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Diploma Thesis

Emission Trading in the European Union

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Declaration

I declare that I have worked on my diploma thesis titled “Emission Trading in the European Union” by myself and I have used only the sources mentioned at the end of the thesis.

In Prague on 7 April, 2010 ______________________________

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Emission Trading in the European Union

Obchodování s emisemi v Evropské unii

Summary

In the thesis, one of the regulation tools to mitigate greenhouse gases emissions in the European Union is analysed. This is done by market driven mechanism of Emission Trading Scheme, which is based up on similar rules as a stock exchange. Willingness to participate in the mechanism and different ways how to explain performance in the European Trading Scheme of European countries are subjects of the thesis. The analysis is done through a study of various economic indicators, and modelling in regression frameworks. Based on the research, it is concluded that the new EU countries benefited from the scheme because of system based on historically set limits. Different points of view on emission polluting show different outcomes which are relevant only when they are explained from wider perspective. Not only economic but also historical, social and political situation of countries is important.

Keywords: Emission trading, European Union, Kyoto Protocol, air pollution, greenhouse gas, carbon dioxide, allowances, pollution permits, emissions

Souhrn

V této práci je analyzován jeden z regulačních nástrojů na snížení emisí skleníkových plynů v Evropské unii. Tento nástroj spočívá v obchodování na burze emisních povolenek v rámci mechanismu Emission Trading Scheme. Předmětem této práce je zjistit ochotu Evropských států účastnit se tohoto mechanismu a je zde vysvětleno hodnocení znečištění z různých pohledů. Analýza je vyhotovena na základě studie různých ekonomických indikátorů, dále je zde zahrnuta analýza lineární regrese. Ze závěru práce vyplývá, že nově přistupující země Evropské unie vydělávají na systému obchodování, což je zapříčiněno převážně nižším nastavením emisních cílů pro tyto země na základě historických hodnot přidělování povolenek. Odlišné pohledy na měření emisí v různých zemích vykazují rozdílné výsledky. Tyto rozdíly je možné interpretovat pouze na základě podrobnější analýzy situace, neboť na vypouštění emisí má vliv nejenom ekonomická situace země, ale také historické, sociální a politické klima.

Klíčová slova: Obchodování s emisemi, Evropská unie, Kjóto protokol, znečištění vzduchu, oxid uhličitý, povolenky, emise

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CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CITL	Community Independent Transaction Log
COP 3	the third Conference of the Parties to the Kyoto Protocol
DTI	Distance to Target Indicator
ECX	European Climate Exchange
ERU	Emission Reduction Unit
ET	Emission Trading
ETS	Emission Trading Scheme (System)
EUA	European Union Allowances
Gg	Gigagram
GHG	Greenhouse Gasses
GWP	Global Warming Potential
HFCs	Hydrofluorocarbons
IPCC	International Panel on Climate Change
ITL	International Transaction Log
JI	Joint Implementation
LULUCF	land-use change and forestry
NAP	National allocation plans
PFCs	Perfluorocarbons
ppm	Parts per million (used in context of CO_2)
RMU	Removal Unit
SF_6	Sulphur hexafluoride
Tg	Teragram
Tg CO_2 Eq	Teragram of Carbon Dioxide Equivalents
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change

1 Introduction

The climate change and the existence of the greenhouse effect have been discussed very often lately. The question whether these changes are caused naturally or by human beings is not the subject of the thesis and it has not been sufficiently proved by any researches yet. The climate changes are increasing the temperature of the Earth, deteriorating purity of water, air and overall living conditions on the Earth. The subject of this work is to point out the climate changes, their causes and explain how it is dealt within the field of air pollution in the area of the European Union. The reduction of emissions and trading possibilities of pollution permits are interpreted.

The European Union has been fully engaged in air pollution since the 1990s; the main turning point came with the third Conference of the Parties of United Nations Framework Convention on Climate Change (UNFCCC) in Kyoto 1997. The European Union has implemented the system of pollution trading since 2005, the European Union Emissions Trading Scheme (EU ETS), which is now in the first period of its existence. In the thesis, the trial period (2005-2007) is analysed, at that time, there were 25 member states; however, Malta and Cyprus have no limits so far, therefore, in this work, 23 countries are analysed.

Countries involved in this system get certain number of pollution permits (allowances), which is equal to pollution each country can emit. The allowances are allocated according to historical performance, and since the pollution is not limited by the area, the system counts with the overall pollution within the whole area of the European Union (the EU Bubble). Within ETS, countries and companies (installations) can trade the allowances freely; the price is set according to supply and demand. Under this system, companies polluting more are not penalised thanks to the purchase of allowances from company that do not use its own allowances, and company polluting less can gain extra money by such transaction. The ETS is mandatory for all EU countries; however, other Kyoto Parties can join the system as well.

The goal of the thesis is to analyse the willingness of determinants to participate on the Emission Trading Scheme, to find out how successful this system is within the

European Union, which countries profited from trading and which lost. Another goal is to find out via linear regression model whether the emissions target fulfilment depends on economic indicators such as GDP per capita, percentage of industry in the economy, Human Development Index and Corruption Perceptions Index, and how these economic indicators influence emission trading. Another part of the thesis is focused on various nuances of emission quantifying, differences in measurement of pollution per capita, per land area and per GDP in market prices is examined. The next part of the thesis is an analysis of price development of emission allowances in the trial period.

2 Objectives of Thesis and Methodology

In this chapter, objectives of the thesis are stated to be fulfilled throughout the thesis and main hypotheses are set to be confirmed or denied. The methodological tools are presented to support the hypotheses and to show the way how to find out the answers posted.

2.1 Objectives

The goal of the thesis is to analyse pollution in the individual EU countries in the trial period (2005-2007) of the emission trading and the ways the pollution is interpreted. Since there are many ways of looking at pollution quantification, in this thesis, pollution per capita, and per living area and per GDP in market prices are examined to find out what is the best way of quantification. Another objective is to study willingness to participate on the Emission Trading Scheme, the outcome should tell us how successful this system is within the European Union, which countries profited from trading and which did not. Another objective of study willingness to participate on the ETS is to find out whether the emissions target fulfilment depends on economic indicators such as GDP per capita, percentage of industry in the economy, Human Development Index and Corruption Perceptions Index, and how these economic indicators influence emission trading; this is done by linear regression model.

All analyses provided in the thesis lead to answer the most important questions, whether the Emission Trading Scheme works well and what countries profited from the trading in the trial period. On the other hand, the paper should also answer what countries were harmed by the system.

2.2 Main Hypotheses

The main hypothesis is that the ETS is a successful tool for reduction GHG emissions and to fulfil the Kyoto Protocol targets. Willingness to fulfil the ETS depends mainly on GDP per capita, percentage of industry in the economy, Corruption Perceptions Index and Human Development Index. Fulfilment ability in each state depends also on history, political situation, current pollution, environmental policy and many other factors. Another hypothesis is that post-communist countries profited by trading in the trial period because of the amount of allowances allocated according to limits set on the basis of historical figures.

2.3 Methodological Tools

Methodological tools used in this work are mainly economic quantitative analysis of how the EU countries profited on the ETS and econometric modelling using single linear regression model. Another tool is qualitative analysis of allowances price development during the trial period. The last methodological tool is comparative analysis of profits or losses from trading per GDP, land area and per capita for each EU country.

The literature review is based on several environmental publications, e.g. Barnes, P. (2008), Callan and Thomas (2007). The main sources for Emission Trading System background and its performance are the United Nations Framework Convention on Climate Change and the Intergovernmental Panel on Climate Change. The economic data in the work comes mainly from Eurostat and the European Climate Exchange.

3 Literature Review Emission Trading

In this chapter, there it is explained how the climate is changing, what the causes of these changes are and what documents has been implemented in order to mitigate the impact of the changes on the Earth as well as on human beings. There are several ways how to handle air pollution, within the EU, it is done through the EU Trading Scheme, which is described below.

3.1 Climate Change

Every single thing human beings use has source in the Earth, all refuse also ends in the Earth. The more the society is developing, the more it is consuming and the more waste is being released. The development is necessary and desirable; however it should be done in the least harmful way in order to save the nature for future generations, this is called sustainable development. Climate change, global warming and emission pollution are closely connected with sustainable development. The aim of scientists and governments is to find out the solution for development undertaken in environmentally friendly way. Climate change has been a hot topic last several years; it has also become a political issue to be solved. Politicians include environmental problems and global warming into their election campaigns to prove that they are aware of these changes, and want to help in finding out the way how to handle them.

The climate on the Earth is changing, the temperature is rising; this can be proved by rising average temperature on the Earth in last decades, snow and glaciers melting, and the average above sea level is also rising. It is difficult to explain by what means the changes are caused and what/who are the subjects of changes. One of the definitions of climate change, according to Intergovernmental Panel on Climate Change IPCC (2007) is: “Climate change in IPCC usage refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity.” This definition takes into consideration the human factor as well as natural; however, the scientists are not compact on this idea, some says the only cause is man, the others say all changes come from the nature. Since there is no certain answer yet, let us take into consideration both factors. Climate change dealing with the air factors is closely connected with the Greenhouse effect.

3.2 The Greenhouse Effect

The Greenhouse effect makes suitable conditions for living on the Earth. The Earth gains the energy from the Sun via short wavelengths light. Almost one-third of the solar energy is reflected back to the space and the other two-thirds are absorbed by the surface, to heat up the atmosphere and the ocean. Without the Sun shine, the Earth temperature would be -18°C, with the atmosphere, it is about 33°C higher, which is 15°C; on the other hand, the temperature should not be too high either. The GHG emitted by the Earth (land, ocean) absorb the long wave infra red radiance, the atmosphere reduces airflow and heats up; therefore the temperature on the Earth is suitable for living. Thus, when higher emissions of certain gases occur, the Greenhouse effect is intensified and the temperature increases (global warming). That is why the gases in the atmosphere causing the warming are called greenhouse gases (GHG). (Goudie et al, 2002: 540). However, without greenhouse effect there would probably not be any life on the Earth. Our planet would be too cold place for any higher life form.

Greenhouse gases are gases existing in the atmosphere and causing the rising temperature. These are mainly water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and sulphur hexafluoride (SF6), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and other halogen containing gases. According to (IPCC, 2008), there are about 25 types of GHG in the atmosphere; the GHG differ in how long they stay in the atmosphere and in the ability to absorb infra red radiation. All these gases have their natural sources and sinks (removals), on the other hand, there are also some sources created by human beings. Measuring of emissions is usually done by two ways, including and excluding LULUCF, which means Land Use, Land-Use Change and Forestry, according to UNFCCC (n.d.e), the definition of LULUCF is: “Activities in the LULUCF sector can provide a relatively cost-effective way of offsetting emissions, either by increasing the removals of greenhouse gases from the atmosphere (e.g. by planting trees or managing forests), or by reducing emissions (e.g. by curbing deforestation). However, there are drawbacks as it may often be difficult to estimate greenhouse gas removals and emissions resulting from activities of LULUCF. In addition, greenhouse gases may be unintentionally released into the atmosphere if a sink is damaged or destroyed through a forest fire or disease." The figures used in this work are without LULUCF to be obvious what the real sources of GHG are.

In the following *Figure 1*, you can see how these gases are distributed in the air, the measures were done in EU 27 in the year 2007, data comes from UNFCCC (n.d.f), excluding LULUCF. The *Figure 1* shows that emissions released contain mainly CO_2, that is also why emission trading is also called carbon trading and the CO_2 equivalent is traded on the market. From the graph, it is obvious that halogen gases are not so significant; however, they stay in the atmosphere for the longest time.

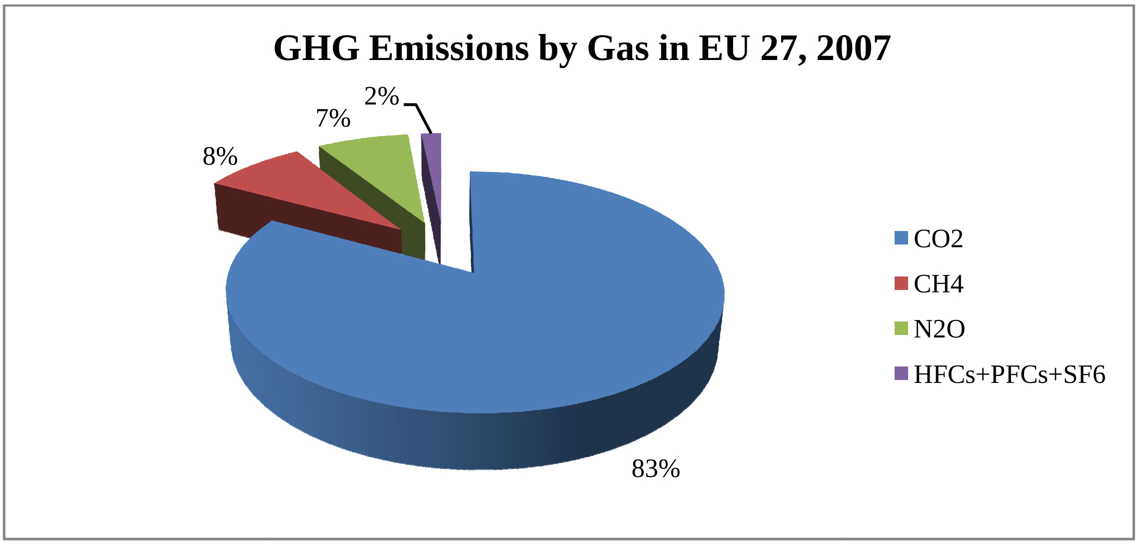

Figure 1 GHG emissions by gas excluding LULUCF, 2007, data: UNFCCC (n.d.f), own graph,

The natural and anthropogenic causes and sinks of the GHG are presented further. Water vapour (H_2O) is the most common GHG, about two-thirds of natural greenhouse effects is caused by H_2O; however its concentration in the atmosphere is rising very slowly. Human activity cannot directly influence concentration of water vapour, that is also the reason this gas is not included in *Figure 1*.

Carbon dioxide is after water vapour the second most significant GHG going through the carbon cycle which consists of the ocean (hydrosphere), the sediments (pedosphere), the plants (biosphere) and the atmosphere. Sources and sinks of Carbon dioxide (CO_2) are either natural or produced by to human beings. Among the natural sources are respiration, volcanism and the sea and the ocean gas exchange. CO_2 is converted into organic compound during photosynthesis (Reay and Pidwirny, 2006). According to IPCC (2008), CO_2 is the most observed GHG mainly because the great part of it is resulted from men's activities: "Emissions of CO_2 from fossil fuel combustion, with contributions from cement manufacture, are responsible for more than 75% of the increase in atmospheric CO_2 concentration since pre-industrial times. The remainder of the increase comes from land use changes dominated by deforestation (and associated biomass burning) with contributions from changing agricultural practices." CO_2 is also produced by combustion in transportation, mainly car and plane.

The amount of carbon dioxide in the atmosphere has been increasing constantly, which is evident from *Figure 2*.

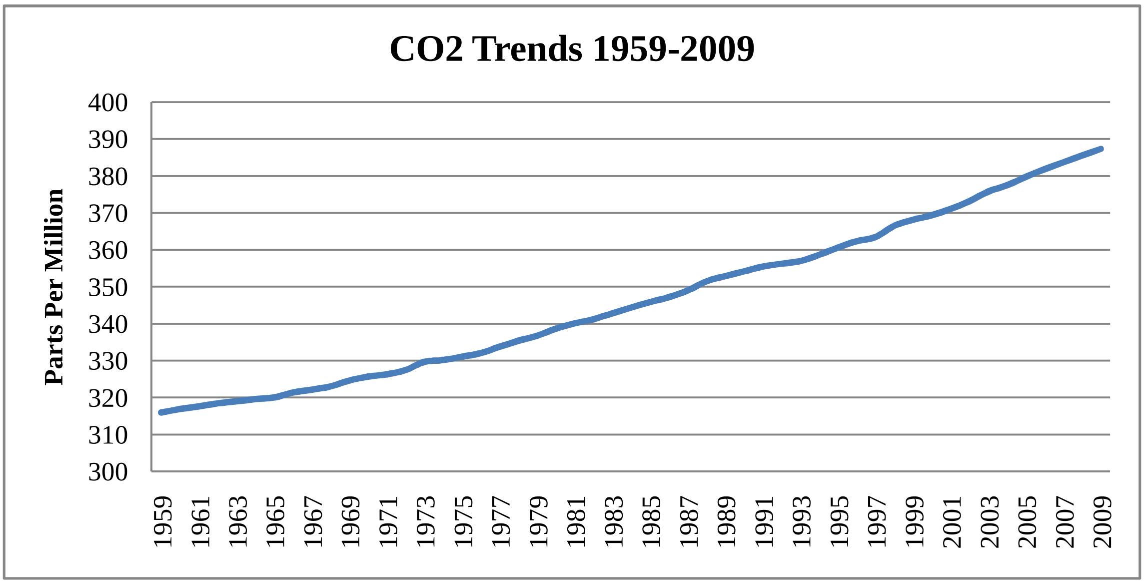

Figure 2 CO_2 trends 1959-2009, data: Earth System Research Laboratory (n.d.), own graph

Since 1959 the concentration has increased from 315 parts per million (ppm) to 390 parts per million in 2005. Ppm is according to Life Science Glossary (2004) is explained as: "very dilute concentrations of substances. Just as per cent means out of a hundred, so parts per million or ppm means out of a million. One ppm is equivalent to 1 milligram of something per litre of water (mg/l) or 1 milligram of something per kilogram soil (mg/kg)."

If the trend of continuous increase of CO_2 keep going, the temperature could continue rising as well, as Pidwirny (2006) says: "Most computer climate models suggest that the globe will warm up by 1.5 - 4.5° Celsius if carbon dioxide reaches the predicted level of 600 parts per million by the year 2050." That is why the CO_2 is so discussed in relation of global warming.

Besides CO_2 another important GHG gas is Methane; human activities causing Methane (CH_4) emissions are waste disposal, biomass burning, energy production from coal and natural gasses. "Once emitted, CH_4 remains in the atmosphere for approximately 8.4 years before removal, mainly by chemical oxidation in the troposphere. Minor sinks for CH_4 include uptake by soils and eventual destruction in the stratosphere," states Pidwirny (2006). Methane is also emitted by breeding cattle and by wetlands.

The other important GHG is Nitrous oxide (N_2O); Pidwirny (2006) says about N_2O: "Human activities that emit N_2O include transformation of fertilizer nitrogen into N_2O and its subsequent emission from agricultural soils, biomass burning, raising cattle and some industrial activities, including nylon manufacture. Once emitted, N_2O remains in the atmosphere for approximately 114 years before removal, mainly by destruction in the stratosphere."

Halogen containing gasses had not occurred until the development of technologies in the 1950s because there are no natural causes of these gases. These gasses also remain in the atmosphere for a long time, depending on the structure. In case of Hydrofluorocarbons (HFCs) it can be according to (IPCC, 2008) from 1 to 270 years, this gas is used for refrigeration and air conditioning. In case of Perfluorocarbons (PFCs) it is thousands of years, this gas is emitted in processing of aluminium.

Sulphur hexafluoride (SF_6) is another GHG, there are only few sinks for SF6, ergo the emissions gather in the atmosphere. This gas is produced in the magnesium industry as US Environmental Protection Agency states that: "Measurements of SF6 show that its global average concentration has increased by about 7% per year during the 1980s and 1990s, from less 1 ppm in 1980 to almost 4 ppm in the late 1990's (IPCC, 2001)."

The next *Table 1* summarizes the natural sources of GHG and anthropogenic causes of the same gases; it also shows how long the gases last in the air.

Greenhouse Gas	Natural Causes	Anthropogenic Causes	Remains in the Air
Carbon dioxide (CO_2)	• respiration • volcanism • sea and the ocean gas exchange	• fossil fuel combustion • food industry • chemical industry • land use change	50-200 years
Methane (CH_4)	• swamps and wetlands	• energy production • landfills • ruminant animals (e.g. cattle and sheep) • rice agriculture • biomass burning • waste disposal	8.4 years
Nitrous oxide (N_2O)	• microbial action in wet tropical forests	• transformation of fertilizer nitrogen into N_2O and its subsequent emission from agricultural soils • biomass burning • cattle and industrial activities including nylon manufacture	114 years
Sulphur hexafluoride (SF_6)		• magnesium industry	3200 years
Perfluorocarbons (PFCs)		• processing of aluminium	thousands of years
Hydrofluorocarbons (HFCs)		• refrigeration and air conditioning	1-270 years

Table 1 Causes of GHG gases, own table

You can see there are sources and removals of GHG, the impact of human activities is evident from the table, human beings produce much more CO_2 and other GHG than nature does, on top of that, they produce GHG (halogen containing gases) that do not occur naturally at all. The problem is that man uses more and more of these gases and they stay in the atmosphere for a very long time.

In *Figure 2* the changes of emissions from the year 1990 until 2007 are presented; it is clear that all but one GHG gases had been reduced, the one is HFCs, which had risen by 125 % mainly because of using air conditioning. Even if e.g. CO_2 has been mitigated, the changes are very slow.

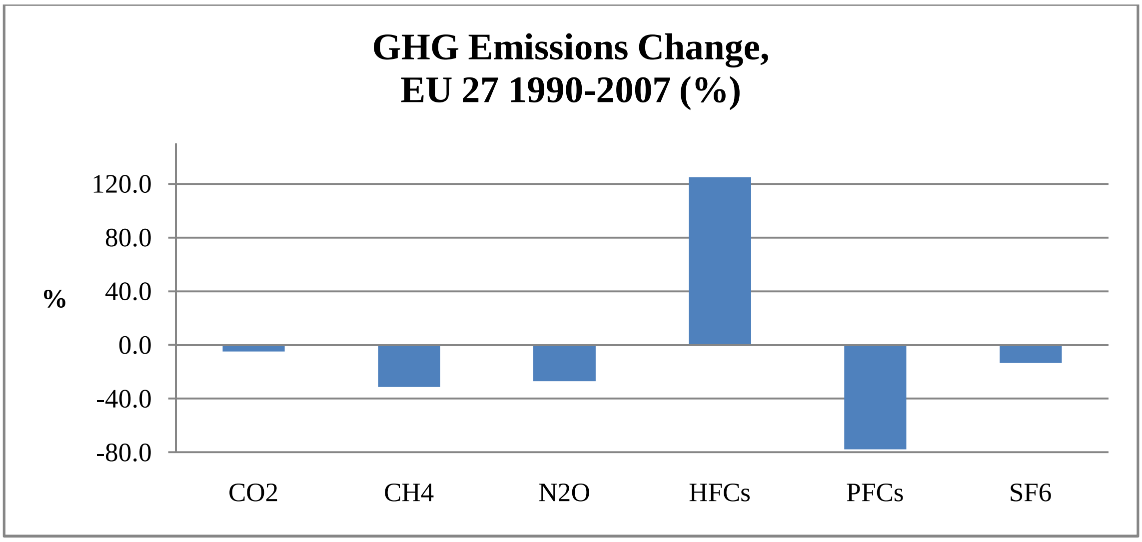

Figure 2 GHG emissions change in EU 27, 1990-2007, data: UNFCCC (n.d.f), own graph

In the *Figure 2*, you can see the shares of sectors on emissions of GHG. It is clear that energy sector is the biggest polluter together with land use change, agriculture and transportation. All sectors are important, however, energy sector together with transportation are two fastest growing (World Resources Institute). It should be said that even if the airline industry is a significant polluter, it was not included in the trading system of emissions in the trial period.

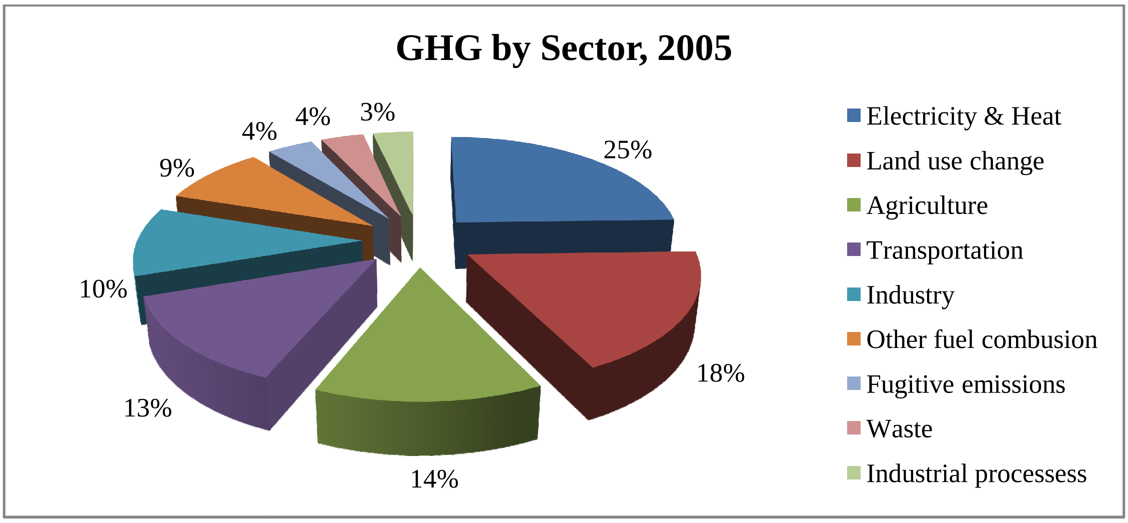

Figure 3 GHG by sector, 2005, data: World Resources Institute, own graph

3.3 Global Warming Potential

The GHG have different influence on climate change, therefore, the GHG impacts are expressed in Global Warming Potential (GWP). GWP measures the potential impact of anthropogenic sources and sinks of GHG on global warming. CO_2 was chosen as a reference gas for calculating the potential as the most common GHG which is also visible form *Figure 1*. The equation of the GWP (1) is defined as: "The GWP has been defined as the ratio of the time-integrated radiative forcing from the instantaneous release of 1 kg of a trace substance relative to that of 1 kg of a reference gas

$$GWP(x) = \frac{\int_0^{TH} a_x * [x(t)]dt}{\int_0^{TH} a_r * [r(t)]dt} \quad (1)$$

where TH is the time horizon over which the calculation is considered, a_x is the radiative efficiency due to a unit increase in atmospheric abundance of the substance in question (i.e., Wm^{-2} kg^{-1}), [x(t)] is the time-dependent decay in abundance of the instantaneous release of the substance, and the corresponding quantities for the reference gas are in the denominator (IPCC, 2001)."

Since the CO_2 is a base unit, it is equal to 1, GWP of CH_4 is 21, N_2O = 310, SF_6 = 23900, HFCs and PFCs contain different substances, for that reason the impact of the change has to be counted individually. It was agreed by UNFCCC that the GWP should be based upon 100 year time horizon. Long-lived GHG are equally distributed in the atmosphere, therefore it is easier to measure their concentration. Short-lived gases are to be found spatially; consequently it is more difficult to measure their impact (US EPA, 2009).

3.4 Externalities

Externalities are factors influencing well-beings of individuals, in this case climate change and pollution can be seen as externality; Johnson (1994-2005) explains the externalities as: “An externality exists whenever one individual's actions affect the well-being of another individual -- whether for the better or for the worse -- in ways that need not be paid for according to the existing definition of property rights in the society.” Externalities can be positive and negative. The climate pollution along with nuclear waste and water pollution is considered as a negative externality (external cost); it is caused when production of one subject results in unintended cost of the other subject. However, the subject causing the externality is not anyhow fined. The fact that people deplete the resources even for future generations, some economists, e. g. Nicolas Stern calls “market failure” (Barnes, 2008). To simplify it, if one lives in the house nearby a factory polluting the air belonging to everyone, the one is negatively influenced by pollution coming from the factory; the one pays unintended social costs.

Public and private goods should be also described here; two types of ownership can be distinguished when describing goods – public and private. Private goods have always an owner, or user, who disposes of the property right. On the other hand, public goods, air, water and land, have, according to Callan and Thomas (2007) two main characteristics, nonrivalness and nonexcludability. “Nonrivalness refers to the notion that the benefits associated with consumption are indivisible meaning when the good is consumed by one individual another person is not prevented from consuming it at the same time.” E.g. the TV broadcasting allows millions of people using the same media in one time. Nonexcludability is explained by Callan and Thomas (2007) as: “The Characteristic that makes it impossible (or prohibitively costly in a less strict sense) to prevent others from sharing in the benefits of a good's consumption." E.g. a public highway cannot be used by just selected people.

The supply of public goods cannot be adjusted to the demand, because these goods are available to everybody in the same quantity. What can be adjusted is the price; these goods have different values for different people, this intention is called willingness to pay (WTP). WTP differs according to wealth of the person, his or her expectations, taste, income, benefits and many other aspects. As Callan and Thomas (2007) say: "The market demand for a public good is the aggregate demand for all viable consumers in the market. It is derived by summing each individual demand vertically to determine the market price, at each and every possible market quantity."

Many factors can influence the change of the Earth's climate (average weather); however, the incoming and outgoing energy should be equal; if it is not, then the temperature rises or decreases. The causes can be either natural or anthropogenic. Firstly, we should consider the natural glacial and interglacial periods where the temperature rises and decreases in natural cycles. The factors for climate change are external and internal; among external factors, greenhouse gas (GHG) emissions are included along with deviations in the Earth's orbit and atmospheric carbon dioxide variations (solar variation). The internal factors are the ocean, land and atmosphere (volcanism, mountain building). (Pidwirny, 2006)

Scientists from U.S. Geological Survey have found out that the emissions from volcanoes into the atmosphere are about 130-230 million tonnes of $CO_{2,}$ compared to CO_2 emissions caused by human activities (fossil fuel burning, cement production) equals to 27 billion tonnes per year (USGS, 2009).

Volcanic eruptions emit high amounts of sulphur dioxide remaining in the atmosphere for about 3 years; scientists have found out that eruptions cause short-term temperature drop. Sun's output radiation also changes over the time; the output changed by 1 % per century may change the Earth's temperature by between 0.5 to 1.0 °C.

Implementing the tradable pollution permits system is discussed in connection with all natural commodities, e.g. problem of water pollution, nutrition trading, and salt trading; these pollution reductions are discussed mainly in the USA, Australia and Chile (Kraemer, Kampa and Interwies, 2004).

Pollution can be also seen as a market failure, which can be defined by the theory of public goods or the theory of externalities. Market failure, according to (Callan and Thomas 2007) is: “The result of an inefficient market condition such as imperfect competition, public goods, imperfect information, nonexistence of markets, and externalities.” The pollution is a market failure because the market does not take into account the cost of negative externalities, on the market; the social costs are not included.

Marginal abatement cost Curve (MAC) in *Figure 4* can illustrate the principle of pollution trading. On the horizontal axis, there is abatement and the vertical represents marginal abatement cost and benefit.

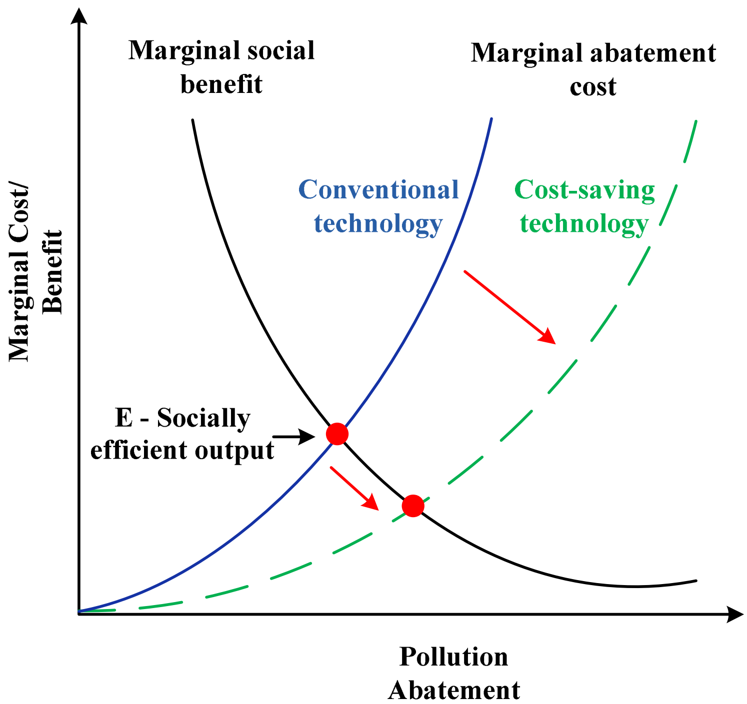

Figure 4 Marginal abatement cost and social benefit curve, own graph

Marginal Social Benefit curve represents demand for a certain good or service in comparison with the price consumers are willing to pay. Using cost saving technologies may bring higher costs at the beginning, however, during time it will bring benefits by the means of fewer costs for pollution permits, and, it will definitely bring benefits to society in the way of less pollution. If one pollution emitter releases more emissions than he is allowed to, he will be paying high fines, or, he will have to buy other allowances anyway. Therefore, it might be profitable for subjects of emissions to invest into new environmentally friendly technologies rather than paying higher fees afterwards. In the real economy this is measured by the net present value of such investment.

3.5 Reducing Greenhouse Gas Emissions

The causes of GHG emissions and global warming were already defined. If the GHG are reduced, the global warming can possibly slow down. The question is how to mitigate the emissions of GHG? According to (Barnes, 2008), four tools can be used to limit emission of GHG: taxes, regulations, investments and caps. First of them is a carbon tax, which would charge for emitting CO_2 and thereby decrease the emissions and bring yield to the government. Barnes (2008) sees one main difficulty: "The big problem with a carbon tax is that it has to be very high to decrease pollution sufficiently. When people are addicted to a substance or source of energy, they're willing to pay a lot more before they stop using it."

The other tool is a regulation, rules imposed by the government to certain businesses. Barnes (2008) states that the regulations can force businessmen to perform more effectively: "Examples of climate-related regulations are automobile fuel-efficiency standards, renewable-energy portfolio standards (requiring utilities to generate a rising percentage of their electricity with solar or wind power), and efficiency standards for appliances and buildings." However, the system would have to work for each sector individually.

Investments is another tool to mitigate GHG, they can occur in a form of expenditures or tax breaks. Their aim is to financially support the activities that the market is not able to support itself. To distinguish the right investments and not to surrender to the pressure of the giant companies may sometimes be difficult.

Caps represent the fourth tool according to Barnes (2008): “To implement a cap, the government issues a gradually declining number of emission permits. Once issued, these permits can be traded. (It doesn’t matter who emits carbon as long as total emissions decline.)” Carbon trading respects demand of this market and also the price is adjusted over the time. If the system is well implemented, it can work well and the individual subjects can gain from the trade. The idea of cap-and-trade originated already in the 1960s (Barnes, 2008). The-cap-and-trade system is analysed further.

3.6 Documents Ensuring Emission Reduction

Several documents deal with the problem of emissions and similar environmental problems, these are e.g. the Declaration of the United Nations Conference on the Human Environment, Stockholm, 1972, Vienna Convention for the Protection of the Ozone Layer, 1985, and the Montreal Protocol on Substances that Deplete the Ozone Layer, 1987 and many others. The first one, Air Pollution Control Act, was introduced in the USA in the year 1955; however, here is a closer look at two most important documents for the EU related to emissions.

3.6.1 United Nations Framework Convention on Climate Change

The Convention was introduced at the United Nations Conference on Environment and Development (UNCED), also known as the Earth Summit, held in Rio de Janeiro in June 1992. The members of Convention have acknowledged that climate on the Earth has been changing and environment has been deteriorating as the human activities have changed to make people’s lives easier. These activities are connected with manufacturing, processing and technical development, which effect in higher production of greenhouse gasses (GHG). The Convention has found out that most of emissions come from developed countries; however, the concentration of these gasses will rise as the developing countries will blossom. The objective of the treaty is to reduce GHG emission to sustain the environment for future generations. The text of the

Convention on Climate Change was adopted in New York, 9th May 1992 and it has been ratified by 192 countries. The Convention entered into force 21st March 1994.

The Treaty contains 26 Articles, Preamble and Annex I and Annex II. In the Preamble, there is stated why the text was created, the recognition that the situation is more difficult for developing countries as well as low-lying and arid countries. According to the United Nations (1992) the situation is presented as: "Recognizing that all countries, especially developing countries, need access to resources required to achieve sustainable social and economic development and that, in order for developing countries to progress towards that goal, their energy consumption will need to grow taking into account the possibilities for achieving greater energy efficiency and for controlling greenhouse gas emissions in general, including through the application of new technologies on terms which make such an application economically and socially beneficial." To explain how protect climate changes, the Articles were written, they deal with objectives and principles binding for ratifying countries; involved countries are listed in the Annex I (industrialized countries), see *Supplement 1* and Annex II (developed countries).

All parties have different responsibilities and national priorities, however, all Parties shall: Collect and publish data concerning anthropogenic emissions, publish national schemes, promote sustainable development, public access to information about climate change and support exchange of information dealing with climate changes. Countries of Annex I and Annex II have some specific fulfilments (United Nations 1992). The Convention encourages countries to reduce emissions, the Kyoto Protocol, which is described further, sets regulations how to manage it.

3.6.2 Kyoto Protocol

The Kyoto Protocol to the United Nations Convention on Climate Change was adopted at the third Conference of the Parties, called COP 3 (the supreme body of the Convention with decision-making power) in Kyoto, Japan, 11th December 1997. It was ratified by the EU countries in May 2002 and it came into force in February 2005. The ratification lasted so long as Parties were waiting for Russia, which was not willing to ratify the document. Russia's ratification was needed because the Protocol had to be ratified by countries representing at least 55 % of pollution from 1990. Russia is the second largest source of GHG in the world after the USA, which has not ratified it at all, even if Clinton Administration signed the document. However, 3 years later it was rejected by Bush Administration. Russia ratified Kyoto only under the condition that EU would support its admission into the WTO. Because of collapse of Russian industry, there was a huge opportunity for Russia to gain by trading.

The Protocol contains 27 Articles and 2 Annexes and defines the first period for countries listed in Annex I to limit emissions of GHG by at least 5 % below 1990 level in period 2008-2012. According to Article 4, paragraph 1 UN (1998), countries commit themselves to: "jointly fulfil their commitments under Article 3 shall be deemed to have met those commitments provided that their total combined aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A do not exceed their assigned amounts calculated pursuant to their quantified emission limitation and reduction commitments inscribed in Annex B and in accordance with the provisions of Article 3. The respective emission level allocated to each of the Parties to the agreement shall be set out in that agreement."

However, each country sets up its own goal; target of the EU countries was to reduce GHG emissions by 8 % in the whole European Union (the area of EU is called EU Bubble); this allows some countries to produce more and some produce less so long as the overall commitment is fulfilled. This is called Burden Sharing Agreement (BSA). The Kyoto Protocol binds industrialised countries to cut GHG emissions by 5.2 % compared to year 1990 during the first commitment period 2008-2012. However, for some parties the different base year was chosen, from our examined Parties, these are some of post communist countries, Hungary, Poland and Slovenia. The base year for each of these Parties is as follows; Hungary, the average of the years 1985 –1987; Poland: 1988; and Slovenia: 1986.

In Annex B of Kyoto Protocol, see *Supplement 1*, there is a list of countries and their reduction commitment. There are also post-communist states listed, to which it is referred further in the thesis.

GHG being subjects of emission reduction are listed in Annex B of the Kyoto Protocol, these are following:

- "Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulphur hexafluoride (SF_6)."

In the *Supplement 1,* there is also a list of industrial sectors examined. Article 24 specifies the conditions that had to be reached before the Protocol had come into force: "This Protocol shall enter into force on the ninetieth day after the date on which not less than 55 Parties to the Convention, incorporating Parties included in Annex I which accounted in total for at least 55 per cent of the total carbon dioxide emissions for 1990 of the Parties included in Annex I, have deposited their instruments of ratification, acceptance, approval or accession" United Nations (1998). This is the reason why the ratification of Russia was so important; without Russia, the Parties would not reach 55 % share of all CO_2 emissions.

Each GHG can be limited individually, or, more gases can be limited at once. Nonetheless, GHG usually have the same source of emissions; therefore in order to cut down the emissions of one gas, the others are also limited. If more gases are emitted, the gas equivalent, GWP, is used to express how dangerous the gas is.

Today, the only traded GHG in the EU is CO_2. This gas is emitted mainly from fossil fuels that are being excessively used up. This is the reason why the oil peak will be reached soon and that is also why fossil fuels should be replaced by renewable resources (Campbell, 2000).

Countries ratifying the Kyoto Protocol pledged to reduce emission of GHG. Countries polluting less can gain from trade via buying and selling; however, even countries polluting more can profit, they can meet their targets thanks to low goals recorded by the Treaty.

3.7 Emission Trading

After realizing why the emission market was established, it is important to understand how the trading is implemented. The emission market is analogous to the exchange stock market where the stocks are traded. On the carbon market, the commodity traded is an allowance (tradable permit) which is bought and sold by various subjects. One allowance is equal to one tonne of emitted CO_2 equivalent and the price is set up according to supply and demand on the market. Every source of pollution (installation) is obliged to keep the same amount of allowances that emits. The subject of trading is the state as well as individual company. An allowance should not to mix with a permit, which is not tradable, it is an administrative permission including monitoring and presenting data where a polluter is bound to make no excessive polluting emissions than stated by a permit, otherwise the polluter would be fined.

“Greenhouse gas emissions permits shall contain the following:

(a) the name and address of the operator;

(b) a description of the activities and emissions from the installation;

(c) monitoring requirements, specifying monitoring methodology and frequency;

(d) reporting requirements; and

(e) an obligation to surrender allowances equal to the total emissions of the installation in each calendar year, as verified in accordance with Article 15, within four months following the end of that year” European Union (2003).

According to this system, the state reallocates the allowances to individual companies; the owner of 1 allowance can emit 1 tonne of CO_2. The reallocation (cap-and-giveaway) is done according to historical amount of pollution (who polluted less in past, will get less allowances now). This is done free of charge, that is why it is called grandfathering. The cap can be reached either by the reduction of emitted CO_2 or by buying additional allowances from the company emitting less. The total number of allowances are fixed; from this, it is obvious that the other company has to reduce its emissions in order to sell the allowances and gain from the trade yet the common goal (to reduce less) is reached (United Nation 1998).

Parties specified in Annex B of the Kyoto Protocol committed to reduce emissions in period 2008-2012. Article 17 of the Kyoto Protocol specifies that trading countries can have some extra emission units which they do not use and sell them to countries that are short of these units. The emissions are divided into assigned amount units (AAUs); the units are sometimes also called 'Kyoto units'.

The units are differentiated according to purpose of their use, the division is according to UNFCCC (n.d.a): "The other units which may be transferred under the scheme, each equal to one tonne of CO_2, may be in the form of: a removal unit (RMU) on the basis of land use, land-use change and forestry (LULUCF) activities such as reforestation; an emission reduction unit (ERU) generated by a joint implementation project; a certified emission reduction (CER) generated from a clean development mechanism project activity."

Fluctuations of these units are monitored by the Registry systems under the Kyoto Protocol. Two types of registry exist: National registries implemented by Annex B parties; the accounts are named according to the government or legal entities under the government. CDM registry – issuing CDM credits and distributing them to national registries, the registries are owned only by CDM parties, CDM explained further.

In the *Figure 5* below, you can see how the registration works. All transactions go through International Transaction Log (ITL) verifying them and checking that all accounts are registered properly. After the Kyoto commitment period is finished, the emission amounts are compared to amounts during the commitment period to evaluate whether the Kyoto targets are reached, as it is stated in UNFCCC (n.d.b): "For the start of the Kyoto commitment period in 2008, EU registries are to switch their connections from the CITL to the ITL. The ITL will conduct "Kyoto checks" on transactions proposed by both EU and non-EU registries. In the case of transactions involving EU registries, the ITL will forward information to the CITL so that it can conduct "supplementary checks" defined under the EU scheme."

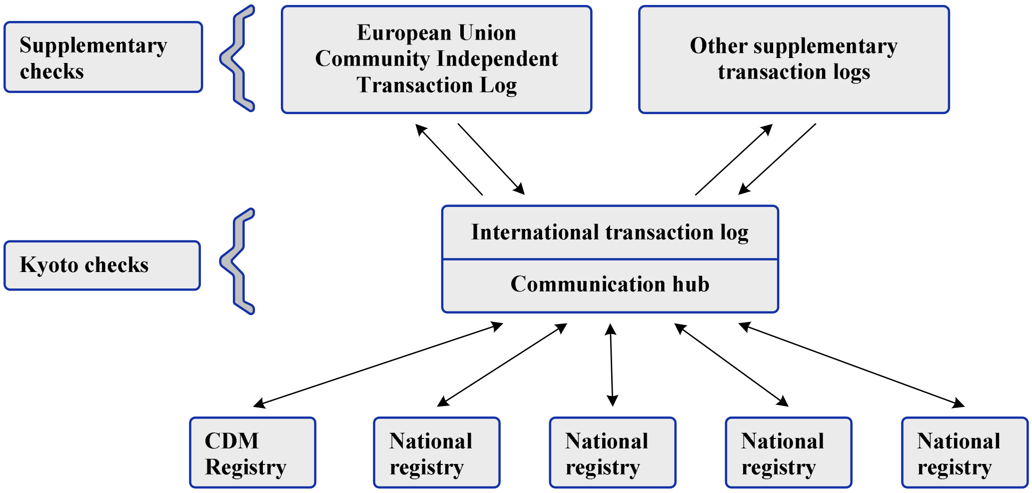

Figure 5 Registration, data: UNFCCC (n.d.b), own graph

3.7.1 Emission Trading Scheme

Several mechanisms have been introduced to control emission trading; some of them are still in force. The UK Emissions Trading Scheme is an example of finished scheme, this voluntary scheme expired in 2006, had already started in 2002, and it was the first multi-industry scheme in the world. The real pioneer was Danish greenhouse gas trading scheme; however, it worked only locally. Since these schemes are not in power anymore, the EU ETS, which is based on UK ETS was implemented and is specified further. Systems dealing with reduction of GHG emissions are also called cap-and-trade systems (defra, 2006).

Cap-and-trade system means limiting the GHG emissions side by side with the possibility to trade the allowances. The cap is understood as the limit of emissions that should not be exceeded; if the limit is surpassed, the additional allowances from other companies can be bought (trade). The limits will be lower until the reduction goal is met and possibly the temperature is stabilised.

The subject to trade are companies emitting high amounts of GHG (installations), these are mainly power and heat generation industry, combustion plants, plants processing steel and iron and factories producing cement, glass, bricks and similar. From the first trading period, the airlines have been also included among these installations.

The EU ETS is treated independently in every member country of the EU by National allocation plans (NAP). National allocation plan is a document stating the maximal amount of emissions confirmed by the Ministry of certain country for the state as a whole, having national account and also for individual companies, which have their own accounts). The NAP is stated for each tradable period explaining how the emissions are distributed. Each member state has its own registry to follow the transfer of emissions; nevertheless, the approval of the National allocation plan heavily depends on the Registries Regulation of the European Commission. This is considered as great regulatory intervention from the EU to each individual state economy. As a consequence of double control, there is no possibility for the state to trade without gaining approval of its NAP (Ellerman and Joskow, 2008).

The allocation, verification and the whole process of trading is done under Directive 2003/87/EC, for details see *Supplement 2,* where important Annexes are cited; the result of Directive is that not individual installations, but each state is responsible for following the rules set by the Commission. Each state gets certain amount of allowances at the beginning of the trading period and distributes them to subjects of trading in their country in 95 % for free, more; the state saves certain amount set by NAP for known and potential newcomers. If the reserve is not redistributed, the state can sell them in the auction at the end of trading period. The companies get the allowances at once and there is no annual limit for allowances to be used up each year, it is up to each company to manage its consumption. The banking, which means saving allowances to other period is allowed, however, borrowing from next period is not.

To pursue the installations to decrease the emissions, member states should set up penalties and so ensure to keep installations within limits. The penalty was EUR 40 per one tonne of CO_2 equivalent in the trial period, in the first period it is even higher, EUR

100 and after 2013 the fine is considered to even rise. Companies emitting extra pollution and paying fines are 'named and shamed' (published) openly.

3.7.2 Emission Reduction Mechanisms

Kyoto Protocol also describes the means of reduction of GHG emissions, the flexible mechanisms allowing to trade emissions are Clean Development Mechanism (CDM), Emission Trading (ET) and Joint Implementation (JI). These mechanisms are called flexible because the flexible amount of emissions is reduced in each EU country with common aim, to diminish emissions in the whole EU. The flexibility stated in the Burden Sharing Agreement (specified above) is compulsory after ratifying. Emission reduction systems are specified further.

The EU ETS is the trail-blazer among emission systems; it entered into force on 25th October 2003. The scheme is based on Directive 2003/87/EC and was implemented on 1st January 2005 by 25 member states of the EU at that time in order to meet the goals set by the Kyoto protocol; nevertheless, the system is independent of the Protocol and it had started even before the Protocol became operative. With the entering into the EU, the candidate states were made to participate in European Trading Scheme automatically. However, in this work, 23 states are analysed because for Malta and Cyprus, no targets were set.

The ETS works not only for the member countries of the EU but it is open for any other country that ratifies the Kyoto Protocol. The new members can get the allowances left for such reasons as a reserve. The main tool is an emission allowance representing one unit of emitted GHG. These allowances exist only in electronic form in owners bank accounts. Company producing more emissions than it has allowances can either change its production process in order to emit less, or to buy allowances the other company do not deplete.

Three trading periods has been set until now, first period (sometimes called trial or pilot) 2005-2007, second period 2008-2012 (which is the first period under the Kyoto Protocol) and 2013 onward periods. Let us call them trial and first periods; the aim of the trial period was not to limit the emissions as much as possible, but to set up a successful operating system. However, some slight changes were made in the system; these changes are published in the ETS Review. The future of ETS after 2012 is not certain; Parties should have agreed on any further document leading to another emission reduction on conference in Copenhagen in 2009, however, no further steps were agreed. There is some speculation of USA and China joining the programme, however, nothing is certain yet, parties should agree on further action until the end of 2010 in order to make necessary measures. The preliminary vision of next agreement is reducing emissions by 20 % compared to 1990 until 2020.

Emission trading is held under trading periods because the amounts of emissions vary during time, therefore the banking and borrowing was allowed in trial period of trading. A company could save some allowances in one year to use them up during the next year and vice versa, use them in advance. Allowances are issued annually, but they are valid for the whole trading period. From the first period on, banking will be allowed, but no borrowing. Allowances used up are handed in at the end of each year; these units are not reused anymore.

There are three possible ways of pollution allowance trading in EU:

- privately, trading allowances between operators within a company
- over the counter, trading via dealer network, contrast to the centralized exchange
- trading on the spot market of one of Europe's climate exchanges, similar to exchange market (the most liquid is considered to be the European Climate Exchange).

The Linking Directive allows emission trading outside the EU; however, only allowed credits are those stated in the Kyoto Protocol, these are Certified Emission Reductions (CERs) and Emission Reduction Units (ERUs) connected with Clean Development Mechanism and Joint Implementation, which are specified further.

CDM is a flexible mechanism defined in Article 12 of the Kyoto Protocol using certified emission reduction (CER) for emission reduction projects in developing countries in order to meet Kyoto targets. CDM allows reducing GHG emissions in developing countries by financial help for the projects from industrialised countries.

One CER is equal to one tonne of CO_2 and can be traded and sold. The CDM is supervised by the CDM Executive Board and each project has to be registered and be approved by Designated National Authorities (DNA). Since 2006 when the mechanism started operating, more than 1 000 projects have been registered and their CERs production is expected to be more than 2.7 billion tonnes of CO_2 in the first period of the Kyoto Protocol, 2008–2012 (UNFCCC (n.d.c)).

JI is the third flexible mechanism specified in Article 6 of the Kyoto Protocol helping countries listed in Annex I to meet GHG emissions targets. Annex I countries can invest money into Joint Implementation Projects in any other Annex I country instead of reducing the emissions in home country. The whole process of receiving credits for JI Projects is described in the Guidelines for the implementation of Article 6 of the Kyoto Protocol from Report of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol on its first session, held at Montreal in 2005. Emission Reduction Unit (ERU) serves as a mediator for receiving the credits for JI Projects. One ERU is equal to one tonne of CO_2. The verification of procedures is supervised by the Joint Implementation Supervisory Committee (JISC), (United Nations, 1998).

When companies change their process into more environmentally friendly, not only they can gain some money, but also the whole society will get opportunity to live in more environmentally friendly way and the nature can be preserved in the sustainable way. Companies emitting more than they have allowances must either purchase some extra allowances, or pay a fine to the amount of extra pollution. Companies having some extra allowances can either sell them on the market, or save them into the next period (banking). It is up to each company how it deals with this issue and what way it chooses, majority of companies, however, chooses the most profitable way for them, even if the way is different for each. If one company invests into environmentally friendly technology, it should return in a profit further on.

4 Economic Analysis

In this chapter, the economic quantitative analysis of how the European countries profited on the ETS is done, and econometric modelling using single linear regression model is presented to verify whether targets fulfilment depends on GDP per capita, percentage of industry in the economy, Corruption Perceptions Index and Human Development Index. Another tool processed is qualitative analysis of allowance price development and the analysis of different emission quantifying per GDP in market prices, per land area and per capita. The last but not least is the comparative analysis of profits or losses from trading for each 23 EU country. There are 23 states analysed in the chapter, because even if in the trial period (2005-2007), there were 25 states in the EU, only 23 of them have targets set by the Kyoto Protocol; Malta and Cyprus have no targets at all. In this chapter, when referring to post-communist states, these are those denoted in the Kyoto Protocol by the star, there are listed in the *Supplement 1*.

4.1 Emission Trading Scheme Target Fulfilment

The targets of emission reduction for the year 2012 are set in the Kyoto Protocol; these targets are expressed in percentage compared to the reference year which is for most countries 1990, however, for some countries the year is different, for Hungary, the it is average of the years 1985 –1987, for Poland 1988 and for Slovenia 1986. Even if the reference year is different, the base index was set to be 100 for all countries in that reference year. The targets set by individual countries are to be seen in *Figure 6*, where it is visible that different countries have different targets. Targets were set mainly according to emissions prior to 1990 combined with excepted trend.

Emission fulfilment is defined as follows (2)

$$E_f = \frac{E_a}{E_t}, \qquad (2)$$

where *Ef* stands for emissions fulfilment, *Ea* stands for actual emissions and *Et* for target emissions. The negative numbers in *Figure 6* illustrate how much a country should reduce its emissions as the opposite to positive numbers representing allowed pollution excess. The target for many countries is 8 % reduction, which is an average, on the other hand, Finland and France have targets on the same level as they had pollution in the reference year, it means they should not pollute more, however, they do not have to reduce emissions either. On the other hand, Portugal can emit even 27 % more until 2012 compared to 1990. As opposite, Luxembourg has the most strict targets from all countries and should mitigate by 28 %.

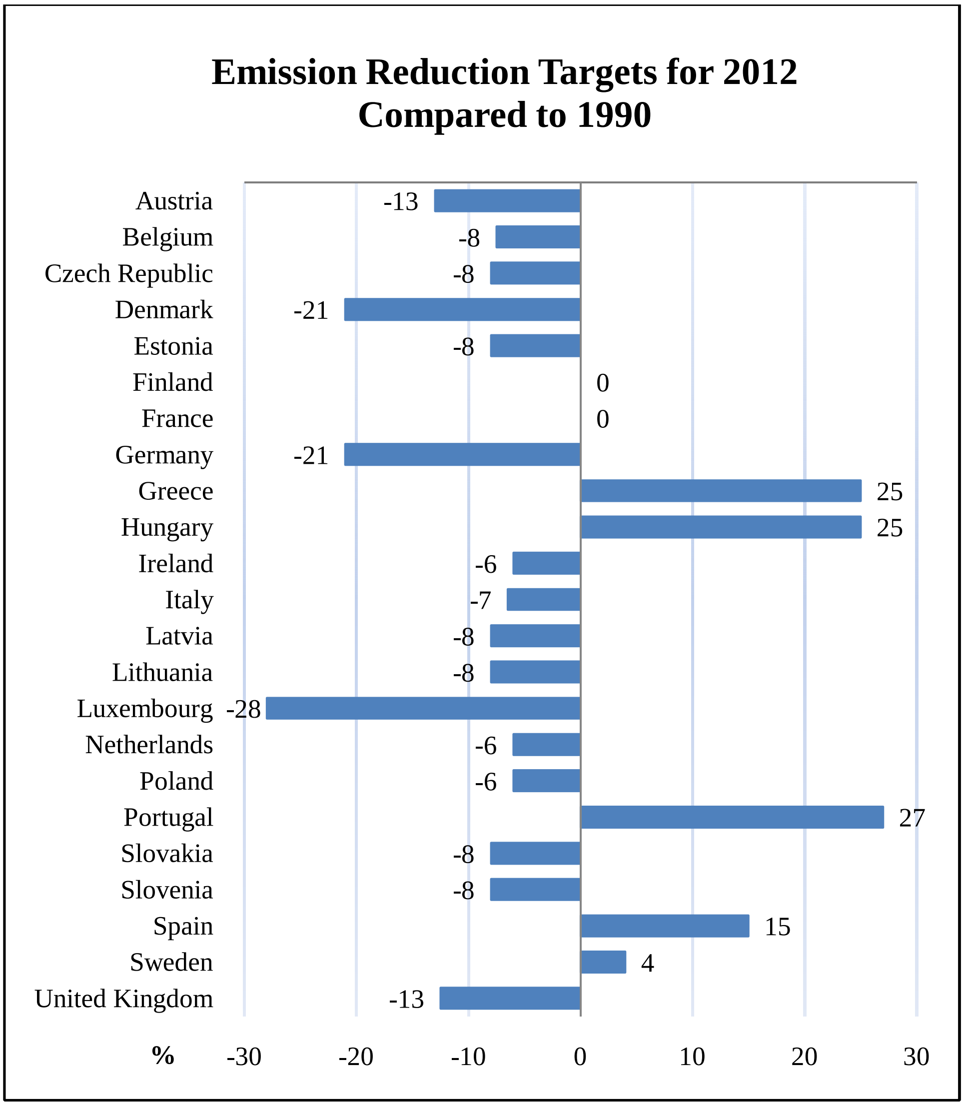

Figure 6 Emission reduction targets for 2012 compared to 1990, data: United Nations (1998), own graph

The results of real emission reduction in year 2007 are presented in *Figure 7*; the emissions in 2007 are compared with emissions from 1990. From the graph, it is obvious, that after 17 years, Latvia, Lithuania and Estonia had made the biggest progress; these countries were able to decrease their emissions by about 50 % compared to committed 8 %. On the opposite side of the graph, there is Spain; even if its emission targets in 2012 are to be 15 % higher than in 1990; it increased its emissions by another 38 %. However, not only Spain is not fulfilling abatement targets, there are also other countries not performing within the agreement.

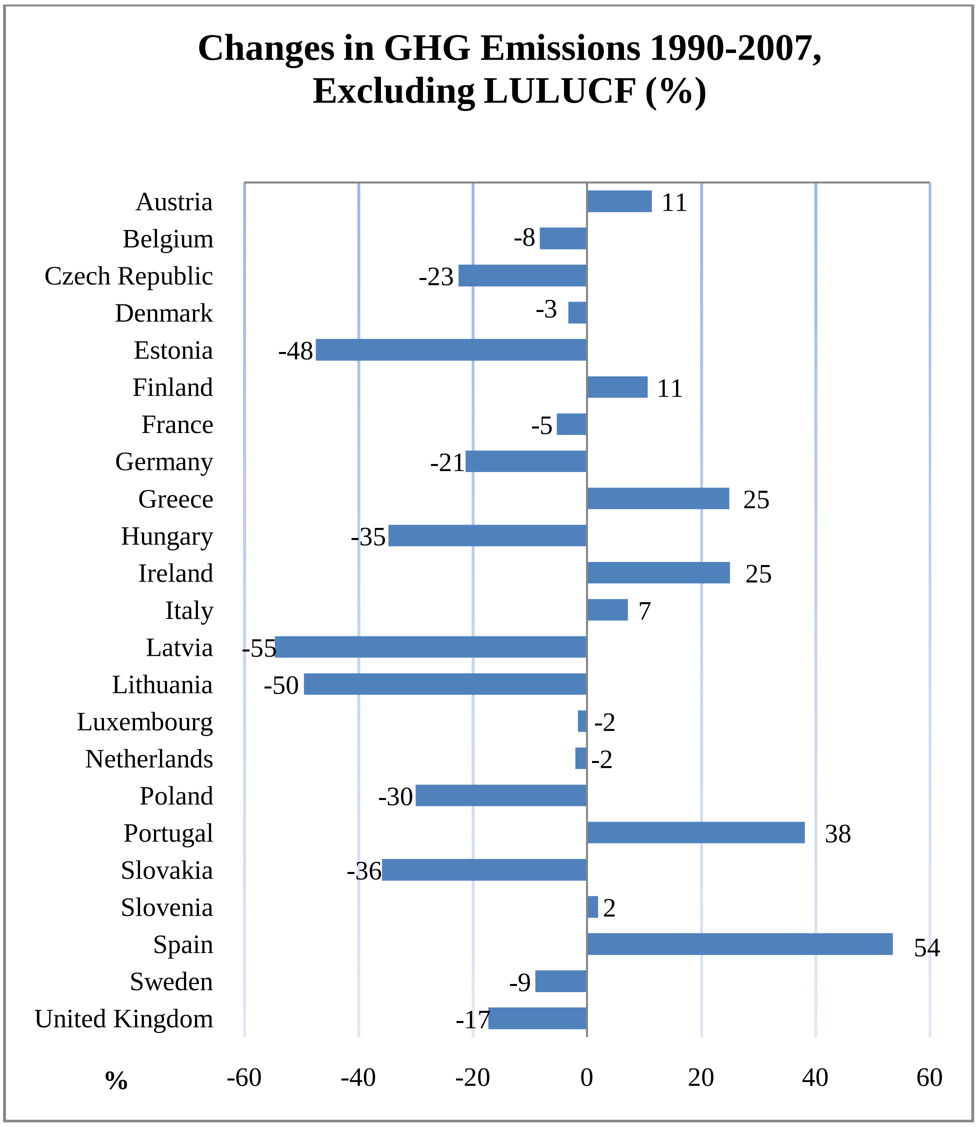

Figure 7 Changes in emissions 1990-2007, Data:UNFCCC (n.d.), own graph

Figure 8 concludes the previous data; you can see the emissions fulfilment of individual states in the year 2007 and compare it to their 2012 targets. It is obvious that individual participants differ in their fulfilments. That is natural; the current EU is more heterogeneous than the old EU15 used to be. The new members joined in past years have their own history, usually changing from centrally planned economies to market ones. These major economic changes in new member states have much in common; typically heavy industry declining on the account of services or light industry. As we know from previous chapter, heavy industry is a big source of GHG. We can therefore generalise that post-communist countries had easier position in fulfilling the targets due to the economy change in the trial period. However, the targets of the Kyoto protocol are set for the year 2012 and many changes can be done by that time.

Looking at well developed market economies such as Austria, we can see that its fulfilment in 2007 was insufficient and Germany and France were just in the boundaries; however, in these days, they have much bigger problems with reduction of pollution. It is due to fact that their economies were using more environmentally friendly processes already in the year 1990 than for example the Czech Republic. Thus, the range of emission burden was so much smaller.

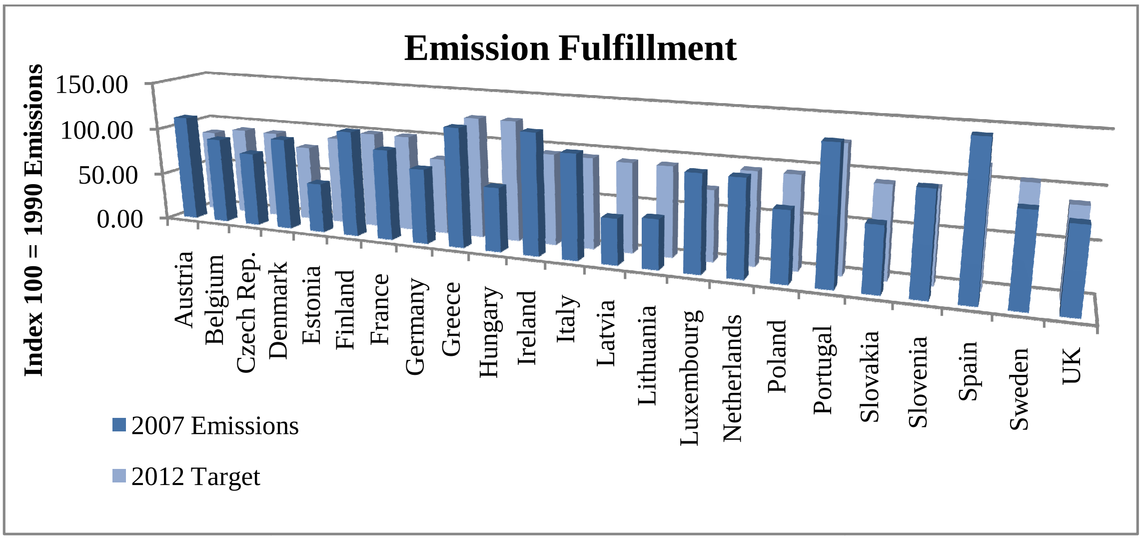

Figure 8 Emission fulfilment 2007, data: European Environmental Agency (n.d.), own graph

On the other hand, if it is said that post-communist countries profited in the trial period, it does not mean that they will be able to fulfil the final targets. The current data shows that these countries are slowly losing their good start position and may have problems with targets later or in the next period.

4.2 Interpreting Emissions Quantification

Another goal of this research is to examine different ways of computing emissions, which consequently affects what policy proposals are made for emission reductions. There are several ways of interpreting emission pollution; what is surprising, looking at releasing emissions from different angles, many different outcomes are gained. The question is what is then, the proper way to measure the emissions? Different outcomes can be explained correctly when understanding economical, political and historical background of each country. Individual country may be perceived as a heavy emitter or relatively non harming emission producer looking from different aspects. The most important data here are emissions per inhabitants and emissions per GDP which are the indicators examined in this thesis.

It is worth mentioning that when describing allocated, verified and sold/bought emissions within the country, it is meant that the country as such and the installations are subjects of the research. Because the installations are not obliged to record transactions connected with emission trading, there are not specific data to distinguish each source of pollution individually. Also, when writing about carbon dioxide emissions which are traded, note that carbon dioxide equivalent recalculated as GWP for gases stated in the Kyoto Protocol is meant.

Every source of pollution obliged to verify emissions gets the amount of allowances for certain period from the national registry. The company has to verify the released emissions at the end of each period and hand in the allowances of the same amount the company emitted CO_2. The amount of allocated allowances and verified emissions do not have to be the same and usually it is not. The company can have more allowances than it released emissions and then it can sell them to other emitter, or if there is a lack of allowances, the company can buy some; however rarely happens that the company has the same amount of allowances as it emits CO_2.

Following, verified emissions for each country are presented and it is analysed whether they correlate with the percentage of industry in each country. And, different interpretations of pollution caused by GHG are expressed per capita, per living area and per gross domestic product. If the country comes out as a heavy emitter from measuring of GHG per GDP in market prices, it does not mean it comes out with the same result from other measuring; the opposite is true. Let us have a closer look at individual points of view on quantification.

4.2.1 Verified Emissions

In *Figure 9*, you can see verified GHG emission for the trial period; these are emissions that installations confessed to their national registries as emitted in the trading period. Verified GHG emissions are calculated using (3)

$$E_v = \sum_{i=1}^{3} Ev_{yt} \, , \qquad (3)$$

where *Ev* are total verified emissions, *y* are the years 2005 until 2007. These figures represent all emissions that subjects obliged to measure emissions produced and recognised. The figures do not include emissions that small subjects which are not obliged to confirm emissions polluted and the emissions subjects to emission do not affirm.

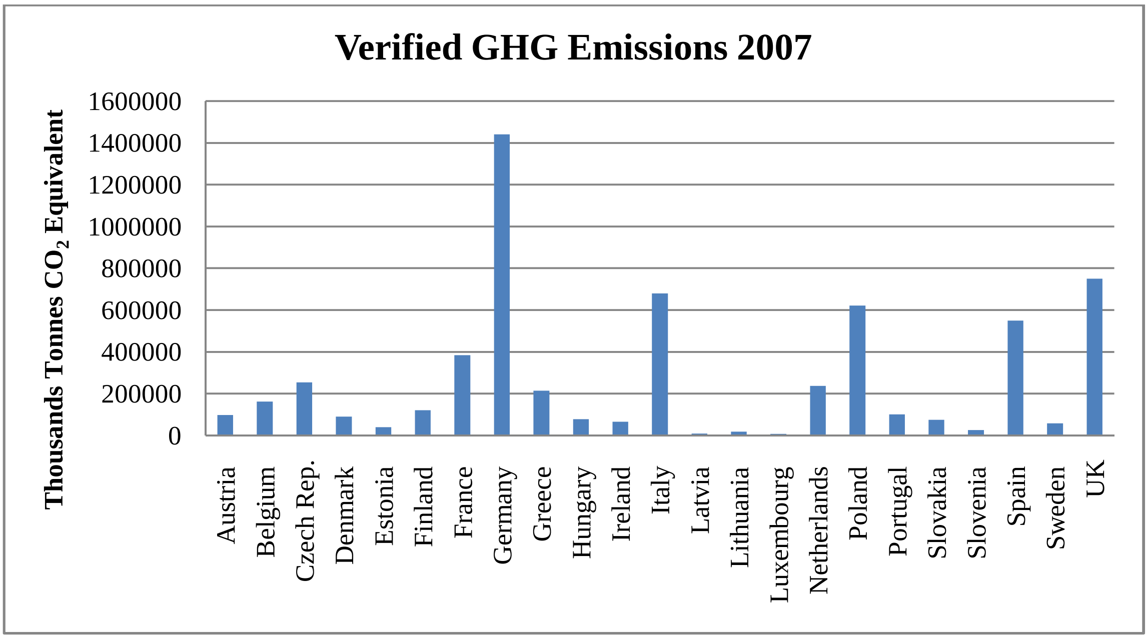

Figure 9 Verified GHG emissions 2005-2007, data: European Environmental Agency (n.d.), own graph

It is significant that huge countries and economies pollute more than smaller economies in absolute numbers, the example of Germany is outstanding. On the other hand, small economies do not pollute so much because of smaller number of power plants, factories and industries in the country. This is the reason why this type of measuring is not the most suitable one, such as Germany and the UK are penalised for the amount of industry they have got.

4.2.2 Percentage of Industry

In the regression analysis, the percentage of industry (4) in the country is considered as an important factor influencing fulfilment of targets each country should meet.

$$I = \sum_{i=1}^{3} I_{yt} \quad , \tag{4}$$

I is defined as percentage of industry, *y* are the years 2005 until 2007. If we take a closer look at *Figure 10*, we can see that Ireland's share of industry in the economy is the biggest one; however, Ireland is one of the countries with the smallest emissions.

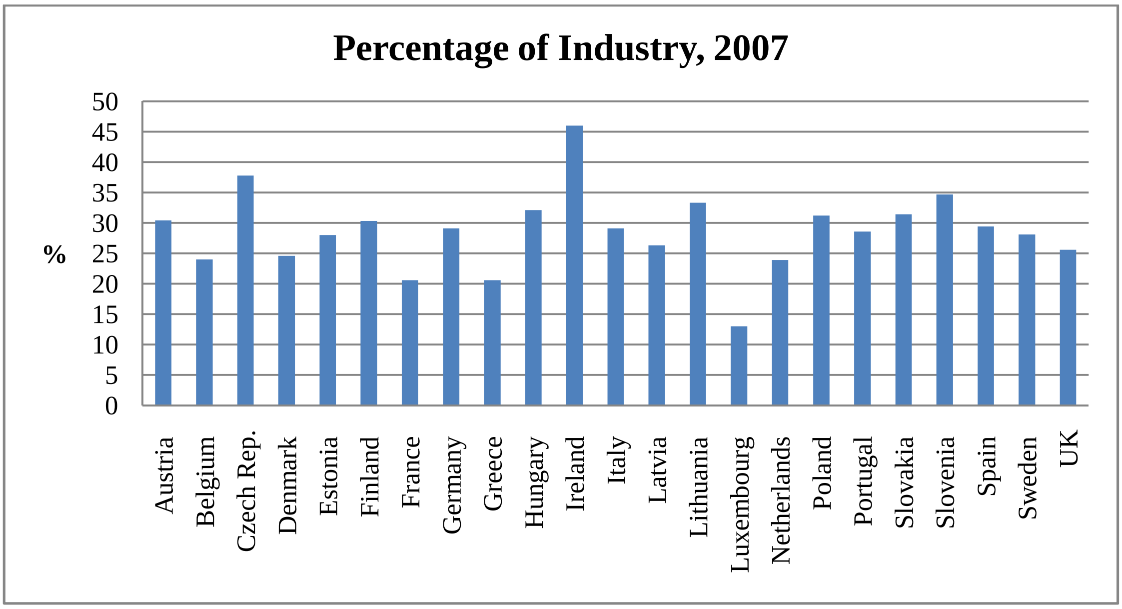

Figure 10 Percentage of industry, data: World Resources Institute (n.d.), own graph

On the other hand, Germany with the highest emissions from all examined countries have similar share of industry in the GDP as Portugal and Sweden, which have much smaller emissions. If we compare it with verified emissions in *Figure 9*, we can see that there is no significant relation between these two variables. Even if one could say that the share of industry would play very significant role in carbon emissions it is not one hundred per cent true. A country can be small and have high amount of industry in the economy, but because it is small, the emissions are low compared to bigger countries, e.g. Belgium and Poland, they have similar amount of industry in the economy, but Poland has much higher emissions in nominal numbers. As opposite, Austria with high percentage of industry in the economy has very low absolute emissions.

4.2.3 Carbon Dioxide per Capita

Another type of measuring emissions is per capita, which is portrayed in *Figure 11*, this can be represented by the following formula (5)

$$E_c = \frac{\sum_{i=1}^{3} Ev_{yt}}{c} \quad . \qquad (5)$$

The nominator here is defined above the denominator *c*, which stands for the average value of inhabitants in the year 2005. E_C represents emission per capita in tonnes. Let us have a closer look at *Figure 11*.

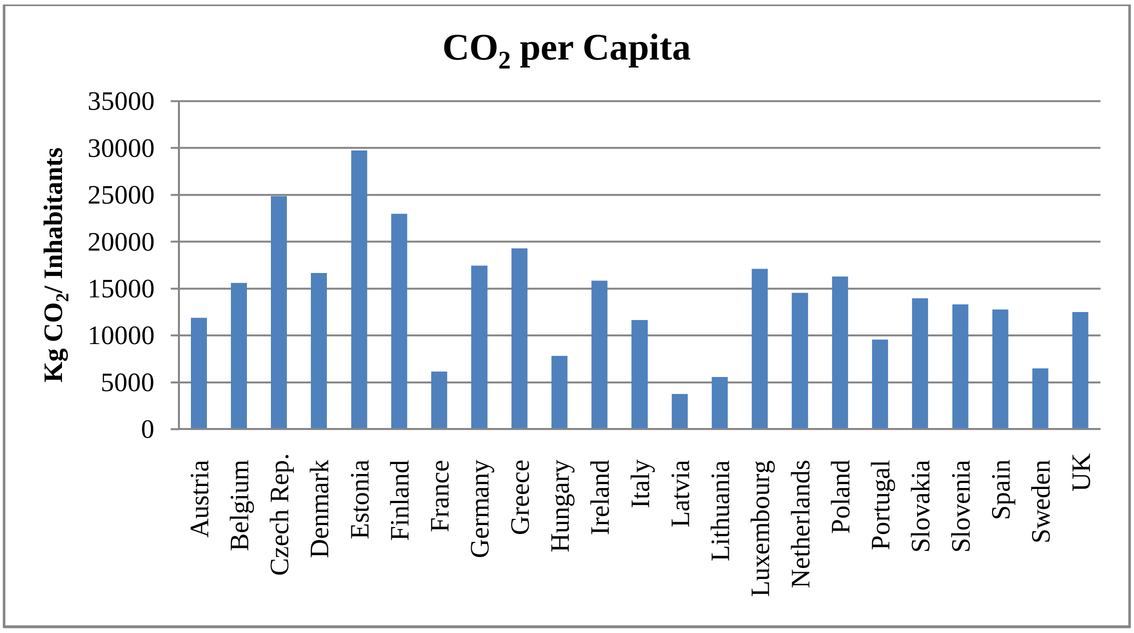

Figure 11 CO_2 per capita, data: Eurostat (n.d.a), European Environmental Agency (n.d.), own graph

Focus on Germany and Luxembourg, these countries have similar CO_2 measured per inhabitants even if in absolute emissions Germany polluted much more than Luxembourg. On the other hand, Latvia and Lithuania had low emissions per inhabitants as well as total emissions because these countries are small and do not have significant industries. Pollution quantified per capita is also related to population density. The highest emissions per capita shows Estonia, even if it has the same population density as the Czech Republic, it has higher emissions measured per capita, but lower emissions in absolute numbers. Compared to Germany, which has the highest absolute emissions, population density in Estonia is eight times smaller, but the emissions per capita are not eight times higher. It can be said that this graph is much more important for comparison of individual polluters, as it does not discriminate for the size of country compared to the graph representing emissions per squared kilometre.

4.2.4 Carbon Dioxide per Gross Domestic Product

Another comparison can be seen in the *Figure 12* bellow, where CO_2 is calculated per GDP in market prices in different countries. This is calculated as follows (6)

$$E_G = \frac{\sum_{i=1}^{3} Ev_{yt}}{G}, \qquad (6)$$

where E_G is emission per GDP and G stands for average GDP between 2005-2007 expressed in market prices. Similar to CO_2 per capita, this graph shows more objective point of view on the polluters, rather than using absolute figures.

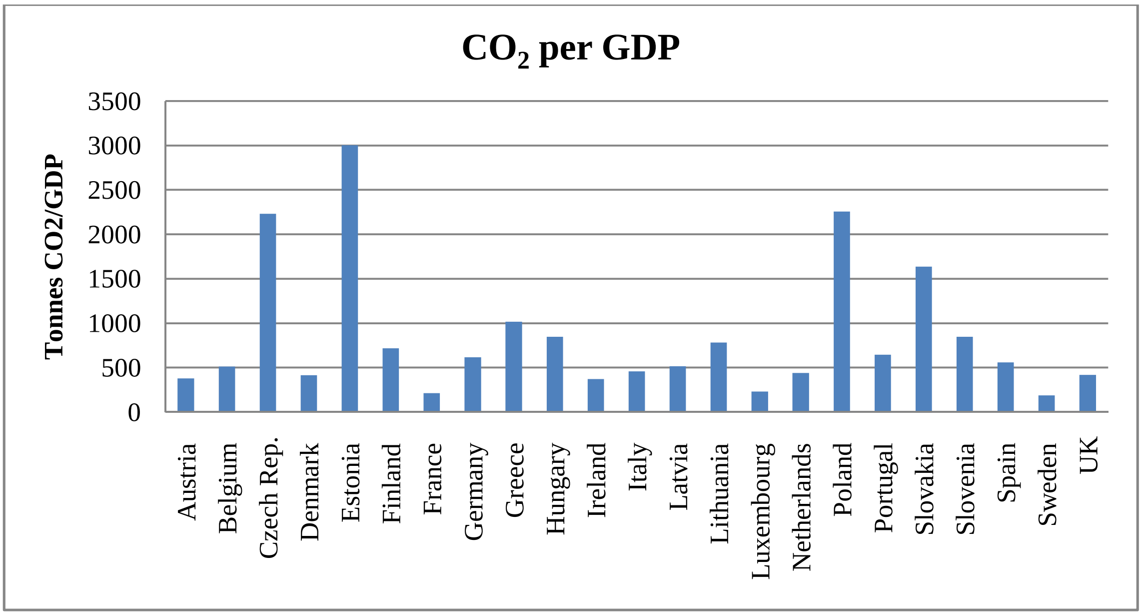

Figure 12 CO_2 per GDP, data: Eurostat (n.d.b), European Environmental Agency (n.d.), own graph

As it can be seen from the *Figure 12*, post-communist countries have higher pollution per GDP as they have lower GDP in market prices and traditionally higher share of heavy industry. Service oriented economies in EU15 have lower pollution per GDP. The differences between the EU countries origin in different historical and political development and will disappear in the long term run. If we look across the EU borders, these natural differences are much more obvious between other countries (e.g. USA versus China).

4.2.5 Carbon Dioxide per Land Area

Finally, the last indicator presented here expressing the emission burden are the emissions per area, in this case, square kilometre. This is calculated using (7)

$$E_s = \frac{\sum_{i=1}^{3} Ev_{yt}}{S} \quad , \tag{7}$$

where *Es* measures emissions per square kilometre, *Ev* is defined as total emissions and *S* stands for total area in square kilometre. The results are presented in *Figure 13.*

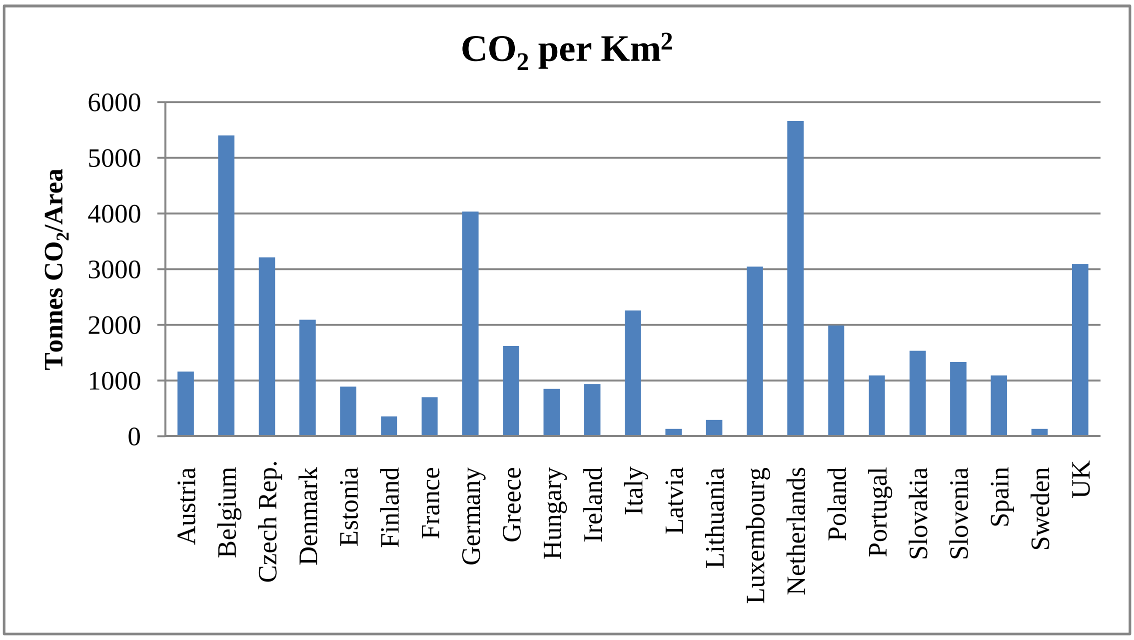

Figure 13 CO_2 per km^2, data: Economic Expert (n.d.), European Environmental Agency (n.d.), own graph

Look at e.g. the Netherlands and Belgium; they have the highest CO_2 emission per area even if the total emissions of these countries are not the highest. This graph, is however less attractive in economic analysis, for, emissions are naturally dependant on the size of the economy or number of population. Size of landscape does not play a significant role in total CO_2 emissions; on the other hand, it may have a serious impact on the local environment.

4.3 Possible Profit/Loss from Trading

Countries emitting less pollution than they have allowance for, can sell those excess allowances to other subjects (other countries or installations), or, to save them for the next period; by contrast, countries emitting more could buy allowances from other countries, or pay heavy fines. Same mechanism applies for companies that can also trade their allowances. However, there is no statistic of such transactions, because subjects of trading do not have a duty to publish trading results. That is the reason we cannot know whether installations emitting more bought additional allowances or paid heavy fines. As the price of fine for one extra tonne of polluted carbon dioxide is EUR 40 and the price of allowances is four times lower, let us consider that no country paid a fine and all excess allowances were sold and all missing allowances were bought on the climate market. Regarding these hypotheses, the profit and loss is counted as (8)

$$P = \sum_{i=1}^{3}(E_A - E_v) * Pr \,, \qquad (8)$$

where *P* stands for profit/loss, E_A are allocated allowances and *Pr* is a median price of allowances for the trial period which is EUR 11.71. Median of prices from most traded values in the trial period was chosen to illustrate possible profits or losses and it was multiplied by the difference between allocated and verified emissions.

In *Figure 14*, possible profits and losses from trading are summarised. You can see that if Poland sold all extra allowances it had, it could make a profit of EUR 1057.11 mil., even if this country is a heavy emitter. This is caused mainly by high emissions released in past and following high cap set by the Kyoto Protocol. However, after transition into market economy, such amount of allowances was not needed, because the emissions were reduced due to change in production process. This is also the case of other post-communist states such as e.g. the Czech Republic, Lithuania and Slovakia. The only exception is Slovenia which was in a loss even if it is not a heavy emitter.

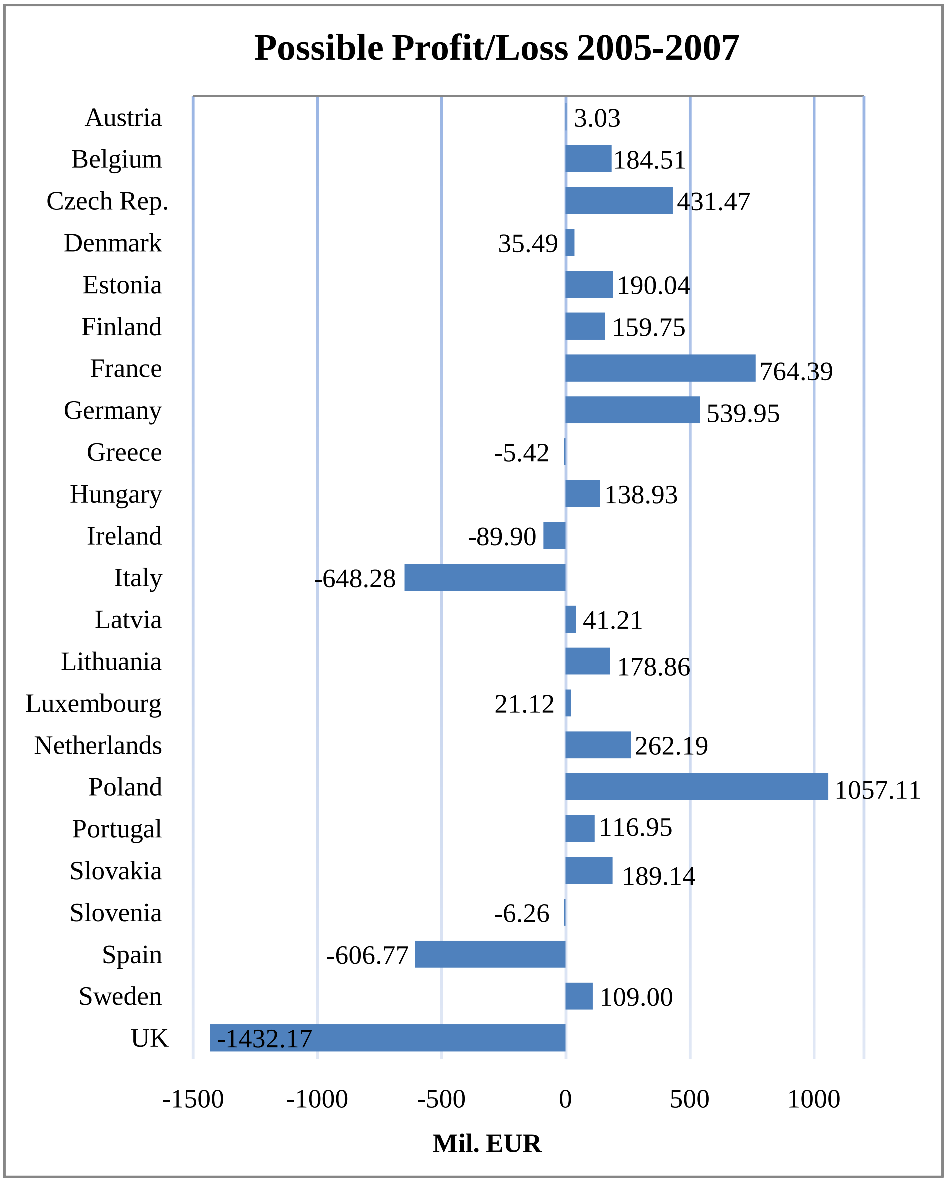

Figure 14 Possible profit/loss in the trial period, data: European Climate Exchange (2010 c), European Environmental Agency (n.d.), own computation

On the other hand, the UK was obliged to buy additional allowances for EUR 1432.16 mil., which is considered as a loss from trading. Italy and Spain had also to invest into extra allowances from other countries because they were short of their own. The reason for loss is that these countries had high current emissions. From countries mentioned, only UK and Italy should lower their emissions according to the Kyoto Protocol, Spain can pollute even more emissions until 2012 compared to 1990, but still it is not fulfilling. And if its trend continuous, it could pay much more in the first trading period.

The above *Figure 14* shows interesting observation that the EU states all together (EU Bubble) profited from the trading. If the differences of allocated and verified allowances of all examined countries are multiplied by the median price of the trial period, the results show us the profit made from trading in the EU area, which is EUR 1634.341 mil. That is because ETS comprises of more countries than just the EU and the graph illustrates that the EU as such was selling allowances more than buying from other states. That means that non European countries were buying allowances from the EU countries and so they could make a profit. Among the other non European states trading under ETS is e.g Japan which also bought some allowances from the Czech Republic.

The results of possible profit and loss may be used by Parties as a model of negotiation for the next period of trading. The fair approach would be that no country profits from the emission trading in long term perspective unless it enforces environmentally friendly technologies. We can only state that this was probably not the case of countries which profited from trading in 2005-2007 period. However, these countries may obtain stricter regulation limits for the next periods.

4.4 Single Linear Regression Analysis

Regression analysis is used to evaluate and explain the relationship between dependent variable and several explanatory variables. Single regression model is used here as a tool of analysing determinants of willingness to participate on ETS. It shows whether the percentage of emission target fulfilment in the year 2007, which is a dependent variable in our case, is a function of independent variables; these are average GDP per capita in years 2005-2007, Human Development Index (HDI), percentage of industry in the economy and Corruption Perceptions Index.

These economic indicators were chosen because they are independent and all together summarise the development of economies and levels of live standard. HDI is an alternative to GDP and it contains components explaining standard of living not included in GDP. HDI combines life expectancy indicator, education and standard of living. HDI can have the value between 0 and 1, where the higher number, the higher level of development.

Corruption Perceptions Index reflects the level of corruption in individual countries; the ranking is between 0 and 10, the smaller the index, the corruption occurs more frequently in that country. Corruption Perceptions Index overview is published yearly by the Transparency International.

To estimate linear regression model, Ordinary least squares method (OLSM) is used, because it is the best linear unbiased estimator. The definition of OLSM according to Encyclopaedia Britannica (2010) is: "method for estimating the true value of some quantity based on a consideration of errors in observations or measurements. In particular, the line (function) that minimizes the sum of the squared distances (deviations) from the line to each observation is used to approximate a relationship that is assumed to be linear."

The core of OLSM is to find out parameters minimizing sum of squares deviation of theoretical and real values of endogenous variable, as shows equation (9) below

$$\sum_{t=1}^{23}(y_t - \hat{y}_t)^2 \ . \qquad (9)$$

According to (Čechura et al, (2008: p.20)) the linear regression model is only proper when several conditions are fulfilled:

- "No omission of significant explanatory variable
- Omission of irrelevant explanatory variables
- Proper choice of working form of model
- Stable estimated parameters, time invariance
- Respect of simultaneous relations among variables
- Random variable *ε* with an expected value of 0
- Homoscedasticity of $u = \sigma$
- No autocorrelation of residuals
- The values of *u* are independent
- No perfect multicollinearity
- The values of *u* are normally distributed."

There are several steps for creation an econometric model:

4.4.1 Formulation of Economic and Econometric Model

In the model, the economic subjects are countries of the European Union, more precisely, 23 member states. In this subject, it should be proved linear equation that the emission target fulfilment depends on GDP per capita, percentage of industry in the economy, Human Development Index and Corruption Perceptions Index are variables examined.

The economic relation is as follows (10)

$$y = (x_1, x_2, x_3, x_4, x_5) \qquad (10)$$

y..... Percentage of 2012 target fulfilment of emission reduction in the year 2007 compared to the base year, which is in most countries 1990 (for Hungary the average of the years 1985-1987; Poland 1988; and Slovenia: 1986)

$x_{1.....}$ Unit Vector of length of 1

$x_{2.....}$ Average base index (100 = EU27) of gross domestic product per capita in years 2005-2007

$x_{3.....}$ Percentage of industry in GDP in each country

$x_{4\ .....}$Average Corruption Perceptions Index in years 2005-2007

$x_{5.....}$ Average Human Development Index in years 2005-2007

f.....General form of mathematical equation

In the econometric model, the endogenous *y* is explained by 5 independent variables (x_1-x_5) plus stochastic variable *u*. Endogenous variable denotes a result of an impact of explanatory and stochastic variables. Exogenous variables are explanatory variables, which mean that endogenous variable is explained by them. Stochastic variable *u* represents the variability in *y* that cannot be explained by the linear relationship with *x*. Stochastic variable contains all other variables not so important to be explained by the model, statistical errors in measurement, or other mistakes arising from rounding off and simplification of mathematical forms. If there were no error term, *y* would be perfectly explained by x, the model would be deterministic; however, this is not this case. The simple regression model can be written out as follows assuming linear functional form (11)

$$y = \gamma_1 x_1 \gamma_2 x_2 \gamma_3 x_3 \gamma_4 x_4 \gamma_5 x_5 + u. \tag{11}$$

In order to make the model complete, it is necessary to include there an intercept term, which is represented by the unit vector (x_1), which has unit length and indicates direction of the model. If there would not be an intercept, if *x* is 0, *y* would be 0 also, so it is the value y would have if all other variables were zero. The economic model becomes econometric by adding a stochastic variable, which was done in (11).

Setting of hypotheses is fundamental at the beginning. Two hypotheses are connected together, zero hypothesis H_0, which is tested and alternative hypothesis H_A. The hypotheses are same for all variables and are interpreted individually. The hypotheses are said to be as follows:

the null hypothesis (12) is

$$H_0: \gamma = 0, \tag{12}$$

in our model it means that the explained variable is not dependent on explanatory variable *x*, the alternative hypothesis is

$$H_A: \gamma \neq 0, \tag{13}$$

which means that the explained variable is dependent on explanatory variable *x*.

4.4.2 Data Collection

Before modelling, it must be said that in the model, there are examined 23 European countries, there is not such a significant difference between individual states in the economy development and in environmental conditions, and the location is also the same so the natural conditions are similar. The results of analysis would be much different if the examined countries would be more diversified, e.g. if all countries in the world would be the subjects of analysis. The data are presented in *Table 2*, they represent 23 European countries monitored in the trial period of trading 2005-2007, data are of panel type, which means there is no long time series and more variables are collected in this time. Each variable contains average data for the whole trading period; these data were chosen as the most suitable indicators explaining emission trading and the fulfilment of the Kyoto targets. The independent variables are GDP per capita, percentage of industry in the economy, Corruption Perceptions Index and Human Development Index. They show economic maturity of each country, which may be important indicator for target fulfilment. Indicators do not contain data of the same base in order to exclude multicollinearity among these variables further in the model.

State	**Percentage of 2012 Target Fulfilment in 2007**	**UV**	**GDP Per Capita**	**Percentage of Industry**	**Corruption Perceptions Index**	**Human Development Index**
Variable	**y**	x_1	x_2	x_3	x_4	x_5
Austria	78.167	1.000	124.000	30.650	8.467	0.952
Belgium	102.664	1.000	118.767	24.150	7.267	0.950
Czech Republic	118.557	1.000	77.933	38.400	4.767	0.899
Denmark	82.206	1.000	122.367	25.300	9.467	0.953
Estonia	177.950	1.000	65.367	28.550	6.533	0.878
Finland	90.662	1.000	114.933	31.350	9.533	0.955
France	106.157	1.000	109.500	20.700	7.400	0.958
Germany	101.804	1.000	115.967	29.550	8.000	0.945
Greece	101.461	1.000	92.967	20.700	4.433	0.938
Hungary	189.970	1.000	63.100	31.100	5.167	0.877
Ireland	75.502	1.000	146.867	46.000	7.433	0.963
Italy	87.465	1.000	103.533	27.850	5.867	0.949
Latvia	197.425	1.000	53.000	23.900	4.567	0.859
Lithuania	183.633	1.000	56.067	34.300	4.800	0.866
Luxembourg	73.394	1.000	266.100	13.800	8.500	0.958
Netherlands	96.509	1.000	77.333	24.250	8.733	0.961
Poland	132.768	1.000	131.000	31.350	3.767	0.876
Portugal	93.314	1.000	52.500	26.800	6.533	0.907
Slovakia	141.104	1.000	76.467	31.500	4.633	0.873
Slovenia	90.373	1.000	63.600	34.650	6.367	0.924
Spain	75.360	1.000	88.267	29.550	6.833	0.952
Sweden	114.664	1.000	103.967	28.550	9.233	0.961
United Kingdom	106.707	1.000	121.333	24.850	8.533	0.946

Table 2 Data set, Data: European Environmental Agency (n.d.),Human development reports(2009), Transparency international (n.d.), World Resource Institute (n.d.), Eurostat (n.d.c), own table

4.4.3 Estimation of Parameters of the Econometric Model

In order to estimate the parameters in the model, OLS method is used. Firstly it is needed to define matrix *X* and vector ***y*.**

$$X = \begin{bmatrix} \vdots & & & & \vdots \\ \vdots & & & & \vdots \\ x_{n1} & x_{n2} & x_{n3} & x_{n4} & x_{n5} \end{bmatrix} \tag{14}$$

$$y = \begin{bmatrix} y_{11} \\ \vdots \\ \vdots \\ y_{n1} \end{bmatrix} \tag{15}$$

Parameters estimation is made in several steps; these are expressed by following equations

$$X^T X, \tag{16}$$

$$(X^T X)^{-1}, \tag{17}$$

$$X^T y\ , \tag{18}$$

$$(X^T X)^{-1} X^T y\ \ , \tag{19}$$

According to the formula for the parameters estimation (19), the parameters are:

$$(X^T X)^{-1} X^T y = \begin{pmatrix} 1076.23x_1 \\ -0.12x_2 \\ -0.77x_3 \\ 5.07x_4 \\ -1038.92x_5 \end{pmatrix}. \tag{20}$$

4.4.4 Verification of the Econometric Model

It is necessary to verify whether the estimated parameters are in accordance with economic hypothesis stated and have statistical characteristic. The verification can be divided into economic, statistical and econometric verification. Economic verification determines the direction and intensity of influence on the explained variable. Statistical verification evaluates statistical significance of estimated parameters of the model and the identity of estimated model with data. Econometric verification proves the conditions needed for application of the model, i.e. multicollinearity of exogenous variables or autocorrelation of residuals.

According to the stochastic equation, it can be derived the direction and the size of influence of stated explanatory variables on the explained endogenous. In the equation, there is also an error term. This error term includes all omitted variables influencing dependant variables, but they are not included in explanatory variables. In this case, the omitted variables are the political situation in each country, national debt, historical situation and the nature of the nation. It also includes errors in measurement and the errors from simplifying the equation. The error term is predicted to be uncorrelated; the best linear unbiased estimators (BLUE) of the coefficients are given by the ordinary least squares. Best linear unbiased estimators mean that estimated parameters have minimum variance among linear estimators, unbiased means that estimated values of parameters are equal to real ones. Correlation Matrix presented below in *Table 3* is also a part of economic interpretation of the model.

Variable	Fulfilment	GDP per Capita	Percentage of Industry	Corruption Perceptions Index	HDI
Fulfilment	1				
GDP per Capita	-0.534395572	1			
Percentage of Industry	0.08038181	-0.332573913	1		
Corruption Perceptions Index	-0.582524213	0.440699967	-0.211833706	1	
HDI	-0.861806414	0.53785344	-0.213589899	0.785157676	1

Table 3 Correlation matrix, own computation

Correlation deals with relationship among explanatory variables; correlation matrix can tell us how and to what extent all exogenous variables are related. But, as opposite of regression, it does not tell us that changes of dependent variable cause changes in independent variables or vice versa. Perfect collinearity or multicollinearity is not desirable because the influence of individual explanatory variables could not be separated. The perfect multicollinearity occurs when the dependency of two or more variables are equal 1, in other words is deterministic. The high multicollinearity usually occurs when explanatory variables do not vary too much, or contains similar data; high multicollinearity can be considered as 0.8 and higher. From the correlation matrix containing correlation coefficient for each variable in *Table 3* above, it is obvious that there is no multicollinearity between any explanatory variables; however, the relationship between Corruption Perceptions Index and HDI is very close. This means that these variables do not vary too much and may contain similar data. However, the multicollinearity is not so high to be removed. Very low indirect correlation is between the Corruption Perceptions Index and percentage of industry in the economy and between HDI and percentage of industry.

We must take into consideration that only 23 states are analysed, which is quite small scale for the model, and, that every value is linked with the targets determined by the Kyoto protocol, which is the reason why the model is not deterministic now. If the system of trading would remain the same, the explanation after ten years of working time the ETS would be more relevant.

4.4.4.1 Statistical Verification

Statistical verification evaluates statistical significance of estimated parameters in the model. There are several steps of statistical verification; these steps are computed in details in *Supplement 4*, the results can be seen in *Table 4* below. The steps are following:

1. Verification of statistical significance of parameters in matrix (17).

The stochastic equation (21) is following

$$y = 1076.23x_1 - 0.12x_2 - 0.77x_3 + 5.07x_4 - 1038.92x_5\,. \qquad (21)$$

The parameters show the size and direction of individual variables. The intercept term in the equation means that in case of having no other exogenous variables that would have an impact on the fulfilment, the ability to fulfil the emission targets would remain stable 1076.23.

Parameter representing average GDP per capita in years 2005-2007 has the size of -0.12. We can see that the relation between GDP per capita and fulfilment of set targets is negative. The explanation of this relation is, if the GDP increases by 1, the estimated fulfilment decreases by 0.12. One could say that logically it is vice versa; that a developed country with high GDP is able to fulfil the targets better due to higher financial resources for more environmentally friendly technology. In this model, the period 2005-2007 is examined; in this case, the explanation is right, countries with lower GDP in market price were able to fulfil the targets better. However, this is only because of the fact that these countries had more allowances allocated due to heavy industry in the 1990s. The results of the model would be more significant when comparing developed and developing countries.

The size and the direction of the parameter of percentage of industry in the economy in each country is presented here. The relation between percentage of industry in economy and fulfilment of emission targets is also negative. If the percentage of industry in the country increases by 1, the ability to fulfil the targets decreases by 0.77. This outcome corresponds with the hypothesis that more industrialised countries emit more and due to that it is more difficult to fulfil stated targets. This explains why more allowances were allocated to the countries with higher percentage of industry in the economy.

Average Corruption Perceptions Index in years 2005-2007 is explained by the equation as: the relation between Corruption Perceptions Index and the fulfilment of emission targets is positive. If the Corruption Perceptions Index increases by one, the fulfilment increases by 5.07. We should recall here that Corruption Perceptions Index is measured in scale of 0-10, where 10 is the best, therefore if the Corruption Perceptions Index increases, the corruption as such decreases. That implies the lower corruption in the country, the better fulfilling of stated targets. However, in the ETS trading, there is not so much space for corruption; the only possibility could be in verification of emissions. There is a lobby in the negotiations of allowances allocation, but not so much space for corruption.

Average human development index in years 2005-2007 has the size of -1038.92, the connection between HDI and the ability to fulfil the emission targets is also negative. This means that if the HDI increases by one, the fulfilment decreases by 1038.92. This is also biased, it can be explained similarly as dependence of fulfilment on GDP; in the period examined, countries with lower HDI were able to fulfil the cap better because these countries had more allowances allocated than more developed countries with higher HDI as it is a complement of GDP indicator.

2. Adjusted residual variance computation can be calculated after computation of sum of squares residuals; the reason of computation is to minimise the residual sum of squares. Let us determine that y_t is a real value of dependent variable and $\hat{y}_t$ is estimated value of the model. The difference between real and estimated *y* is the residual $\hat{u}_t^2$, which is minimised by residual sum of squares, is counted in (22)

RSS = $\sum_{t=1}^{23}(y_t - \hat{y}_t)^2$, (22)

which is the same as $\sum_{t=1}^{23} \hat{u}_t^2$. (23)

To calculate standard error, $\overline{S_u^2}$ is computed, $\overline{S_u^2} = \frac{\sum_{t=1}^{23}(y_t - \hat{y}_t)^2}{23-5}$, (24)

where in the nominator, there is RSS and in the denominator, there is number for degrees of freedom 23-5 (quantity of variables observed minus the number of explanatory exogenous variables), which is 18. Because there are 23 states observed in the model and 5 explanatory variables examined, which mean 18 degrees of freedom, in other words, there are 18 values that are free to vary.

In the model, it is $\overline{S_u^2}$ =384.3568037. (25)

3. Variance of estimated parameters computation is calculated as (26)

$$s_{ii} = \overline{S_u^2}(X^T X)^{-1} = \begin{pmatrix} S_{11} & \dots & \\ \vdots & \ddots & \vdots \\ & \dots & S_{ii} \end{pmatrix}, \qquad (26)$$

This variance-covariance matrix is also needed for calculating standard error; coefficient on diagonal of this matrix are multiplied by $\overline{S_u^2}$. The results of adjusted residual variance for each variable are presented in *Table 4* below.

4. Standard deviation of estimated parameters or standard error for each variable is also important to know, it express the accuracy of the regression parameters; however, it does not show the accuracy of estimated coefficients. It is counted as the square root of coefficient variances, or adjusted residual variance, as following, $S_{bi} = \sqrt{S_{ii}}$. (27)

For details of standard errors see *Table* 4 below. If the standard error is small, it shows that the parameter estimated is sufficiently accurate. In other words, it shows us the degree of uncertainty in the estimated coefficients. The larger the sample is, the smaller the standard error is. If we look at our model, we can see that the standard error is high in the case of unit vector and HDI; on the other hand, the standard error is low in case of other three variables.

5. Testing of hypotheses is done by T-test, which is computed as (28)

$$t - value = \frac{absolute\ value\ of\ parameter}{standard\ deviation} = \frac{|\gamma|}{S_{bi}} \quad (28)$$

and the results are presented in *Table 4* below.

6. Statistical significance of estimated parameters

To measure the level of significance of the model, the t-value (28) is computed and compared with α. T-value in this table measures what is the probability of the sample result if we assume the null hypothesis is true. The significance level for the student test (t-test) was chosen α=0.05, which is for 18 degrees of freedom 2.1009. The meaning of α=0.05 is that the probability of making error is 5 %, in other words; the confidence interval is 95 %. Five percent is right enough for this sample, for bigger samples, lower size of test would be used. In *Table 4*, S means significant, I means insignificant (not statistically different from 0).

Variable	**Unit Vector**	**GDP**	**Percentage of Industry**	**Corruption Index**	**HDI**
S_{ii}	25470.64601	0.012877804	0.464056109	14.03369549	37642.25039
S_{bi}	159.5952568	0.11348041	0.681216639	3.746157429	194.0161086
t-value	6.743487657	1.096029148	1.137177384	1.353846241	5.354797836
t-tab. (α=0.05)	2.1009	2.1009	2.1009	2.1009	2.1009
Significant/ Insignificant	S	I	I	I	S

Table 4 Statistical verification, own computation

If the t-value is higher than α, then the null hypothesis is rejected, which is presented as the variable is significant, if the t-value is lower, the null hypothesis is accepted. The *Table 4* says that GPD and HDI are significant and the Corruption Perceptions Index and percentage of industry in the economy are insignificant. These results are a bit biased, one would say that the level of GDP and percentage of industry in the economy are the most significant factors for fulfilments of reduction targets set by the Kyoto protocol, however, the model shows the opposite.

The quality of estimated equation is evaluated by coefficient of determination R^2, in our case $R^2 = 0.78897924$ (29)

Coefficient of determination shows the amount of change of dependent variable explained by changes in explanatory variables, in this case, it is 78.9 %, and it means that the model is explained from 78.9 %. The measure of goodness of fit is based on dispersion of total variation in the dependant variable S_y^2, theoretical regression variation $S_{\hat{y}}^2$ and residual S_u^2. That is

$$S_y^2 = S_{\hat{y}}^2 + S_u^2 \,, \tag{30}$$

$$S_y^2 = \frac{\sum_{t=1}^{23}(y_t - \bar{y})^2}{23} \,, \tag{31}$$

And $S_{\hat{y}}^2 = \frac{\sum_{t=1}^{23}(\hat{y}_t - \bar{y})^2}{23}$, (32)

where $\hat{y}_t$ are theoretical values of explained variable and $\bar{y}$ is average of real values of explained variable. In this model:

$$S_y^2 = 1425.456797 \,, \tag{33}$$

$$S_y^2 = 124.65582 \,. \tag{34}$$

The coefficient of determination shows that the model is well built. Nevertheless, the fulfilment of emission reduction is not dependent on GDP per capita or Corruption Perceptions Index; on the other hand, it is related to HDI, and for certain, to other omitted variables in the model, such as political and social situation and historical background. The problem of insignificance of variables may be caused by their near multicollinearity, even if the coefficient of determination seems well explaining the equation. If the irrelevant variable is included in the model it may sometimes help to reduce this variable. However, even if the superfluous were removed, the significance of variables remained unchanged. There may be a mistake of omission of an important variable; however, the most significant factors to explain this issue are difficult to be quantified, e.g. culture, history, political situation and other factors. The explanation is also connected with historically set limits of pollution.

4.5 Emission Trading Market

The emission allowances are traded on several European exchanges, the most liquid one is the European Climate Exchange (ECX) which is only one trading purely emission derivatives, the others are e.g. Bluenext and Commodity exchange Bratislava, which is the first nonstop exchange in the world. For instance, Czech company CEZ trading on the energy market is a member of ECX as well as Bluenext. However, for trading on a carbon market, the installation does not have to be a member of any exchange; it can trade through other members as it is usual on other exchanges. As the conditions and prices on all exchanges are correlated, to simplify, in the thesis, the situation on the ECX is elaborated further on.

The ECX is similar to any other stock exchange, it started operating in April 2005, and the future contracts were traded there from the beginning as the options followed from the year 2006. On the EXC, already 100 leading global businesses are trading as the members and the volumes of trade grow. As the European Climate Exchange (2010a) states: “ECX volumes are experiencing tremendous growth. ECX 2009 volumes increased by 82 % year on year equivalent to €68 billion.” Since the beginning, according to the European Climate Exchange (2010b) “Approximately 2.3 billion EUAs in total have been granted yearly to the 12,000 energy-intensive installations covered by the EU ETS Directive.”

On the ECX, it is possible to trade in two ways, i.e. the Intercontinental Exchange (ICE) Futures Europe Member or by order-routing as a client of an ICE Futures Europe

Member. Under the ICE Futures Europe Membership, there are two categories of membership, General Participant and Trade Participant. Potential members have to apply and pay €2,500 and annual fee €2,500. Another exchange fees are charged for each transaction (European Climate Exchange, 2009b).

Two types of allowances of CO_2 are traded there; European allowances (EUAs) and Certified Emission Reduction (CERs). EUA have been traded on the market since the beginning, CER were introduced on the ECX in 2008, and both are traded as Futures and Option contracts. CER are units bought or sold under the Clean Development Mechanism (explained earlier in the chapter 2.6.1).

When buying/selling future contracts, the holder has the obligation to undergo business under set conditions (set date and price) in future. Buying/selling option contract gives the right to the holder to exercise trade before expiry date; however, the seller has the obligation to make a business buyer wants to. In any case, the buyer has to pay premium to the seller. We can distinguish call and put options; call option represents the right to buy a contract, on the other hand, put options gives the holder the right to sell a contract. The expiration date of Futures and Options is every quarter which is little less flexible for traders.

Nowadays, there are even more derivates on this market; to make trading even more interesting, in 2009, EUA and CER Daily futures were introduced. These new derivatives brought traders higher opportunity to hedge their risk because they offer next-day payment and delivery of allowances.

Another innovation on ECX to 2008 is spread trading where the trader can take advantage of different price of different future contracts and so lower the risk. EUA/CER trading is also possible; this trading is available for December contracts in the whole first trading period. This trading brings new opportunity to make trading more profitable (European Climate Exchange, 2010c).

Since the thesis deals with the trial period of trading when the EUAs were traded, only these units are taken into consideration further. A lot (contract) represents 1000 EU allowances, where 1 allowance is equal to one tonne of CO_2 equivalent. For traders, it is be advantageous to lock the price for the future.

4.5.1 Price Development

The last goal of this thesis is to look closer at the price development of emission allowances on the European Climate Exchange. The analysis contains comparison of futures contracts for one year in different time throughout the trading period. The price evolution is illustrated in *Figure* 15.

Figure 15 Price development 2005-2007, Data:European Climate Exchange 2010c, own graph

The black line illustrates December 2005 futures contract price at the date on bellow axes, the red line shows the development of futures contracts with expiry December 2006 and the blue line represents the evolution of futures contracts expiring in December 2007.

At the beginning of trading, in April 2005, the allowances were traded at EUR 16.90, during the first year the investors were threatened that the allocated allowances would not be sufficient for them and they were buying in high amounts for the high prices, which went up even to EUR 30. In the middle of 2006, it was obvious that countries were polluting less than was expected, thus the prices dropped down to EUR 20. According to (Ellerman and Joskow (2008: 13) the explanation can be that the prices of oil and natural gas were high; therefore some subjects could prefer investments into coal instead.

However, during the period, the traders realised that the allowances allocated are as much as necessary, as we already said; there were a surplus of allowances in the EU. And the price dropped significantly down to EUR 0.08 at the end of year 2007, which was the end of trial period. Soon after beginning of the first trading period, the price went again up to EUR 10-15.The consequence is that if the investor bought futures with expiry December 2007 in the middle of 2005, he lost a sufficient amount of money; on the other hand, if the investor sold the same futures in year 2005, he made a great profit. Nowadays, in first quarter of the year 2010, the price of futures December 2010 is about EUR 13.

5 Conclusions

Emission trading is one of the key tools of reduction anthropogenic impact on the Earth's environment. The main subject of emission trading is carbon dioxide, which results from many natural as well as human activities. However, by regulating carbon emissions, bigger pressure on overall efficiency and use of environmentally friendly technologies is made. In the European Union, carbon trading is done by the Emission Trading Scheme, in which all European installations as well as some non European installations trade their allowances in order to fulfill the targets determined by the Kyoto Protocol. This Protocol is a legal base for last two decades of global warming mitigation efforts. Currently, new international agreement is being developed to continue with these efforts involving even more Parties. Because one country cannot fight the problem of the climate change on the whole planet on its own, the attempt has to be global and centralised to be efficient.

Emission trading is a form of external regulation, which also impacts economies of individual countries. To understand the problem better, it is important to know how each country differs from others in terms of emissions pollution. There are several ways how to quantify emissions. The quantification in nominal numbers of pollution is not the best way of measuring, while strong economies such as Germany are penalised for the amount of industry it has got. The fair way how to measure pollution is to count it per number of inhabitants in the country or per GDP. In respect to GDP, the biggest EU polluters are Estonia, Poland and the Czech Republic. The emissions per land area are also not very precise, as small countries, on the opposite, are disadvantaged. For example the Netherlands has the highest emissions per land area even if the actual pollution is not among the highest.

The willingness to pay for emission allowances is expressed by profit and loss from trading. If one country reduces its emissions, it does not have to pay extra money for additional allowances. Even if Poland is among heavy emitters, it profited most from trading, because of historically set limits of pollution. On the other hand, the trading for the UK, Italy and Spain was very costly as these countries had high actual emissions.

On the opposite, their emissions per GDP were low as these countries are economically well performing.

One of the hypotheses was that fulfilment of emission reduction is related to GDP, Corruption Perceptions Index and Human Development Index, the hypothesis was mostly rejected. From the econometric model arises that fulfilment of emission reduction is not related to GDP or Corruption Perceptions Index, on the other hand, it is related to HDI, and for certain, to other omitted variables in the model, such as political and social situation and historical background. This result is a bit biased, because one would say that the level of economy in the country is significant indicator of willingness to fulfil the emission targets. The explanation of this can be that other factors influencing pollution mitigation are not included in examined model.

It can be said that it does not matter whether countries are rich or poor; the fulfilment depend also on historically based allocations of allowances. The EU countries with heavy industries in the 1990s have higher caps for emitting CO_2 equivalent compared to countries with market economies at that time. Post-communist countries changed their industries from centrally planned to be market system; it was natural for them to change production process to more environmentally friendly. This is the reason why these countries profited in the examined period; their limits for emission reduction were set high. On the other hand, huge market economies have the targets set quite low, because in the year 1990, these economies had already more environmentally friendly technologies; thus, it is more difficult for them to fulfil these targets now.

The willingness to reduce GHG emissions is connected with the price development of allowances. The price of allowances was similar for the whole trial period; however, it dropped significantly at the end of trading, which can be interpreted by surpluses of allowances in the EU countries. This is profitable from the whole EU Bubble point of view, because the implication is that the EU countries were selling allowances mainly to non European countries. The outcome is the reduction of overall EU emissions, which proves that the ETS works well in the EU area. However, the future of emission trading is not certain, there is still no successor of the Kyoto Protocol yet, but, the assumptions are that trading period conditions 2013-2020 will be stricter.

The main hypothesis was that the EU ETS is a successful tool for reduction GHG emissions; this is validated by the reduction of pollution in the entirely EU and selling excess allowances to non European countries. The last hypothesis assumes that post-communist countries profited by trading in the analysed period; this statement can be proved, because these countries reduced emissions most and thus they could make benefit from selling extra allowances. However, as the subjects of the ETS are not obliged to record allowances bought or sold, the actual economic outcome can not be precisely calculated.

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7 Supplements

Supplement 1 Kyoto Protocol Annexes

Supplement 2 Directive 2003/87/EC of the European Parliament and of the Council

Supplement 3 Measuring of Emissions

Supplement 4 Ordinary Least Squares Method

Supplement 1 Kyoto Protocol Annexes

Annex A

Greenhouse gases

Carbon dioxide (C02)
Methane (CH4)
Nitrous oxide (N20)
Hydrofluorocarbons (HFCs)
Perfluorocarbons (PFCs)
Sulphur hexafluoride (SF6)

Sectors/source categories

- Energy
  - Fuel combustion
    - Energy industries
    - Manufacturing industries and construction
    - Transport
    - Other sectors
    - Other
  - Fugitive emissions from fuels
    - Solid fuels
    - Oil and natural gas
    - Other
- Industrial processes
  - Mineral products
  - Chemical industry
  - Metal production
  - Other production
  - Production of halocarbons and sulphur hexafluoride
  - Consumption of halocarbons and sulphur hexafluoride
  - Other
- Solvent and other product use
- Agriculture
  - Enteric fermentation
  - Manure management
  - Rice cultivation
  - Agricultural soils
  - Prescribed burning of savannas
  - Field burning of agricultural residues
  - Other
- Waste
  - Solid waste disposal on land
  - Wastewater handling
  - Waste incineration
  - Other

Annex B

Party	Quantified emission limitation or reduction commitment (percentage of base year or period)
Australia	108
Austria	92
Belgium	92
Bulgaria*	92
Canada	94
Croatia*	95
Czech Republic*	92
Denmark	92
Estonia*	92
European Community	92
Finland	92
France	92
Germany	92
Greece	92
Hungary*	94
Iceland	110
Ireland	92
Italy	92
Japan	94
Latvia*	92
Liechtenstein	92
Lithuania*	92
Luxembourg	92
Monaco	92
Netherlands	92
New Zealand	100
Norway	101
Poland*	94
Portugal	92
Romania*	92
Russian Federation*	100
Slovakia*	92
Slovenia*	92
Spain	92
Sweden	92
Switzerland	92
Ukraine*	100
United Kingdom of Great Britain and Northern Ireland	92
United States of America	93

* Countries that are undergoing the process of transition to a market economy.

Supplement 2 Directive 2003/87/EC of the European Parliament and of the Council

ANNEX I

CATEGORIES OF ACTIVITIES REFERRED TO IN ARTICLES 2(1), 3, 4, 14(1), 28 AND 30

1. Installations or parts of installations used for research, development and testing of new products and processes are not covered by this Directive.

2. The threshold values given below generally refer to production capacities or outputs. Where one operator carries out several activities falling under the same subheading in the same installation or on the same site, the capacities of such activities are added together.

Activities	**Greenhouse gases**
Energy activities Combustion installations with a rated thermal input exceeding 20 MW (except hazardous or municipal waste installations) Mineral oil refineries Coke ovens	Carbon dioxide
Production and processing of ferrous metals Metal ore (including sulphide ore) roasting or sintering installations Installations for the production of pig iron or steel (primary or secondary fusion) including continuous casting, with a capacity exceeding 2,5 tonnes per hour	Carbon dioxide
Mineral industry Installations for the production of cement clinker in rotary kilns with a production capacity exceeding 500 tonnes per day or lime in rotary kilns with a production capacity exceeding 50 tonnes per day or in other furnaces with a production capacity exceeding 50 tonnes per day Installations for the manufacture of glass including glass fibre with a melting capacity exceeding 20 tonnes per day Installations for the manufacture of ceramic products by firing, in particular roofing tiles, bricks, refractory bricks, tiles, stoneware or porcelain, with a production capacity exceeding 75 tonnes per day, and/or with a kiln capacity exceeding 4 m3 and with a setting density per kiln exceeding 300 kg/m3	Carbon dioxide
Other activities Industrial plants for the production of (a) pulp from timber or other fibrous materials (b) paper and board with a production capacity exceeding 20 tonnes per day	Carbon dioxide

ANNEX II

GREENHOUSE GASES REFERRED TO IN ARTICLES 3 AND 30

Carbon dioxide (CO_2)

Methane (CH_4)

Nitrous Oxide (N_2O)

Hydrofluorocarbons (HFCs)

Perfluorocarbons (PFCs)

Sulphur Hexafluoride (SF_6)

ANNEX III

CRITERIA FOR NATIONAL ALLOCATION PLANS REFERRED TO IN ARTICLES 9, 22 AND 30

1. The total quantity of allowances to be allocated for the relevant period shall be consistent with the Member State's obligation to limit its emissions pursuant to Decision 2002/358/EC and the Kyoto Protocol, taking into account, on the one hand, the proportion of overall emissions that these allowances represent in comparison with emissions from sources not covered by this Directive and, on the other hand, national energy policies, and should be consistent with the national climate change programme. The total quantity of allowances to be allocated shall not be more than is likely to be needed for the strict application of the criteria of this Annex. Prior to 2008, the quantity shall be consistent with a path towards achieving or over-achieving each Member State's target under Decision 2002/358/ EC and the Kyoto Protocol.

2. The total quantity of allowances to be allocated shall be consistent with assessments of actual and projected progress towards fulfilling the Member States' contributions to the Community's commitments made pursuant to Decision 93/389/EEC.

3. Quantities of allowances to be allocated shall be consistent with the potential, including the technological potential, of activities covered by this scheme to reduce emissions. Member States may base their distribution of allowances on average emissions of greenhouse gases by product in each activity and achievable progress in each activity.

4. The plan shall be consistent with other Community legislative and policy instruments. Account should be taken of unavoidable increases in emissions resulting from new legislative requirements.

5. The plan shall not discriminate between companies or sectors in such a way as to unduly favour certain undertakings or activities in accordance with the requirements of the Treaty, in particular Articles 87 and 88 thereof.

6. The plan shall contain information on the manner in which new entrants will be able to begin participating in the Community scheme in the Member State concerned.

7. The plan may accommodate early action and shall contain information on the manner in which early action is taken into account. Benchmarks derived from reference documents concerning the best available technologies may be employed by Member States in developing

their National Allocation Plans, and these benchmarks can incorporate an element of accommodating early action.

8. The plan shall contain information on the manner in which clean technology, including energy efficient technologies, are taken into account.

9. The plan shall include provisions for comments to be expressed by the public, and contain information on the arrangements by which due account will be taken of these comments before a decision on the allocation of allowances is taken.

10. The plan shall contain a list of the installations covered by this Directive with the quantities of allowances intended to be allocated to each.

11. The plan may contain information on the manner in which the existence of competition from countries or entities outside the Union will be taken into account.

ANNEX IV

PRINCIPLES FOR MONITORING AND REPORTING REFERRED TO IN ARTICLE 14(1)

Monitoring of carbon dioxide emissions

Emissions shall be monitored either by calculation or on the basis of measurement.

Calculation

Calculations of emissions shall be performed using the formula:

Activity data × Emission factor × Oxidation factor

Activity data (fuel used, production rate etc.) shall be monitored on the basis of supply data or measurement.

Accepted emission factors shall be used. Activity-specific emission factors are acceptable for all fuels. Default factors are acceptable for all fuels except non-commercial ones (waste fuels such as tyres and industrial process gases). Seam-specific defaults for coal, and EU-specific or producer country-specific defaults for natural gas shall be further elaborated. IPCC default values are acceptable for refinery products. The emission factor for biomass shall be zero.

If the emission factor does not take account of the fact that some of the carbon is not oxidised, then an additional oxidation factor shall be used. If activity-specific emission factors have been calculated and already take oxidation into account, then an oxidation factor need not be applied.

Default oxidation factors developed pursuant to Directive 96/61/EC shall be used, unless the operator can demonstrate that activity-specific factors are more accurate.

A separate calculation shall be made for each activity, installation and for each fuel.

Measurement

Measurement of emissions shall use standardised or accepted methods, and shall be corroborated by a supporting calculation of emissions.

Monitoring of emissions of other greenhouse gases

Standardised or accepted methods shall be used, developed by the Commission in collaboration with all relevant stakeholders and adopted in accordance with the procedure referred to in Article 23(2).

Reporting of emissions

Each operator shall include the following information in the report for an installation:

A. Data identifying the installation, including:

— Name of the installation;

— Its address, including postcode and country;

— Type and number of Annex I activities carried out in the installation;

— Address, telephone, fax and email details for a contact person; and

— Name of the owner of the installation, and of any parent company.

B. For each Annex I activity carried out on the site for which emissions are calculated:

— Activity data;

— Emission factors;

— Oxidation factors;

— Total emissions; and

— Uncertainty.

C. For each Annex I activity carried out on the site for which emissions are measured:

— Total emissions;

— Information on the reliability of measurement methods; and

— Uncertainty.

D. For emissions from combustion, the report shall also include the oxidation factor, unless oxidation has already been taken into account in the development of an activity-specific emission factor.

Member States shall take measures to coordinate reporting requirements with any existing reporting requirements in order to minimise the reporting burden on businesses.

ANNEX V

CRITERIA FOR VERIFICATION REFERRED TO IN ARTICLE 15

General Principles

1. Emissions from each activity listed in Annex I shall be subject to verification.

2. The verification process shall include consideration of the report pursuant to Article 14(3) and of monitoring during the preceding year. It shall address the reliability, credibility and accuracy of monitoring systems and the reported data and information relating to emissions, in particular:

(a) the reported activity data and related measurements and calculations;

(b) the choice and the employment of emission factors;

(c) the calculations leading to the determination of the overall emissions; and

(d) if measurement is used, the appropriateness of the choice and the employment of measuring methods.

3. Reported emissions may only be validated if reliable and credible data and information allow the emissions to be determined with a high degree of certainty. A high degree of certainty requires the operator to show that:

(a) the reported data is free of inconsistencies;

(b) the collection of the data has been carried out in accordance with the applicable scientific standards; and

(c) the relevant records of the installation are complete and consistent.

4. The verifier shall be given access to all sites and information in relation to the subject of the verification.

5. The verifier shall take into account whether the installation is registered under the Community eco-management and audit scheme (EMAS).

Methodology

Strategic analysis

6. The verification shall be based on a strategic analysis of all the activities carried out in the installation. This requires the verifier to have an overview of all the activities and their significance for emissions.

Process analysis

7. The verification of the information submitted shall, where appropriate, be carried out on the site of the installation. The verifier shall use spot-checks to determine the reliability of the reported data and information.

Risk analysis

8. The verifier shall submit all the sources of emissions in the installation to an evaluation with regard to the reliability of the data of each source contributing to the overall emissions of the installation.

9. On the basis of this analysis the verifier shall explicitly identify those sources with a high risk of error and other aspects of the monitoring and reporting procedure which are likely to contribute to errors in the determination of the overall emissions. This especially involves the choice of the emission factors and the calculations necessary to determine the level of the emissions from individual sources. Particular attention shall be given to those sources with a high risk of error and the abovementioned aspects of the monitoring procedure.

10. The verifier shall take into consideration any effective risk control methods applied by the operator with a view to minimising the degree of uncertainty.

Report

11. The verifier shall prepare a report on the validation process stating whether the report pursuant to Article 14(3) is satisfactory. This report shall specify all issues relevant to the work carried out. A statement that the report pursuant to Article 14(3) is satisfactory may be made if, in the opinion of the verifier, the total emissions are not materially misstated.

Minimum competency requirements for the verifier

12. The verifier shall be independent of the operator, carry out his activities in a sound and objective professional manner, and understand:

(a) the provisions of this Directive, as well as relevant standards and guidance adopted by the Commission pursuant to Article 14(1);

(b) the legislative, regulatory, and administrative requirements relevant to the activities being verified; and

(c) the generation of all information related to each source of emissions in the installation, in particular, relating to the collection, measurement, calculation and reporting of data.

Supplement 3 Measuring of Emissions

State	Allocated Emissions	Verified Emissions	Difference of Allocated/ Verified Emissions in Thousands EUR	kg CO_2/ Capita	Tonnes CO_2/km^2	Percentage of Industry	Tonnes CO_2/GDP
Austria	97765629	97506837	3032.89	11889.10728	1162.761299	30.4	379.64
Belgium	178690906	162933891	184514.47	15597.95132	5402.675608	24.0	511.31
Czech Republic	290759913	253914360	431466.66	24843.44671	3214.105823	37.8	2232.43
Denmark	93114184	90082676	35493.01	16646.81834	2090.376294	24.6	414.33
Estonia	56290413	40061039	190041.59	29729.67844	890.2453111	28.0	3001.75
Finland	133903906	120262466	159747.82	22965.70549	355.8061124	30.3	716.22
France	450154951	384877666	764393.67	6131.274004	699.7775745	20.6	212.75
Germany	1486273037	1440162660	539948.1	17456.33745	4035.719538	29.1	617.61
Greece	213487296	213949914	-5421.73	19304.76594	1621.360852	20.6	1015.16
Hungary	90708498	78844308	138927.44	7808.261985	847.7882581	32.1	845.89
Ireland	57714569	65392457	-89897.67	15830.8415	934.1779571	46.0	371.13
Italy	624455563	679816982	-648277.31	11628.28198	2256.556504	29.1	457.30
Latvia	12163293	8644387	41207.49	3747.944663	132.9905692	26.3	516.91
Lithuania	34394402	19119524	178858.54	5581.814742	294.1465231	33.3	781.18
Luxembourg	9687963	7883552	21124.84	17092.45279	3048.550657	13.0	232.11
Netherlands	259317094	236927138	262186.9	14530.48114	5659.448165	23.9	438.14
Poland	712657980	622384223	1057108.54	16303.94806	1988.447997	31.2	2256.35
Portugal	110726424	100739038	116947.77	9567.537114	1094.133265	28.6	646.29
Slovakia	91444383	75291846	189139.92	13982.23488	1536.568286	31.4	1637.81
Slovenia	26075969	26611366	-6264.85	13321.73569	1330.5683	34.7	845.86
Spain	498109995	549925554	-606765.36	12777.66408	1089.431782	29.4	560.04
Sweden	67619251	58311169	108996.68	6470.828147	129.5803756	28.1	186.23
United Kingdom	627952451	750254927	-1432168.13	12491.77783	3093.834751	25.6	418.08

Supplement 4 Ordinary Least Squares Method

Data set

State	Percentage of 2012 Target Fulfilment in 2007	Unit Vector	GDP Per Capita (base index), 100=EU27	Percentage of Industry	Corruption Index	Human Development Index
Variable	y	x_1	x_2	x_3	x_4	x_5
Austria	78.167	1.000	124.000	30.650	8.467	0.952
Belgium	102.664	1.000	118.767	24.150	7.267	0.950
Czech Republic	118.557	1.000	77.933	38.400	4.767	0.899
Denmark	82.206	1.000	122.367	25.300	9.467	0.953
Estonia	177.950	1.000	65.367	28.550	6.533	0.878
Finland	90.662	1.000	114.933	31.350	9.533	0.955
France	106.157	1.000	109.500	20.700	7.400	0.958
Germany	101.804	1.000	115.967	29.550	8.000	0.945
Greece	101.461	1.000	92.967	20.700	4.433	0.938
Hungary	189.970	1.000	63.100	31.100	5.167	0.877
Ireland	75.502	1.000	146.867	46.000	7.433	0.963
Italy	87.465	1.000	103.533	27.850	5.867	0.949
Latvia	197.425	1.000	53.000	23.900	4.567	0.859
Lithuania	183.633	1.000	56.067	34.300	4.800	0.866
Luxembourg	73.394	1.000	266.100	13.800	8.500	0.958
Netherlands	96.509	1.000	77.333	24.250	8.733	0.961
Poland	132.768	1.000	131.000	31.350	3.767	0.876
Portugal	93.314	1.000	52.500	26.800	6.533	0.907
Slovakia	141.104	1.000	76.467	31.500	4.633	0.873
Slovenia	90.373	1.000	63.600	34.650	6.367	0.924
Spain	75.360	1.000	88.267	29.550	6.833	0.952
Sweden	114.664	1.000	103.967	28.550	9.233	0.961
United Kingdom	106.707	1.000	121.333	24.850	8.533	0.946

Matrix X

1.00	124.000	30.650	8.467	0.952
1.00	118.767	24.150	7.267	0.950
1.00	77.933	38.400	4.767	0.899
1.00	122.367	25.300	9.467	0.953
1.00	65.367	28.550	6.533	0.878
1.00	114.933	31.350	9.533	0.955
1.00	109.500	20.700	7.400	0.958
1.00	115.967	29.550	8.000	0.945
1.00	92.967	20.700	4.433	0.938
1.00	63.100	31.100	5.167	0.877
1.00	146.867	46.000	7.433	0.963
1.00	103.533	27.850	5.867	0.949
1.00	53.000	23.900	4.567	0.859
1.00	56.067	34.300	4.800	0.866
1.00	266.100	13.800	8.500	0.958
1.00	77.333	24.250	8.733	0.961
1.00	131.000	31.350	3.767	0.876
1.00	52.500	26.800	6.533	0.907
1.00	76.467	31.500	4.633	0.873
1.00	63.600	34.650	6.367	0.924
1.00	88.267	29.550	6.833	0.952
1.00	103.967	28.550	9.233	0.961
1.00	121.333	24.850	8.533	0.946

Vector y

78.167
102.664
118.557
82.206
177.950
90.662
106.157
101.804
101.461
189.970
75.502
87.465
197.425
183.633
73.394
96.509
132.768
93.314
141.104
90.373
75.360
114.664
106.707

Matrix X^T

1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
124.000	118.767	77.933	122.367	65.367	114.933	109.500	115.967	92.967	63.100	146.867	103.533	53.000	56.067	266.100	77.333	131.000	52.500	76.467	63.600	88.267	103.967	121.333
30.650	24.150	38.400	25.300	28.550	31.350	20.700	29.550	20.700	31.100	46.000	27.850	23.900	34.300	13.800	24.250	31.350	26.800	31.500	34.650	29.550	28.550	24.850
8.467	7.267	4.767	9.467	6.533	9.533	7.400	8.000	4.433	5.167	7.433	5.867	4.567	4.800	8.500	8.733	3.767	6.533	4.633	6.367	6.833	9.233	8.533
0.952	0.950	0.899	0.953	0.878	0.955	0.958	0.945	0.938	0.877	0.963	0.949	0.859	0.866	0.958	0.961	0.876	0.907	0.873	0.924	0.952	0.961	0.946

Matrix X^TX

23	2344.933333	657.8	156.8333333	21.30066667
2344.933333	284236.4333	64901.51667	16783.38	2191.553978
657.8	64901.51667	19750.2	4430.48	608.0622
156.8333333	16783.38	4430.48	1141.234444	146.4027333
21.30066667	2191.553978	608.0622	146.4027333	19.75711867

Matrix $(X^TX)^{-1}$

66.26823	0.0131068	-0.0372615	1.0079118	-79.221341
0.0131068	3.35E-05	5.282E-05	-1.835E-05	-0.0193369
-0.0372615	5.282E-05	0.001207	0.0004383	-0.0060931
1.0079118	-1.835E-05	0.0004383	0.036512	-1.3686698
-79.221341	-0.0193369	-0.0060931	-1.3686698	97.93569

Matrix X^Ty

2617.816412
246332.6868
75315.09926
16956.63995
2397.269507

Estimated Parameters calculated by $(X^TX)^{-1} X^Ty$

γ_{11} =	1076.228645
γ_{12} =	-0.124377837
γ_{13} =	-0.774664155
γ_{14} =	5.071721154
γ_{15} =	-1038.917038

Correlation Matrix

Variable	Fulfilment	GDP	Percentage of Industry	Corruption Perceptions Index	HDI
Fulfilment	1				
GDP	-0.534395572	1			
Percentage of Industry	0.08038181	-0.332573913	1		
Corruption Perceptions Index	-0.582524213	0.440699967	-0.211833706	1	
HDI	-0.861806414	0.53785344	-0.213589899	0.785157676	1

Calculation for Model Verification

Country	y	ŷ	u	u^2	y - ȳ	$(y - \bar{y})^2$	(ŷ - ȳ)	$(\hat{y} - \bar{y})^2$
Austria	78.167	90.95388825	-12.787	163.5015471	-35.651	1270.993014	-22.864	522.7724
Belgium	102.664	92.28557895	10.378	107.7055416	-11.154	124.420592	-21.533	463.64967
Czech Republic	118.557	127.3234539	-8.767	76.85595543	4.739	22.4542936	13.505	182.39445
Denmark	82.206	99.68060174	-17.475	305.3604696	-31.612	999.3229373	-14.138	199.86899
Estonia	177.950	167.2942091	10.656	113.5396957	64.132	4112.862759	53.476	2859.6937
Finland	90.662	93.48609484	-2.824	7.976464142	-23.156	536.2130023	-20.332	413.39063
France	106.157	88.47563143	17.681	312.6347738	-7.661	58.69080365	-25.342	642.24096
Germany	101.804	98.05710919	3.747	14.0401178	-12.014	144.3357432	-15.761	248.40898
Greece	101.461	96.26424635	5.197	27.00665339	-12.357	152.6970778	-17.554	308.13795
Hungary	189.970	159.3619978	30.608	936.8256127	76.151	5799.050952	45.544	2074.2462
Ireland	75.502	59.20351529	16.298	265.6408656	-38.316	1468.123277	-54.615	2982.7534
Italy	87.465	85.25251806	2.212	4.894724494	-26.353	694.490327	-28.566	815.99275
Latvia	197.425	181.8532698	15.572	242.4754388	83.607	6990.094972	68.035	4628.7837
Lithuania	183.633	167.6726253	15.960	254.7250878	69.815	4874.082515	53.855	2900.3094
Luxembourg	73.394	79.92213803	-6.528	42.61011808	-40.424	1634.068201	-33.896	1148.9366
Netherlands	96.509	93.71824355	2.791	7.789662541	-17.309	299.5967945	-20.100	404.00442
Poland	132.768	145.0078897	-12.240	149.8060475	18.950	359.1122295	31.190	972.80268
Portugal	93.314	140.1216055	-46.808	2190.97628	-20.504	420.4289828	26.304	691.87414
Slovakia	141.104	158.4940595	-17.390	302.4039285	27.286	744.5361435	44.676	1995.9409
Slovenia	90.373	114.1530213	-23.780	565.4760536	-23.445	549.6597689	0.335	0.112169
Spain	75.360	87.96664233	-12.606	158.9168566	-38.458	1478.993572	-25.851	668.29812
Sweden	114.664	89.26414618	25.400	645.1386841	0.846	0.715076065	-24.554	602.89689
United Kingdom	106.707	102.0039259	4.703	22.12188872	-7.111	50.56330306	-11.814	139.57483
SUM	113.818			6918.422467		32785.50634		25867.084

Model Verification

Variable	Unit Vector	GDP	Percentage of Industry	Corruption Index	HDI
S_{ii}	25470.64601	0.012877804	0.464056109	14.03369549	37642.25039
S_{bi}	159.5952568	0.11348041	0.681216639	3.746157429	194.0161086
t-value	6.743487657	1.096029148	1.137177384	1.353846241	5.354797836
t-tab. (α=0.05)	2.1009	2.1009	2.1009	2.1009	2.1009
Significant/Insignificant	S	I	I	I	S

S = Significant (t-value > t-tab)
I = Insignificant (t-value < t-tab)