as said above, the S-content in malodorous gases can overload the absorption capacity in the lime kiln.
However, the variation of the amount of energy of the gas makes it difficult to produce lime of good and uniform quality. Separating off methanol from the gases minimizes the problem with varying gas quality. The separated methanol can then be fed in liquid phase to the lime kiln or to a dedicated burner for malodorous gases. In cooking and evaporation, a part of the malodorous compounds are transferred to the condensates. In addition to reduced sulphur compounds, the condensates contain methanol and some other oxygen consuming compounds (BOD load). (12.)

4.3.4 Chlorine compounds from bleaching and bleaching chemical Preparation

The bleaching process removes color from the pulp by adding chemicals to the pulp in varying combinations, depending on the end use of the product. The same bleaching processes can be used for any of the pulping process categories. In bleached Kraft pulp mills using chlorine dioxide as bleaching chemical chlorine compounds from the bleach plant and the ClO_2 – production are released to the atmosphere. In table 4.11 some examples of measured values are presented and compared with values set under normal conditions in permits in Sweden (IPPC.2002).

Table 4.9 measured values chlorine of bleached pulp (11)

Name of the mill (reference year)	Condition in the permit [kg active chlorine/t of bleached pulp]	Measured values [kg active chlorine/t of bleached pulp]
Husum (1995,96)	0.2 annual	0.0-0.04 kg Cl_2 and ClO_2 as chlorine/ t of pulp; monthly grab (one 0.4)
Skärblacka (1996)	0.3 monthly	0.08 annual average
Mönsterås (1997)	0.05 annual	0 (TCF)
Gruvön (1997)	0.2 monthly	0.02 (one week average)
Skoghall (1997)	0.2 monthly	0.05 (one week average)
Skutskär (1997)		0.0004 bleachery 0.006 ClO_2-production

4.4 Pulp and Paper GHG Emission Sources

Greenhouse gas emissions from the pulp and paper source category are predominantly CO_2 with smaller amounts of CH_4 and N_2O. The GHG emissions associated with the pulp and paper mill operations can be attributed to: (1) the combustion of on-site fuels; and (2) non-energy –related emissions sources, such as by-product CO_2 emissions from the lime kiln chemical reactions and CH_4 emissions from wastewater treatment. These are emitted directly from the pulp and paper plant site. In addition, indirect emissions of GHG are associated with the off-site generation of steam and electricity that are purchased by or transferred to the mill. Table 4.10 shows the relative magnitude of nationwide GHG emissions (in million metric tonnes of CO_2 equivalents per year) from stationary sources in the pulp and paper manufacturing sector. Secondary manufacturing facilities are not engaged in manufacturing primary pulp or paper products, but instead convert paper products into other products (e.g., paperboard into containers, coated/laminated papers). Some converting operations may operate small fossil fuel fired package boilers. Direct and indirect emissions from secondary manufacturing operations are included in table 4.10, along with emissions from primary manufacturing operations.

Table 4.10 Sweden GHG from mill industry (11)

Emission Source	Million metric tonnes of CO_2e per year
Direct Emissions	
Direct emissions associated with fuel combustion (excluding biomass CO_2)	57.7
Wastewater treatment plant CH_4 releases	0.4
Forest products industry landfills	2.2
Use of carbonate make-up chemicals and flue gas desulfurization chemicals	0.39
Secondary pulp and paper manufacturing operations (i.e., converting primary products into final products)	2.5
Direct emissions of CO_2 from biomass fuel combustion (biogenic)	*113*
Process-related CO_2 including CO_2 emitted from lime kilns (biogenic)	*unavailable*
Indirect Emissions	
Electricity purchases by pulp and paper mills	25.4
Electricity purchases by secondary manufacturing operations (i.e., converting primary products into final products)	8.9
Steam purchases	unavailable

4.5 Environmental control

The pulp mill uses huge amounts of water. In fact the pulp and paper industry is one of the largest industrial process water consumers. The sources of the large amounts wastewater containing suspended solids, and compounds that increase the BOD (biochemical oxygen demand) are wood handling and debarking, and the screening and cleaning operations that take place during the pulping process.The condensates from digesters and evaporators are a low-volume, but high BOD, effluent. Some of these condensates also contain reduced-sulfur compounds. Water effluents from the bleaching process also contain AOX, which is a measure of the halogens (chlorine) present in organic matter. Virtually all Kraft pulp mills have wastewater treatment systems to reduce effluents. In the past ten years, there has also been a desire to reduce the use of chlorine chemicals to bleach the pulp. Processes that make use of chlorine dioxide and oxygen compounds and ozone have gradually replaced the bleaching processes employing elemental chlorine. (12.)

The Falling Film (FF) evaporator eliminates the disadvantages of Rising Film. These evaporators obtain high final black liquor dry solids concentrations. In addition, this evaporator operates efficiently at low effective temperature differences, which allows the good control of evaporator loading.

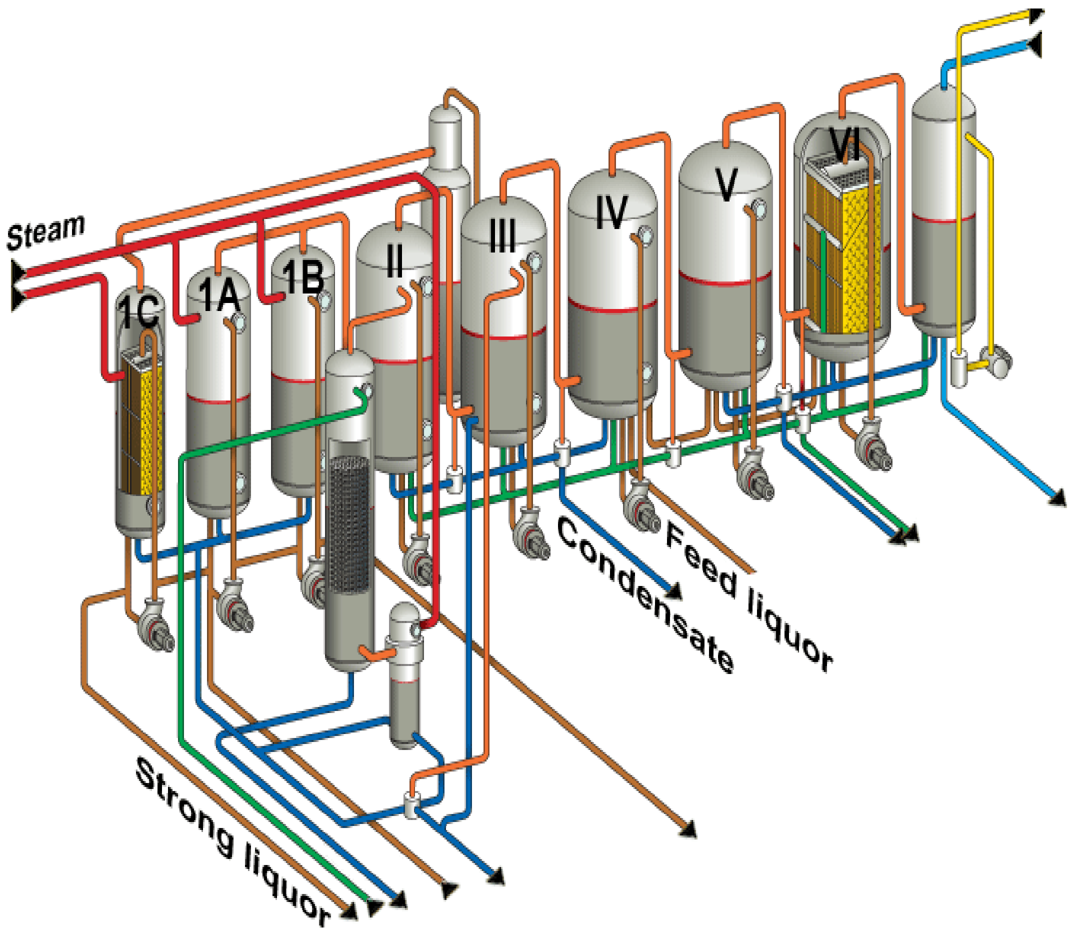

Figure 4.11 Falling film (FF) evaporator

4.6 Energy use in forest industry GHG

The pulp and paper manufacturing process is highly energy intensive. Natural gas, fuel oil, biomass-based materials, purchased electricity, and coals are the major energy-related GHG emission sources for Finnish pulp and paper mills. When biomass-derived GHG emissions are not counted, the remaining four energy sources accounted for an estimated 80 percent or more of the industry's energy related GHG emissions in 2006.Thus, a primary option to reduce GHG emissions is to improve energy efficiency. In 2005, the pulp and paper manufacturing industry consumed over 2,200 trillion Btu (TBtu), which accounted for around 14 percent of all fuel consumed by the Finnish manufacturing sector. (13.)

Steam is the largest end use of energy in the pulp and paper industry, with more than 1,062 TBtu used in 2005. The next largest end use of energy is electricity, with approximately 339 TBtu of electricity (purchased and self – generated) consumed in 2005. Therefore, energy efficiency initiatives that are targeted at reducing steam system losses and improving the efficiency of process steam-using equipment are likely to reduce energy use at pulp and paper mills. (13.)

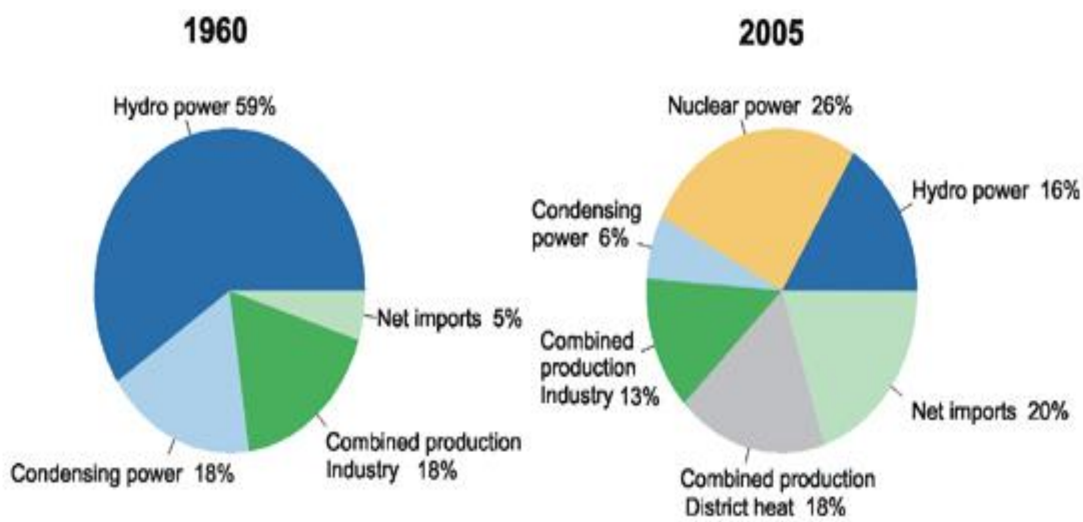

Figure 4.12.Electricity supply (13)

The growth in the use of electricity in Finland was fastest between the two World Wars, but still it continues. At moment, around a quarter of the electricity used in Finland is produced with nuclear power as can be seen figure 4.12. The first four nuclear power plants in Finland were built at the turns of the 1970s and 1980s and roused no major political discussion. In 1986, a tragic accident took place in the Chernobyl nuclear power plant in the Ukraine, and subsequent to it nuclear power plant projects were put in ice almost everywhere. The Finnish parliament voted against the fifth nuclear power plant in 1993 but decided in favour of its construction in 2002. The construction began in 2003.

The Imatra power plant is still the largest hydro power plant in Finland, producing electricity with seven units. Around one-fifth of the electricity used is imported. Finland has also joint the Nordic electricity market since 1998. Imports from the Nordic countries fluctuate dependent on the hydro power situation in Norway and Sweden. (13.)

4.7 The effects of climate change on forest industry

Climate strongly influences forest productivity, species composition, and the frequency and magnitude of disturbances that impact forests. (14.)

- Climate change has very likely increased the size and number of forest fires, insect outbreaks, and tree mortality in the Interior West Morocco, and Alaska, and will continue to do so.
- An increased frequency of disturbance is at least as important to ecosystem function as incremental changes in temperature, precipitation, atmospheric CO_2, nitrogen deposition, and ozone pollution.
- Rising CO_2 will very likely increase photosynthesis for forests, but this increase will likely enhance wood production in young forests on fertile soils.
- Nitrogen deposition and warmer temperatures have very likely increased forest growth where adequate water is available and will continue to do so in the near future.

- The combined effects of rising temperatures and CO_2, nitrogen deposition, ozone, and forest disturbance on soil processes and soil carbon storage remain unclear.
- Higher temperatures, increased drought, and more intense thunderstorms will very likely decrease the cover of vegetation that protects the ground surface, increase erosion and promote invasion of exotic grass species in arid lands.
- Climate change in arid lands will create physical conditions conductive to wildfire, and the proliferation of exotic grasses will provide fuel, thus causing fire frequencies to increase.
- Arid lands very likely do not have a large capacity to absorb CO_2 from the atmosphere and will likely lose carbon as climate-induced disturbance increases.
- Current observing systems are very likely inadequate to separate climate change effects from other effects.
- No coordinated national network exists to monitor change associated with disturbances and alteration of land cover and land use.

4.8 Climate changes policies in Finland and Morocco

IPCC warning effort claimed a quick answer to mitigate the mentioned predictions. At the 1992 Summit in Rio, UN Frame Convention Climate Changes ultimate goal was stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic human induced interference with the climate stem. Such a level should be achieved within a period sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner. (15.)

With just this information, one can imagine quickly which dilemma is appearing: How can society mitigate a climate change that has already started, maintaining its rhythm of development? This question stated to be in mind of policy makers in the 1960s. Nevertheless, the first milestone on the matter is considered the Declaration of the United Nations Conference on the Human Environment. Other meetings, summits and development goals followed this conference.

4.8.1 Kyoto protocol

One of the most well known facts in environmental history took place in 1997 at the third Conference of the Parties of the UN Framework Convention on climate Change (UNFCC).

Kyoto Protocol was defined as well as targets to cut the six main GHG emissions in developed industrialized countries. The protocol sets an average GHG reduction target of 5.2% over the period 2008-2012 and uses 1990 as base year. To avoid retaining development efforts, no target was set for emission levels in developing countries. Kyoto protocol started to become applicable on February 16th of 2005 when it was ratified by Russia, as the condition of 55 nations accounting for at least 55% of CO_2 emissions was accomplished. (15.)

As mentioned, the target was the reduction of GHG emissions. However, this reduction seemed impossible over period 2008-2012 unless worldwide economy retrocede. Consequently, three innovative flexible mechanisms were defined to reduce the totality of costs of achieving the emissions targets. UNFCC justifies the mechanisms stating that they entail some economical and effective opportunities to reduce emissions as well as they enable a reduction of emissions in other countries. Over passing the country limits of emission reducing measures is justified by the cost of measures- the location of the project might be an influent parameter in overall costs- but the benefit is the same, wherever the action is executed, as the atmosphere is global.The three flexible mechanisms are emissions trading, project mechanisms and absorption focus. (15.)

4.8.2 Finland: national energy and climate change

State council gives to parliament a commentary explanation of climate program concerning obligations of the Kyoto protocol. Government promises to push forward things which concern use of the renewable energy, saving of the energy and reduction of the greenhouse gas emissions with the help of Kyoto mechanisms. (15.)

4.8.3 Communal climate strategy

The purpose of the communal climate strategy is to reduce greenhouse gas emissions with the help of sustainable development principle. At first community inspects their greenhouse gas emissions, which arise from for example in use of the energy and in energy production and makes development predictions and sets its own targets for the emission reduction. The strategy is then accepted by town council who puts it in action and follows up the compliance of observance of the strategy. (15.)

4.8.4 Energy agreement for industries

The agreements between Ministry of Trade and Industry and separate organizations are frame agreements from the actual energy agreement. The target of energy agreement is to minimize the specific energy consumption and to take in action models which support energy efficiency. Energy saving agreement is part of the energy strategy whose purpose is to stop the growth of energy consumption during next 10 to 15 years. Agreements further on help to achieve the targets of the international climate agreements. Committing to a long-range and systematic improvement of energy efficiency, it is also possible to affect to environmental emissions. (15.)

4.8.5 Emissions trading in Finland

The meaning of emissions trading is that a plant which has smaller emissions than allowed can sell extra amounts to some other plant that can buy allowances to satisfy the emissions amounts. The decrease of the emissions is done in the plants where it is most economic. Different factories and countries get certain amounts of emissions allowances. Emission trading is applied for the factories whose capacity is over 20 MW. Factories of this area need certain permits which guarantee the rights to let carbon dioxide to the atmosphere. In Finland the allowances are given to about 550 plants which include plants like paper mills, districts heating etc. The allowances are now given for years 2009-2011. The overall amount of allowed CO_2 releases which can be released during the years 2009-2011 is 136 tons of CO_2. (15.)

4.8.6 Climate agreement in Morocco

Morocco ratified the United Nations' Framework Convention on Climate change in 1996 and the Kyoto protocol in 2002, and hosted the seventh Conference of the Parties in Marrakech. It submitted its first national communication in 2001 and is currently preparing its second. Its first national communication showed that Morocco is very vulnerable to climate change, particularly in two key sectors of the domestic economy- water resources and agriculture. For the benefit of its own sustainable development and in order to contribute to industrialized countries mitigation efforts under the clean development mechanism (CDM) Like all members of an international community that is increasingly aware of the dangers of climate change, Morocco believes that the steps taken so far fall short of what is needed to guarantee peace of mind about the future of our planet. On the basis of the various scientific conclusions reached by the Intergovernmental Panel on Climate Change (IPCC), Morocco will support any proposal designed to significantly curb global warming, and believes it is time to reflect on how to achieve that. Given the historical responsibility of the industrialized countries, and to ensure that achieving this objective does not damage developing countries development prospects, a strong commitment by the industrialized countries- all the industrialized countries- would be desirable. (16.)

Since the earth summit, Morocco has been actively on a regular basis in international efforts to protect the Earth's climate. Since ratifying the Convention, Morocco has made institutional arrangements to deal with climate change. It prepared its first national communication and submitted it at the seventh Conference of the Parties. The results of the greenhouse-gas inventory show that Morocco's contribution to worldwide greenhouse-gas emissions is very small (less than 2 TEQ CO_2 per inhabitant per year), but this has not stopped Morocco from taking practical steps to mitigate greenhouse-gas emissions through energy-saving projects, projects to control energy use and the promotion of renewable energy sources. (16.)

5. PREDICTION AND DANGEROUS CLIMATE CHANGE, CAN WE SOLVE THE CLIMATE CHANGE

5.1 Predicting climate change

Climate prediction tells us about changes in the average climate, its variability and extremes. They are made by climate models. climate models are a mathematical description of the process in the Earths climate system; atmosphere, ocean , land cryosphere. The representation of climate processes in the model are based on experimental measurements in the real atmosphere, ocean etc, and these can be chosen within the constraints of these experiments to give the best possible agreement between model simulation of current climate and observations.

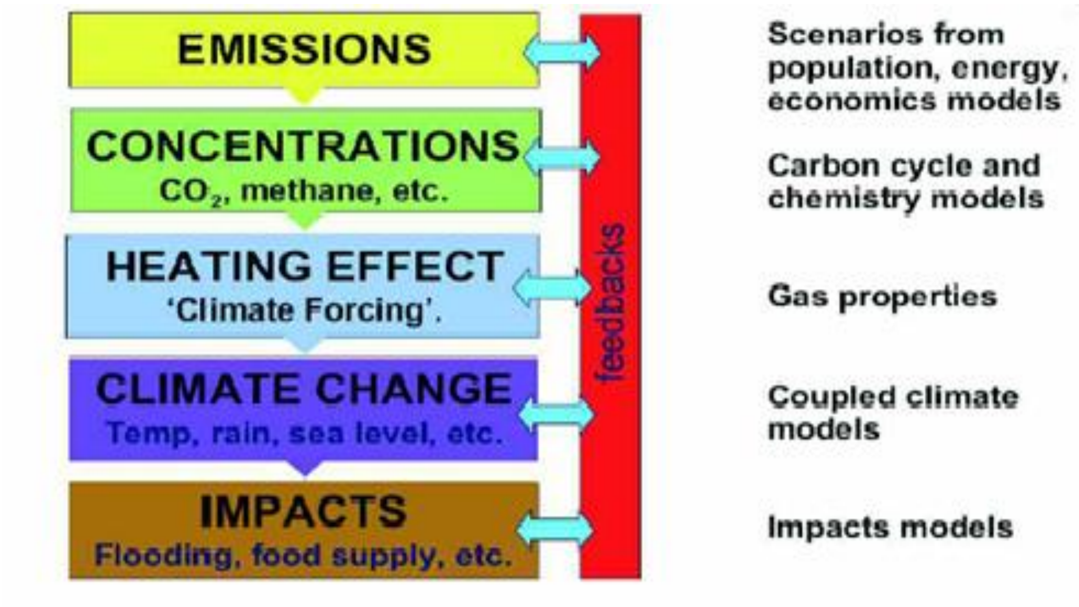

Figure 5.1 Stages in prediction of climate change (4)

How quickly the climate will change in the future depends upon two factors: how much greenhouse gas emissions grow, and how sensitive the climate system is to these emissions. We predict future climate change in a number of stages, as can be shown in figure 5.1. The first thing we need to estimate is the future emissions of greenhouse gases and other gases which affect climate change. These projections are deduced from separate models which take into account population growth, energy use, economics, technological developments, and so forth. (4.)

5.1.1 CO_2 emissions

The rapid increase in carbon dioxide emissions observed during the last 250 years is expected to continue for several decades to come. Various scenarios have been examined, depending on factors like use and efficiency. Even the best case scenario predicts further increases in carbon dioxide emissions until about 2040. Many of the scenarios indicate that by the middle of the 21st century emissions of carbon dioxide should at least start to level off, though some predict increase in emissions throughout this century.(13.)

Though the different scenarios predict a wide range of trends in carbon dioxide emissions, the predicted net effect on atmospheric carbon dioxide concentrations in the future is fairly consistent. All predict further increase in carbon dioxide concentrations by the end of the is century, with some of the scenarios predicting a doubling or even trebling of today's levels of carbon dioxide. (13.)

5.1.2 Temperature change

Average global temperatures are now some 0.75 ^{0}C warmer than they were 100 years ago. Since the mid-1970s, the increase in temperature has averaged more than 0.15 ^{0}C per decade. This rate of change is very unusual in the context of past changes and much more rapid than the global average, whereas temperatures over land have warmed more rapidly, at almost 0.3 ^{0}C per decade. Over the last ten years, the rate of warming has been slightly lower than during previous decades. But this does not mean that global warming has slowed down or even stopped. It is entirely consistent with our understanding of natural fluctuations of the climate within a trend of continued long term warming.

As result of such fluctuations, global average temperature trends calculated over 10-year periods have varied since the mid-1970s, as shown in figure 5.2 from a modest cooling of 0.02 ^{0}C per century. However, even with this long term rise, natural variations in climate can be expected to lead to ten –year periods with little or no warming, both globally and regionally, and other ten year periods with very rapid warming. This complex behavior of the climate system shows why we need to examine much longer periods than 10 years if we are to fully understand and quantify how the climate is changing. In its most recent assessment in 2007, the IPCC concluded that increases in man-made greenhouse gas concentrations are very likely to have caused most of the increase in global average temperatures since the mid 20th century. (4.)

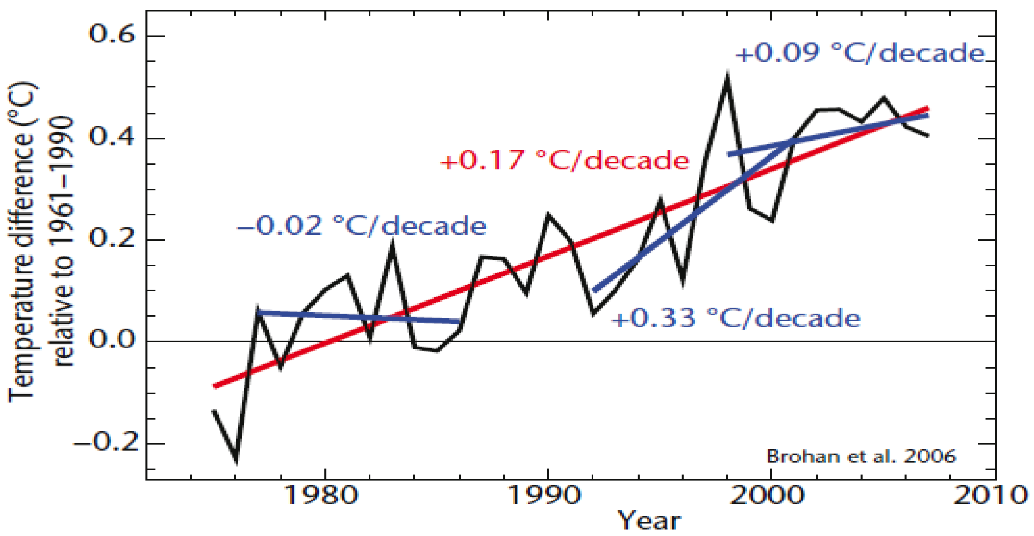

Figure 5.2 The global average temperature between 1975 and 2007(4)

The graph shows the global average temperature anomaly from 1975-2007, relative to the 1961-1990 average. The black line shows the trend over the full 33 years. The blue lines show the varying rate of the trend over the full 323 years. The blue line shows the varying rate of the trend over various 10-year periods. (4.)

5.1.3 Temperature in Finland

It is estimated that the temperature in Finland will rise faster than the global average. Finland's annual mean temperature is expected to rise by 2-6 ^{0}C by the end of the century. Temperatures will rise more in winter compared to the summer, and more in the northern than in the southern regions. Annual precipitation will rise by some 10% and, in this respect too, the change will be more pronounced in winter. With regard to rainfall, the occurrence of both extremes, long dry spells and heavy rains, will increase. However, in terms of winds and storms the changes will be less dramatic. Climate variability will remain, meaning that cold spells will continue to occur but they will gradually become more infrequent, while periods of warm weather will become more common. Greenhouse gas emission trends will have an impact on the intensity of climate change, particularly towards the end of the century. If emissions are high, winter temperature may rise by up to 6-9 ^{0}C from the present day. (17.)

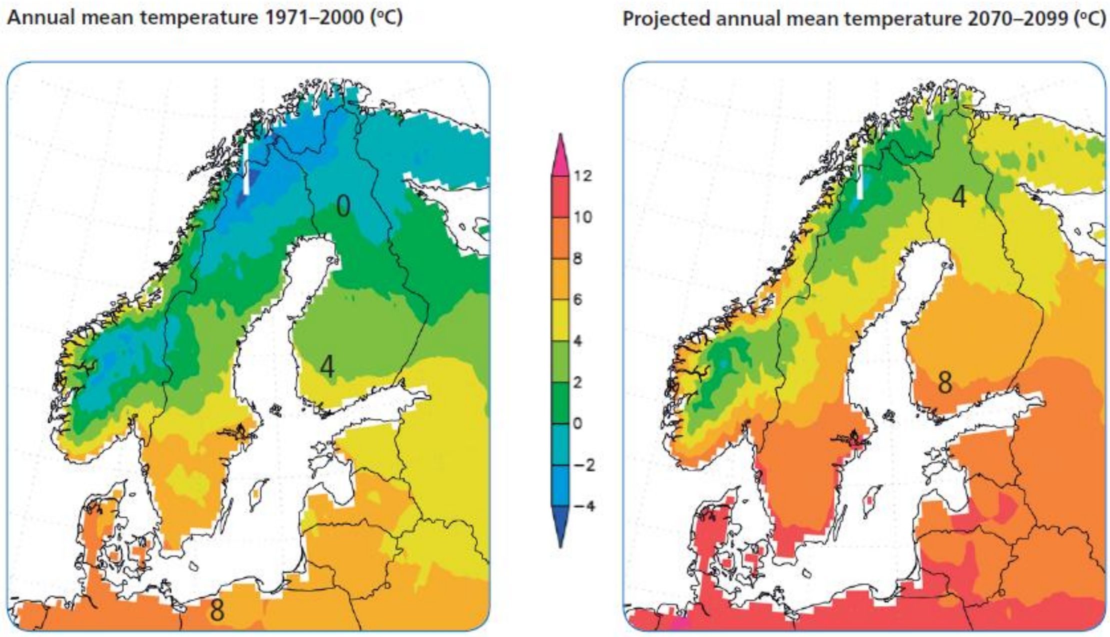

Figure 5.3 The temperature in Lapland

5.1.4 Animal and plant species change

The impacts of climate change on Finnish nature are difficult to predict. Finland's animal and plant species have adapted to a cold climate. A longer growing season and a rise in the temperature may bring along rapid and significant changes in the occurrence and abundance of species. While Finnish animal and plant species are likely to become more abundant, many more northern species which depend on the cold climate are in danger of extinction. In Finland's inland waters floods and their timing and the volume of water resources will change. Higher temperatures are likely to increase eutrophication. In the Baltic Sea, climate change will reduce ice cover, increase water column stratification, dilute salinity and cause an increase in algal blooms. Such changes will have an impact on the marine species, such as economically significant fish stocks. (17.)

5.1.5 Sea level rise

A common feature of global warmings stories in the media is sea level rise. Sea level rise through the thermal expansion of water and ice melt around the world, and cause portions of the Greenland and Antarctic ice sheets to melt or slide into the ocean poses a potentially very serious threat to millions of people.Like temperature change, predictions vary widely, from a low of 20 cm to a high of around 60 cm.The main consequences of sea –level rise will probably come from an increase in extreme high water levels, which arise from storm surges as mid-latitude depressions or tropical storms and cyclones track across the area. The effect of sea-level rise can also be expressed as a change in the frequency of a given high water level. (17.)

5.2 Avoiding dangerous climate change

- Climate change threatens the basic elements of life for people around the world-acees to water, food production, health, and use of land and the environment.
- The impacts of climate change are not evenly distributed -the poorest countries and people will suffer earliest and most. And if and when the damages appear it will be too late to reverse the process. Thus we are forced to look a long way ahead.
- Extinction of polar and alpine species
- Unsustainable migration rates
- Ice sheet disintegration(and subsequent increase in global sea levels)
- Severe regional climate change
- Droughts /Floods
- Climate change may initially have small positive effects for a few developed countries, but it is likely to be very damaging for the much higher temperature increases expected by mid -to-late century.

5.3 Can we solve climate change ?

In my opinion we can not avoid climate change because we have left it too late. Ten years ago if the major countries of the world had embarked on far reaching policies to reduce their greenhouse gas emissions we would have a good chance of avoiding most of the effects. All the sientists suggest that in this century and the next the climate is going to be changed in many ways hostile to humans and life in general - we are not going to avoid that.

The question of solving it is out of the question. It is not like urban air pullution, where when it gets bad enough you introduce some laws on catalytic converts and it goes away, because we have set off a huge process of change in the global climate system which has its owwn dynamic. The following are suggestions that can help reduce climate change:

The government, organizations and individuals should make it their responsibility to educate the public to do the following activities:

- Using fossil fuels as an energy source should be minimized, relying more on cleaner, renewable energy sources such as wind and solar.
- Wasting less energy by improving the energy efficiency can reduce the amount of the carbon dioxide emissions and also save a lot of money.
- Government actions are needed to be able to reduce the greenhouse gas emissions.
- The government can contribute to the amount of the carbon dioxide emissions produced from pulp and paper mill by phasing in taxes (for example Finland will do that at the beginning of 2012)
- Reduce your home electricity use
- Walk, bike, carpool or take transit to get to one of your regular destinations each week
- If you are moving, choose a home within a 30 minute bike, walk or transit ride from your daily destination. A conventient place to live reduces the amount you drive, which means you will lower your greenhouse gas emissions and other pollutions.
- Re-forestation
- Protect the soil and control erosion

- Increase Non Governmental Organizations (NGOs), such as Greenpeace, WWF and others, are pressing the industry (and authorities) to decrease various environmental impacts → often beyond the legislation in the country in question.
- Recycling of the paper fiber is a must today (e.g in EU) → recycled fiber is usable up to 4-5 times.
- Life cycle analysis philosophy of each product (raw materials. production, use, removal etc.)
- Effluent free mills in the future (if environmentally necessary)
- Decrease of energy consumption in general
- Decrease of water consumption in general
- Sustainable forestry industry management
- The main goal of new pulping processes: 1) reduced pollution (low water use, TCF, sulphur free pulping), 2) use of various wood species, 5) lower investment costs compared to conventional pulping.
- Reduce emission of greenhouse gases to the atmosphere
- Manage wastes well preferably using 3 Rs (Reuse, Recycle and Reduce)
- Plant more trees
- Save and conserve existing trees
- protect water sources
- stop cutting trees
- International agreements like the kyoto Protocol are one step in the right direction, but not enough.

6 EXPERIMENTAL PARTS

Due to the broadness of the effect of climate change on sample test sheets, thesis work focused on examining the influence of humidity on the properties of mechanical and chemical pulp sheets obtained from Finland and Morocco.

6.1 Introduction to the work

The control of relative humidity is generally recognized as an important consideration in the proper storage and display of paper materials. However the effects of humidity on paper collections are not as well understood, although the dangers of humidity extremes are recognized. Maintaining humidity within these limits is prudent, but the necessary degree of humidity control within those bounds is not known. Since very tight control of the relative humidity (RH) can be expensive, understanding the risks of paper damage from humidity fluctuations is important when investing in climate control systems.

The purpose of this work was to analyze the effect of air humidity on paper properties and also provide humidity of surrounding air and other properties. Moisture absorption is among the most problematic properties of paper. This study also provides a look at the variables' effect on properties of hand- sheets made in paper laboratory work. Paper sheets were made from chemical pulp and mechanical pulp. The properties of each paper sheet were tested in order to indicate the difference between two sources of pulp. In addition, the purpose is to find how humidity affects on paper properties.

In theory part, the character and properties of mechanical and chemical pulps was introduced. Also refining and general properties of the sheets were explained. Then, in the experimental part, different strength and optical properties were measured from commercial sheets. All the steps in the preparation of paper sheets and the calculation of pulps needed to prepare sheets were explained.

The experiments required for this study were carried out in the facilities of Saimaa University of applied Sciences in Imatra. The standards followed for this study are listed in appendix 1.

6.2 literature review

6.2.1The effect of humidity on paper properties

- **Moisture in paper**

In equilibrium conditions, the moisture content of paper depends on the ambient relative humidity and temperature of the surrounding air. The moisture content is highest in humid and cold conditions. It is also history-dependent, affected by the preceding in humid and cold conditions. It is also history-dependent moisture content. Time –dependent moisture sorption phenomena are important in some applications. The pulp furnish used in papermaking affects the moisture content of paper. This relates in part to the chemical interactions of water with the cellulosic fiber wall structure, and in part to the internal and external fibrillation and fines content of the pulp. The fibre wall structure change when water is removed. Depending on the pulp, these changes may be partially irreversible during paper drying. (19.)

- **Relative humidity and water content of air**

The relative humidity, RH, of air refers to the amount of water vapour in air relative to the amount in saturation. The saturation moisture content increases with increasing temperature. Thus relative humidity alone does not give the concentration of water in air; also temperature is important. Thus is helpful to remember when one considers the moisture content of paper in different conditions. The climatic system is never in thermodynamic equilibrium. In summer, sunshine evaporates water from sea, lakes and other bodies of water. Relative humidity can be almost %. In winter, water condenses and freezes on cold surfaces, making the ambient vapour pressure and saturation vapour pressure low. Wood fibers are hydroscopic-they absorb water ready. (19.)

The moisture content of paper is the ratio of absorbed water divided by the total mass of paper. When in equilibrium with the surrounding air, the moisture content of paper depends on the relative humidity of air and the equilibrium temperature. Figure 6.1 shows the relationship between temperature relative humidity, and water vapour pressure in air.

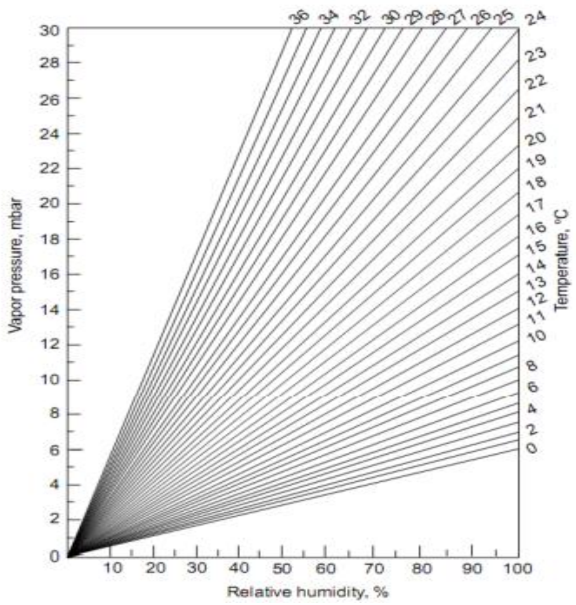

Figure 6.1 Humidity and water content (19)

- **Water content as a function of temperature**

At certain relative humidity, paper is drier when T is higher dependence is weak a noticeable change requires a temperature change of ± 10 ^{0}C tropical climate, however, generally is problematic because of moist paper this is reason of high RH in tropic(both air and paper are moist). The moisture content of paper of with decreasing relative humidity, as shown in figure 6.2 there is slight difference in the moisture content, depending on whether one starts from humid or dry conditions.

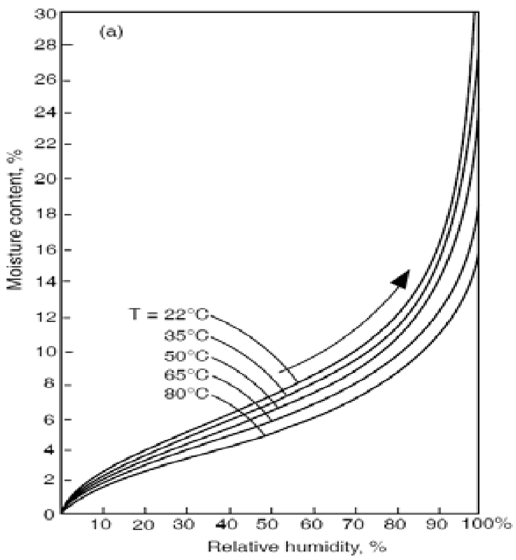

Figure 6.2 Relative humidity and moisture (19.)

- **Interactions of water with fiber**

In the previous section we considered the moisture content of paper. The amount of absorbed water is then a small fraction of the papers dry mass when it has been dried in an oven. In the other extreme, the water content in a wet pulp or paper can be clearly than the dry mass. Solids content in such cases, for example when considering the wet paper web on the paper machine.

The water retention value, WRV, of a pulp is a common measure of the total amount of water retained by a wet pulp. The measurement gives the amount of water contained by the pulp after a certain centrifuge treatment. Its values can range from 50%, for an unbeaten high-yield chemical pulp or the long fibre fraction of mechanical pulp, to over 200%of well beaten chemical pulps.

Papermaking fibres absorb water in four ways;

- As free water;
  - Inter-fibre free water in the pores between fibers
  - Inter-fibre free water in the lumen of fibres
- As free water;
  - Freezing bound water in the pores of the fibre wall.
  - Nonfreezing bound water chemically bonded to the hydroxylic and carboxylic acid groups in fibres.

- **Effect of water on the microfibril level**

According to Scallan (18.), fibers swell upon water absorption because water molecules penetrate between hydrogen-bonded micro-fibrils in the fiber wall, as shown in figure 4 the amount of bound water increases, and the degree of internal bonding of the fibre wall decreases. The opposite occurs during desorption. The beating of chemical pulps increases the delimination of the fiber wall.

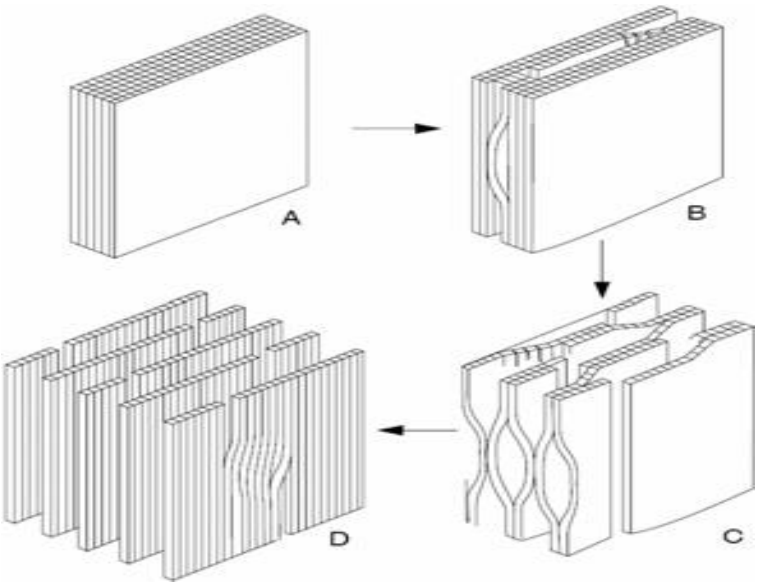

Figure 6.3 Loss bonding between microbrils in absorption of water

- Water is bound to the OH-groups of fiber components
  - Cellulose, hemicelluloses and lignin have different number of OH-groups
- Water is absorbed between micro-fibrils, loosening the structure
  - Fibers swell
  - In desorption microfibrils again bond to each other
  - Hornification is permanent bonding between micro-fibrils, taking place in drying, thus reducing swelling ability.
  - Hornification occurs only in chemical pulps. Hornification probably arises from the irreversible collapse of pores between microfibrils indicated from D to B in figure 6.3. Beating can partially reverse hornification.

- **The effect of humidity on the strength properties of paper**

Tear strength improves slightly as the humidity level increase. This is explained so that the energy required for the tearing is divided into a bigger area and therefore it is needed more energy to tear the specimen. Generally speaking the strength properties decrease as the humidity or moisture content of the environment increase as can be seen in figure 6.4

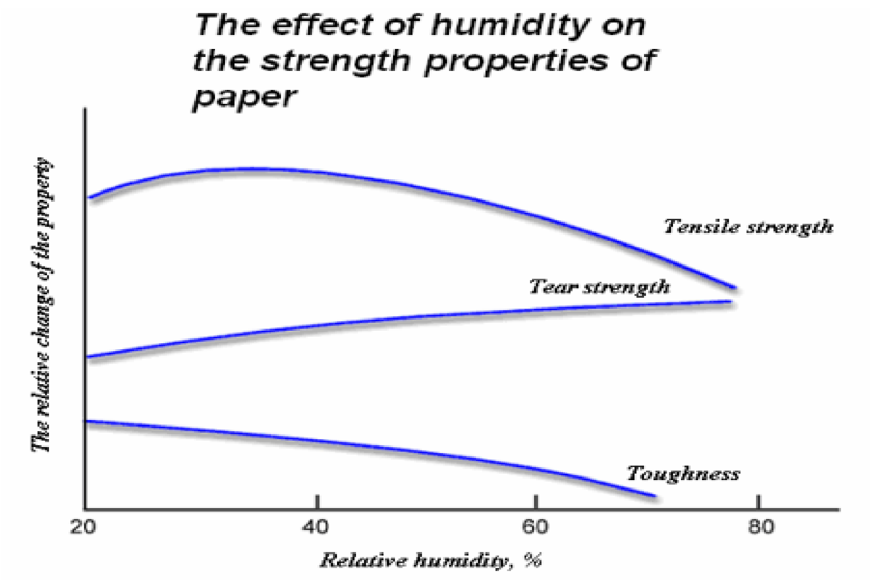

Figure 6.4 The effect of humidity on strength properties (20)

6.2.2 Fibre properties of mechanical and chemical pulps

Mechanical pulp (GW, PGW or TMP) gives paper a good printability and good opacity, even at low basis weight. TMP provides better strength properties, whereas PGW improves optical properties. Mechanical pulp is usually cheaper than chemical pulp. Yield of chemical pulp is considerably lower than that of mechanical pulps; ca. 40 to 55%.This is a consequence of the loss of almost all the lignin and much of the hemicelluloses in the process. Chemical pulp is used to increase strength and to warrant both paper and printing machines runnability. Chemical pulp gives better brightness to paper, but due to the higher brightness and lower light scattering it decreases opacity. (18.)

Due to the high lignin content, mechanical pulp fibers are rigid, which limits their bonding ability and increases the coarseness of mechanical pulps. This means that chemical pulp contains almost two times more fibers per weight unit as the long fibers and high quantity of fines resulting in smaller average fiber length.

Table 6.5 presents a summary of the properties of mechanical and chemical pulps and differences between them.

Table 6.5 The summary of fibre properties of mechanical and chemical pulps

Property	Mechanical pulps	Chemical pulps
Yield of wood	High	Low
Amount of lignin	High	Low
Amount of hemicelluloses	High	Low
Degree of polymerization	High in cellulose	High
Charge in water suspension	More anionic	Less anionic
Water affinity	More hydrophobic	More hydrophilic
Long fibers per unit mass	Few	Many
Specific unit mass	Large	Small
Fines content	High	Low
Fines:		
Structure	Lamellar	Fibrillar
Bonding ability	Good	Excellent
Fibers:		
Structure	Stiff,coarse,straight	Slender,surly,kinky
Shape	Short and thick	Long and thin
Bending stiffness	High	Low
Degree of collapse	Less collapsed	More collapsed

6.2.3 Refining

Refining is done to improve some strength properties of the paper. Refining is done with straight plate or council disc shape plate. The refining of the chemical pulp affects the inner and outer fibrillation and the breaking of the fibers. As a result of fibre breaking and outer fibrillation, fines are created. This leads to better formation and higher density in the produced paper. Outer fibrillation also causes the fibres to be more bound. On the other hand the inner fibrillation causes fibres to flex and swell more. When refining a chemical pulp, the growth in the binding potential of the fibres and the diminishing effect of the bonds to the light scattering is greater than the optical effect of the fines forming in the refining. Thus the brightness of chemical pulp deteriorates during refining. (18.)

6.2.4 The role of sizes

Paper strength largely depends on fibre strength, inter-fibre bonding strength, number of bonds and evenness of bond distribution in the sheet. One of the common practices in realizing good strength properties for paper is size treatment. This is achieved in the wet-end (internal sizing) or dry-end (surface sizing). Some common sizing agents are rosin, alkyl ketene dimer (AKD), alkenyl succinic anhydride (ASA), starch, etc.

The main objective of sizing is to hinder the penetration of liquid medium into base paper by way of reducing the surface energy at the contact interface since it is practically impossible to prevent the absorption because of the porous nature of paper web. (18.)

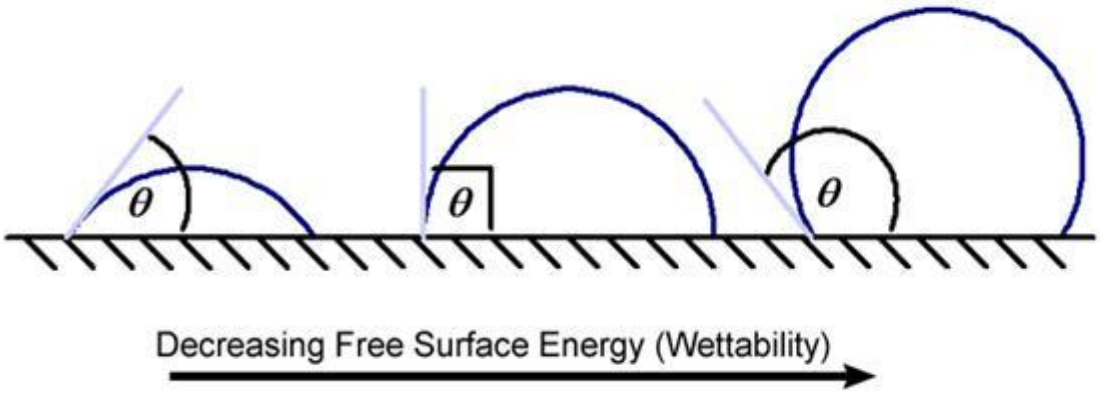

Figure 6.6 Effect of fibre surface energy on wetting (18)

The rate of liquid penetration into the constituent capillary pores of the paper web, on the assumption that the pores are even and similar and for a strongly sized paper, is given by Lucas-Washburn as:

$$L = \sqrt{\frac{r\gamma\cos\theta}{2\eta}}\sqrt{t} \quad (6)$$

Where L is the liquid penetration distance over time t

r is capillary radius

γ is surface tension of liquid

θ is contact angle at paper-liquid interface

η is liquid viscosity

6.3 Experimental procedure

The experimental details of this work comprise of pulp collection, beating / refining, sheet-forming and examination of basic strength properties of the test sheets.

Firstly, the machine was used to measure the dry content of chemical pulp and result was 15.32%. The consistency of mechanical pulp was 52 g/l. And it was calculated how many chemical and mechanical pulps are needed to prepare. According to the requirements of pulp above, 10 pieces of sheet (2g/sheet) for all types in both different categories of pulp were made by using the standard sheet mould.

6.3.1 Pulp collection

Pulp samples were available in sheet-form and 360g oven-dry weight birch samples were collected as required for refining. This amount of pulp was soaked in about five litres of water and shredded into pieces.

6.3.2 Beating / refining

The Valley beater was used for refining. Before the refining, the drain plug of the Hollander was closed and 18 litres of water at 20°C ± 5°C was measured and the Hollander was switched. All the chemical pulp and the soaking water were added to the Hollander during 3-5min. At this moment, the total volume was about 23 liters and the consistency approximately 15,7g/l.

One 5.5 kg of weight was fixed on the lever arm of the beater for disintegrating the pulp. Since the pulp with an initial dry content of 20 percent or more normally disintegrates within 20 minutes of refining. Pulp that has a dry content of less than 20 percent should disintegrate within 5 minutes. The pulp collection and refining processes were executed in similar manner for pine pulp sample which was also used for this work. Used equipment is shown in Figure 6.6.

Figure 6.7 PFI mill

6.3.3 The measurement of SR of the refined pulp

SR-number is a relative measure to infiltration. It is specified through the measuring instrument. SR number is measured by filtrating 1 liter of stock (consistency 2g/l) through the wire of the apparatus. SR-number of pulp is the higher the faster the infiltration slows down influenced by the fiber cake that develops to the screen.

The drainability of the pulp by the SR apparatus is determined. The sealing cone placed in the closed position and set the SR measuring cylinder set beneath the side orifice. Whilst stirring, 1000±5ml of homogeneous pulp suspension is transferred (consistency is 2g/L) to a clean measuring cylinder. The sample which was refined carefully is mixed and the stock poured rapidly but smoothly into the drainage chamber. And then, the sealing cone was raised and the SR number read when no more water drips from the side orifice. SR number was measured twice. The average SR number was 17ml for refining 5 minutes. A part of pulp was taken out from the beater and another 30 min more for refining; the average SR number of the rest of the pulp was 30ml.

6.3.4 The measurement of dry content of mechanical pulp

After that, used the machine the dry content of mechanical pulp is measured to be 15.32%. The consistency of chemical pulp was 15.7g/l. And it was calculated how much chemical and mechanical pulp must be prepared.

6.3.5 Sheet-forming

According to the requirements of pulp above, 10 pieces of sheet (2 g/sheet) to every kind of two different categories of pulp were made by using the standard sheet mould. Paper sheets were prepared with circulation water sheet former, and distillated water recycling was used during sheet making (except for retention sheets).Under the sheet former there was a pool which collected distillated water. A pump recycled water between the pipe system and the pool, and mixed it at the same time. The volume of the pool was 26 dm^3 and the additional water escaped through the leak-off pipe. Sheet former was filled on the top with wire water and pulp. After forming, the sheets were couched from the wire to blotters. The pH of the wire water was always set to approximately 5.3.

6.3.6 Pressing and drying

After the sheets were formed, wet pressing was performed. A sheet pressing was done with L&W sheet press. The machine generates needed pressure with hydraulic cylinder which presses down the metallic plate against the pile of fiber mats and blotters. Pressing process has two phases. Duration of the first pressing phase was 4 minutes and the pressure was 0.5 Mpa. The second phase takes 2 minutes and pressure is the same as in the first stage. Wet fiber mats were put to the pressing machine between blotters. Figure 6.7 shows used equipment

Figure 6.8 L&W press machine

Final sheet making process was drying with Oy E.Sarlin AB is drying drum, figure 6.8 The drying temperature was 90 ^{0}C. Sheets were put against hot drying cylinder between two blotters and drying duration was 4 hours.

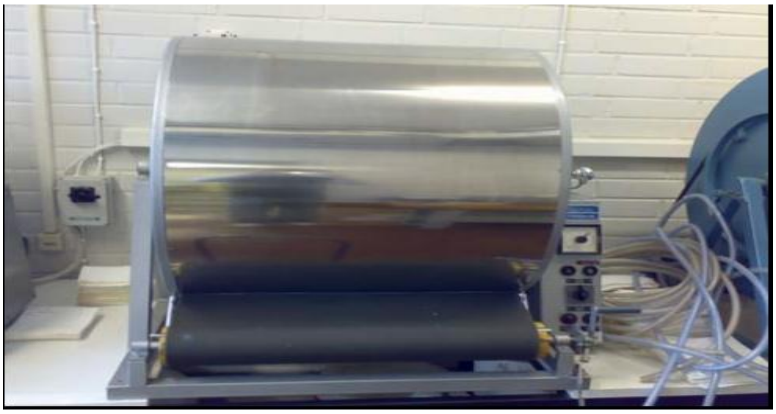

Figure 6.9 Oy E.Sarlin AB is drying drum

Finally 6 hand-sheets were made from chemical pulp, 3 sheets were conditioned at constant climate room (Temperature 23 ^{0}C, humidity 50%) and other 3 sheets were conditioned in normal climate room, all the sheets were put during 4 hours inside drying drum.

Other 6 hand-sheets were made from mechanical pulp, 3 sheets were conditioned at constant climate room (Temperature 23 ^{0}C, humidity 50%) and another 3 sheets were conditioned at normal climate room, all the sheets were put during 4 hours inside drying drum. Then after 4 hours, the basis weight (the sample pieces are cut (141mm * 141mm. A=0.02m^2), thickness, air permeance, roughness, optical properties, tear strength and tensile properties of these paper sheets were measured.

6.3.7 General properties of the paper

The basic properties of any type of paper include for example basis weight, thickness, density and bulk.

6.3.7.1 Basis weight

Basis weight is the most fundamental property. This is expressed as the weights in grams per square meter (g/m2).The basis weight of paper sheets are measured from the trimmed sheets (area of the trimmed sheets is 0.02 m^2).

6.3.7.2 Thickness, density and bulk

The normal expression for thickness of paper is µm. Measure the thickness using a pile of six trimmed sheets using a motor driven micrometer. The sheets should not move during the measurement. The density of the paper is the mass per unit volume calculated as the ratio between basis weight and thickness of the material in Kg/m^3.The bulk is the inverse number of the density expressed as cm^3/g. (21.)

6.3.7.3 Air permeability

The air permeance of paper is normally measured using air leakage instruments of different types. These instruments measure in one way or another the flow of air through a defined area of the paper caused by a defined difference in pressure between the different sides of the paper sample. The air permeance measured using Bendtsen tester is the volume flow of the air that pressure difference (1,47kPa) provides through $10cm^2$ area. (21.)

6.3.7.4 Roughness

Roughness of the paper is the amount of the air that flows through the paper surface and the metal ring that is set to the paper when the pressure differences are set toward unit of time.

6.3.7.5 Optical properties of the paper

The opacity of paper measures how opaque it is. It is usually expressed as the ratio of the reflection value measured against a black surface to the reflectivity value (in percents). The higher the opacity the more opaque the paper is. Opacity is the ratio of a refraction index of an individual sheet determined against a black background to the Y value of the same paper. Opacity portrays the paper's ability to prevent the print of a same kind of paper located underneath the paper from shining through. (21.)

6.3.7.6 Tear strength properties of the sheets

The tear strength of the paper is the mean force required to continue the tearing of the paper from an initial cut in a single sheet or a pad of sheets. Tear strength simulates the situation when there is some defect in the border of the paper web, eg. a hole, tear or stick. Then the strength of the continuous tear is smaller that it is in the whole paper web. Measurement is made with an Elmendorf-type tester. Unit of tear strength is mN. Dimensions of paper samples used for tearing tests were 50mm wide and 62 mm long. Tearing test was performed along the longer side of paper. Length of the tear was 47 mm. For each measurement four samples were used, and a total of 15 measurements were carried out for each grade.

6.3.7.6 Tensile strength

Tensile strength of the paper is the highest force that the paper strip can stand without breaking when applying the load in a direction parallel to the length of the strip. Tensile strength was measured with L&W tensile tester equipment, shown in figure 3. Before measuring, the right size of strips was cut from the sheets. For tensile strength tests strips must be 15 mm wide. Tensile strength was measured from 10 strips. The used equipment is shown in figure 6.5.

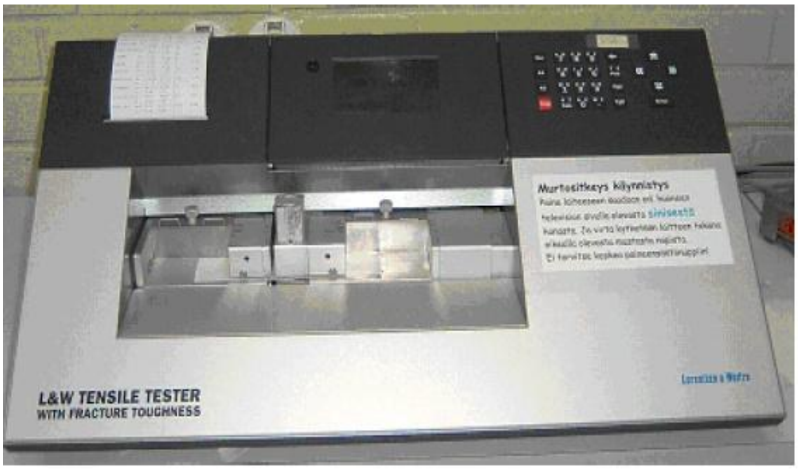

Figure 6.10 Used L&W Tensile tester

6.3.7.7 Bursting Strength

Bursting strength tells how much pressure paper can tolerate before rupture. It is important for bag paper. Bursting strength is measured as the maximum hydrostatic pressure required to rupture the sample by constantly increasing the pressure applied through a rubber diaphragm on 1.20 - inch diameter (30.5 mm) sample. (21.)

Bursting strength depends on basis weight of paper. To normalize the bursting strength for various papers, bursting strength is reported as:

6.3.8 Calculations

The target basis weight for each test sheet = 80g/m^2 (7)

The equivalent sheet mass = $\frac{80g/m^2}{\pi \cdot (0.1m)^2} \approx 2.5g$ (8)

Initial dry content of pulp = 94% (9)

360g dry pulp equivalent taken = $\frac{360g}{0.94} \approx 383g$ wet pulp (10)

Pulp consistency at refining = $\frac{360g}{23l} \approx 15.7g/l$ (11)

Pulp needed for ^{0}SR number = $\frac{2g}{15{,}7g/l} = 0.127l$ of refined pulp (12)

Estimated ^{0}SR number of refined pulp = 24 (13)

Actual dry content of pulp = $\frac{360g}{(5000+18000+383)g} \cdot 100\% = 1.54\%$ (14)

<u>360 g</u> is the needed dry weight of pulp

<u>5000 g</u> is the dry weight plus water in pulp (calculated based of dry weight of pulp).

<u>18000 g</u> is the mass of water added

<u>383</u> g is the mass of other components (fillers and starch)

So, the formula 14 is about the final dry weight of the pulp to be used for making the test sheets.

The corresponding mass of each component of a test sheet was calculated with respect to its reference dry content as follows:

Needed amount of wet pulp = $\frac{2.5g}{1.54\%} \cdot 100\% = 162.33g/sheet$ (15)

6.4 Results

The results of the test made in the experimental part are below. “Conditioned climate means (Temperature 23 ^{0}C, humidity 50%) and” Normal Climate means normal laboratory temperature”

Table 6.11The result of testing of hand –sheets made from ***mechanical pulp***

Category	Basis weight /sheet (g/m2)	Average Thickness (mm)	Density (Kg/m3	Bulk (cm3/g)	Air permeance (ml/min)	Roughness (ml/min)	Tensile strength (Nm/g)	Tear strength (mNm/g2)
Normal Climate	**63.1**	**0.194**	**629**	**3**	**5**	**3**	**0.2**	**4.1**
Conditioned Climate	**63.9**	**0.1701**	**627**	**3.2**	**5**	**5**	**0.34**	**5.9**

Table 6.12 The result of testing of hand –sheets made from ***Chemical pulp***

Category	Basis weight /sheet (g/m2)	Average Thickness (mm)	Density (Kg/m3	Bulk (cm3/g)	Air permeance (ml/min)	Roughness (ml/min)	Tensile strength (Nm/g)	Tear strength (mNm/g2)
Normal Climate	**82.1**	**0.132**	**675**	**1,5**	**5**	**4**	**0.61**	**3.1**
Conditioned Climate	**82.3**	**0.1327**	**676**	**1,6**	**5**	**5**	**0.68**	**3.9**

Comparing the results of testing of hand –sheets made from mechanical pulp. The papers, which were put at conditioned climate room, are almost less thick than the papers which were put in normal climate room. And the paper became rougher and more difficult to tear and pull. These all show that paper at constant climate room and paper in normal constant climate room have a big difference between these paper properties.

As can be seen in figures 6.13 and 6.14, the paper properties of papers made from chemical pulp put in normal climate room are almost the same as the papers which were put in the constant, because the properties of paper depend on the type of fibres used. The fibre properties of chemical pulp were shown in the theory part.

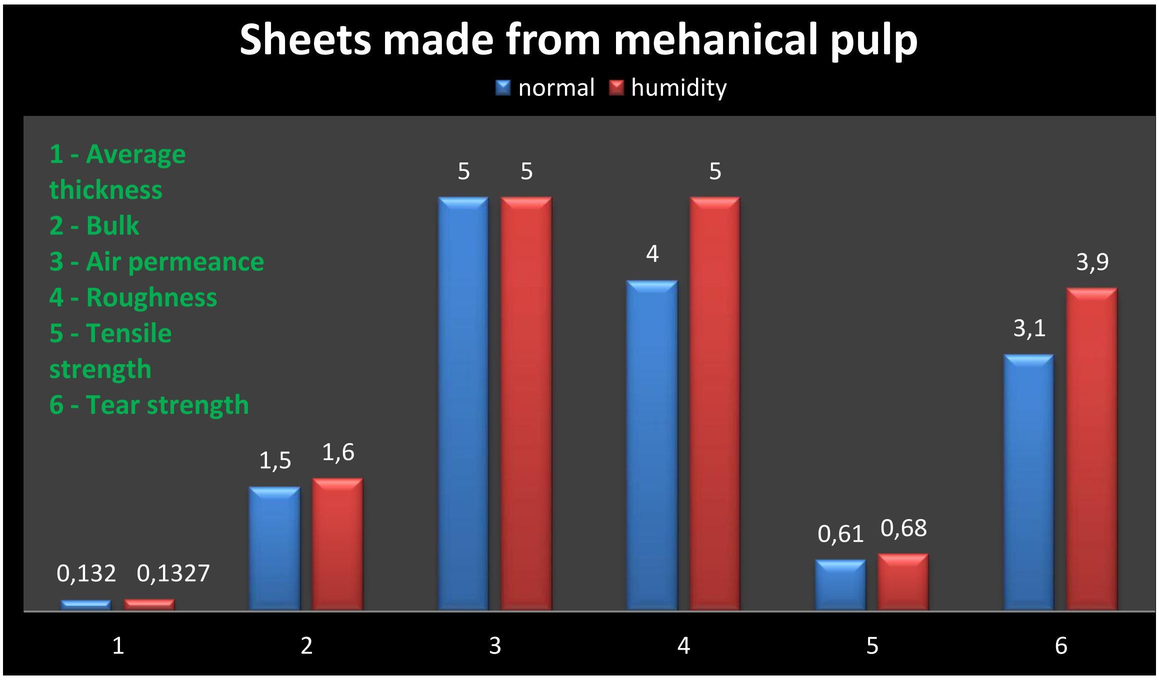

Figure 6.13 Sheets made from mechanical pulp

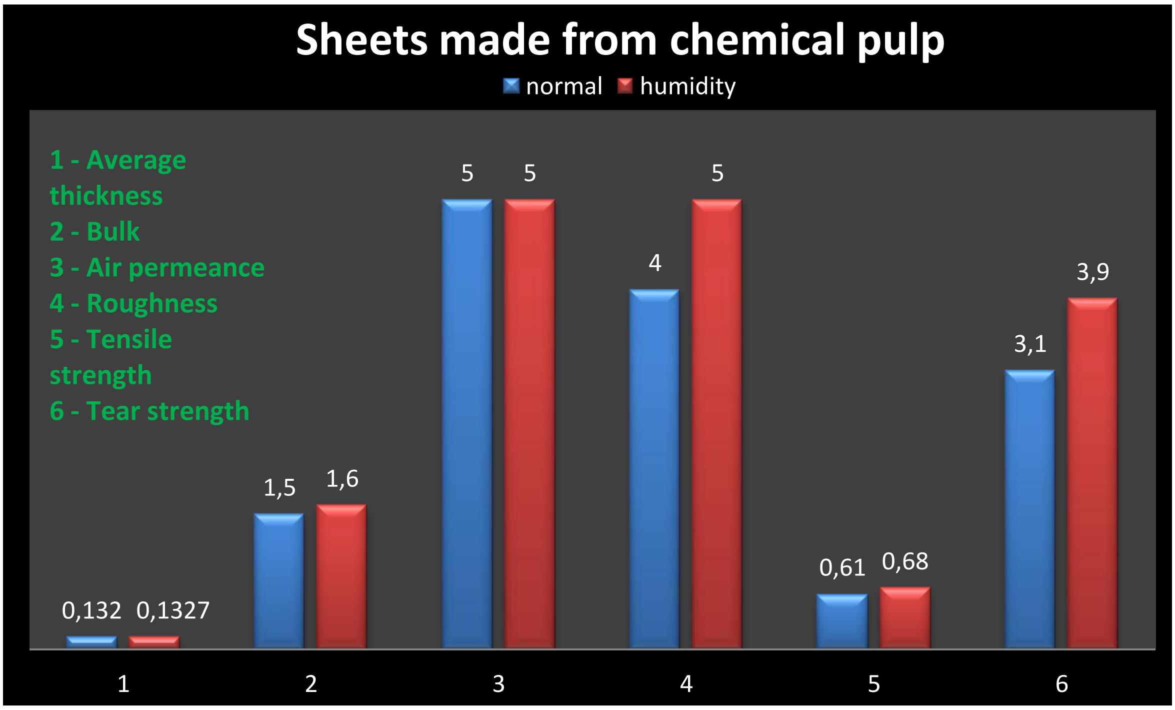

Figure 6.14 Sheets made from chemical pulp

6.5 Conclusion and discussion

The effects of the variables of humidity on paper properties are obvious.

- Different papers are made from different pulp and have different paper properties. The properties of paper depend on the type of fibres used.
- Higher wet pressing degree brought higher density of paper sheets. The air permeance and roughness were reduced as the wet pressing degree increased.
- Mechanical paper sheets have lower weight than chemical paper sheets.
- The density of paper sheets which were made from chemical pulp is bigger than mechanical
- The tensile and tear strength values are increased, when mechanical papers were put in constant temperature room.
- Thickness is reduced while mechanical sheets paper is put at constant room temperature.
- The humidity effects the hand-sheet paper, which was made from mechanical pulp more than the sheets made from chemical pulp.
- The result obtained from this study demonstrated some level of agreement with the literature. The widely published compromise in the finished product could be clearly seen from the analysis of the results especially as it affects on tensile and tear strength properties. The effect of air is humidity was also pronounced particularly under the bursting strength tests.
- It could therefore be said that despite the variances and unavoidable errors relating to experimental work, this study was a success because of its correlation to various literature documentations.

7 CONCLUSION

There is a lot of evidence that the climate of the earth is changing. Human activities are releasing greenhouse gases into the atmosphere and already changing the climate. Human society will face new risks pressures. Economic activities, human settlements, and human health will experience many direct and indirect effects. The poor and disadvantaged are the most vulnerable to the negative consequences of climate change. The international community is tackling this challenge through the climate change convention. While the amounts of greenhouse gases from forest industry and other pollutants in the atmosphere have increased, the climate has been changing rapidly. Climate is changing and there will be more rainy days. Change is bigger in winters than in summers. If we do not change our behavior, the temperature in Finland and Morocco will get higher, even if it will be by half a degree in ten years. So, if we do not reduced pollution (low water use, TCF, sulphur free pulping) from pulp mill and replace fossil fuels, in 2100 the temperature will be even five degrees higher than now. In winter the temperature would be about six degrees higher than now and we would have only a little snow.

Finland and Morocco are two nations which are totally different on greenhouse gases emissions. While Finland ranks as the world’s most modern and cleanest with high technology that supports the least carbon dioxide emission, Morocco occupies the same place as France in the atmosphere pollution level. The situation in Finland could be sustained but Morocco must improve and completely change in the positive direction. Although Finland has increased use of renewable energy and increased capacity of nuclear power, it still has a lot to do to achieve the targets of the Kyoto Protocol. Morocco, the first country in North Africa and Middle East to announce an environment charter, has among its large projects a solar energy project that would supply equivalent of 30% of the current electricity need in Morocco. Morocco is also planning for an equivalent amount of wind energy along the western and northern coast lines. But still Morocco has a lot to do to decrease a considerable amount of GHG emissions. Effluent free mills in the future (if environmentally necessary)

Sustainable forestry industry management and Decrease of water and energy consumption in general.

Pulp and paper industry is responsible for a big amount of greenhouse gases emissions, mainly derived from its consumption of energy. Therefore, emissions related to heat and power demand through papermaking process should be determined and analyzed in detail in order to set appropriate targets and invest in successful emission reducing measures.

In the past production was the major goal of pulp and paper industry. And nowadays the main subject of new pulping processes should be: 1) reduced pollution: Sulphur release to be decreased in pulp mill, because are detrimental both to human health and the environment, 2) simple cooking process closed systems, 3) use of various wood species, 4) application to all wood species, 5) using modern technology and improve knowledge for example Sulphur dioxide can be reduced using various-related technique.

Finland owns the greatest forest coverage in Europe and Morocco owns greatest forest coverage in North Africa, but the difference is that Finland pollutes much less compared to Morocco, and it has much more advanced industrial technology and management system. Morocco must adopt modern technologies and improve knowledge. At the same time, the developed countries should offer assistance and necessary support to improve the quality of the industrial performance in developing countries. These two points makes the learning and co-operations scale of the forest industry.

Actions concerning renewable-based energies and consolidation of best efficient technologies, will primary imply a specific support of energy from government and the industry (paper and pulp). In addition, understanding the wide range of operating pulp mill conditions and their consequences on the behavior of the process, in the perspective of both the economical and environmental aspects, is in many cases critical for the success of the control system.

To be able to slow the rate and intensity of climate change from the increased greenhouse gas emissions, there are a lot things that need to be changed. First of all Sulphur release to be decreased in pulp mill, using fossil fuels as an energy source should be minimized, relying more on cleaner, renewable energy sources such as wind and solar. Wasting less energy by improving the energy efficiency can reduce the amount of the carbon dioxide emissions and also save a lot of money. Government actions are needed to be able to reduce the greenhouse gas emissions. The government can contribute to the amount of the carbon dioxide emissions produced from pulp and paper mill by phasing in taxes (for example Finland will do that at the beginning of 2012).

Global warming necessarily is all bad. As said, what is happening is happening very rapidly. We have to look at this in global context. We all live together on this planet and, for all of us, we will be affected in one way or another by the adverse effects of global warming on food security, water security, migration of populations who can no longer live where they currently live, cities in danger from rising sea-levels, from extreme weather. Wherever we look the impacts are damaging.

I must say we do not have much time and we must act urgently. The only way we can maintain our integrity and dignity is not to retreat into apathy and indifference but to become more active. Telling the truth does not mean you stop acting if the truth is very bad. If you are not despairing, you are not listening to the scientists because that is the reality. It is too late to avoid dramatic climate change this century, but there are degrees of change that can be influenced by what we do over, in particular, the next decade or two.

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List of standards used at work Appendix1

- Laboratory beating of pulp - PFI mill method - ISO 5264/2 - 1979(E)
- Determination of drainability of pulp by Schopper-Riegler method - ISO 5267/1 - 1979(E)
- Determination of fibre length - TAPPI single fiber mode
- Preparation of laboratory sheets for physical testing -- Part 2: Rapid-Köthen method- ISO 5269-1:1998(E)
- Determination of tearing resistance (Elmendorf method) - ISO 1974:1990(E)
- Determination of tensile properties - ISO 1924 - 1:1992(E)
- Determination of bursting strength - ISO 2758:1983(E)
- Determination of thickness, density and specific volume - ISO 534:2005
- (E) Determination of air permeance (medium range) -- Part 3: Bendtsen method - ISO 5636-3:1992