Cap and trade policies to battle climate change

Sfyris Evangelos

SID: 3303160004

SCHOOL OF SCIENCE & TECHNOLOGY

A thesis submitted for the degree of

Master of Science (MSc) in Energy Management

APRIL 2018

THESSALONIKI – GREECE

INTERNATIONAL HELLENIC UNIVERSITY

Cap and trade policies to battle climate change

Sfyris Evangelos

SID: : 3303160004

Supervisor: Sartzetakis Eftychios

Supervising Committee Members:

SCHOOL OF SCIENCE & TECHNOLOGY

A thesis submitted for the degree of

Master of Science (MSc) in Energy Management

APRIL 2018

THESSALONIKI – GREECE

Abstract

This dissertation was written as a part of the MSc in Energy Management Hellenic University.

The main issue of this dissertation is the Cap and Trade programs. Reference, analysis and a historical retrospective are made for the emission trading systems all over the world as well as the European Union emission trading system.

There is a reference to climate change and its impacts, but also solutions and how to improve them. The Kyoto Protocol is being analyzed, and finally we mention the case of Greece and its non-compliance with the EU ETS.

Sfyris Evangelos

29/4/2018

Contents

Abstract ..... **iii**

Contents ..... **v**

1 Introduction **1**

2 Climate Change **3**

2.1 WHAT IS CLIMATE CHANGE 3

2.2 WHAT CAUSES CLIMATE CHANGE 3

2.3 SOLUTIONS TO CLIMATE CHANGE 6

3 Kyoto Protocol **8**

3.1 GENERAL 8

3.2 WHAT IS THE KYOTO PROTOCOL 9

3.3 FLEXIBLE MECHANISMS OF THE PROTOCOL 10

4 Emission Trading System **11**

4.1 CAP AND TRADE SYSTEM 12

4.1.1 What is cap and trade *12*

4.1.2 What cap and trade means *13*

4.1.3 How cap and trade works *13*

4.1.4 Cap and trade failures *14*

4.2 EU ETS 17

4.2.1 History of EU ETS *18*

4.3 REVIEW OF PAST TRADING SYSTEMS 23

4.3.1 Lead Trading *23*

4.3.2 Sulfur Dioxide Allowance Trading *24*

4.3.3 NOx Trading *25*

4.4 RECENT PROGRAMS IN THE USA 28

4.4.1 California' AB-32 Cap and Trade System *28*

4.4.2 The Regional Greenhouse Gas Initiative *29*

5 The case of Greece 31

5.1 THE CASE OF PPC 34

5.1.1 The problems that arise in Greece 34

6 Conclusions 36

7 Bibliography 37

1 Introduction

Over the last few years, we have seen an unprecedented human effort for ever greater economic growth. This has the effect of bringing radical changes to the environment in the last forty years. The use of more and more natural resources, which are already limited, has the consequence of damaging the environment and if this continues without limitation the effects will be irreversible.

Large amounts of pollutant emissions such as carbon dioxide are released daily into the atmosphere. This has the effect of creating the greenhouse phenomenon, global warming of the planet and the extreme weather phenomena that their appearance is becoming more and more common.

Mostly since the 1980s, the problem of climate change has become globally perceived. The world community, taking on the underlying risks, has decided to find solutions to take tough measures both locally and globally to address this threat.

Thus, as a first step, in 1997 in Kyoto, Japan, through the cooperation of the States at the United Nations Conference, the Kyoto Protocol was signed. This protocol is a joint decision to take measures and rules to reduce pollutants in the atmosphere and reduce the effects of climate change.

Through the Kyoto Protocol, emissions trading systems, the world's first pollutant trading programs, have emerged. Through trade in pollutants and the cap and trade program, which is the main subject of this dissertation, countries across the world could by means of legally and binding rules, reach the desired levels of pollution to improve the problem of climate change.

Thus, in this work, a reference is made to climate change, its effects and solutions to improve the problem. We then refer to the Kyoto Protocol for its operation as well as its mechanisms.

Continuing, the pollutant emissions trading system, the cap and trade system and all the methods used by it, but also the problems being raised, are analyzed.

There is a reference to the largest European environmental program, the European Union Emission Trading System, and a historical retrospective of this. In addition,

various emission trading schemes have been described which have helped significantly to reach the Kyoto Protocol.

Lastly, we refer to Greece, to the problems that exist in our country and to the non-compliance with the rules of the Protocol as well as in the case of PPC of the largest power generation company in Greece.

2 Climate Change

2.1 What is climate change

Climate change has been at the heart of world news for at least 30 years because of its rapid impact on both ecosystems and structures of international relations. Climate change is responsible for the emergence of extreme phenomena such as ice melting, global warming, floods, fires extreme weather events, ocean acidification and other such phenomena that did not exist in the previous years.[1]

Climate conditions on Earth are determined by a continuous flow of energy from the sun. The solar thermal energy penetrates the Earth's atmosphere and heats its surface. As the surface temperature increases, Earth sends, in the form of infrared radiation, thermal energy back into the atmosphere. A portion of this energy is absorbed by gases, so-called greenhouse gases, such as carbon dioxide, nitrous oxide, methane, fluorinated gases and water vapor, thereby trapping energy and maintaining the average temperature of the earth at about 15-16 ° C. These levels of temperature are essential to preserving life for humans, plants and animals. Without these gases, the earth's temperature would reach -19 ° C, freezing most life forms that live on it.[2]

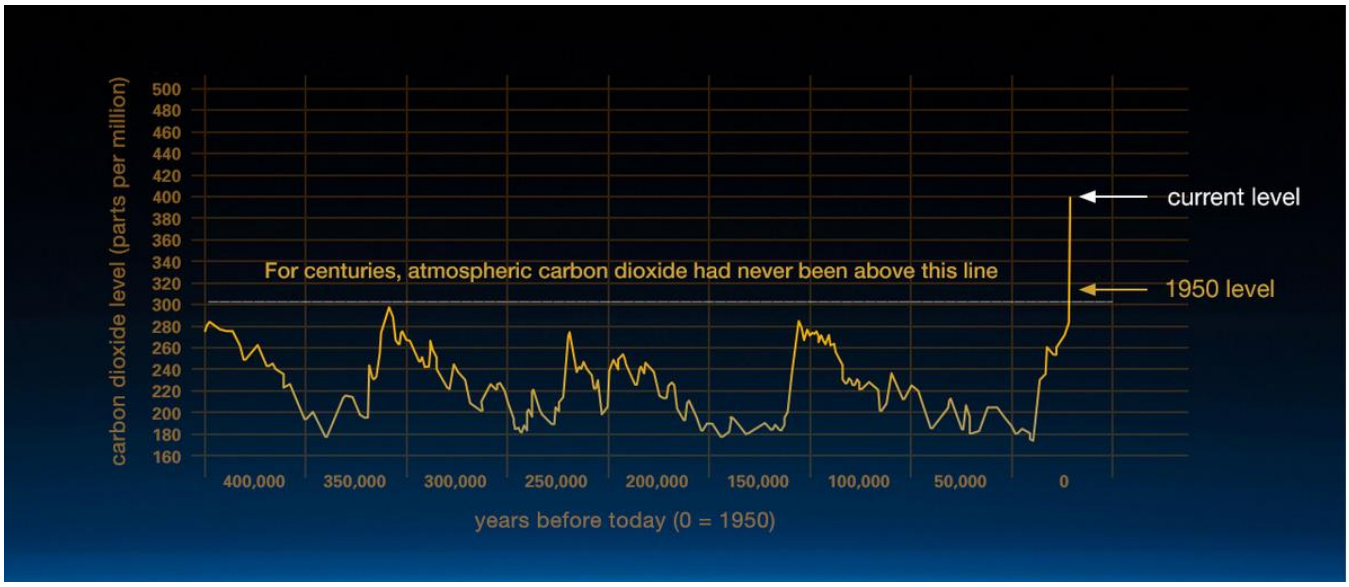
2.2 What causes climate change

The main cause of climate change is the excessive use of mineral resources such as lignite, coal, oil and gases the burning of which releases enormous amounts of CO2 into the atmosphere. In this way, the layer of the greenhouse gases covering earth holds more and more energy which increases the average temperature of the planet. The significant amount of CO2 that is concentrated in the atmosphere rises rapidly, and this increase is significantly higher than any natural process. The result is the inability of natural systems to adapt to new data. That leads to temperature rise, what we call global warming.

Carbon dioxide (CO2) is the most important of the gases that maintain the desired temperature levels on Earth. The naturally occurring CO2 emission and absorption processes are the natural cycle of gas and are responsible for maintaining a balanced concentration of CO2 in the atmosphere. Through the decomposition of plants, volcanic eruptions, breathing animal organisms, CO2 is released into the atmosphere which is reabsorbed by photosynthesis and dissolution in water.

CO2 is the greenhouse gas most commonly produced by human activity and responsible for *63% of the global warming* due to these activities. Its concentration in the atmosphere *is now 40% higher* than at the start of industrialization. Other greenhouse gases are released in smaller quantities but they trap heat far more than CO2, and in some cases, they are much stronger. Methane accounts for 19% of global warming by human-made causes and nitrogen oxide for 6%. [3]

Nature has provided for the almost perfect preservation of the CO2 emitted balance and the corresponding amount absorbed. However, small changes due to human activities may also affect this fragile balance.



Picture 1: The history of CO2 levels (Source: NASA)[4]

In the picture above, NASA data can distinguish carbon dioxide emissions from millenniums to the present. We noticed that CO2 emissions did not exceed 300 parts per million (as shown in the chart) until 1950, over thousands of years ago. From this point onwards, after human intervention and the lack of respect for it, CO2 emissions have increased dramatically in just 50-60 years.

All this began with extreme human intervention, in the natural cycle of CO2 over the last 150 years. The reckless burning of fossil fuels, cutting of the trees that absorb greenhouse gases coupled with some livestock activity that contributes to methane emissions, have irreparably damaged the CO2 cycle. It is clear that increasing global warming does not necessarily mean a warmer climate for everyone in all parts of the world. As the planet heats up, it changes the climate system, contributing to the increase in the occurrence of extreme and unpredictable weather phenomena. The result is that other areas will be warmer, colder, and the humidity levels of the planet will be affected, otherwise creating drought conditions or sometimes too much rainfall.

Below we mention some of the reasons for increased carbon dioxide emissions.

Combustion of coal, oil and natural gas produces carbon dioxide and nitrous oxide.

Deforestation: Deforestation is the permanent destruction of forests in order to make the land available for other uses. An estimated 18 million acres (7.3 million hectares) of forest, are lost each year, according to the United Nations' Food and Agriculture Organization (FAO).[5] Trees help regulate the climate because they absorb CO2 from the atmosphere. Therefore, when they are reduced, this positive effect is lost, and the coal that will be stored in them is released into the atmosphere, exacerbating the greenhouse effect.

Increase livestock: cows, sheep and goats produce large amounts of methane when digesting their food.

Nitrogen fertilizers are responsible for nitrous oxide emissions.

Fluoride gases have a tremendous heating effect, up to 23,000 times that of CO2. [3]

So, according to scientists and climatologists in all over the world, human intervention is the one that is largely responsible for overheating the planet. If no particular attention is paid to the environment over the coming years, the results may be irreversible with extremely unpleasant effects.

2.3 Solutions to climate change

The major issues raised by climate change have been mentioned above. But what are the solutions to remedy this problem? Below are some general solutions to reduce pollutants and improve the climate change phenomenon.

Eliminating the burning of fossil fuels: Coal, oil and natural gas are the most used fossil fuels that produce significant amounts of energy per unit mass through the combustion process. The use of coal as a fuel predates recorded history. This part is one

of the hardest to forego because these types of fuels are widely used for heating, the creation of electricity, the creation of plastic, fuel for engines etc. so we understand its importance in the energy world. Of course, if their use will be reduced, the results will be evident over the next 30 years.

Stop cutting down trees- Deforestation: Every year, 17 million acres of forests are cut down. Timber harvesting in the tropics alone contributes 1.5 billion metric tons of carbon to the atmosphere. That represents 20 percent of human-made greenhouse gas emissions and a source that could be avoided relatively easily.

Renewable Energy: For over 1 billion people all over the world, the access to the energy required to meet very basic needs remains a daily struggle. Access to electricity, heating and cooling is impossible, and these areas and the people living in them are unable to meet their needs, which are considered to be the case for the rest of the world. Connecting to central grids is financially prohibitive and may take decades to be able to connect, and even if connected, it is not certain if their needs will be fully met.

Thus, Renewable Energy Distribution Systems produce and distribute their services independently of any central system. They work in a complementary way and offer an opportunity to the regions that are in a position to synchronize with the rest of the world with modern energy services and many benefits. These benefits are not one-dimensional but multi-faceted. In addition to addressing the needs of the areas we mentioned and mitigating climate change, which are the key issue in the future, facilitate living, communication, include income growth but also reduce dependency on fossil fuels as well as from their import. [6][7]

Efficient energy use: Energy efficiency is the key to ensuring a safe, reliable, affordable and sustainable energy system for the future. It is the one energy resource

that every country possesses in abundance and is the quickest and least costly way of addressing energy security, environmental and economic challenges.[8]

Efficient use of energy is an objective to reduce the amount of energy needed by each production sector. Reducing energy use or improving energy efficiency has many advantages. Energy efficiency can help to reduce pollution emissions as less energy requires the less fuel and hence reduce pollutants that will be directed to the atmosphere. The reduction of energy costs and at the same time reducing economic costs is a great asset. Even the upgrading of existing machines or buildings in a better energy class can help with the problem of climate change.

In that way energy efficiency and renewable energy are said to be the twin pillars of sustainable energy policy.[9]

Climate change as mentioned above is one of the significant issues of our time. Temperatures have already risen 1.4 ºC since the start of the 20th century and will likely rise at least another 2 ºC over the next years. These extreme phenomena combined with the irrational exploitation of natural resources have already been created a situation with highly unpleasant effects worldwide. So we can support all these facts by saying that climate change is capable of bringing more suffering to overcome even than the effects of the world economic crisis that we are facing today.

The immediate solutions proposed by the members of the international community are not just about reducing the frequency of appearance of the phenomena that cause climate change. The effective treatment and the only imperative solution is the engagement of all states so that they can adapt and confront the new conditions that have emerged or are about to follow. So the primary objective of the international community should be an integrated plan accepted and achievable by all, that could lead to a new energy era.

Moves that will be made in the future should have long-term visions so that not only the current generation but also future ones are affected. If we change the way we think and the way we behave in the environment in the next few years, especially after the industrial revolution, we will see significant differences in the future. If we do not change rotation, then the damage that have been caused and caused to the environment will be permanent and irreversible. However, how can we move on to today's assessments situation and to move forward with future prospects and innovations?

Investing in environmentally-friendly practices and turning to renewable sources is a one-way street.

The regulations that have already been put into "measures for the amount of carbon dioxide released into the atmosphere, the stabilization of gas emissions, the cost per ton of carbon dioxide, etc." will be the determinants that will lead to the desired results.

The collapse of ecosystems, rising health risks, the risk of floods in coastal areas, the maintenance of international peace, the rise in temperature and many other sectors are already experiencing the devastating consequences of climate change. International cooperation is the secret to reducing pollutants and mitigating climate change by starting point the Kyoto Protocol.

3 Kyoto Protocol

3.1 General

Over the last decades, our way of life and the growing prosperity of our society have dramatically affected the energy sector and its role in our daily habits. The energy prospects had changed significantly in this context. Increased energy demand in both developed and underdeveloped countries, uncertainty about energy supplies, the sharp rise in oil prices and the fear of continuous global warming and ice melting have made us realise that energy is no longer a given good but something that we need to use with caution. So, perceiving the dangers, the world leaders have pledged to increase the use of renewable energy, that kind of energy that can replace the fossil fuels, reduce the CO2 emissions and bring back the balance in the energy world so that the planet would not be so overburdened. Energy efficiency, stimulating investment in renewables and new technologies contribute to sustainable development and security of supply but also to the creation of new jobs, economic growth, improved competitiveness and a healthier energy sector than the previous years both to people and to the environment. In this context, climate change is not only one of the most significant challenges that we are facing, but it’s also a great opportunity.

All this was a distant dream four decades ago but now there is an urgent need the promotion and use of renewable energy sources in a comprehensive legislative framework. Only such a framework can offer business circles the long-term stability they need to make sensible decisions and invest in renewable energy with as little cost as possible so that the European Union and worldwide enters a course guaranteed a safer, cleaner and more competitive energy future which can endure for many more years.

3.2 What is the Kyoto Protocol

The first steps to tackle the climate change and the greenhouse effect, were noted in 1992 in United Nations Conference on environment and development, held in Rio de Janeiro.[10]

The second step was signing the Kyoto Protocol. The Kyoto Protocol to the United Nations Framework Convention on Climate Change was adopted at the third session of the Conference of the Parties in Kyoto, Japan, on 11 December 1997. The Kyoto Protocol entered into force on February 2005. Currently there are 192 parties (191 States and 1 regional economic integration organization) to the Kyoto Protocol to the UNFCCC. [11]

The Kyoto Protocol is a "roadmap", which includes the necessary steps for the long-term response to climate change caused by an increase in greenhouse gas emissions. Accordingly, the countries that signed the protocol in the first place, were committed to reduce greenhouse gas emissions in the first commitment period that is 2005-2007, by a specific target of at least 5% lower in relation to 1990 emissions especially for: carbon dioxide CO2, methane CH4, nitrogen oxide N2O, hydrofluorocarbons HFC, sulfur hexafluoride SF6 and perfluorocarbons PFC. [10]

So in theory, the Kyoto Protocol sets the limits of CO2 emissions, imposes sanctions and creates a system of pollutant emission inventories worldwide. Some countries and regions, including the European Union, were on track by 2011 to meet or exceed their Kyoto goals, but other large nations were falling woefully short. The two biggest emitters of all, the United States and China, produced more than enough extra greenhouse gas to erase all the reductions made by other countries during the Kyoto period. Worldwide, emissions soared by nearly 40% from 1990 to 2009, according to the Netherlands Environmental Assessment Agency.[12]

In order that countries that have committed themselves to the objectives of the Protocol should achieve the desired emission reduction rates and stabilize the concentration of greenhouse gases in the atmosphere, they may choose between their domestic policies and national measures, or they can choose to follow some of its so-called "Flexible" Mechanisms of the Protocol, which are provided by the latter and operate on the basis of market economy.

3.3 Flexible Mechanisms of the Protocol

The ‘’Flexible’’ Mechanisms of the Protocol are separated in two categories, the ‘’Project-based Mechanisms’’ that is the mechanisms that provide the investments in environmental-friendly programs in the most cost-effective way so as not to burden the global economy and the ‘’International Emissions Trading’’ (IET) which permits exchanges of emission licenses between countries.

The first of the two ‘’Project-based Mechanisms’’ is the *Clean Development Mechanism (CDM).* The CDM allows emission-reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one ton of CO2. These CERs can be traded and sold, and used by industrialized countries to a meet a part of their emission reduction targets under the Kyoto Protocol. The mechanism stimulates sustainable development and emission reductions while giving industrialized countries some flexibility in how they meet their emission reduction limitation targets. The CDM is the main source of income for the UNFCCC Adaptation Fund, which was established to finance adaptation projects and programs in developing country Parties to the Kyoto Protocol that are particularly vulnerable to the adverse effects of climate change. The Adaptation Fund is financed by a 2% levy on CERs issued by the CDM. [13][14]

The second ‘’Project-based Mechanism’’ is the *Joint Implementation or JI*. Under Joint Implementation, countries with commitments under the Kyoto Protocol are eligible to transfer and acquire emission reduction units (ERUs) and use them to meet part of their emission reduction target. JI also allows a country to invest in environmentally-friendly growth programs in another country where investment costs are lower than at national level.[15]

Joint implementation offers Parties a flexible and cost-efficient means of fulfilling a part of their Kyoto commitments, while the host party benefits from foreign investment and technology transfer.

Joint Implementation was widely regarded as less potentially problematic: because emission credits would be accompanied by a corresponding transfer of emission caps, JI projects could not inflate the overall cap adopted by industrialized countries. For the same reason, however, crediting could not start until the first commitment period of the Kyoto Protocol began in 2008. [14]

The third mechanism and the main subject of this dissertation are the carbon market mechanisms or *Emissions Trading Schemes (ETSs).* This mechanism is becoming increasingly popular policy instrument, a government, market-based approach to address the climate change and control pollution by providing economic incentives for achieving reductions in the emissions of pollutants.

It permits the achievement of environmental targets in economic and political efficient terms through the licensing of allowances, granting the right to emit a specific quantity of greenhouse gases over a specified period. Its main advantages are the flexibility in its design, its economic efficiency and the low-cost facilities.

In what follows we will review the theoretical foundations of emission trading system, we will analyze their efficiency properties, and we will examine the main problems.

4 Emission Trading System

The main problem of this climate change period is that we treat the atmosphere as free dumping ground. No one has to pay to pollute the air, and the increasing concentration of warming gases remains a significant problem. A transition to a clean energy economy is difficult, but a first step is putting a price on climate-warming emissions. Under the emission trading scheme, polluters have to pay while guaranteeing that they'll meet emissions-reduction goals.

Emission trading systems contribute to economic efficiency by facilitating emission reductions where it is cheapest to achieve them. Polluters who would find it

costly to reduce their emission are allowed to buy emission allowances from polluters that can abate at lower costs. In a ‘perfectly’ working market, the costs of reducing an additional unit of emissions would be balanced and total costs of reaching a given environmental target would be minimized.

Generally speaking, the Emissions Trading System is the most efficient of the three flexible greenhouse gases emission reduction mechanisms adopted by the Protocol of Kyoto.

4.1 Cap and trade system

4.1.1 What is cap and trade

There are two main types of trading schemes: *“Cap-and-trade systems”* and “*baseline-and-credit systems”.*

Under a baseline-and-credit system, there is no fixed limit on emissions, but polluters that reduce their emissions more than they otherwise are obliged to can earn ‘credits’ that they sell to others who need them to comply with regulations they are subject to.

The cap and trade system is the emission trading system that will concern us, as it is the main body of this dissertation.

A cap-and-trade system sets a ceiling on total allowable emissions but, within this limit, allow system participants to buy and sell allowances at will. These rights constitute the common "trading currency" at the core of the system. Every entitlement permits its holder to emit a ton of CO2. The fact that there is a ceiling on the total number of allowances creates market failures.

At present, for each market year under the current system, Member States shall draw up national allocation plans setting out their total emissions under the ETS and the number of allowances received by each installation in their country. At the end of each year, installations must return the rights corresponding to their emissions. Businesses that keep their emissions below their rights can sell their rights over. Those who have difficulty aligning emissions with their rights can choose either to take measures to reduce their emissions - to invest in more efficient technologies or to use less carbon-intensive energy sources - or to buy the additional rights they need on the market, or a combination of these two possibilities. A determining factor for these choices is

probably their relative cost. In this way, emission reduction is achieved with the best cost-effectiveness ratio.

4.1.2 What cap and trade means

Cap: A "cap" is a legal limit on the number of greenhouse gases our economy can emit each year. Over time, the legal limit diminishes—the cap gets tighter— until we hit our targets and launched a clean-energy economy. The cap acts as a solid backstop behind all other climate policies. Energy efficiency standards for vehicles and appliances, smart-growth plans, building codes, transit investments, tax credits for renewable energy, public investment in energy research and development, utility regulatory reforms—all manner of public actions can move us toward our climate goals. But the cap is our only guarantee that we will get there. There is no substitute for the certainty of an emissions cap.

Trade: "Trade" means that, by law, companies may swap among themselves the permission to emit greenhouse gases. In other words, there is a market for pollution "permits" or "allowances." The point of such a trading system is to put a price on pollution that will travel throughout the economy, motivating businesses and families to find ways to trim greenhouse gases. By turning the permission to pollute into a commodity that is bought and sold, everyone up and down the economic ladder gets new opportunities to make and save money. Trade hitches the flexible power of the marketplace—the mobilized ingenuity of millions of diverse, dispersed, innovative, self- interested people—to our climate goals. Cap and trade is a compelling combination: guaranteed results, flexible means.

4.1.3 How cap and trade works

Here are the basic steps to operate a cap and trade systems:

Recording greenhouse gas emissions. Each country's regulatory authority estimates how many companies of that kind exist and moves on to record the emissions of these companies.

Setting emission allowance levels. Decides how much carbon pollution to allow and require permits so the number of permits would not exceed the cap. In that way, allowance levels and cap match so to ensure that we hit our goals.

Distribution of permits. Permits can be valid for one year or a period depending on the regulatory authority. There are two methods of permits distribution: the first one is selling the permits to firms through an auction and the second one is to give them away free of charge (grandfathering), based on some historical framework such as past energy sales, historical emission levels etc.

Impose the cap. Every year or every predetermined period, the affected firms will fill a report that they will verify that they hold enough permits to cover their emissions. Thus, those companies that emit more will buy permits and those who don't exceed the emission levels will sell theirs.

Lower the emissions. Through a predictable schedule, each year fewer emission permits will be distributed so to reach to the targets. Firms need to ensure that for every period they need to have sufficient allowances to submit otherwise will have to pay fines.

The system of tradable emission rights promotes sustainable production and use of renewable energy sources, encouraging system participants to reduce emissions significantly higher of the already set emission limits, to sell the extra allowances.

It is also considered to be a very important part of the sharing of obligations to respect the need for sustainable development across the countries and the participants of the program and to take account of the different starting points for each Member State.

So, the distribution of rights and obligations between the member states and firms should be characterized by the sense of equality and solidarity.

4.1.4 Cap and trade failures

What has been said so far about cap and trade system was based on perfect market conditions. But if market conditions are not ideal, there will be some problems to be mentioned below.

More generally, the emissions trading system initially proposes cost-effective emission reductions, not an environmentally efficient solution. This means that the results will be delayed because the sustainability of the firms is the primary factor in the system.

Therefore, to lead to national quantitative targets for emission reductions, extremely critical and sensitive decisions on the permitted amounts of pollution with commonly accepted criteria by all Member States must be taken.

MARKET POWER

As has been noted in the past, there are some anti-competitive effects on the market power regarding the Emission Trading System. Initially, the existence of strong participants in a cap and trade regime may prevent the final allocation of permits from being independent of the initial allocation. Thus, a large company which is a potential seller of emission rights has the power to withhold market permits to increase the allowance prices and act as a monopoly. On the contrary, if it is a potential purchaser of rights, it is motivated to buy fewer permits to keep the price low and increase revenue or decrease cost in the permit market. [16]

Since trading behavior depends decisively on the initial allocation, lack of independence is observed and the cost-effectiveness relationship is not achieved. These results are mainly found in a market with few sellers and buyers who can determine their prices because of their number. In this case, the cost-effective allocation is achieved only if the large participants in the market receive the number of permits at the beginning of the period, so they don't have any trade motivation.

The interaction of the permit market is therefore complicated by the influence of the power market in the final distribution of permits. For example, a company with a dominant position on the market can use its ability to handle the price of the permits, increase the cost of production for its rivals, so they buy less technological cost-effective abatement technology. In this way, this company has a major market advantage and will tend to buy more permits or sell less than it would if there was no exclusionary effect on the product market.

So, when the dominant firm receives a very large share of permits and is the seller, the degree to which market power leads to the final allocation is much worse than if that firm receives no permits and is a buyer on the market. In that case, the final distribution would be closer to the efficient allocation than in a competitive market.

Only when the dominant firms exercise their power in the product market and not in the permit market, the final allocation will be totally independent of the initial allocation.[17]

TRANSACTION COSTS

When we talk about transaction costs, we mean the cost that affects the permit market. They are costs that arise from the exchange of goods and services and not from their production, and concern those who have to communicate with each other. They are divided into some categories that we will analyze below.

Initially, searching for information is one of the basic functions. A lot of information is not available in the markets so that brokers can make some choices about pollution controls, cost savings, commercial information, and more, to reduce the transaction cost.

Analysis, decision making and negotiation are also important if we look at how much money and how much time businesses spend on legal issues, insurance services, brokers, etc. Negotiating and making a good decision can save a lot of money from the company thus being an important part of the transaction cost.

Transaction costs can lead to a violation of the independence property.

In the case of increasing marginal transaction costs, independence does not hold. Under such conditions, as the initial allocation of allowances to a source is increased, its equilibrium control level will be reduced, thus increasing the departure of the post-trading equilibrium outcome from the cost-effective outcome. However, increasing marginal transactions costs are unlikely to be an important case in practice, because such costs are unsustainable: parties would simply split their transactions into smaller trades to economize

Finally, under decreasing marginal transaction costs, a theoretically important case, independence does not hold. Such transaction costs might result where brokers offer quantity discounts on their services, or where there are positive information externalities at the market level. In this case, a shift in the allowance allocation away from the cost-effective equilibrium leads to a post-trading outcome that is closer than otherwise to the cost-effective equilibrium. This counterintuitive result is because decreasing marginal transaction costs mean that there are scale economies of trading of which firms can take advantage.

UNCERTAINTY

Uncertainty about future prices of emission rights can lead to a failure of the cap and trade system. Firms and especially smaller one, to avoid the risk of price fluctuations and especially their rise, invest too much in abatement technology. On the other hand, large companies tend to invest less in reducing technologies to offset low prices in the future.

Directly associated with the uncertainty of future prices is the transaction costs that may affect the final distribution of permits. The uncertainty increases the risk of trading, its cost and the opportunity to have profitable transactions for both sides.

4.2 EU ETS

The European Union Emissions Trading System (EU ETS) or European Union Emissions Trading Scheme is the world's largest cap and trade program and arguably the most important market-based application to mitigate the climate change. It is also the largest program for the countries that participate in it including the 28 European Union Member States, Norway, Iceland and Liechtenstein. It was launched in 2005 and is a cornerstone of the EU's policy to battle climate change and a key tool for reducing greenhouse emissions cost-effectively. The EU ETS, limits emissions for more than 11,000 heavy energy using installation between the countries that we've mentioned above and covers around the 45% of the EU's greenhouse gas emissions.[18], [19]

It works under the cap and trade principal, where a maximum cap is set on the total amount of greenhouse gases while the cap is reduced over time so that the total emissions fall. The total number of allowances from these permits corresponds to the sum of the already determined allowable quantity of emissions. Therefore, the state primarily identifies an allowable quantity of emissions, and then, by auction or free of charge, issues licenses to companies. The developed countries listed in Annex I of the Protocol, if they wish to exceed their allowable emission limit, have the option of acquiring greenhouse gases emission allowances from one or more developing countries, with a basic condition of course that they will not have exceeds their own emission limits.

Thus, after each year or a predetermined-period, firms must deliver enough permits to cover all its emissions. If this doesn't happen, heavy fines will be imposed. If

the firm reduces its emissions, it can keep the spare permits to cover its future needs or else sell them to another company that is short of allowances.

With this system, companies are given the opportunity to make reductions of their emissions in much higher levels than expected to sell additional allowances and make profits. Sustainable development is thus promoted, and with the use of renewable energy sources, thousands of companies reduce in a cost-efficient way their emissions of pollutants.

4.2.1 History of EU ETS

Let's make a historical retrospective of the EU ETS starting with the first phases of the program. As far as the European Union is concerned, even during the negotiations on the Kyoto Protocol, there was a negative and cautious attitude towards the Emission Trading System. Thus, following the ratification of the Kyoto Protocol and the acceptance of the terms by the European Union and the United States of America, negotiations have accepted the targets for quantified emission reductions.

This was the beginning of the program so it could start working. In 1997, the Kyoto Protocol set emission reduction targets in 37 industrialized countries for the first time. However, some common beneficiaries of emission reductions have to be found in all the countries that are part of the program.

Thus, in 2000 the European Commission presented a green paper with the first ideas for the design of the EU ETS. The EU ETS Directive was adopted in 2003, and the system was launched in 2005 with the phase 1 (2005-2007).

Phase 1 (2005-2007)

The first phase of the program was piloted as a preparatory for the second phase, which was an important step to start the program to work and to begin to implement the objectives set by the Kyoto Protocol.

As a first step, a carbon price was finalized, free permits were granted for pollutant emissions in Europe and the infrastructure required to monitor the recording and verification of pollutant emissions by the companies covered was established in all the countries that participated in the program. At this stage, the first ‘’penalties’’ for non-compliance with the targets, which were 40€ per ton of pollutants (mainly CO2), were also presented.

In this phase, all the allowances that freely distributed to the firms exceeded emissions because of the absence of reliable emissions data.

As for the prices in this period, there were significant fluctuations due to the "young age" of the program and the lack of data on pollutant emissions. Thus, it is noted that in January 2005, the price of permits per ton of CO2 was approximately at 8€. One year after that in early 2006, the price exceeded 30€. After that and the generous allocation of permits in 2005, it became clear that the prices went in the wrong way so in April 2006 the price fell by about a half and it returned to its initial 8€.

Country	Verified emissions			Change
	2005	2006	2007	2005–2007
Austria	33,372,826	32,382,804	31,751,165	−4.9%
Belgium	55,363,223	54,775,314	52,795,318	−4.6%
Cyprus	5,078,877	5,259,273	5,396,164	6.2%
Czech Republic	82,454,618	83,624,953	87,834,758	6.5%
Germany	474,990,760	478,016,581	487,004,055	2.5%
Denmark	26,475,718	34,199,588	29,407,355	11.1%
Estonia	12,621,817	12,109,278	15,329,931	21.5%
Spain	183,626,981	179,711,225	186,495,894	1.6%
Finland	33,099,625	44,621,411	42,541,327	28.5%
France	131,263,787	126,979,048	126,634,806	−3.5%
Greece	71,267,736	69,965,145	72,717,006	2.0%
Hungary	26,161,627	25,845,891	26,835,478	2.6%
Ireland	22,441,000	21,705,328	21,246,117	−5.3%
Italy	225,989,357	227,439,408	226,368,773	0.2%
Lithuania	6,603,869	6,516,911	5,998,744	−9.2%
Luxembourg	2,603,349	2,712,972	2,567,231	−1.4%
Latvia	2,854,481	2,940,680	2,849,203	−0.2%
Netherlands	80,351,288	76,701,184	79,874,658	−0.6%
Poland	203,149,562	209,616,285	209,601,993	3.2%
Portugal	36,425,915	33,083,871	31,183,076	−14.4%
Sweden	19,381,623	19,884,147	15,348,209	−20.8%
Slovenia	8,720,548	8,842,181	9,048,633	3.8%
Slovakia	25,231,767	25,543,239	24,516,830	−2.8%
United Kingdom	242,513,099	251,159,840	256,581,160	5.8%
Total	**2,012,043,453**	**2,033,636,557**	**2,049,927,884**	**1.9%**

Picture 2: Verified emissions (2005-2007) [20]

In the above table, we observe the emissions changes during the first phase of the EU ETS program over the period 2005-2007. As we can see, only 11 of the 24 countries managed to reduce their emissions with Sweden leading it with 20.8% reduction in 2007 compared to 2005. The other countries reduced their emissions to a smaller percentage.

The remaining 13 countries that participated in the first phase of the program did not manage to reduce their pollutant emissions but instead increased with the highest

increase being recorded in Finland with 28.5% in 2007 compared to 2005. Greece notes that it has increased emissions of 2% of this period.

Another important element we see in the table is the size of each country's emissions at the beginning of the program we are analyzing. Germany had the largest pollutant emissions of 474,990,760 tCO2-eq in 2005 in all the countries, which was 2,012,043,453 tCO2-eq, i.e. less than 25% of the total pollutants of the European Union at that time. Italy, the United Kingdom, Poland and Spain were amongst them at a lower level.

Phase 2 (2008-2012)

The second phase of the EU ETS is linked to the first commitment period of the Kyoto Protocol with specific targets for emissions reductions.

The main features of the second phase are: 3 new countries, Iceland, Liechtenstein and Norway joined the program. There was a 6 to 7% lower cap on license fee concerning 2005. Emission permits were granted free of charge for the period 2005 -2007. On January 23, 2008, though, tabled a proposal for a directive on the full restructuring of the Community Emission Trading Scheme, which proposes phasing out the free supply of pollution permits and replacing it with a Europe-wide auction. In that way, the large number of free licenses continues to exist, but there is a 10% reduction compared to the first phase.

In this phase, the non-compliance with the targets amounts to a penalty of EUR 100 per ton. Total international credits reached the equivalent of 1.4 billion tons of CO2 equivalents. One of the most important features was that in this phase there had been verified annual emission data from the phase 1, which have greatly helped to analyze the market, allocate and set licensing prices and to set the level of the cap.

Although in the first phase allowed trading only in CO2, the second phase broadened the program to include some other GHGs.

As for the prices in phase 2, increased to over 20€ in 2008 but the fell at the beginning of 2011 at 10€ and have remained in that range since then.

Phase 3 (2013-2020)

The third phase of the EU ETS is the phase of the program we are currently running. With an experience of 13 years since 2005, which piloted the emissions trading

system in Europe and has gathered data on pollutant emissions over the years, the European Union has moved on some innovative initiatives.

The experience of the past years has shown some mistakes about the program and some movements that were not expected. For this reason, the European Commission has revised the EU ETS 2009 for the third phase of the program.

Initially, it was noted that the EU project did not bring about the necessary changes and substantial transformations to their businesses and their turn to renewable energy or low-emission technologies as expected. The question then arises as to whether the cost-effective amount was the program and how it worked on its own. Finally, there were fraudulent and competitive environments among businesses, which was defamation for the EU ETS.

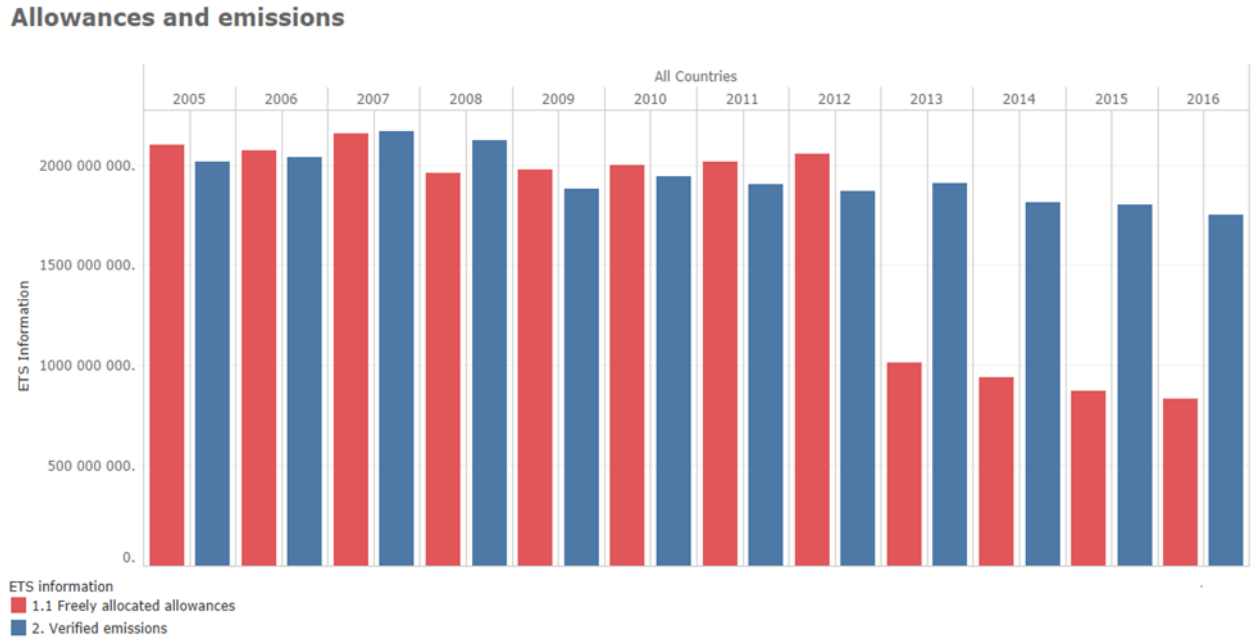
So the EU has made some corrective moves and changes to restore the balance on the market and to achieve the goals that have been set.

One of these changes was the differentiation of the emission limit, which had to be applied uniformly across the European Union. A major change in the third phase of the program was the modification of the basic licensing method. This has changed from ‘’grandfathering’’ to auctioning and some allocations have remained free according to benchmarks.

“Grandfathering” allocates emission budgets cost-free according to emissions in a specified base year. It was the basis of the UNFCCC targets and is found to a great extent in the Kyoto targets (base year 1990/1995). Grandfathering under a strongly declining emissions path due to a tough concentration target will lead to extremely challenging targets for countries with strongly rising business-as-usual emissions. Thus Non-Annex B countries will stiffly oppose global grandfathering. At the same time, grandfathering advantages countries with high emissions in the reference year/period chosen, which are industrialised countries. Grandfathering by itself does not take account of the equity issue. However, initial grandfathering is a crucial dimension of most compromise proposals. [21]

The auctioning process is an important process usually conducted at the national level under the supervision of EU ETS Auctioning Regulation to avoid past and future fraud to ensure transparency and impartiality.

Since the beginning of 2013, the allowances of all verified emissions were auctioned. The cap decreases by 1,74% every year to reduce emissions. The goal is that until 2020 the emissions will be reduced by 20% compared to 2005.



Picture 3: Allowances and emissions of all countries (2005-2016) [22]

The above image shows the allowances and emissions of all European countries that participated in the EU ETS for the period 2005-2016.

Emission units are set as tonnes of CO2 equivalent.

So, as we can see from the graph, in the first years of the program, and especially until 2012, the licenses given free of charge by the operators were much more than verified emissions. For example, in 2012, free licenses granted to companies were 2.054.046.075 tonnes of CO2 equivalent while in the same year the verified emissions were 1.867.031.803 tonnes of CO2 equivalent. Thus, we understand that the difference between the licenses granted and the fewer emissions that had come as a profit to the companies after they were selling the extra permits.

Since the beginning of Phase 3, however, we have seen a different approach from regulators to free-of-charge licensing. Thus, in 2013 and throughout Phase 3, the licenses that were given free of charge decreased significantly. In 2013, the free licenses granted were just 1.012.479.787 tonnes of CO2 equivalent, half of those granted in the previous year. Until 2016, we see a continuing downward trend in granting free licenses. This has contributed to the better implementation of the program so as to increase pressure on businesses and to achieve the targets for reducing carbon dioxide emissions.

As far as the emissions for the period analyzed in the above graph are concerned, we see a gradual decrease. In 2007, carbon dioxide emissions reached the highest point of 2,164,732,601 tCO2-eq with 2016 at the lowest point, up to 1,750,238,539 tCO2-eq.

4.3 Review of past trading systems

This part of the work will refer to older emission trading system. We will analyze their function, how they dealt with the problem of pollutant emissions and what their results have been. We'll examine their design and performance environmentally and economically. Let's note that all these programs were the proponents of the current Emission Trading System in Europe and around the world.

In the previous years, around the middle of the 1980s-early 1990s, the first phenomena of climate change had made their appearance. The global warming problem and pollutant emissions were not yet widespread, and there was no relevant information as it happens today. Also, the unpleasant effects were not yet obvious to a large extent.

Thus, those who knew about these devastating phenomena had to take no action to prevent them. Some measures accepted by all so that they can be implemented by most of the countries and all with the aim of reducing pollutant emissions. With these thoughts, the first emission trading systems began about 30 years ago.

Originally the international community was reluctant. Governments with tradable emission rights were controversial, and the practices followed were in the face of reactions from economists and government representatives.

The first moves and experiences with market-based environmental policies were in the United States, starting to reduce and control the pollutants in the atmosphere in the local and regional air, mainly NOx and SO2.

4.3.1 Lead Trading

In the early 1970s, there was a concern in the United States of America about the presence of lead in gasoline and its use as an additive. Thus, due to the fear of atmospheric pollution by carbon monoxide and hydrocarbon emissions, the EPA has begun imposing regulations to reduce the lead content of gasoline. [23]

Thus, in the early 1980s, the lead was around 10% of its original gasoline share. It was one of the first marketing programs since the 1980s, which refineries produced gasoline with a lower percentage of lead than allowed, won lead credits which they

could sell. If they did not sell the lead credits, they could save them for later use, specifically to cover the lower caps that existed in the future.[17] There was no explicit allocation of permits, but the system implicitly awarded property rights by historical levels of gasoline production.[24]

The lead gasoline phase is believed to have been successful and relatively cost-effective.[25] Trading resulted in leaded gasoline being removed from the market faster than anticipated. A key component of the success was the relatively low transaction costs, as well as the already existing market between refiners for products such as gasoline additives.

EPA estimated savings from the lead trading program of approximately 20 percent compared with alternative approaches that did not provide for trade (U.S. Environmental Protection Agency, Office of Policy Analysis 1985), and the program provided significant incentives for cost-saving technology diffusion.[26]

The first environmental program in which trading played a central role, EPA's leaded gasoline phasedown served as a proof of concept, showing that a tradable emission rights system could be environmentally effective and economically cost-effective.[23]

As in other programs to follow, banking played a very important role. By enabling intertemporal substitution, it contributed a significant share of the gains from trade.

4.3.2 Sulfur Dioxide Allowance Trading

In the 1990s, in the United States, a market-based instrument for regulating emissions of sulfur dioxide took place. Since the 1980s, there has been a concern about SO2 emissions and the environmental impact of these emissions. The acid rain was the main problem that caused by these emissions and the negative human health effects led them to take measures against SO2. So a solution has to be found to limit these emissions, which would help businesses reduce pollution as low as possible.

This created the most important application for the United States, a cap and trade system for reducing sulfur dioxide (SO2) emissions. This system established under Title IV of the Clean Air Act Amendments of 1990. The program was divided into two phases, Phase 1 (1995-1999) and phase 2 (2000-2010).[27] Its intention in Phase 1 was to reduce SO2emissions from 260 most polluting electric generating units, by 50%,

about 10 million tons,[17] below the 1980 levels. In the second phase almost 3,200 electric generating units, participated in the program almost the whole units in the continental United States.

This system of reducing sulfur dioxide (SO2) emissions based on cap and trade methodology. In that way, the government gave power plants, allowances which they substituted tons of SO2 emissions. Thus, if annual emissions of a power plant were reduced below its allowance allocation, the owner could sell the extra allowances to make the profit or could save them for future use. On the other hand, if annual emissions of a power plant exceeded its allowance allocation, the owner could reduce emissions or buy allowances from someone with lower emissions that could sell them.

We find the total (annualized) cost of reducing emissions by 3.9 million tons (relative to the counterfactual) in 1995 to have been about $726 million. (All cost figures include annualized capital costs, along with increases, if any, in operating and fuel costs.) This is an average cost of $187 per ton of emissions reductions, or about $210 per ton on average if emissions reduced at no cost are excluded from the total. (These no-cost reductions all involved switches to low-sulfur Powder River Basin coal that also lowered delivered fuel price.) These per-ton abatement cost figures are at the low end of the range of earlier estimates, which varied from $180 to $307 per ton of emissions reduction for reductions between 3.1 and 4.4 million tons. We estimate emissions reduction through switching to more expensive lower-sulfur coal have cost $153 per ton of emissions reduction on average, while scrubbing costs $265 per ton on average, with considerable variation around both these averages.

The SO2 allowance cap and trade program was and is until today, the first important trading program. With the help of this program, there has been a significant reduction in sulfur dioxide emissions over the years in operation. As in the Lead trading program, here both banking and finance were essential. At last, some free allowances

given to power plants played a significant role to build political support, and this was very important for later cap and trade programs.

4.3.3 NOx Trading

Nitric oxide (NO) and nitrogen dioxide (NO2) are together referred to as nitrogen oxides (NOX). Combustion of fossil fuels is by far the dominant source of NOX emissions. The emissions are not dependent solely on the amount of nitrogen in the fuel

but also on the air-fuel mix ratio. NOX contributes to acid deposition and eutrophication which, in turn, can lead to potential changes occurring in soil and water quality. [28]

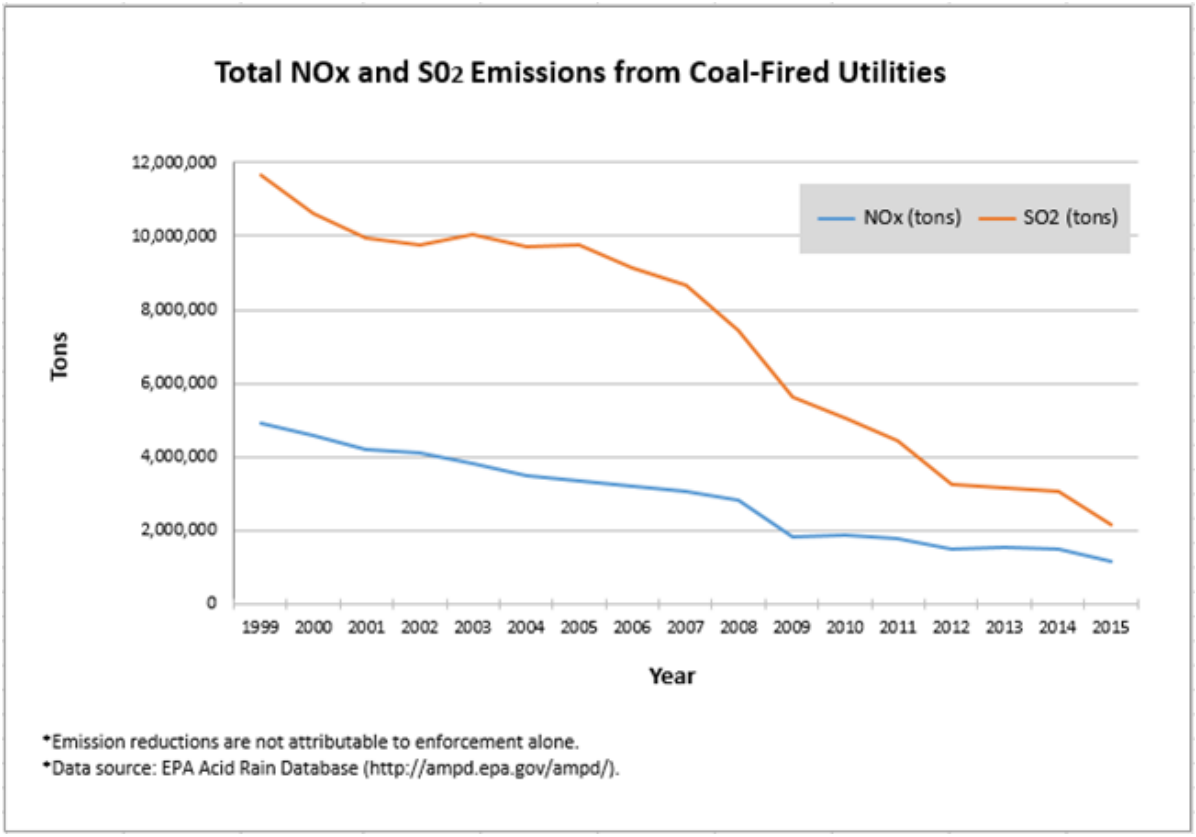
In 1999, in the Eastern United States, under US Environmental Protection Agency (EPA) Guidance, twelve northeastern states and the District of Columbia developed a regional NOx cap and trade system. The program is known as the North-east Ozone Transport Region. [29]

It was a cap and trade program created to reduce the regional transport of NOx Emissions from power plants and other large combustion sources in the regions we've mentioned above. All affected states adopted the model rule.

From the beginning of the program and in the period 2003 to 2008, the NOx emissions dramatically reduced from power plants and industrial sources especially during the summer months, contributing significantly to improvements in ozone air quality in the eastern United States.

Its target was to reduce summertime ground level by more than 50% as compared to 1990 levels. NOx emissions fell from 1.9 million tons in 1990 to 500 thousand tons in 2006[30] and during the first year of emissions trading the price of allowances where low. So this program appears to have been successful and efficient.[31]

The following charts show EPA's progress in reducing emissions from under-controlled coal-fired utilities, cement, glass, and acid plants.p



Picture 4: NOx and SO2 Emissions from Coal-Fired Utilities [32]

The period analyzed in the above diagram covers the years 1999 to 2015. We note that in this period, there have been significant reductions in both SO2 and NOx emissions.

Regarding SO2 emissions, we are seeing a steady downward trend starting in 1999 with pollutant sizes of around 12,000,000 tons. By the middle of 2008 pollutants had fallen to half the initial stage, and by 2015 the measurement showed little more than 2,000,000 tons of SO2.

With regard to NOx, in 1999 the emissions were around 5 000 000 tonnes and, following a downward trend in 2015, emissions dropped to around 1,500,000 tonnes.

What seems clear in the diagram is that SO2 and NOx pollutant reduction programs have been successful since in both cases the emission reductions were large and achieved in a relatively short period of time.

The SO2 allowance cap and trade program was and is till today, the first important trading program. With the help of this program there has been a significant

reduction in sulfur dioxide emissions over the years in operation. As in the Lead trading program, here too banking and finance were extremely important. At last, some of the free allowances given to power plants played a significant role to build political support and this was very important for later cap and trade programs.

4.4 Recent programs in the USA

4.4.1 California' AB-32 Cap and Trade System

The AB 32 Scoping Plan identifies a cap-and-trade program as one of the strategies California will employ to reduce the greenhouse gas (GHG) emissions that cause climate Change. This program is one of the newest cap and trade programs that will help California To meet its goals of reducing GHG emissions to 1990 levels by the year of 2020. Moving past 2020 to 2030, Governor Edmund G. Brown Jr. established an ambitious 2030 greenhouse gas reduction target of 40 % below 1990 levels. The future target of the program is achieving an 80% reduction from 1990 levels by 2050. [33]

More specifically, the targets for 2030 set by the program are: 50% reduction in petroleum use in vehicles and a low carbon fuel standard that requires refineries to reduce the carbon the content of motor vehicle fuels, double energy efficiency savings at existing buildings, Carbon Sequestration in the land base, reduction of short-lived climate pollutants and a renewable portfolio standards that increase the share of renewable electricity supply by 50%.

The program started on January 1, 2012, with an enforceable compliance obligation beginning with 2013 GHG emissions. The facilities subject to the cap and trade program will be able to trade allowances to emit GHGs either they exceed or they reduced the emissions under the limitation that established by the program.

AB 32 includes the major GHGs and groups of GHGs that are being emitted into the atmosphere. These gases include:

1. Carbon dioxide (CO2)
2. Methane (CH4)
3. Nitrous oxide (N2O)

4. Hydrofluorocarbons (HFCs)
5. Perfluorocarbons (PFCs)
6. Sulfur hexafluoride (SF6)
7. Nitrogen trifluoride* (NF3)

4.4.2 The Regional Greenhouse Gas Initiative

RGGI is the first sector-specific cap-and-trade system that applies to CO2 emissions from electric power plants with capacities to generate 25 megawatts or more —164 facilities in the nine RGGI states.[34] RGGI is a cooperative effort among the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont to cap and reduce carbon dioxide (CO2) emissions from the power sector.

Through independent regulations, based on the RGGI Model Rule, each state's CO2 Budget Trading Program limits emissions of CO2 from electric power plants, issues CO2 allowances and establishes participation in regional CO2 allowance auctions.

The program began in 2009 with a goal of limiting emissions from regulated sources to 2008 levels in the period from 2009-2014. The emission cap was set to decrease 2.5% each year beginning in 2015 reaching an ultimate level 10% below 2008 emissions in 2019.[17]

The program has required participating states to auction at least 25% of their allowances and to use the proceeds for renewable energy, energy efficiency or other improvements.[23]

Over the three years period (2012-2014), the RGGI program led to $1.3 billion (net present value) of economic value to the nine-state region. [35] RGGI CO2 cap represents a regional budget for CO2 emissions from the power sector.

We can see below the historical cap levels from the period 2009-2017.

2009-2011: RGGI cap was 188 million allowances per year for the nine-state region

2012-2013: RGGI cap was 165 million allowances per year for the nine-state

2014: RGGI cap was 91,000,000, RGGI adjusted cap was 82,792,336

2015: RGGI cap was 88,725,000, RGGI adjusted cap was 66,833,592

2016: RGGI cap was 86,506,875, RGGI adjusted cap was 64,615,467

2017: RGGI cap was 84,344,203, RGGI adjusted cap was 62,452,795[36]

The RGGI cap and RGGI adjusted cap for the future years 2018-2020 are as follows.

2018: RGGI cap is 82,235,598, RGGI adjusted cap is 60,344,190

2019: RGGI cap is 80,179,708, RGGI adjusted cap is 58,288,301

2020: RGGI cap is 78,175,215, RGGI adjusted cap is 56,283,807

The program's auctions have generated more than 1$ billion in revenues for the states that participating. Some of this revenue was invested to finance government programs that can reduce energy demand or hence CO2 emissions. [35]

System	Geographic Scope	Coverage & Sectors	Time Period	Allowance Allocation Method	Cost Containment Mechanisms	Environmental and Economic Performance
Leaded Gasoline Phasedown	USA	Gasoline from Refineries	1982-1987	Free	Banking	Phasedown completed successfully, faster than anticipated, with cost savings of $250 million/year
Sulfur Dioxide Allowance Trading	USA	SO_2 from Electric Power	1995-2010	Free	Banking	Cut SO_2 emissions by half, with cost savings of $1 billion/year; but market closed due to regulatory of judicial actions
Regional Clean Air Incentives Market (RECLAIM)	South Coast Air Quality Management District, CA	NO_x & SO_2 from Electric Power & Industrial Sources	1993-present	Free	---	Emissions lower than with parallel regulations; un-quantified cost savings; electricity crisis caused allowance price spike and temporary suspension of market
NOX Trading in the Eastern United States	12-21 U.S. States	NO_x from Electric Power & Industrial Sources	1999-2008	Free	---	Significant price volatility in first year; NO_x emissions declined from 1.9 (1990) to 0.5 million tons (2006); cost savings 40-47 percent
Regional Clean Air Incentives Market (RECLAIM)	South Coast Air Quality Management District, CA	NO_x & SO_2 from Electric Power & Industrial Sources	1993-present	Free	---	Emissions lower than with parallel regulations; un-quantified cost savings; electricity crisis caused allowance price spike and temporary suspension of market
Regional Greenhouse Gas Initiative	Nine northeastern U.S. States	CO_2 from Electric Power	2009-present	Nearly 100% Auction	Banking, Cost Containment Reserve, Auction Reservation Price	Cap non-binding then barely binding due to low natural gas prices; has generated more than $1 billion for participating states
AB-32 Cap-and-Trade	California, USA	CO_2 from Electric Power, Industrial, & Fuels	2013- 2020	Transitions from Free to Auction	Banking, Allowance Price Containment Reserve, Auction Reservation Price	Covers 85% of emissions; reduces competitiveness effects w/output-based updating (OBU) allocation; linked with Quebec cap-and-trade system
European Union Emissions Trading System	27 EU Member States plus Iceland, Lichtenstein, & Norway	CO_2 from Electric Power, Large Industrial, & Aviation	2005-2020	Transitions from Free to Increased Use of Auctions	Limited Banking, previous use of offsets from CDM	Over-allocation by member states in pilot phase; suppressed allowance prices due to "complementary policies," CDM glut, slow economic recovery

Picture 5: Evaluation of cap and trade programs worldwide [23]

The above table makes an assessment of the most important cap and trade programs in the world.

5 The case of Greece

Greece has not yet designed a national strategy for adapting to climate change, although it is geographically one of the most vulnerable in the Mediterranean. The adaptation of Greece is a necessity and not a luxury. Our country's dependence on the natural environment is extremely large to be ignored, even in times of economic crisis.[2], [37]

As noted in the study of Greece, Greece is a country with an extremely long coastline, about 16,300 km. (as much as 1/3 of the planet's periphery), of which about 1,000 km are areas of high vulnerability to climate change. The vulnerability lies in the risk that the average sea level in our country will rise, which is estimated to be between 0.2 and 2 meters by 2100.

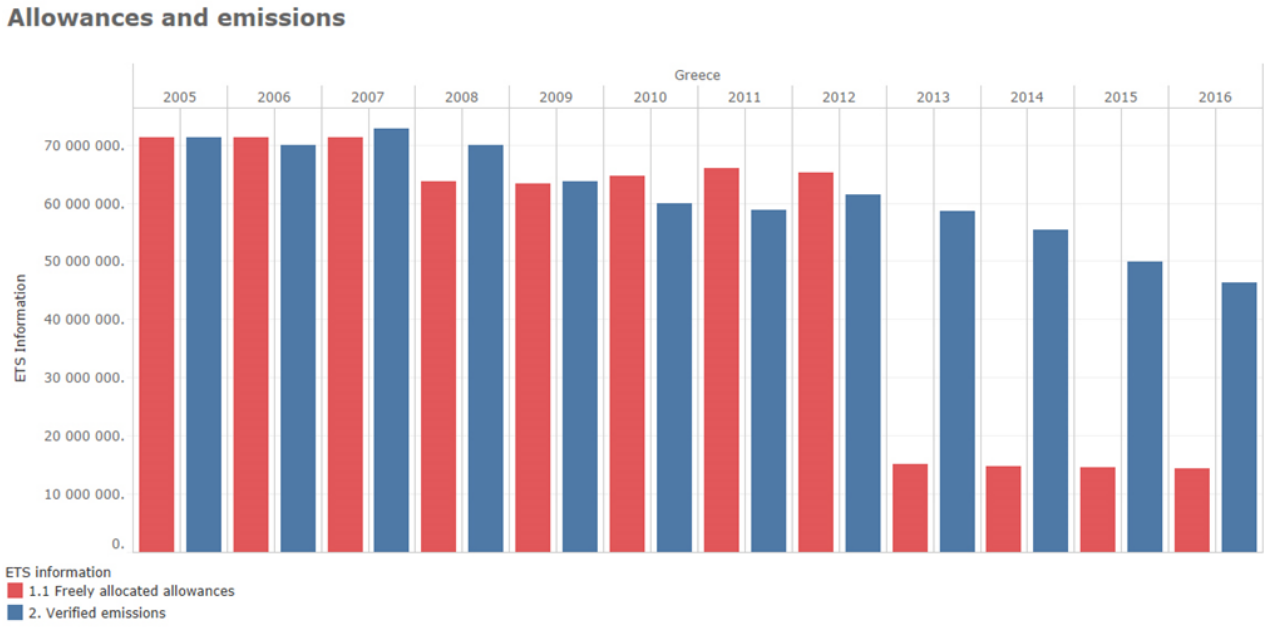
From the entire coastline of Greece, about 20% is a coastline with moderate to high vulnerability to the expected, by estimates, developments. "The risk, especially for some regions, is very high, but it is impossible to list them. The most affected will be those in the great Delta of the rivers, such as Nestos and Axios, Messolongi, etc. ", Mr Zerefos points out - adding that before 1950 the rise of the sea level due to natural causes was the order of 1 - 1.5 millimeters per year, or 15 centimeters per century. "This has very serious consequences, not only on coastal ecosystems and crops, but also on the destabilization of the tourist areas of the country (sandy beaches, etc.), which will risk in such a way that the famous sandy beaches, e.g. in Hawaii ".

Climate change has already had far-reaching effects, ranging from rising temperatures to rising sea levels as a result of the melting of polar ice, as well as the more frequent occurrence of storms and floods. These changes will, in turn, have a serious impact on the integrity of ecosystems, water resources, public health, food supply, industry, crops, transport and infrastructure. The severity of the expected impacts of climate change varies depending on the region.

Addressing climate change requires measures to reduce greenhouse gas emissions and adapt to global and regional levels. At the national level, tackling climate change is one of the key priorities of our government and ministry.

Actions to tackle climate change need to involve a change in the existing development model towards a sustainable, green economy with low or no carbon emissions using state-of-the-art technology. The development of this model should be based on the horizontal coordination of mitigation and adaptation policies in the energy, industrial, agricultural and many other sectors. The cost of limiting emissions and adapting to climate change may seem initially high, but it is very low compared to the costs we will have to pay for inaction.

The Community trading system started on 1 January 2005 and covered only carbon dioxide emissions from large stationary sources (installations belonging to the categories of activities identified in Annex I of the Directive). The first phase was completed in 2007, while the second phase covered the 2008-2012 period. The third phase concerns the years 2013-2020 and includes, in addition to fixed installations and airlines falling under the criteria of Annex I of the Directive. [38]



Picture 6: Allowances and emissions for Greece (2005-2016) [22]

The above image shows the allowances and emissions of Greece during the EU ETS program for the period 2005-2016. Emission units are set as tons of CO2 equivalent.

As can be seen from the diagram, as in a previous chart for Europe, as in the case of Greece, the free licenses available to businesses were dramatically reduced when the third phase of the EU ETS program commenced in 2013.

Since 2005, starting with the analysis of the above chart, we can see that the free licenses did not exceed the pollutant emissions by much, even in 2008, the pollutants were more than the permits granted. For the 2010-2012 period, we can see that the free licenses granted were far more than pollutant emissions.

For example, in 2011, the permits granted were 66,015,014 tCO2-eq while emissions were measured at 58,838,181 tCO2-eq. Thus, we understand that the difference between the licenses granted and the fewer emissions that had come as a profit to the companies after they were selling the extra permits.

Since the beginning of Phase 3, however, we have seen a different approach from regulators to free-of-charge licensing as in the case in all countries that participated in the program. Thus, in 2013 and throughout Phase 3, the licenses that were given free of charge decreased significantly. In 2013, the free licenses granted were 15,030,093 tCO2-eq, i.e. one quarter of the number of licenses from the previous year. Verified emissions in the same year remained at high levels at 58,632,976 tCO2-eq.

As far as the emissions for the period analyzed in the above graph are concerned, we see a gradual decrease. In 2007 pollutant emissions in Greece were at their highest point at 72,717,011 tCO2-eq, while in the last year of the chart, 2016 emissions were reduced to 46,299,722 tCO2-eq.

The logic of the accumulation of surpluses in an industry sector also applies to their distribution per company, the vast majority of surpluses being concentrated in only a few enterprises. The companies with the largest cumulative surpluses for the period 2008-2011 were identified. The survey showed that 18.7 million "surplus" free allowances were distributed to only 10 companies, accounting for 87% of the total surplus of the Greek metallurgical industry.[39]

Unsolicited pollution permits can be re-released to the market for revenue or "stored" for use in the third poll of emissions trading (2013-2020), thus protecting companies from future compliance costs.

5.1 The case of PPC

The Public Power Corporation SA is the largest electricity generation and supply company in Greece with approximately 7.4 million customers. It has a large infrastructure in lignite mining, power generation, transmission and distribution. It owns about 68% of the installed capacity of the power plants in Greece, including lignite, hydro and oil stations as well as natural gas and renewable energy units (RES) in its energy mix [40] and It controls almost 100% of the Greek electricity market.

The largest proportion of emissions in the European ETS is attributable to the power generation industry. PPC had to buy 17 million pollution rights to cover its 195Mt of emissions during the 2008-2011 period. PPC, although one would expect its size as a company and its years of operation to have the necessary tools to be able to defeat some of the energy requirements imposed by the European Union. Instead, it has failed to take decisive measures and continues to work with obsolete methods with the lignite units. Its progress with renewable energy sources is minimal as the existing installations in Greece in renewable energy sources are only 44, with the generation of electricity for 2017 to 308000 MWh. [41]

Things would be even worse if this economic downturn did not coincide with the resulting decline in electricity demand (PPC's emissions in 2011 have dropped by 10% since 2008).

Since 2013, most European electricity companies are obliged to obtain all the rights they need from the free market - PPC will mean an increase in the rights they buy from 4% to 100%. Although this development has been expected for years, PPC has done little to upgrade its energy portfolios and reducing compliance costs. [37]

5.1.1 The problems that arise in Greece

Problem 1: emission ceilings have repeatedly been put at the wrong level

In order to make investment by companies attractive to emission abatement measures and technologies, the maximum limit should be set below the expected emissions. Otherwise, the rights available on the market outweigh the demand, resulting in a sharp drop in their prices. Such a decline occurred both in the pilot phase of operation of the Facility (2005-2007) and in the second marketing year (2008-2012), during which, mainly as a result of the economic crisis, industrial emissions were

steadily below the maximum limit. The price of CO2 has been rescued from its complete misuse, thanks to the ability to store excess rights and use decades later - when it may be more difficult.

The ceiling for the 3rd trading period was also set before the start of the economic crisis, with completely different estimates of industrial plant emissions. Its effectiveness is therefore significantly reduced while transferring rights from the previous phase will contribute to its further weakening.

Problem 2: generous access to compensation mechanisms

As the initial scenarios on which the ETS was designed predicted far higher emissions than the current and thus increased, adjustment costs, the EU allowed companies to access international compensation mechanisms (for the period 2008-2020, access to about 1.6 two compensation units).

With the limits permanently higher than actual emissions, access to these mechanisms has proved to be unnecessary. However, due to the low price of these rights, over 555 million units have been introduced into the facility since 2011, contributing to the surge of more than 950 million allowances.

According to the European Commission's forecast, the surplus is expected to reach 2 billion by 2020, with three quarters coming from the hedging mechanism.

Problem 3: Excessive free of charge rights

To facilitate the adoption of the rights market mechanism and to protect the competitiveness of European industries, the majority of Member States granted the manufacturing rights amount sufficient to cover projected emissions throughout the second period. The free allocation of allowances would be generous even under favorable economic conditions, but the economic crisis was even more prominent. The consequences were: Expansion of national allocation plans across the EU, pushing up the allowable emission limits for the first and second periods, and indirectly the threshold for the 3rd period.

The premium to the manufacturing industry with huge surpluses of unnecessary rights, which could resell (mainly to electricity companies) to generate revenue or store for future use.

Based on the new product benchmarking indexes introduced by the EU, free allocations to electricity generators will be terminated from 2013 onwards, and industry-wide reductions will be significantly reduced. However, certain sectors exposed to 'carbon leakage risk.' will continue to receive free pollution rights, despite the fact that the assessment of the relative risk was made by the EU carbon price at € 30 / the today's price ranges to less than € 7 / t.

Also, the assessment of the relevant sectorial report did not take into account the climate policies outside the EU that are expected to have until 2015.[19]

6 Conclusions

The main issue of this work is the emission trading system, namely cap and trade. We have been dealing with climate change and impacts both at an economic and environmental level, we have analyzed the predecessors of the emission trading systems, as well as the current programs aimed at reducing pollutants and improving the problem of climate change.

Through this dissertation, we realized that Transnational Cooperation and joint climate strategy were a major step forward in tackling the effects of the climate change phenomenon.

The necessity of pollution reduction programs has become clear, because without them and their regulatory the firms and the economic giants will never work environmentally friendly. We also understood the need for a spin on renewable energies.

Then, we realized the importance of the previous emission trading system, which had a positive effect on the creation of the European Union Emission Trading System, as well as on the other programs around the world.

As far as Greece is concerned, it has not been able to adapt to the provisions of the Kyoto Protocol from the outset, as a credible emissions record system could not work. We then found that many elements of the cap and trade program did not work properly because, for example, emissions were put at wrong levels, many free licenses were given, and they suppressed the proper functioning of the program. Firms in Greece did not need to comply with new data since licenses granted until 2013 allowed them not only to emit pollutants but to make a profit.

We conclude that with the right amount of licenses, the right level of caps in the emission trading systems and the compliance of countries that are not yet making their emission reductions, with stronger measures can achieve the right results for tackling of the consequences of climate change. The concepts Environment and Economy are two very closely related concepts, and for this, every economic move that drives profits must take into account the consequences to the environment because the effects can become irreversible.

7 Bibliography

[1] NASA, "Nasa Climate Change." [Online]. Available: https://climate.nasa.gov/evidence/.

[2] W. Hellas, "WWF Climate Change." [Online]. Available: http://www.wwf.gr/sustainable-economy/clean-energy/climate-change.

[3] (European Commission) EC, "European Comission Climate Change." [Online]. Available: https://ec.europa.eu/clima/change/causes_el.

[4] NASA, "Nasa Climate Change Evidence." [Online]. Available: https://climate.nasa.gov/evidence/.

[5] FAO, "Food and Agriculture Organization." [Online]. Available: http://www.fao.org/publications/sofo/2016/en/.

[6] S. Vinci *et al.*, "Energy Access Outlook 2017: From poverty to prosperity," *Energy Procedia*, vol. 94, no. March, p. 144, 2017.

[7] EPA, "EPA Solutions for climate change-fossil fuels."

[8] IEA, “Internation Energy Agency, energy efficiency.” [Online]. Available: https://www.iea.org/topics/energyefficiency/.

[9] E. Prindle, Bill , Maggie, “The Twin Pillars of Sustainable Energy: Synergies between Energy Efficiency and Renewable Energy Technology and Policy,” *ASA Refresher Courses in Anesthesiology*. .

[10] M. Grubb, “Kyoto and the Future of International Climate Change Responses : From Here to Where ?,” *Int. Rev. Environ. Strateg.*, vol. 5, no. 1, pp. 1–24, 2012.

[11] UNFCCC, “United Nations, Climate Change.” [Online]. Available: https://unfccc.int/process/the-kyoto-protocol/status-of-ratification.

[12] J. G. J. Olivier, G. Janssens-Maenhout, J. A. H. W. Peters, and J. Wilson, *Long Term Trend in Global Co2 Emissions*. 2011.

[13] UNFCCC, “UNFCCC, Clean Development Mechanism.” [Online]. Available: https://cdm.unfccc.int/about/index.html.

[14] T. Delay, M. Grubb, C. Willan, and T. Counsell, “Global Carbon Mechanisms: Emerging lessons and implications,” pp. 1–92, 2009.

[15] UNFCCC, “UNFCC, Joint Implementation.” [Online]. Available: https://unfccc.int/process/the-kyoto-protocol/mechanisms/joint-implementation.

[16] R. W. Hahn, “Market Power and Transferable Property Rights,” *Q. J. Econ.*, vol. 99, no. 4, p. 753, Nov. 1984.

[17] R. W. Hahn and R. N. Stavins, “The Effect of Allowance Allocations on Cap-and-Trade System Performance,” *J. Law Econ.*, vol. 54, no. S4, pp. S267–S294, 2011.

[18] (European Commission) EC, “The EU Emissions Trading System (EU ETS),” *Eur. Comm. Clim. Action*, no. July, p. 6, 2016.

[19] a. D. Ellerman and P. L. Joskow, “The European Union’s emissions trading system in perspective,” *Econ. Manag.*, vol. 17, no. 3, p. 56, 2008.

[20] (European Commission) EC, “European Comission, verified emissions data.” [Online]. Available: http://europa.eu/rapid/press-release_IP-08-787_en.htm?locale=en.

[21] A. Michaelowa, S. Butzengeiger, M. Jung, and M. Dutschke, *Beyond 2012– Evolution of the Kyoto Protocol Regime*. 2003.

[22] (European Commission) EC, “European Comission, Allowances and emissions

data." [Online]. Available: https://www.eea.europa.eu/data-and-maps/dashboards/emissions-trading-viewer-1.

[23] R. Schmalensee and R. Stavins, "Lessons Learned from Three Decades of Experience With Cap-And-Trade," *NBER Work. Pap.*, pp. 1–26, 2015.

[24] R. W. Hahn, "Economic Prescriptions for Environmental Problems: How the Patient Followed the Doctor's Orders," *J. Econ. Perspect.*, vol. 3, no. 2, pp. 95–114, 1989.

[25] S. Kerr and D. C. Mare, "Transaction Costs and Tradable Permit Markets: The United States Lead Phasedown," *Motu Econ. Public Policy Res. Draft Manuscr.*, vol. MEL0259, 1998.

[26] S. Kerr and R. G. Newell, "Policy-Induced Technology Adoption: Evidence from the U.S. Lead Phasedown," *J. Ind. Econ.*, vol. 51, no. 3, pp. 317–343, Sep. 2003.

[27] a. D. Ellerman, "Markets for clean air: the U.S. acid rain program," *Reg. Sci. Urban Econ.*, vol. 32, no. 1, pp. 139–144, 2000.

[28] "No Title." [Online]. Available: https://www.eea.europa.eu/data-and-maps/indicators/eea-32-nitrogen-oxides-nox-emissions-1.

[29] R. W. Hahn, S. M. Olmstead, and R. N. Stavins, "Environmental Regulation in the 1990s: A Retrospective Analysis," *Harvard Environ. Law Rev.*, vol. 27, pp. 377–415, 2003.

[30] R. Stavins *et al.*, "Environmental Economics and Policy," vol. 1, no. 1, 2007.

[31] A. E. Farrell and L. B. Lave, "Emission Trading and Public Health," *Annu. Rev. Public Health*, vol. 25, no. 1, pp. 119–138, 2004.

[32] EPA, "Environmental Protection Agency, NOx and SO2 emissions." [Online]. Available: https://archive.epa.gov/epa/enforcement/national-enforcement-initiatives-fiscal-years-2014-2016-reducing-air-pollution-largest.html.

[33] CalEPA, "California Environmental Protection Agency." [Online]. Available: https://calepa.ca.gov/climate/.

[34] J. L. Ramseur, "The Regional Greenhouse Gas Initiative : Lessons Learned and Issues for Policymakers," 2013.

[35] P. J. Hibbard, A. M. Okie, S. F. Tierney, and P. G. Darling, "The Economic Impacts of the Regional Greenhouse Gas Initiative on Nine Northeast and Mid-

Atlantic States,” pp. 1–85, 2015.

[36] “The Region Greenhouse Gas Initiative.” [Online]. Available: https://www.rggi.org/program-overview-and-design/elements.

[37] W. Hellas, “Η εφαρμογή του Συστήματος Εμπορίας Δικαιωμάτων Εκπομπών στην Ελλάδα,” vol. 50, pp. 1–12, 2013.

[38] Ypeka, “Υπουργειο Περιβαλλοντος και Ενεργειας.” [Online]. Available: http://www.ypeka.gr/Default.aspx?tabid=456.

[39] Sandbag, “Sandbag Emissions.”

[40] PPC, “Δημόσια Επιχείρηση Ηλεκτρισμού.” [Online]. Available: https://www.dei.gr/el/i-dei/i-etairia/omilos-dei-ae/dei-ae.

[41] PPC, “ΔΕΗ Ανανεωσιμες Πηγες Ενεργειας.” [Online]. Available: https://www.dei.gr/el/i-dei/i-etairia/omilos-dei-ae/dei-ae.