Global problems, rapid and massive regional changes in the 21st century call for genuine long-term, awareness, planning and well focused actions from both national governments and international organizations. This book wishes to contribute to building an innovative path of strategic views in handling the diverse challenges, and more emphatically, the economic impacts of climate change. Although the contributors of this volume represent several approaches, they all rely on some common grounds such as the cost-benefit analysis of mitigation and adaptation, and on the need to present an in-depth theoretical and practical dimension. The research accounted for in this book tried to integrate and confront various types of economics approaches and methods, as well as knowledge from game theory to country surveys, from agricultural adaptation to weather bonds, from green tax to historical experience of human adaptation. The various themes and points of views do deserve the attention of the serious academic reader interested in the economics of climate change. We hope to enhance the spread of good solutions resulting from world wide disputes and tested strategic decisions.

WAKE UP! It is not just the polar bears' habitat that is endangered, but the entire human form of life.

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Price of Unsustainability

Gábor Kutasi (ed)

PRICE OF UNSUSTAINABILITY

Economic Impacts of Climate Change

Editor:
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Content

Foreword to the Price of Unsustainablity

The Brundtland Report on sustainability of development issued in 1987 has early explained the responsibility of human activities for transition of natural environment. Peter S. Heller's book, the 'Who will pay?' (Heller 2003) can be called one of the first mile stones in thinking about financial impacts of long-term processes of the 21st century global economy, as the climate change among others. Since the 'Who will pay?', the particular specified economics literature has been enlarging.

The horizon of global problems and regional social changes in the 21st century demands more long-term, forward-looking awareness and planning from national governments. Heller (2003) named the demographic changes, the global climate change and the globalization as main channels of very long-term challenges. These processes open new dimensions, also, in fiscal planning by causing cost of anticipation, mitigation, adaptation or other way of treatment.

According to O'Hara (2009), *"(...) global warming hypotheses have been a contested terrain as advocates sparred with critics, resulting in controversy and analysis, but no firm resolution either way at the level of public debate. All this has suddenly changed in the light of the 'global warming' thesis gaining the upper hand. The influence of (...) publication of the IPCC Report (2007a,b,c,d), the Stern Review (2007), the UNDP Report (2007), and the Garnaut Report (2008) (...)have meshed with the election of more moderate governments in several continents to change the public view of these matters. 'Climate change', as it is now called, has become an accepted institution, even by most of those who previously argued against 'global warming'"*

The global warming expected from climate change might be prevented by a restriction on carbon emission. This mitigation can be realized by several market friendly or discretionary institutional ways. A market friendly pricing of externalities is the carbon emission tax. The EU emphasizes the importance of environmental sustainability in relative outstanding extent in global comparison. The EU has been an initiator of international cooperation for the mitigation of climate change and has essential role in the creation of the Kyoto Protocol for example. The international cooperation can cope more easily with quantitative regulations like permit trade (namely quota trade), since taxation is part of sovereign fiscal policy. But therefore, green taxation is absolutely a national and a little bit single market responsibility to foster the mitigation. Therefore, it is important to check carbon tax practices of EU countries, whether are they so enthusiastic in national competence level as in global representation.

Climate change is a long-term challenge for the Earth, and preventive actions should be taken very soon before the impacts meanwhile it is very uncertain to forecast the exact far future damages of different regions when exact scale of regional warming is an unsure variable in the equation of economic impacts. Scenarios and action plans have been developed, but there is an important factor that makes their execution questionable: the hesitation of decision-making stakeholders. Hesitation is rooted both in uncertainty and expectations concerning each other's strategies. Such a survey environment also demands game theory to understand and forecast the strategy of stakeholders.

During the last few decades the global knowledge on climate change and global warming has got broader. The topic became a crucial part of the EU strategy. The research team on climate change has analysed the economics aspects. We know for sure that something is changing around us and we heard a million times that if we utilize the Earth that much than we will cause permanent and irreversible damage. Scenarios, institutional framework, theories, behaviour patterns, financing dilemmas, cost-benefit methodology, market reactions, fiscal impacts, climate policies, resource policies are reviewed and analysed under the topic of climate change economics by the research team. The following studies covers the broad range of research made on climate change in methodological, policy making, industrial, country level and macroeconomic aspects.

The chapters of this book are based on a two and a half year long research activity of climate change research team of the Workshop on Innovation Trends in International Comparison, *Knowledge based society* sub-project, research project TÁMOP-4.2.1/B-09/1/KMR-2010-0005 financed by the EU and the New Széchenyi Plan. The research was ran by the researchers, teachers and students of Corvinus University of Budapest.

In part I. the authors investigate the climate change impacts from general, global and particularly theoretical view. As a preliminary guide for the economics of climate change *Krisztina Hegedüs* clarifies the terms, the origins, the possible processes of warming, namely defines what the process of nature is under the term of climate change. Geographical, climate, chemical fats got surveyed. Natural science disputes are review.

Then the overview comes on international institutionalization of actions against climate change by *Ágnes Tőrös*. International organizations and treaties, protocols, or multinational NGOs try to promote the mitigation or the adaptation and thus prevent the human activities presumably causing climate warming.

After all, some theoretical questions got examined. First of all, *Gábor Kutasi* reviewed the appearance of climate change problem in the strategic game theory. Broad range of game theory application is put into the context to show the opportunities of this discipline. The application of numerous versions of prisoner's dilemma, the evolutionary games, the common pool resource problem, negotiation games and decision trees is presented in detail.

Norbert Szijártó reviews the methodological aspect of climate change, especially, the aggregation of individual, social and global costs and benefits induced by climate change. He concluded that the assessment of the total and/or marginal costs of environmental change is a methodological challenge for the range of factors involved. The reader can get view on the complexity of cost assessment and critical factors in scenarios and modelling.

Izabella Feierabend overviews the different possibilities of mitigation from different points of view and analyses the possibilities of adaptation to climate change. The necessity of reduction of green house gas emission and the adaptation action are shown to be unavoidable cost by international coordination. Her conclusion is that a successful mitigation strategy demands a coherent adaptation strategy.

To price the externality of carbon emission, the economics know two types of items: quota and tax. Meanwhile analysis on carbon taxation appears in the chapter in on fiscal aspects, the use and pricing of quota is detailed by *Norbert Szijártó*. His focus is on the theory and practice of trade on CO2 quotas. Such practical dilemmas are dissected in this chapter like how to define an applicable price for carbon emissions, or how to trade with quotas.

Krisztina Losonc introduces possible scenarios on crowds of labour migration induced by climate change. The starting framework of these scenarios is based on the Intergovernmental Panel on Climate Change established by the UN Environmental Program. Four likely scenarios of migration are detailed in sense of possibility, factors and impacts.

Gergely Rezessy introduces us to the subsidence of climate change to the capital markets. The weather bonds are a type of speculation on future weather probabilities. The function of weather derivatives is to hedge against risks related to weather. Types of derivatives and pricing practices or modelling are surveyed by this chapter thereby a little bit give view behind the business secrets of weather speculations.

In part II, specific fields of the climate problem are investigated by focusing on certain sectors and regions. In line, *Gábor Kutasi* enlightens a part of fiscal impacts. The purpose is to gather the practices and to model the impacts of climate change on fiscal spending and revenues, responsibilities and opportunities, balance and debt related to climate change. The methodology distinguishes fiscal cost of mitigation and adaptation, besides direct and indirect costs. It includes evaluation of the propensity of policy makers for action or passivity. Scenarios got drafted to see the different outcomes. There is a summary and synthesis of estimation models on CC impacts on public finances, and morals of existing/existed budgeting practices on mitigation. Not just costs, but taxation items are also examined. In this case the focus is on the application opportunities of carbon emission tax. The purpose is to estimate the impacts of introduction of carbon emission taxation in EU countries, implied by climate change mitigation and adaptation. The climate change is a long-term challenge. The action for prevention should be started very soon before the impacts meanwhile its occurrence is very uncertain. The possible threat of climate change demands actions from public polices and put burden and responsibility on fiscal policy, too. In case of reducing CO2 emission, the situation is a typical externality problem. That is why the chapter builds on Pigovian tax model in fiscal mitigation on the potential change of temperature.

Krisztina Hegedüs surveys the Russian policy on natural resources and tries to find the answer for the following questions. How will global warming change Russia's climate system? What are the consequences both in Russia's environment and in the Russian economic system? Is it possible that, along with the many negative environmental and economical effects, there could be some economic advantage? How does Russia try to avoid the unfavourable climate changes? This survey is just as important as the Chinese one since Russia controls very significant share of natural resources and supplies Asian and European markets.

Ágnes Tőrös analyses a case study of an emerging country, China in climate policy. This phenomenon (namely being emerging) is special since the emerging countries have gotten involved into mitigation with a time delay. Besides, their catch-up process is built particularly on outsourcing polluting, carbon emitting industries from the high developed regions, thus creating export capacities. For such industrial investors, the emerging economies' attractiveness is based on their cheap outdated technology and loose regulation and implementation on pollution restriction. It is very likely, that China will choose a way for mitigation which does not endanger the economic catch-up process. The chapter concludes that China has significant climate vulnerability, what is even multiplied by the volume of population and the length of national seashore. As climate policy has not got significant traditions in emerging countries, like China, their international cooperation is determined by international help very much.

Tamás Mizik and Szilvia Palakovics analyze the agricultural impacts of climate change. This sector is particularly a significant a victim, particularly a mitigating factor in the carbon emission problem. Agricultural production requires various inputs including significant amount of water, pesticides, fertilizers, fodder, etc. Agriculture uses lots of chemicals and pollutes air and soil, contributes to erosion, salinisation, loss of forests and biodiversity, etc. However, plants are able to absorb CO2. The main result of the survey whether the common agricultural policy of EU can adjust to the warming or not.

Csaba Horváth surveys the climate change as a challenge for the human kind from historical perspective. He analysed different historical resource shocks on human civilizations to derive the adaptation capability of the past and present civilization. How will the global society react when the desertification, rise of sea level etc. start to ruin the available natural resources? This chapter answers not only whether we should be optimistic or pessimistic on the adaptive capability of human kind, but also gives a historian methodology how to evaluate this capability.

Gábor Kutasi

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I

ECONOMICS OF CLIMATE CHANGE

Krisztina Hegedüs

1. Scenarios and roots of climate change

There have been more and more words about climate change and global warming in the last few decades. But what do we really understand them? Is it logic that the climate change derived by human behaviour or is it an independent process of nature that occurs no matter how we try to stop it? Is the climate change a global warming or global cooling method? We know for sure that something is changing around us and we heard a million times that if we exhaust the resources of the Earth than we will cause permanent and irreversible damage.

In the first part of this chapter we will see the facts. There will be a few different perspectives from a few different institutions publication about the methodology of measurement on climate change. In the second part of the chapter we shall distinguish how big part of the changes may be the results of the human activities, or is it even possible to distinguish what causes the climate change. In the last part of this chapter the IPCC's scenario will be explained on the case if the process of the climate change can not be stopped, or if human kind does not do anything for mitigation.

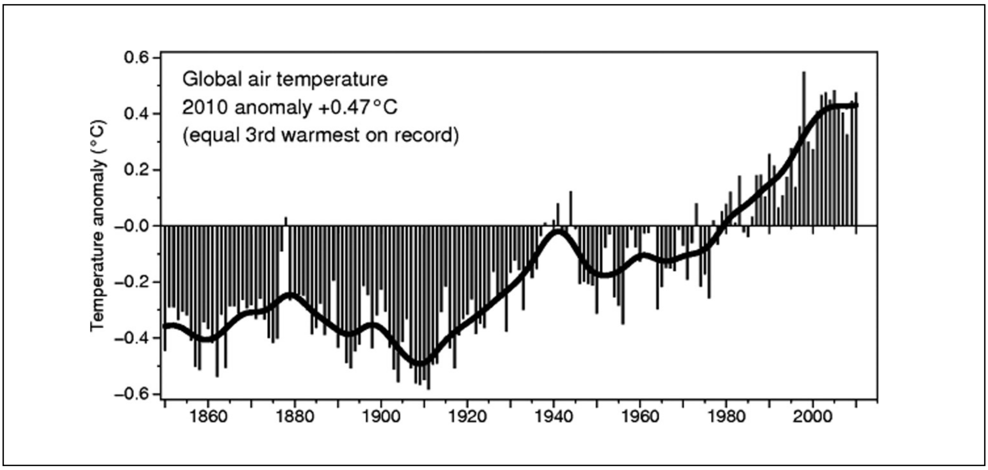
1.1 What are the facts?

Usually when we hear the term "climate change" global warming comes up first. But is it so obvious? Because some ones argue that it is even a global cooling method going on. The climate change is not only the change in the temperature of the air, but its side effects, too. For example with the increase of the average temperature, the ice caps melt which modifies the water temperature, which leads to oceans circulation upheaval. When volume and distribution of precipitation changes we have to face with an increasing number of extreme phenomena. Naturally, as the regions of the World have different climate, the climate change affects these regions differently. In this chapter there will be a look at statistical facts about how our climate changes and the methods of its measurement.

Air temperature

According to the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report the global surface air temperature has been the highest in 1998 and 2005 since 1850 (we have reliable data since 1850). The surface temperature has increased from 1950 even faster. The total surface air temperature has increased from 1850-1899 to 2001-2005 is 0.76°C ± 0.19°C. The period 2001-2010 was 0.2°C warmer than the previous decade (1991-2000). Almost all years of this decade is in the 10 warmest years from 1850, the only exception is 2008, but still the 12th warmest from 1850. Figure 1 concludes these data. It seems obvious looking at this time series that it is a warming period since 1850. However the average temperature for the period 1901-2000 was 13.9°C, which means that the change was from 13.5°C to 14.3°C.

Figure 1 Global air temperature for the period 1850-2010



The time series shows the combined global land and marine surface temperature record from 1850 to 2010.
Source: Climatic Research Unit (CRU) at the University of East Anglia
http://www.cru.uea.ac.uk/cru/info/warming/

For the whole picture, we have to add some different opinion about the size of the warming. Those who are sceptic about the climate change usually add that the temperature in the 1850s was the coldest in last 8000 years (http://www.climatecooling.org/). So if we compare the data to that period we might get false information about today's warming. Also there are other opinions claims that temperatures in the Bronze Age, the Roman Age and the Medieval Period were higher than today. Furthermore they say that the period between 1400-1800 called "The Little Ice

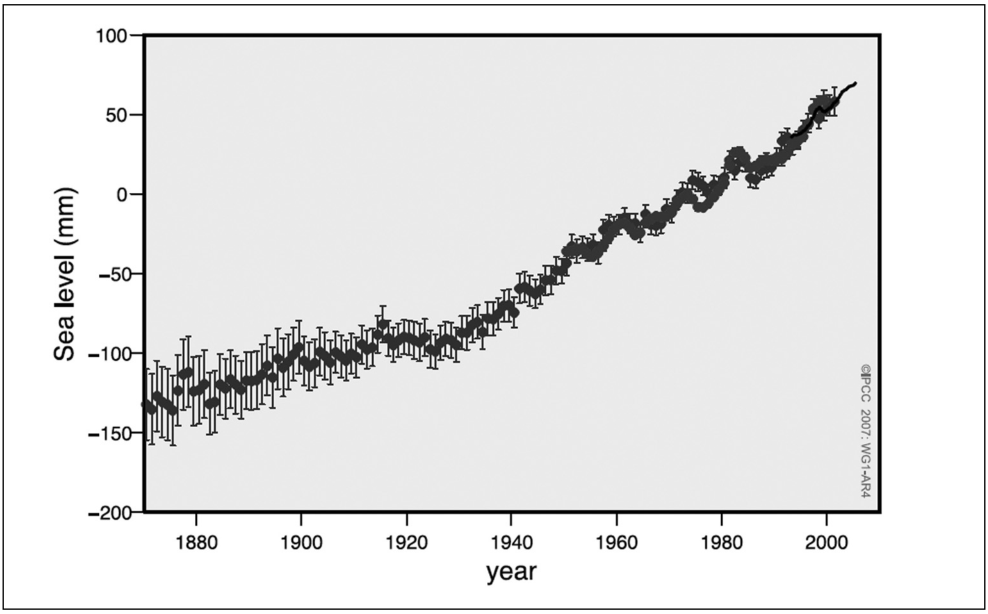
Age", the temperatures back than were several degrees cooler and the warming started in the 1700s, before the human contribution to the CO2 level started to grow (Pohanka; 2010)

However there are studies that declare, that a 0.76°C ± 0.19°C change may seems small, but it is sizeable, when we say that the average rate of warming in the last 10000 years (from the end of the last glaciations) was about 5°C, so 0.05°C per century, and this 5°C warming caused the huge transformation of the Earth surface, such as the disappearance of massive ice sheets and a sea level rise of about 120 meters (Pittock; 2009).

Sea level

There are several problems with the estimation of the rise of sea level. Since about 1950 it has been estimated from tide gauge data, but these data shows the changes in the water level and vertical land movement also, therefore these two components have to be separated to estimate the sea level. Another problem with the measurement of the change of sea level is that there are much more tide gauges in the Northern Hemisphere (mainly near North America, Europe and Japan), so the measuring instruments are not equally distributed in the oceans, and this can affect the results. Since1992, data can be measured with satellite altimetry, which gives more reliable data (IPCC; 2007). Even together with those measurement problems, the fact that the global sea level have risen over the past 100 years is not questioned. The estimated change is about 10-20 cm rise during the last century (Raper; 2000). It is approximately the same volume as it was declared in another widely used study in 2009. In that study, the authors found 1.61 ± 0.19 mm/year sea level rise over the past 100 years (Wöppelmann et al.; 2009). Both studies are close to the IPCC estimates shown by Figure 2 Also there are some misunderstandings in the origin of the rising level. The main reason of the rise is the thermal expansion of the oceans, which changes the net mass balance of glaciers and ice sheets. However the melting of the sea ice and the floating ice shelves do not affect the sea level directly, because they already displace the water and the form of the water (solid or liquid) does not matter (Raper; 2000).

Figure 2 Sea level rise[1]



Source: IPCC; 2007 p. 60

In case of sea level rise, we have to mention ice melting. The biggest land covered by ice is Antarctica in the South Pole, with about 90% of the world's ice. The ice cover in Antarctica is an average of 2,133 meters thick. The average temperature is about -37°C there, so worry on ice melting is unnecessary, but if the hole ice coverage from Antarctica would melt, the sea level would rise by approximately 61 meters (Brain; 2011).

On the other hand ice in the North Pole is not that thick as ice in the South Pole, but that ice land is floats on the Arctic Ocean, so it would not raise the sea level even if it would melt.

At last there is an important amount of ice covering Greenland. If all the ice would melt in Greenland, it would raise the sea level with 7 meters. The problem is with Greenland that it is nearer to the equator that Antarctica, therefore the temperature there is higher, so there is higher likelihood that the ice will melt (Brain; 2011).

[1] Annual averages of the global mean sea level are based on reconstructed sea level fields since 1870, tide gauge measurements since 1950 (thicker line) and satellite altimetry since 1992 (black line). Units are in mm relative to the average for 1961 to 1990. Error bars are 90% confidence intervals.

So Antarctica and the Greenland ice melt is what IPCC defines as the very likely contribution to the higher sea level. However, measuring the actual level is not easy. There are some arguments about how it should be estimated. IPCC estimates that the Greenland ice melt contributed to the sea level rise by 0,14 - 0,28 mm/year between 1993-2003. The uncertainties are even bigger in the case of Antarctica, because there might be observed growth and shrinkage, too, in the ice thickness. Thus, Antarctica's contribution to the sea level is between -0,27 to +0,56 mm/year between 1961-2003 (IPCC; 2007).

According to the Arctic sea ice it has shrunk annually average by about 2,7 ± 0,6% per decade since 1978. Naturally the summer extent is larger. It is about 7,4 ± 2,4% per decade (IPCC; 2007). Table 1 concludes all the sources of the sea level rise and estimated contributions.

Table 1 Observed rate of sea level rise and estimated contributions from different sources2

Source of sea level rise	Rate of sea level rise	
	1961-2003	**1993-2003**
Thermal expansion	0.42 ± 0.12	1.6 ± 0.5
Glaciers and ice caps	0.50 ± 0.18	0.77 ± 0.22
Greenland Ice Sheet	0.05 ± 0.12	0.21 ± 0.07
Antarctic Ice Sheet	0.14 ± 0.41	0.21 ± 0.35
Sum of individual climate contribution to sea level	1.1 ± 0.5	2.8 ± 0.7
Observed total sea level rise	1.8 ± 0.5?	3.1 ± 0.7?
Difference (Observed minus sum of estimated climate contributions)	0.7 ± 0.7	0.3 ± 1.0

Source: IPCC; 2007 p.7

Extreme weather events

Extreme weather events are the phenomena that have the largest impacts on human life by causing a big amount of damage in economic cost and human life. We keep on feeling that there are more of these events now than it was in the past. But is it true perception? First of all we need to define what could be called extreme weather event. There is no generally accepted definition since extreme weather events are easy to recognize, but difficult to define. The concept of extremeness is highly

[2] 'a' data prior to 1993 are from tide gauges and after 1993 are from satellite altimetry

depends on the circumstances and the terms "severe," "rare," and "extreme," are often used as synonyms is contexts of weather events. We call something a severe event if the phenomenon creates huge losses either in human life, financial capital or environmental disaster (loss of species). Rare events have low probability of occurrence. (Because of their rareness, humans can not well adapt to them. Because of the huge vulnerability these events usually accompanied with huge losses). Extreme events are events that have extreme values of certain important meteorological variables. Events like these are not necessarily causing high volume of damages, but still result measurable costs, usually, because of the extreme values of certain meteorological variables, like large amounts of precipitation (e.g., floods), high wind speeds (e.g., cyclones), high temperatures (e.g., heat waves), etc. Extreme is generally defined as taking maximum values above pre-existing high thresholds (Diaz-Murnane; 2008).

With these definitions we should try to collect the events that can classify as extreme weather event: Tropical cyclones and hurricanes, Extratropical cyclones (or windstorms), Convective phenomena like: tornadoes, waterspouts, and severe thunderstorms (these phenomena can described by extreme local wind speeds and precipitation amounts on horizontal scales of up to about 10 km), Mesoscale phenomena like polar lows, mesoscale convective systems, and sting jets (these features can described by extreme wind speeds and precipitation amounts on horizontal scales from 100 to 1,000 km), Floods of rivers, lakes, coasts, Drought (meteorological drought is defined usually on the basis of the degree of dryness in comparison to some "normal" or average amount and the duration of the dry period), Heat waves (periods of exceptionally warm temperatures can have profound impacts on human health and agriculture, duration is a key component determining the impact), Cold waves/spells (for example: extremely cold days or a succession of frost days with minimum temperatures below 0,8°C), Fog (extremely low visibility has major impacts on various sectors such as aviation and road transport) (Diaz-Murnane; 2008).

The frequency and the changes occurred from global warming is hard to measure when it comes to extreme weather event. Even IPCC gives us likelihoods[3] instead of concrete statistics. There are several uncertainties due to limited amount of data. Although there are strong likelihoods that there were significant changes after 1960 and according to IPCC the changes most likely going to grow during the twenty-first century.

[3] Likelihood terminology that IPCC uses: *Virtually certain* > 99% probability, *Extremely likely* > 95% probability, *Very likely* > 90% probability, *Likely* > 66% probability, *More likely than not* > 50% probability, *About as likely as not* 33 to 66% probability, *Unlikely* < 33% probability, *Very unlikely* < 10% probability, *Extremely unlikely* < 5% probability, *Exceptionally unlikely* < 1% probability

Table 2 Changes in extreme events[4]

Changes in phenomenon	**Confidence in observed changes (post-1960)**	**Confidence in projected changes (during the twenty-first century)**
Higher maximum temperatures and more hot days over nearly all land areas	Very likely	Virtually certain
Higher minimum temperatures, fewer cold days and frost days over nearly all land areas	Very likely	Virtually certain
Reduced diurnal temperature range over most land areas	Very likely	Virtually certain
Intense precipitation events, (frequency or proportion of total rainfall)	Likely	Very likely
Increased risk of drought in mid-latitude continental areas	Likely	Likely
Increase in tropical cyclone peak wind intensities and rainfall, with lower central pressures	Likely in some regions	Likely
Extreme extra-tropical storms: increased frequency/intensity and polewards shift	Likely	Likely
Coastal storm surges and flooding more severe (due to both highermean sea level and more intense storms)	Very likely due to sea-level rise last century	Virtually certain

Source: Pittock; 2009 p

1.2 Regional differences

After we saw the aspects of the global climate change, it could be useful to see the differences between the regions. As the climate change does not affect the regions the same way, for example there could be regions where the increase of temperature is less observable than in other areas. Each area must face its own problem. The coastal areas can worry about the sea level, in some areas the precipitation will rise, while in other areas the desertification could be observed. How will the climate change affect in different regions, and what is the biggest individual problem of them? Let's see it region by region, but also in Figure 3 we can see all regions.

Europe

In Europe the weather is warming above the global average. It was +0.90°C for the period between 1901 and 2005. The largest warming is the winter in north Europe and the summer in the south. The north became more like the south as it could have

[4] IPCC 2007 report estimates of confidence in observed changes during the twentieth century, and projected changes in the twenty-first century, for extreme weather and climate events

a Mediterranean climate, while in the south drought season is increasing (Hopkin; 2005). Thus, annual precipitation is increasing in the north and decreasing in the south, while in the central region precipitation is increasing in the winter, but decreasing in the summer. Heat-waves are likely to increase in the south. Snow season is likely to shorten and snow depth is likely to decrease in whole Europe (IPCC; 2007).

North America

The annual mean warming in North America is likely to be above the global average. The largest warming is the winter time in the northern region and in the summer in the southwest. The winter temperature is increasing more that the global average in the northern part of North America. More precipitation expected in Canada and the northeast US, but less precipitation will occur in the south. Snow season and the depth of the snow is decreasing in most part of North America, except in Canada, where the snow depth is increasing (IPCC; 2007). In the northern part of the continent the melting Antarctica ice causing problems in the ecosystem.

South America

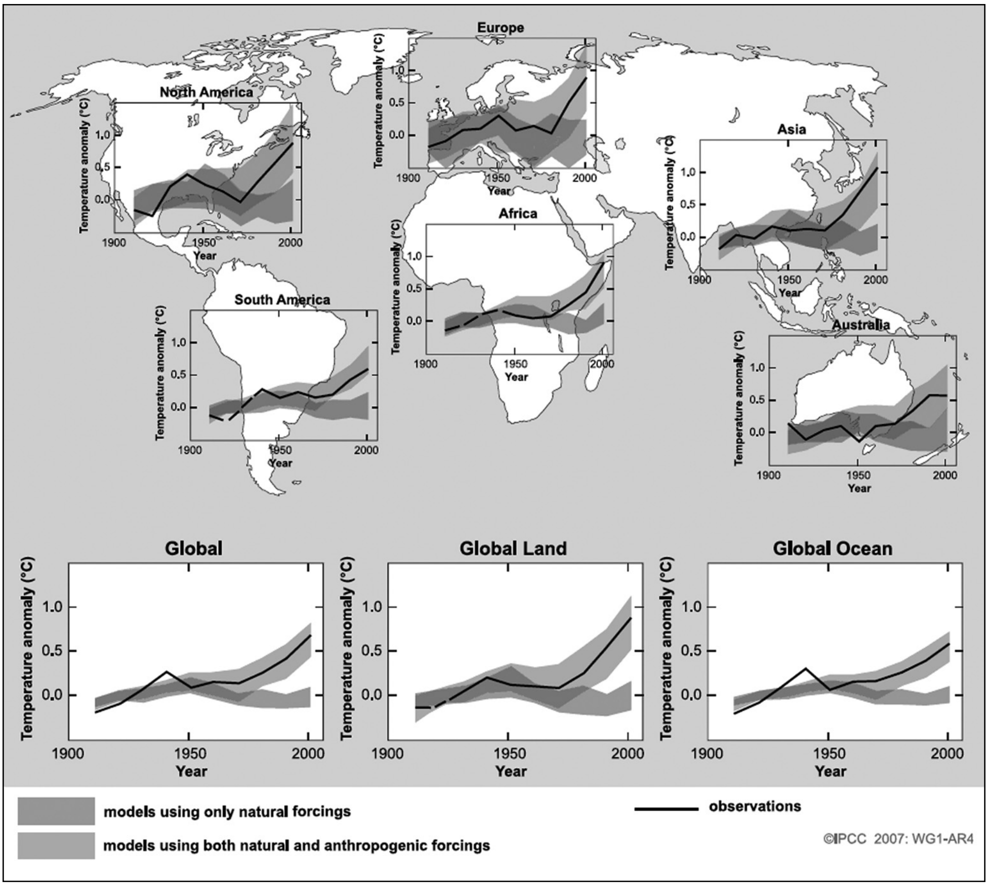
In this continent the global warming and the temperature growth is likely to be so much as the global average in the world. The warming will be the largest in the area of the Amazonia and Mexico. The annual precipitation will decrease in Central America and in the southern Andes, however it may vary highly locally, because of the atmospheric circulation in mountainous areas. Nevertheless, tropical storms can contribute a significant fraction of the rainfall in the hurricane season in this region. Thus, it might be modified by the possibility of increased rainfall in storms (IPCC; 2007).

Asia

According to IPCC all around Asia, it is very likely to warm much above the global average during this century. Only Southeast Asia will likely to warm as much as the global average, so less than other Asian regions. Together with warming, more and longer lasting heat-waves appear mainly in East Asia. It is also likely to have fewer cold days. Precipitation is very likely to increase in the winter season, in almost all parts of Asia, while summer precipitation increases everywhere in Asia except the Central Asia. The intensity of rain will likely to change. Extreme rainfalls and winds associated with tropical cyclones are expected more frequently in East, Southeast and South Asia (IPCC; 2007). In Siberia the permafrost zone melting could cause problems. The Asian landmass has a huge impact on the climate cycle through ocean circulation. The huge rivers in Asia supply fresh water to the Arctic

Ocean, which is the main source of the cold heavy water that sinks down and drives currents around the world (Hopkin; 2005). So if these sources warm up that would be a problem not just for Asia, but the whole planet.

Figure 3 Global and Continental Temperature Change[5]



Source: IPCC; 2007 p.11

[5] Comparison of observed continental- and global-scale changes in surface temperature with results are simulated by climate models using natural and anthropogenic forcing. Decadal averages of observations are shown for the period 1906 to 2005 (black line) plotted against the centre of the decade and relative to the corresponding average for 1901 to 1950. Lines are dashed where spatial coverage is less than 50%. Deeper grey shaded bands show the 5% to 95% range for 19 simulations from 5 climate models using only the natural forcing due to solar activity and volcanoes. Lighter grey shaded bands show the 5% to 95% range for 58 simulations from 14 climate models using both natural and anthropogenic forcing.

Africa

The African continent is very likely to warm during the next century with higher intensity than the global average. The drier subtropical regions warm above the moister tropic. Precipitation is likely to decrease in northern Sahara, Mediterranean Africa, but it is likely to increase in East Africa. That means that the world's largest desert, the Sahara can widen and the desertification of that region can go further. Meanwhile the increase of tropical rainfall can amplify the problem of malaria, as the mosquitoes that carry the disease likes rainy weather. So, more rain means more mosquitoes (Hopkin; 2005).

Australia and New Zealand

In Australia the warming is likely to be similar to the global average. There is less warming expected in the south, especially in winter. In New Zealand, the rise of global temperature is likely to be under the global average. However the frequency of extreme high daily temperature increases both in Australia and New Zealand, and lower frequency of cold extreme temperature predicted. Precipitation decrease is expected in South Australia, on the other hand increase in precipitation is likely in South New Zealand. Extreme intensity of daily precipitation increasing in most areas, excluding the areas where significant decrease of rainfall predicted. In southern areas of Australia there are likely to be more drought season (IPCC; 2007).

Polar Regions

Both the Arctic and the Antarctica are likely to warm in this century.

The Arctic is very likely to warm above the global average mainly in winter and the smallest warming expected during summer. Precipitation in the Arctic is very likely to increase mainly in winter. The Arctic ice is also very likely to decrease. However it may not affect the sea level, but it is uncertain how it is going to change the circulation of the Arctic Ocean (IPCC; 2007).

The Antarctica is very likely to warm during this century. The Antarctica is in the center of the scientist attention, it has a protected wilderness status, and it could influence the world's climate both positively and negatively. With the warming researchers fear that the West Antarctic ice sheet will break up and fell into the ocean, which would raise the sea level with several meters. However with the precipitation and snowfall increase it is possible that the frozen land growing in size, which would mean that it locks up water what otherwise, would end up in the ocean (Hopkin; 2005). Also growing number of extreme weather events is possible, but the frequency is uncertain (IPCC; 2007).

1.3 Human caused changes in the climate

After the statistical facts we have seen, in this sub-chapter we try to get some answers. The most important question whether the climate change seen in the previous sub-chapter has been happening because of the human intervention on the nature or these changes would happen anyway, because it is in the Earth long-run cycle and we reached a warming period? To answer this question we shall know about the history of these cycles and a few necessary things about the process of the warming and how humans can contribute to this process. Also we will see some different opinion about whether human kind is responsible for the changes or not.

There are several and popular opinions whether the human activity is what is responsible for the climate change by the growing amount of the greenhouse gas emission. There are scientist who claims that rapid warming started after the industrialization and current changes occur because of the changes in the Earth's atmosphere from waste gases due to industry, farm animals and land clearing, cropping and irrigation (Pittock; 2009). About between one-third and one-half of the land surface has changed due to human lifestyle and the carbon dioxide concentration emerged by 30% since the Industrial Revolution. Also more than half of the surface fresh water is under human use in several ways (Hill; 2004). Studies identifing human impact on current climate change and tring to separate it from inevitable changes of natural climate variability usually consist two parts: First, they identify an unusual change that would not have occurred without human contribution. Second, they try to put together the outcomes and its roots.

The most common 'unusual change' is the increasing amount of greenhouse gas emission as the result of the human contribution to the climate change since the Industrial Revolution human kind started to burn fossil reserves of the Earth. But how greenhouse gas emission leads to global warming and which forms of gases goes under the term of greenhouse gases?

To have life on Earth, there is need for the energy from the Sun. This energy is electromagnetic radiation in the form of visible light, with small amount of infrared and ultraviolet radiation. The visible energy is passes right through the atmosphere. About 30% of the sunlight is deflected by the outer atmosphere and scattered back into space (West; a). The rest reaches the Earth's surface and our planet's surface absorbs the solar energy and releases it back to the atmosphere as a type of slow-moving energy called infrared radiation. But some of the infrared radiation absorbed by greenhouse gases in the atmosphere and sent back towards the Earth's surface. This way the Earth's surface warms. So the greenhouse gases regulate our climate as they keep the Earth warm by trapping heat and holding it in. Without it the average temperature on Earth would be colder by about 30°C. So to maintain the present ecosystem we need the greenhouse gases. The problem is that, by the human activity, there could be easily more greenhouse gases in the atmosphere than needed to provide an ideal temperature. It seems that more greenhouse gases means more infrared radiation trapped and held which leads to a warmer surface temperature (West; a).

What are the greenhouse gases and how humans contribute the growing greenhouse gas emission? There are natural greenhouse gases, such as water vapour, carbon dioxide, methane, nitrous oxide, and ozone. Others like hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF6) result exclusively from human industrial processes (West; b). The Kyoto Protocol specifies six greenhouse gases to be regulated. These are: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6) (Pittock 2009).

Human contribution to the greenhouse gas emission could come from many different sources. First, burning fossil fuels – just like natural gas, coal and oil – increases the level of carbon dioxide in the atmosphere (Pittock 2009). Burning solid waste, wood and wood products increases the carbon dioxide level, too. Second, some agricultural and industrial processes lead to nitrous oxide emission. Third, some farming practices and organic waste decomposes raise the emission of methane. Fourth, factories produce long lasting industrial gases, which do not occur naturally. Hydrofluorocarbons (HFCs) once were used in refrigerants and other industries, but nowadays they got phase out of use because of their potential to destroy atmospheric ozone. Perfluorocarbons (PFCs), and sulphur hexafluoride (SF6) both are industrial gases used in the electronic and electrical industries, fire fighting, solvents and other industries (Pittock 2009). Deforestation is the fifth kind of way how human activity adds the increased value of greenhouse gas emission. As trees use carbon dioxide and emit oxygen, the fewer the trees are, the less oxygen they can perform. But it would be important for the optimal balance of gases. The last, but not least the human population growth contributes to the global warming. The more we are the more energy is needed, namely more fossil fuels, more farming etc. (West; a).

So what changes have occurred in the greenhouse gas emission since the Industrial Revolution, why IPCC convinced that it is very likely that the current warming is due to human activity?

Before the Industrial Revolution, the levels of carbon dioxide in the atmosphere were about 280 parts per million by volume (ppmv). Recent levels are about 370 ppmv. This number shows an extremely high level of concentration, as the concentration of carbon dioxide and other key greenhouse gases is higher than at any time in the past 650,000 years in the atmosphere today, and probably higher than in the past 20 million years (West; c). The situation with the other greenhouse gases is pretty similar. The emission of other greenhouse gases has jumped, too, after the industrialization. The atmospheric concentration of methane grew from the pre-industrialization level of 715 parts per billion (ppb) up to 1774 ppb to 2005. The concentration of nitrous oxide increased from 270 ppb (pre-industrial level) to 319 ppb to 2005. "*Radiative forcing is a measure of how the energy balance of the Earth-atmosphere system is influenced when factors that affect climate are altered.*" (IPCC; 2007 p. 101) Radiative: because these factors change the balance between incoming solar radiation and outgoing infrared radiation within the Earth's atmosphere. Forcing: because it indicates that the radiative balance has been upset. "*Radiative forcing is usually quantified as the 'rate of energy change per unit area of the globe as measured at the top of the atmosphere', and is expressed in units of 'Watts per square meter'*" (IPCC; 2007 p. 101). CO2 has the biggest radiative forcing by far, so carbon dioxide changes the climate the most.

However there is another point of view among many scientists. According to their researches *(see for example: Pohanka, Archibald and various website exist in the topic like: http://www.isthereglobalcooling.com/, http://www.climatecooling.org/, www.geocraft.com etc.)* there is no strong evidence for the global warming, even less evidence that it is caused by human activity. They state that the Earth has started to warm up somewhat 18 000 years ago after the 100 000 year long Ice Age. Back then the oceans where more than 90 meter lower than today. Only about 15 000 years ago, the temperature was so warm that glaciers melted and established the current environment. Since the last Ice Age, average global temperature has risen about 5°C. If we see that in perspective, the global warming is what allowed us to live like we live today.

These studies states, too, that global warming and global cooling are controlled primarily by 4 factors (geocraft.com; 1998):

- Cyclical variations in the sun's energy output
- Eccentricities in Earth's orbit
- The influence of plate tectonics on the distribution of continents and oceans
- The so-called "greenhouse effect," caused by atmospheric gases such as gaseous water vapor (not droplets), carbon dioxide, methane, and nitrous oxides, which help to trap radiant heat which might otherwise escape into space.

The greenhouse effect is not even the most important factor, more importantly human could not cause it, because 95% of the greenhouse gases come from natural water vapour. The other 5% is like: 4,72% comes from ocean biologic activity, volcanoes, decaying plants, animal activity, etc. and only 0,28% comes from human activity (Pohanka; 2010).

Greenhouse gases make up 2% of the total atmosphere. As for carbon dioxide, it only makes up 3,62% of the greenhouse gases. And only 3,4% of atmospheric CO2 comes from human sources. Additionally CO2's ability to absorb heat is logarithmical, therefore the more CO2 there is, the less heat it can absorv. So with these numbers we can see how minimal the human contribution is. So, why to bother to reduce it with such high costs, when we can hardly influence the Earth's cyclical periods (Pohanka; 2010).

1.4 Scenarios

In the previous sub-chapters we examined how the climate has changed, also we provided a bit of the future in the regional changes and we outlined a few possible reasons why the current climate change occurs. In this chapter we will show the most popular scenarios about the future of the climate change. As it is sure to state that our climate is changing whether it is caused by human kind or not, we should prepare the future changes. So far the IPCC scenario is the standard and most referenced scenario. In Figure 4 we can see the different options of the different possible events and in the box there are the refered explanations of the option. As Figure 4 shows the temperature change ranging from 1,4 to 5,8°C by 2100. This is a really wide range. As we saw in the previous sub-chapter, in the past 18 000 years from the latest Ice Age, the temperature increased about 5°C and it changed the entire living conditions of the planet. Therefore warming might not our biggest problem yet, but it could be if the scenario redeems its promises.

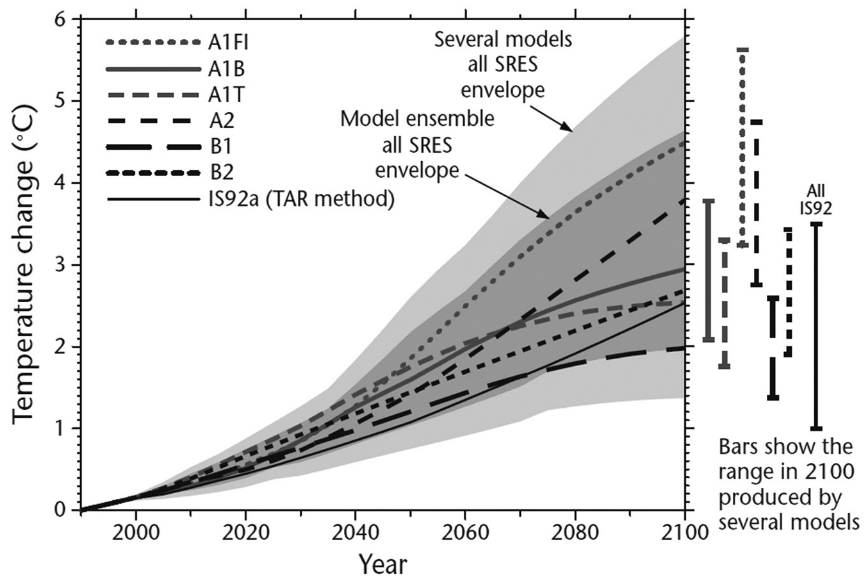
SRES also covers greenhouse gas emission scenarios. The scenarios also predict increase in the emission of the greenhouse gases. Almost all kind of greenhouse gas concentration in the atmosphere is likely to doubles, what indicates the temperature warming. Also with warming there comes the sea level rise, which according to the IPCC's fourth assessment report could range from 18 to 59 cm growth. This prediction includes thermal expansion of the oceans and water that melted from mountain glaciers and a contribution due to increased ice flow from Greenland and Antarctica.

According to IPCC there will be several irreversible changes by 2100. These are changes such as the slowdown of the Atlantic Meridional Overturning Circulation (MOC)[6], the fast disappearance of the Arctic sea ice, the rapid disappearance of the glaciers or ice caps, increased melting of Greenland and the Antarctic ice cover,

[6] Atlantic Meridional Overturning Circulation (MOC) transports heat northward throughout the Atlantic Ocean

desertification in many area. These events could indicate changes the ecosystem and could cause many economic damage. Therefore if it is a slightest chance that we can do anything to avoid these changes than we should do everything that we could.

Figure 4 Emission Scenarios by IPCC[7]



Source: Pittock 2009 p.79

[7] Global average temperature projections for six illustrative SRES scenarios, as depicted in the 2001 IPCC report. The darker shading represents the envelope of the full set of 35 SRES scenarios used as input to the climate models, using the accepted average climate sensitivity of 2.8°C. The lighter shading is the envelope based on a range of climate sensitivities in the range 1.7 to 4.2°C. The bars show, for each of the six illustrative SRES scenarios, the range of model results in 2100. For comparison, the IPCC IS92 range of warming's in 2100 is also shown.

THE EMISSION SCENARIOS OF THE IPCC SPECIAL REPORT ON EMISSION SCENARIOS (SRES)

- **A1.** The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereaf-ter, and the rapid introduction of new and more efficient technologies. Major under-lying themes are convergence among regions, capacity building and increased cul-tural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system.
- The three A1 groups are distinguished by their technological emphasis: fossil-intensive (A1FI), non-fossil energy sources (A1T) or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).
- **A2.** The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increas-ing population. Economic development is primarily regionally oriented and per cap-ita economic growth and technological change more fragmented and slower than other storylines.
- **B1.** The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and in-formation economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.
- **B2.** The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermedi-ate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

An illustrative scenario was chosen for each of the six scenario groups A1B, A1FI, A1T, A2, B1 and B2. All should be considered equally sound.
The SRES scenarios do not include additional climate initiatives, which means that no scenarios are included that explicitly assume implementation of the United Nations Framework Convention on Climate Change or the emissions targets of the Kyoto Protocol.

Source: IPCC 2007 p. 18

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Ágnes Tőrös

2. International cooperation against climate change: institutions, policies and their efficiency

2.1 Introduction

In the 20th century nature of the world economy has started to change significantly, and the former state-centric constellation disappeared. Several development factors that induced the change are still active and nowadays we live in a much different world. The world economy consists of transnational networks; these complicated systems have a great impact on the world of states. The transnational actors' (multinational corporations, non-governmental organizations etc) influence became very essential as they are able to mobilize the society, have high expertise (think tanks), but it is also important to note their financial strength and moral effects (norm entrepreneurs).

In today's unifying world, none of the regions, countries or any minority groups can avoid the global forces, permanent global changes form the everyday life. Isolated communities do not exist anymore, states penetrate each other, the significance of spatial distances erodes, and everyone is everyone's neighbours (distant, functional neighbourhoods). After John Burton this phenomenon is often called `cobweb' model of world society, where nearly all of the actors feel the impact of individual decisions.[8] The cobweb metaphor describes the situation perfectly. It includes the diminishing importance of national boundaries and, also, the system's main characteristic, namely interdependence. Today state-sovereignty is limited, economic and cultural processes excess the states' authority defined territorially. Furthermore as a consequence of the globalization the traditional distinction between foreign and domestic policy is not possible, therefore the so called "intermestic" concept is introduced. This new system requires strong cooperation between states and non-state actors.

Their collaboration is very crucial as in parallel with the unification of the world problems also turn common, so the humanity faces global issues. The political, economic and environmental cross-border problems affect everyone. For its

[8] More information: John Wear Burton (1972) World society, Cambridge University Press

severe implications climate change and global warming is one of the most serious issues among other problems. Since the countries potential to solve the environmental problems seems unambiguously limited, the notion of "global governance" must come to the front: cooperation and obligatory international standards are needed.

2.2 Main framework of the international cooperation: UNFCCC

Due to the increased human activities, the concentration of carbon dioxide in the air stepped up since the Industrial Revolution. This phenomenon heavily contributed to climate change. As the problem has become worse and worse, it has turned out that the damage will move further and will result an additional warming of the Earth's surface and atmosphere and may adversely affect natural ecosystems and human kind. Counter actions were needed. It was clear that these problems should be handled at international level; countries have to solve the revealed problems together, so a multi-level cooperation. The first international negations started in 1979, the international conference on climate change was held in Geneva. In 1987 Montreal Protocol on Substances that Deplete the Ozone Layer came into existence with the aim of reducing emission of chlorofluorocarbons (CFCs). This was the first time when wide range of countries approved an international agreement on the topic (Hardy 2003).

The most important step against climate change was the creation of the UN Framework Convention on Climate Change (UNFCCC) in which there was recorded not only the reasons of climate change, namely greenhouse gas (GHG) emission, but also the possible threats to mankind. Furthermore, the general principles, commitments were codified and a new institutional framework was established for the sake of the cause. After considerable discussions and work the Convention was accepted in 1992, at the Earth Summit held in Rio de Janeiro. Article 2 of the UNFCCC states the Treaty's goal as ''stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (UN, 1992).

The Convention is a milestone in the history of the international fight against climate change, but it should be recognized that it does not include many specific or concrete target. Beside general objectives the tasks undertaken by Parties are also quite simple. Article 3 strengthens this feature: "*the Parties have a right to, and should, promote sustainable development*" (Ibid). This Convention means only a framework, it has no mandatory limits and it is considered legally non-binding.

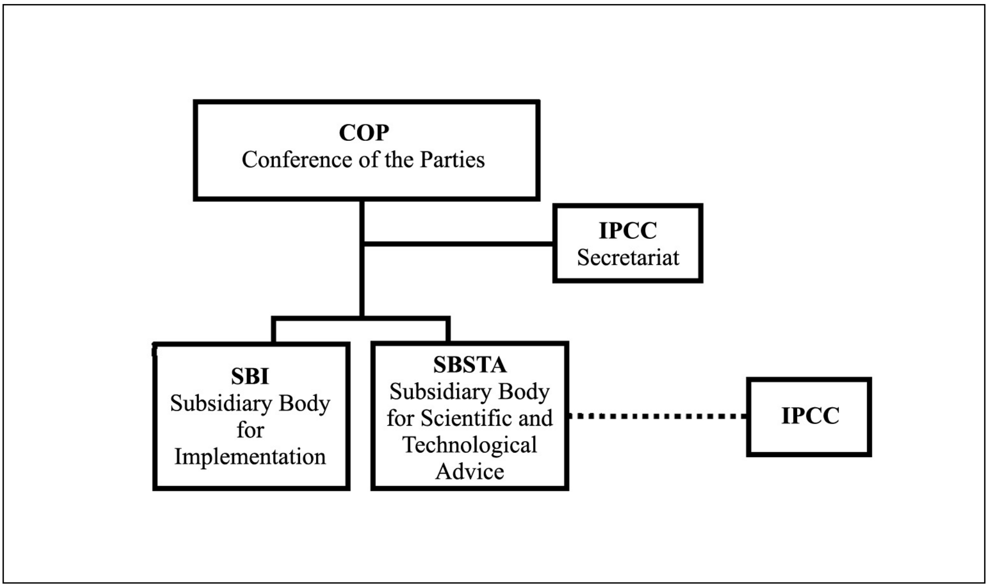
The Treaty gave the opportunity for the cooperating Parties to meet regularly, create further action plans and fix targets in protocols. The Parties were classified into different categories. Annex I includes industrialized countries, like members of OECD and transition countries (Former Soviet Union, and Central European States). Annex II mainly consists of OECD members of Annex I, these countries are required to provide financial support to enable developing countries to undertake emissions reduction activities under the Convention. The Treaty has 194 member states now.

As a response to climate change the UNFCCC sets out both *adaptation and mitigation*, while the first form has become fashionable only lately. The Treaty focused originally rather on reducing the source of climate change, so policy on the issue emerged first as mitigation policy. The reason for that is very simple, at the time of writing the Convention; it was widely believed that mitigation is more effective. Nevertheless later adaption projects have also increased in number (Schipper, 2006).

Since the UNFCCC entered into force, the Parties have been consulting regularly in the Conferences of the Parties (COP). The COP is often called the supreme decision-maker body of the Convention, as it monitors the states' efforts and the overall completion of the Convention; and ensures the continuity of the fight against climate change. The first COP session was held in 1995, where the Parties reached agreement on the Berlin Mandate. At that point an ad hoc group was established with the aim of implementing some type of legal instrument to strengthen the commitment of Annex I Parties (Weyant, 2004).

There is another important organization to mention called Intergovernmental Panel on Climate Change (IPCC). The leading international body was created in 1988 by the United Nations Environment Programme (UNEP) and World Meteorological Organization (WMO) to provide in depth technical information about climate change and its consequences. The scientific facts brought up by the first IPCC Assessment Report in 1990 unveiled the substance of climate change. The report contributed to the creation of UNFCCC as from that time on there was no doubt that the topic deserves a political platform. Work of the scientific body is highly respected, while it publishes informative documentations and helps to understand all the relevant issues regarding climate change. IPCC got the Nobel Prize in 2007.

Figure 1 Structure of the UNFCCC



Source: Own construction after the text of the Convention

2.3 Kyoto Protocol

Main points of the regulation

The second IPCC report published in 1995 and the following two years of negotiations has contributed largely to the adoption of the Kyoto Protocol. It was a huge step forward that on the 3rd Conference of the Parties (COP 3) after formal and informal negotiations such an international agreement was adopted which set legally binding targets. The road to the agreement was not free from conflicts as the Parties were on different opinion in many topics. The US wanted to preserve pollutant emission level according to data from 1990, but the European Union supported the idea to reduce it by 15%. The Alliance of Small Island States (AOSIS) called for a radical reduction. Developing countries were not in unity either, while China and India wanted to preserve the 1990's level of emission, from Latin American states' point of view reduction was the only acceptable solution.

Despite debates Protocol is considered a great success because participating nations have committed themselves to tackling the issue of global warming and greenhouse gas emission. Parties included in Annex I undertook collectively to reduce their overall emissions by at least 5 percent below 1990 levels in the five year period 2008 to 2012. This obligation means for them a binding target in terms of a multi-gas index, but the commitments are differentiated by countries. The Protocol named by details those gases which are GHG's. Six types of gases were listed, which means an extension of the category compared to the Montreal Protocol. The reason for that is meanwhile some chemicals revealed poisoning too. The Protocol was adopted on 11st December 1997, in Kyoto, and entered into force on 16th February 2005. As of August 2011, 191 states have signed and ratified the protocol. The only exception is the United States, after the signature, the country have not ratified the Protocol yet. The high participation shows that most of the countries had some sort of bad experience with the issue, so the threat is believed real.

The Kyoto Protocol listed 3 types of flexibility mechanism for implementation. One option for fulfilling their commitments is participating in *emissions trading.* According to the rules the Parties has accepted reduction goals. These targets of the countries for reducing the emission are expressed as levels of assigned amounts. If in a country pollution exceeds this number, it has the right to buy quota from another state. This system is reckoned to be a carbon market, while quotas can be traded like any other commodity.

Second, by the *clean development mechanism* (CDM) a developed country can get emission reduction credits for investing in a project which facilitates sustainable development in developing countries. The mechanism has two purposes: to strengthen sustainability in the host country and to achieve cost-efficient emission limitation by the investor. The second goal can be realized as in a developing country a unit reduction is carried out with a lower unit cost. If such investments create real additional emission reduction, investor countries get so called certified emission reduction units (CERs) depending on the amount of avoided carbon dioxide emission. CER unit is a type of carbon dioxide quota; it entitles the owner to emit 1 ton carbon dioxide equivalent greenhouse gas.

The third opportunity called *joint implementation* (JI) is similar to the second one, but members of the participating countries are different. Under JI a developed country can receive emission reduction credit if it helps to finance specific projects that reduce net emissions in another developed country. As the second mechanism, this solution offers also several advantages: the donor country fulfills its target, the recipient gains foreign direct investment and advanced technology and the atmosphere will benefit also (UN, 1998).

Critics and the Protocol's future

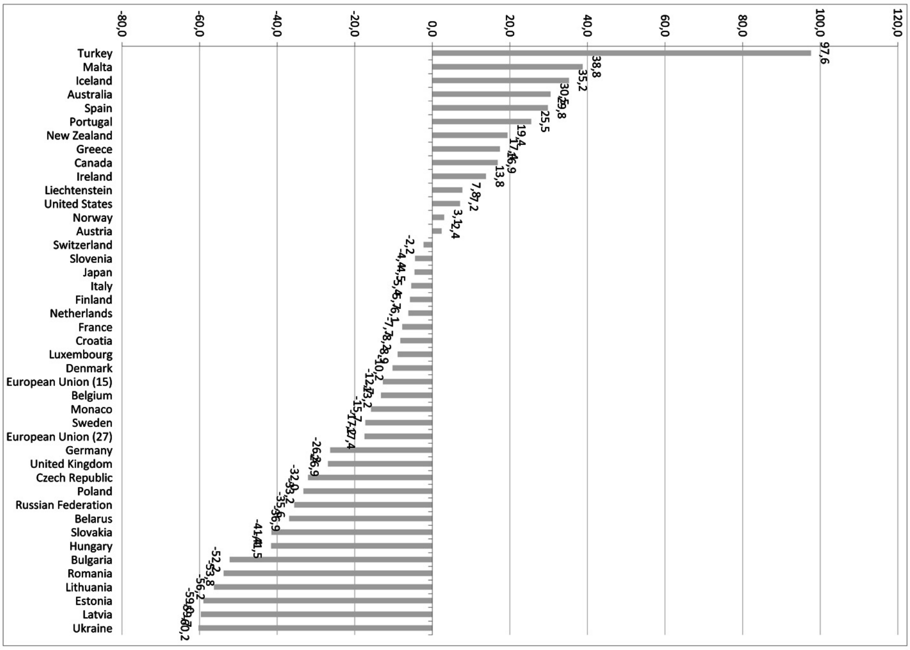
Adoption of the Protocol has a historical significance; nevertheless it has been under a lot of pressure. It has come under attack while it could not stop the increase of greenhouse gas emission. According to critics it has no long term view. It is unfortunate that the regulation covers only a part of the world, developing countries were not involved as responsible Parties, and many developed countries have changed their opinion and refused to comply with the rule (e.g. the United States and Canada). The lack of proper institutional infrastructure has resulted that the initiation can be seen rather as a forum of discussions; it deteriorates the efficiency that there is no strong enforcement and penalty. It is also uncertain how to measure emission reductions and there is no correct monitoring. Based on the opinion of Esty (2008) Kyoto protocol does not have enough economic and legal incentives for global action. He considers that regulations should be developed in such a way that those create economic interests to restrain emissions in participating countries. The regulations are legally insufficient because nobody is accountable for doing damages. The expert therefore suggests that in the future three aspects must be considered: effectiveness, fairness and legitimacy. Jamieson (2010) criticizes the existing system from an ethical point of view. Ha claims poor countries suffer the most from climate change, those who are less likely to be responsible for the presence situation. He expresses his solidarity with them because their will cannot prevail on the international negotiations, great powers dictate the terms.

The efficiency of the Protocol can be reflected by the data, Figure 2 shows different results in the level of emission change. In fact most of the participants performed well above their commitments, so these countries couldn't complete the way they agreed to. However Russia and other transitional economies and some countries that underwent structural changes (United Kingdom and Germany) are exception (Pizer, 2006).

Compared with other solutions many experts questioned the effectiveness of this type of control, since there is no consensus among them which economic tools is the most effective way to handle global warming. Many of them support the carbon tax instead of quantity-type system, arguing taxation is a long standing policy, every country has practice. This kind of indirect tax practically can be seen as a price instrument, while it sets a price for carbon dioxide emission. By using taxation, market price volatility of carbon can be eliminated which is a negative feature of cap and trade system. There are several other advantages of taxation, e.g. it is harder to find a loophole to avoid it, revenues appear immediately in the budget and it involves a lower chance of corruption and violation. Its main disadvantage is that it does not force world economy to reach a certain level carbon dioxide concentration or temperature level (Nordhaus, 2011).

No matter which instrument is chosen by policymakers, its effectiveness can be improved by several tools. Abatement subsidies, tradable emissions allowances and performance standards could be introduced. According to economic analyses technology push polices (like technology and R&D incentives) are very useful because they can lower the cost of emission reducing. More constructive technologies are carbon capture and storage, nuclear and solar technology. Moreover, it is important to start a dialogue between countries in that case, too. They should develop technological cooperation and help each other. The gain from technology spillovers must be emphasized as well, so countries have the task to remove obstacles (Fisher, 2009).

Figure 2 GHG Change from base year (1990) to latest reported year (2009) (%) excluding LULUCF, in Gg CO2 eq.



Source: UN Statistics, available at
http://unfccc.int/ghg_data/ghg_data_unfccc/time_series_annex_i/items/3814.php

Since the Kyoto Protocol provides rules only for a specific period of time, Parties have begun to build the Post-Kyoto era before the contract expires. On the 13th Conference of the Parties (COP-13) decision was made about the schedule of the negotiations after 2012. Bali Action Plan was adopted and an ad hoc workgroup was formed to conduct the work. A large breakthrough was expected from COP-15 meeting, but because of the different priorities of the countries no progress was made. Copenhagen Summit, in 2009 was a failure (Armeni, 2010); experts were disappointed because Parties could not find a common voice. In fact the opposition of the two great powers namely United States and China has contributed also a lot to the negative outcome. While China insisted on getting financial support, the United States refused the idea that China requires special treatment in the future.

It must be acknowledged that the Copenhagen Accord is only a political statement not eligible to handle climate change issues due to its non-legally binding character. It only calls countries to curb greenhouse gas emission and it does not contain any global long-term mitigation goal. However, the Parties could agree on the further promotion of the developing countries and a new fund was established for them. Despite of the unsuccessful summit in 2009, the continuation could be promising. Though many topics were postponed to the next summit, the reduction goals of Copenhagen Accord could be legitimized in the future and a legally binding agreement can be reached.

Progress assessment and alternatives

Fight against climate change is extremely hard because of its complexity. It is a limiting factor that it can not be determined exactly who is responsible for the emission. As a consequence the polluter pays principle does not work in reality. Therefore, it is necessary to speak about global responsibility but several countries – especially developing ones – are not intend to accept it. The developing countries argue that they have the same right for development, even if their progress causes also massive effects in the environment. Eventually their point of view is acceptable, considering that these countries have started to develop in recent years and they have great lag of modern technologies and welfare. They must dictate the tempo of development if they would like to cope with their social conflicts. Of course, it has some side effects like increasing pollution. For current situation developed countries have a much greater stake of responsibilities due to their activities in 20th century. The available data indicate that atmospheric carbon dioxide concentrations rose from 280 ppm pre-industrial level to 379 ppm by 2005. The rate of growth was uneven, however it has accelerated dramatically in the last 10 years, with the value of 1,9 ppm/yr (IPCC, 2007). This phenomenon generates dispute between newly industrialized and developed countries.

The so-called *north-south conflict* is only one, but important aspect of climate change. Nevertheless, several other issues can be listed. It is a very essential problem that effects of local pollutions do not occur only at the spot of the emission; it has regional and global negative result as well. The fact that climate change already has visible physical and biological consequences causing great harms at one place, while other territories do not have these signs brings another obstacle to the dispute, and limits the chance of a global consensus. Free-rider behavior is typical, specific polluters are less motivated to revise their usual practice. Countries are also influenced by the uncertainty of the future; they tend to think that the problem will never affect them, so they postpone the needed response. According to Mendelsohn (2003), one of the hardest things is to determine the future vulnerability of countries. Experts are attempting to quantify the expected outcome in many areas with simulations, but numbers are often unreliable. According to this, it is better to take into consideration the trends. But to sum up, the officially accepted view suggests that some ecosystems (mountain regions, the dry Mediterranean areas, the low-lying coastal areas) are particularly vulnerable.

The creation of a supranational system of norms (*policy-imposed behavioral change*) is undoubtedly a huge step forward in solving the problem of climate change. It is important to see, that there are some shortcomings of the existing system, therefore introduction of new incentives is inevitable. The issue of climate change requires national response and social mobilization in addition to global collaboration. Decisions of the UNFCCC are based on controversial policies and usually the dominant power wins. In order to limit the role of political interests which have a significant role in hindering the process, the so-called bottom-up principle should be considered and incorporated into the institution. In this context, it would be useful to enhance the interaction between the stakeholders, it must be attained that families, communities get the knowledge of the relevant information. If they can accept it sooner or later the positive attitude will be a part of their national culture. It is important that consumers, producers should become socially sensitive in that case. This requires that scientific knowledge become widely available, education and mass media should pay more attention to climate change. Unfortunately, there is little evidence so far that social mobilization (*self adopted behavioral change*) has been achieved. Many specialists confirm that although the inter-governmental cooperation has been developing and progressing slowly, the population is still very under-informed. If this situation persists, measures taken to reduce carbon dioxide emissions won't be effective.

Table 1 The most prominent NGOs within the climate change debate

NGO	Objective	Year	Origin
Business alliances			
The Global Climate Coalition	to coordinate business participation in international policy dispute on climate change	1989	US
European Roundtable of Industrialists	to strengthen Europe's economy and improve its global competitiveness	1983	EU
Research-based organizations			
The Pew Center on Global Climate Change	to educate the public and key policy-makers about the risks, challenges and solutions to climate change	1998	US
Resources for the Future (RFF)	to provide interdependent, non-partisan research and policy analysis	1952	US
Worldwatch Institute	to inform policy-makers and the public about emerging global problems and trends and the complex links between the world economy and its environmental support systems	1974	US
Wuppertal institute for Climate, Energy and the Environment	to systematically address both the global environmental challenges and the complex task of ecological structural change	1989	Germany
World Resources Institute (WRI)	to move human society to live in ways that protect Earth's environment for current and future generation	1982	US
Campaigning groups			
Greenpeace	campaigns against environmentally damaging activities	1971	Global
WWF	to halt and reverse the destruction of our natural environment	1961	Global

Source: Gough, C. – Shackley, S. (2001) The Respectable Politics of Climate Change: the Epistemic Communities and NGOs, *International Affairs*, 77(2) pp. 341-345

However, certain forms of advocacy system are operating; among others NGOs are very active at the lower levels. These non-profit organizations use to deal with the formulation of policies; they participate in official international meetings, work internationally with government and business leaders, and facilitate talks between government officials, climate specialists, and civil society groups all over the world. Their work is to facilitate the flow of information, and to organize educational events. They play a great role in cutting global emission and accelerating a clean industrial revolution. NGOs' have different profiles, depending on what their mission is. Therefore NGOs employ different methods, practices, and work on other issues. After Gough – Shackley (2001) three categories can be named. Usually research-based organizations develop creative policy solutions to environmental issues; introduce new concepts, approaches or interpretations. Other organizations', think-tanks' activity refers only to the production of research papers on several topics like biodiversity, extreme weather events etc. The authors of these publications possess great scientific skills, so the output of the knowledge construction institute is recognized to be high quality. Some NGOs operate on very different level, the lobbying and campaigning institutions communicate through media, want to reach the mass, use market techniques to "sell" climate change.

In conclusion, a lot of measures were taken at global level over the past two decades to combat against climate change. Despite these steps it is also obvious that institutions are useless if there is no any constrains for implementation. Progress can be achieved if nations reach consensus and lay down those appropriate rules which help to handle the problem. In that case commitments do not matter, only actual steps are important. Corporate social responsibility also can help a lot to solve the situation. However, result is not guaranteed even if both solution opportunities work, while effects of the steps are delayed and there is a big uncertainty around the scientific methods also.

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Gábor Kutasi

3. Climate change in game theory

"The issues of how best to govern natural resources used by many individuals in common are no more settled in academia than in the world of politics "
Elinor Ostrom (1990)

3.1 Introduction

Rubas et al. (2006) establish, that *"game theory has not been widely used in applications of seasonal climate forecasts largely because of the increase in information requirements and increased methodological knowledge necessary to develop and solve games. (...) Though rarely used in studies on climate forecast problems, game theory has been used in climate related studies such as climate change studies (Ward 1996, Forgo et al., 2005) and climate variability studies (McKelvey et al., 2003)."* The previously quoted Rubas et al. (2006) give a very broad view of the economics and survey methodology of climate change, detailing the game theory as well. Besides Forgó et al. (2005), very specific modelling and surveys of the negotiations have been created by Courtois, P. (2002), Yang (2003), Courtois & Tazdaďt (2007), and Pinto & Harrison (2003).

The study provides an overview of the application possibilities of game theory to climate change. The characteristics of games are adapted to the topics of climate and carbon. The importance of uncertainty, probability, marginal value of adaptation, common pool resources, etc. are tailored to the context of international relations and the challenge of global warming.

The complexity of the theme also requires borrowing some themes from international relations theories, behaviourism, ecological economics, and international political economy. As a basis for application of the game theory, the general theses by Ostrom (1990), Owen (2008), Harsányi & Selten (1988), Olson (1965), Myerson (1997), Dixit & Skeath (1999) and Harding (1968) are applied.[9]

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3.2 Characteristics of games

In the case of modelling of pro-actions and reactions for changing temperature, the characteristics of events, actions and behaviours must be known. In climate change, uncertainty is a dominant character. Technically speaking, uncertainty means there is no saddle point in the game (Owen 2008). This means that the payoff of the game is not sure but depends on the actors' expectations and their probable reactions on each others' actions, or on the probability of certain external events. Especially in the field of climate change, uncertainty is accumulative.[10] There are even scientific disputes whether the change of average temperature is really taking place, and if so, whether it has been caused by the CO_2 emission from human activity. (About the challenges of economic forecast see Rubas et al. (2006).)

If climate change is taking place globally, it does not mean a generally same rate of temperature change in every region and territory of the Earth. (It is possible that a more or less rise in temperature or even cooling down will be a likely outcome in certain regions.) The physical impact of the various effects can be different. In some regions, the rise of sea level might take costal territories, in others strong diseases might break out due to warmer climate, in still other territories the agricultural lands would dry out, and somewhere else the disappearance of ice and snow would create land cultivation opportunities or ruin winter tourism, etc. But what is the likelihood at the level of a continent, a country, a county or a city/village? If there are more scenarios, what mitigation and adaptation actions are effective? What is the critical mass or scale of action? Will the actors wait for each other to act? Who should act first? Should the state intervene, motivate, initiate? And so on. If such uncertain probabilities are accumulated (namely multiplied) the final likelihood of effective actions can be low.

The source of uncertainty can be asymmetry in information, moral hazard, irresponsibility (no ability to carry out commitments), negative selection (counter selection), decentralized governance, myopic self interest. Asymmetry in information can be rooted in technology and science difference or different positions in information reception streams. However, uncertainty can also be used as weapon in climate negotiations to keep opponents guessing, thus making them uncertain and slow (Dixit & Skeath 1999, p. 187, 264, 272).

[10] About circular and cumulative causation and irreversibility see Thorstein Veblen, Gunnar Myrdal, Nicholas Kaldor, K. William Kapp and Nicholas Georgescu-Roegen referred in Berger 2008, 2009, about cumulative uncertainty see Frank Knight (1921), J.M. Keynes (1921, 1936), and G.L.S. Shackle (1970)

The latter, in case of climate change and the related carbon emission, is not very likely if we consider the global information systems of the 21st century. Moral hazard, namely causing risk and cost for someone else by one's behaviour or decision is a very typical occurrence in negative externality situation just like environmental damage as CO2 emission. Irresponsibility can be understood as sociopath behaviour, also adoptable into international relations just like North-Korean nuclear threat and war threat psychosis. In case if carbon emission, irresponsibility could mean the ignorance of negative global externalities from emission. Negative selection is very theoretical in case of climate change games. Generally, it means that always the lower quality, less credible, less able etc. option or actor is preferred. Among the behaviour games we will see cases, when the smaller/weaker actor can enforce its own preference on the bigger/stronger actor (see called bluff and suasion games). Decentralized governance is relevant in game uncertainty and climate change as it increase the number of actors and move further the scale of problem (global) and level of competence (regional) from each other. Thus, the likelihood of free riding will increase. Possible occurrence of myopia as uncertainty factor means ignorance of long-term externalities for short-term profit, welfare, comfort etc. The examples of peace treaties of World War I or absence of green-house-gases treatment can be mentioned for myopia in international relations (Keohane, 1984, p. 92-98).

The payoff function of a game means the composition of probable individual cost-benefit balances of different scenarios for the same problem. The total payoff of a game can be negative, zero and positive sum. It is possible also to have variable sum game if the sum of total payoffs is not constant in different scenarios (outcomes). Static and dynamic games can be distinguished, as in static means constant, dynamic means changing preferences (Owen, 2008). The exiting and challenging aspect of payoff matrix definition related to climate change is that it is the result of a national welfare optimization in relevance to green house gas damage due geophysical and socioeconomic transformation.

In case of climate change, because of its complexity and high uncertainty, the variable sum and dynamic approach is the most useful to model the behaviour of actors of international relation. As certainty of occurrence and local/regional impact of temperature change gets stronger, it has repercussion on the preference of decision makers in the international space. Change in preferences can be caused, also, by change in political leadership or regime (Keohane, 1984, p. 116). For example, the end of Clinton governance and the beginning of G.W. Bush governance had resulted significant difference in the U.S. attitude to the Kyoto protocol in the presidency level. Very complex structure of possible choices can result also variable international community payoff in dependence of multi-country actions. And here comes the question of timing dilemma: The further we are before the change of temperature and its physical impact, the higher is the uncertainty of the occurrence of climate change, thus the lower is the motivation to mitigate, however the cheaper and the more efficient is the mitigation. The closer we get to the realization of climate change impacts, the higher is the certainty but the mitigation or adaptation cost, too. Namely, the mix of probability, the scale of temperature change, the current cost of adaptation and the expected damage will determine a marginal value for the private and public and international actors as benchmark to decide the timing of mitigation/adaptation.

In game theory, the assumption of a rational player entails the maximization of individual benefits. This theorem introduced the importance of conditionality, since the probability of certain alternatives depends on circumstances (Myerson, 1997, p. 12). In the timing of start-up the actions, there is an important factor, namely, when it does worth to mitigate or adapt. This can be simply described by the net present value (NPV) calculation. Just as generally, the aim of an economic actor is to maximize the net marginal benefit of the action (CEPS&ZEW, 2010).

$$F = \max\{MB - MC\} \tag{1}$$

Until MB > MC, namely marginal benefit is bigger than marginal cost, there is no motivation to start or extend the adaptation. For planning of timing of adaptation or mitigation to climate change, this maximization should be dynamic, so the optimum NPV of adaptation cost and climate damage is looked for. (Rubas et al., 2006)

$$\text{NPV (climate change)} = \text{PV(adaptation cost)} - \text{PV(climate damage)} \tag{2}$$

According to the model of Hasson et al. (2010) with all-or-nothing trade-off between the preventive mitigation and the reactive adaptation, the timing depends on the expected payoff for having and having not a disaster.

In Hassons et al. (2010) model, the expected payoff depends on the probability of the disaster, the vulnerability of the individual, the budget necessity of mitigation, budget necessity of adaptation, existing financial instruments. Investment in mitigation lowers the probability of a disaster for all subjects, while adaptation lowers the actual cost of a disaster only for that individual subject. The total mitigation by the group is divided by the total budget available to all subjects, so the more people that invest in mitigation, the lower the probability of disaster.

Investment in adaptation may have on the economy other than preparing for a climate change disaster. The cost of a disaster is also affected by the degree of vulnerability. The more vulnerable are the actors, the higher will be the damage of a disaster. Likelihood of disaster is determined by "*total mitigation and an element of chance*", which means partly endogenous and partly exogenous determination.

Namely, the return from mitigation is larger if all players mitigate, but there is still risk of a climate change disaster.

That is why the social dilemma is described by the marginal per capita return (MPCR) for mitigation (m) and adaptation (a) in the followings:

$$\text{MPCRm} < \text{MPCRa} < n * \text{MPCRm}, \tag{3}$$

where n is the total number of actors.

The relation between MPCR values expresses, that because of the exogenous chance for disaster, the cost is too much, if every one mitigated, since it can not prevent absolute surely the disaster. That is why it is expectable, that, depending on the above mentioned factors, there will be some actors, who will and should not mitigate, if the community/society want to pay the optimum cost for prevention.

The players of a game are not necessarily rational decision makers, but they could be iterating actors. Namely, strategic choices can be made through experiments of strategic alternatives. This version of strategic games is analysed by the evolutionary game theory. The iteration presumes the importance of dynamics and the frequency of findings from the competition of strategic alternatives (Maynard Smith, 1982; Weibull, 1995; Dixit & Skeath, 1999). In evolutionary theory and in the evolutionarily stable strategy model by Maynard Smith (1982), it is important, to have more opportunities to attempt. In the ecosystem, the opportunity for several attempts is ensured by the high number of individuals in a population. In international relations, the repetition of a test is possible as the states are immortal and infinite actors (even though in some cases, some states disappear). In this way of decision-making, primarily not the absolute but the relative quality and the frequency of attempts will determine the adequate or acceptable strategy among the alternatives. Some examples for evolutionary games are the following: hawk vs. dove, war of attrition, stag hunt, tragedy of commons, prisoners' dilemma, assurance game, chicken game (Dixit & Skeath, 1999, p. 430-451).

For example, the hawk vs. dove game is a situation when there is one type of player, such as a group of countries, who can choose among alternatives. The hawk strategy variation means taking as much resource as possible and levy as much cost on partner as possible. The dove is on the contrary. In a dual game, both players can try both types of alternatives. The war of attrition is a variation of the hawk vs. dove in so far as there are alternative resources. If hawk picks one, the dove still has other resource seeking opportunities. (The hawk strategy is actually called bourgeois strategy in the latter game.) (Maynard Smith, 1982; Dixit & Skeath 1999, p. 447-450).

Especially in the case of negotiation games in international negotiations, the interesting aspect is the number of replication options, whether it approaches to limited number or to infinity. The number of possible replication will determine whether game has a finite or infinite horizon (Kandori, 2006). It is very likely that the existence of a saddle point will limit iteration. Meanwhile, more equal total payoff functions with various distributions will induce a permanent war of attrition, thus creating a game that approaches to infinity. In the case of a finite game, the distance of the horizon can strongly determine the approach of the players. For example, global warming seems so far in the future for mortal or short-sighted economic and political actors that some of them view it as an infinite game. Just as if there were infinite time to test the different alternatives. The U.S. governments have been switching between contract and market approach concerning the internalization of carbon emission. Republican administrations insisted on the market-driven pricing, while the Democrats supported the U.S. join the Kyoto protocol. However, infinite games can be played by the social norms of the so called folk theorem (Abreu et al., 1994). Kandori (2006, p. 1-3) mentions three general ways to achieve efficiency in infinite games: competition, contracts, long-term relationship. The general example is two gas stations next to each other with the three alternatives on pricing. The trigger strategy will determine the progress of iteration. The trigger strategy depends on the character of the players: whether they are doves or hawks, active initiators or passive followers, aggressive competitors or collaborating, and also on the assessment about the opponent.

Climate negotiations can be regarded as an infinite repeated game with the three alternatives. For example, adhering to an agreement on carbon emission limits equals with contracting. Or, everyone becomes a free rider and do not limit emission at all, thus the competitive Nash-equilibrium is enforced by a long-term warming damage. Frequently, temporary deviation from the quota with return to the norm later can be considered a long-term cooperation situation where players always want to realize their best short-term payoff, but after deviation, they regularly give up the Nash-equilibrium. (About repeated games see Myerson, 1997, p. 308-365.)

The microeconomic game theory examines individual strategies in dependence of expectation on other individuals' behaviour. In the mainstream international political approaches (realism by Morgenthau and Kenneth Waltz or constructivism by Alexander Wendt) consider the actors of international relations just like rational individuals in the microeconomics. Thus, games can be transplanted to international relations, like treating the global climate change and regulation of carbon emission. In theses of Keohane (1984, 1989) and Keohane & Hoffmann (1991) the application of game theory is to analyze the international relations is exemplary. This literature uses variable sum games, dilemmas, dynamic preferences, uncertainty, to explain cooperation, harmonization or conflicts. It is also important in international relations theory, that Keohane (1984) applied the bounded rationality by Herbert Simon when not maximization of net benefits, but satisfactory solutions are accepted, or such principals are driving the participants' decisions as the empathy in relations, humanitarianism, pacifism, Wilson's moralism, internationalism and reciprocity.

3.3 CPR-problem in climate change

The examination of international relations with the instruments of microeconomics can be started with a characteristic occurrence which is very often in the decentralized international space. It is the common pool resource (CPR) problem. In the microeconomics, this problem was described and explained by Garrett Hardin (1968) as the tragedy of commons. In the common herding field in community ownership, the rational individual herders' behaviour is to add more and more animals onto the field and this way the cattle will overgraze, thus ruin the grass field. This type of *"motivation to increase the using without limit in a limited world"* (Hardin, 1968, p. 1244) is very often temptation in case of the international resources, just like the climate. The climate, more precisely the average level of temperature in a region can be understood as a resource for certain type of living, land cultivation, transportation, access to costal territories, use of technologies, health conditions etc. This resource – according to natural sciences – can be ruined by excessive carbon-dioxide emission. So, the common pool resource and its possible overuse got identified. In optimum case, the users of the common pool resource should agree, how to sustain and finance (or operate) this resource. But Olson (1965) recognized according to the rational individual model of microeconomics, that if someone can not be excluded from the use of the resource, he/she is not too much motivated to contribute to the financing, sustaining of it, but to behave as a free rider.

Ostrom (1990. p. 8-21) gathered the developed solutions for CPR problem: the Leviathan, the Privatization, the self-financed contract-enforcement. The Leviathan model related to Hobbes, who saw the solution of overuse of community resources in a strong central power, which punishes the excessive access and this way changes the original payoff of excessive users. This model has two weak points: the corrupt executives will cancel the penalty, and the central authority might operate with incomplete information, thus can not effectively punish. Besides, in international relations, in post-hegemonic cooperation (or multi-polar system, see later) there is no chance to have an external strong power (the Leviathan) threatening the carbon emitters with sure punishment (Ostrom, 1990, p. 12). The second option, the privatization, according to Demsetz (1967) and Smith (1981), means that the common pool resource should get distributed to private ownerships, and private owners will take care for the completeness of own share. In case of climate impacts and temperature it is an irrelevant option as this is an indivisible resource. The third solution, the self-financed contract-enforcement means that the users watch and control each other, as they know mostly the "capacity" of the resource, and as they are present in the use, they can have complete information about the state of the resource and the behaviour of other users. In micro level, this is a broadly used solution e.g. in case of issuing fishing, angling or hunting licences. That is the way what has been realized by the Kyoto protocol, too[11].

In case of the carbon emission as an international CPR problem, the emission can be understood as a negative CPR since more emission is worse, and its opposite (positive) CPR is the stable temperature and all the economic and social opportunities related to this climate. The CPR problem is that CO2 emitting countries do not want to bother with the level and impacts of emission, do not want to join any reduction targeting or do not want to take the cost burden of mitigation and adaptation with reference to uncertainty.

From the view of organization theory applied for international organizations, there is a very general practice to try to solve international CPR problems. Namely, it is very close to Coase's ownership school approach that recommends the delegation of the ownership to those who can distribute or trade the use and set the price of the resource in the most efficient way (Coase, 1960). In international relations, it means many cases, that countries create international organisations who get the right to regulate, monitor, maybe penalize, make decisions, do justice to disputing parties etc. In case of international oceans, external space, nuclear energy, international trade or monetary regimes there are such international owners of the common pool resources (many times with questionable efficiency). In case of carbon emission, such international organisation (a Leviathan) has not been established, but the ownership has been split among international country players who can have control over

[11] However, the mentioned solutions tries to create a coordinated game on the use of CPR, Ostrom (1990, p. 42-50) still identified institutional problems rooted in uncertainty and difference in mobility, damage and dependency of users. The problem of supply raises the question: Why would the members of a society be motivated to supply the institutions governing the common pool resources? New institutions and rules, besides solving an existing CPR problem, create new CPRs. The problem of credible commitments means, no one wants to be looser or – as written by Ostrom (1990) – "sucker", namely, no member is willing to contribute and risk any cost if other members' commitment got questionable. The problem of mutual monitoring enlightens the necessity of voluntary activity which burden cost of punishment on the participants. The appropriation problem raises the question, how to allocate in spatial and temporal horizon. The provision problem points on the necessity of appropriate construction and maintenance. (About credibility problem see also Dixit & Skeath (1995, p. 315-320).)

the private emitters and trade quotas with each other, thus set the current global price of ton of CO2 emission.

Table 1 and table 2 shows such prisoners dilemmas for CPR problem which are applied for climate change mitigation/adaptation strategies. Table 1 illustrates a two countries (or two groups of countries) situation, where the dilemma is to pay the cost of mitigation and adaptation or not to do anything for lower carbon emission. If a country chose to mitigate and adapt, she must pay the cost (C). Depending on strategies, in a simplified version, if both players mitigate, there is no change of temperature, so cost of damage is zero (T0). If one of them does not act, than at least 1 Celsius warming happens, so some economic damage will be realized (T1). If no one acts, more serious, let us say, 4 Celsius warming occurs with bigger economic damage.

The game of Table 1 is an evolutionary case since it can be understood as an example for the hawk vs. dove game, as the preservation of the current climate is a "resource" without alternatives. A hawk-meets-dove situation is when the hawk country would be the 'no action' country levying all mitigation cost burden on the partner (dove) country. Note, however, that the prisoners' dilemma can actually be interpreted as an evolutionary stable strategy if there is Nash-equilibrium (Weibull, 1995). In this case, Maynard Smith (1982) calls it 'assessor' strategy. The assessor analyses the opponent player and will choose a strategy that matches the opponent's character the most. Thus we can get to the symmetric and asymmetric variants of dilemma just like the called bluff, the stag hunt or the suasion game (see below).

Table 1 Climate change prisoners dilemma, country to country

	Country A		
Country B	STRATEGIES	Mitigate and adapt	No action
	Mitigate and adapt	C+(T0) C+(T0)	T1 C+(T1)
	No action	C+(T1) T1	T4 T4

C= cost of mitigation and adaptation, T0= no temperature change, zero damage, T1= damage, caused by rising temperature by 1 Celsius, T4= damage, caused by rising temperature by 4 Celsius, T4 >> C, T4 >> T1
Source: author

Table 2 Climate change prisoners dilemma, public to private players

		Public Policy	
	STRATEGIES	Subsidies the cost of adaptation	No subsidies for private sector
Private Economic Actors	Pay the cost of adaptation	C/n +(T0) C/(1-n) +(T0)	T0 C+(T0)
	Expect action from Public Policy	C+(T0) T0	T5 T5

C = cost of mitigation and adaptation, n + (1-n) = 1, T0 = no temperature change, no damage, T5 = damage, caused by rising temperature by 5 °C, T5 >> C
Source: author

Table 2 shows an intra-national situation with public and private group of players, where the dilemma is to pay the cost of mitigation and adaptation or wait for the other type of national actors. Namely, the public policy makers can decide whether they pay subsidies and introduce green taxes to motivate lower carbon emission, or do not subsidize the private sector at all in mitigation/adaptation. The private sector players can decide, whether they participate in financing, they can share the cost (C/n + C/(1-n)), and they can reserve the current temperature, in a simplified version, so they will not suffer damages (T0). If only one of the types (public or private) is willing to finance, but the other one is reluctant, cost of adaptation (C) will be levied on the willing player, but, let us say, the economic damages can be avoided (T0). If no one is ready to finance, the economic damage will be extremely big (T5) for both of them.

These games are calibrated so that both players' 'no action' strategy is so threatening that it must be avoided (if T4 damage is bigger than C cost and T1 damage, and T5 > C). But co-action is not secured. In Table 1, the co-action depends on the relation of C and T1 (T0 = 0). If T1 > C, it is worth to mitigate, otherwise it is rational to wait for the other player. In Table 2, it is obvious that both C/n and C/(1-n) is bigger than zero, so it is rational to wait for the other player. This way of thinking leads us to the *no action* + *no action* payoff in both games, heading for a trouble that can threaten with both players acting at least individually. But the result is that they wait for each others to act so that they can return to passivity again, etc. It can be established that there is no saddle point in the two examples. Of course, the matrixes can be rewritten in a dynamic view, as time passes, T0 or T1 damage cannot be limited, but will increase. The same can happen with T4 and T5, or even with C, especially if probability is introduced since neither of them are constant.

Setting emission quotas and watching each other for control is the practice of self-financed contract enforcement by Ostrom (1990) or the long-term cooperation of infinite repeated games by Dixit & Skeath (1999, p. 347-354). Such games have a serious weakness called imperfect monitoring. (Abreu et al., 1990,; Fudenberg et al., 1994; or repeated games with incomplete information by Myerson, 1997, p. 364.) The continued payoff changes when a player deviates. Imperfect monitoring is able to signal deviation but is unable to identify individual deviations. The only way to deter leakage is to punish all the players simultaneously (Dixit & Skeath, 1999, p. 356-358). This will result a community loss. Thus, the penalty cannot be levied on the free rider, and will lose its disciplining power. Kaldori (2006, p. 9-11) described the following climate change case to imperfect monitoring:

> *"For example, a country may not verify exactly how much CO_2 is emitted by neighboring countries. (...) Published meteorological data indicates the amount of CO_2 emission (...). According to the nature of the signals, repeated games with imperfect monitoring are classified into two categories: the case of public monitoring, where players commonly observe a public signal, and the case of private monitoring, where each player observe a signal that is not observable to others. Hence, the CO_2 emission game and the joint project game are examples with imperfect public monitoring (published meteorological data and the success of the project are publicly observed)."*

3.4 Behaviour game examples for climate change practice

Behaviours related to climate change be easily modelled with two-player games. "*Game theory is concerned with the actions of individuals who are conscious that their actions affect each other.*" (Rasmusen, 1992, p. 21.) According to Ravenhill et al. (2005) the following games can be applied in international relations: for symmetric (equal) actors, the basic prisoners dilemma, the coordination game (also known as battle of sexes), the assurance game (also known as stag hunt) and the chicken game; with asymmetric (weaker vs. stronger) actors, the called bluff, harmony and suasion games.

The prisoners dilemma is a simple example to demonstrate the decision dilemma of situation with different payoffs depending on the partner's action (Dawes, 1973; Dawes, 1975; Harsányi & Selten, 1988). This is a no-communication game, when the players must deduct each other's strategy from past experience. This dilemma is the basis of the following modified situations. It could be good a framework to model the following: Shall a participating country exceed the settled emission quotas? Cheat or not cheat on emission reports? Do short-term individual and long-term global interests meet in CO_2 emission?

The coordination game is a situation when cooperation has added value. The original game is that the primary value for the husband and the wife is to be together, the secondary is to enjoy their different favourite entertainment (football vs. opera). In this game, the optimum (maximized total payoff) can be achieved if one of the partners is dominant or selfish, and the other one seeks the partner's preference. Otherwise, the primary value will not be realized. This is a good base game for those games when one of the actors must yield to pressure. For example, the rise of temperature might cause desert in Europe, but melt ice in Siberia, thus European agriculture will be damaged, but Russian agricultural capacities will be bigger. Someone must yield and give up their own benefits for the partner's favour. Climate change can be prevented, but Russia will not have more lands for cultivation, or European lands will become deserts (not cultivable).

The assurance game[12] describes a state when players are unable to seize an opportunity for cooperation that seems obvious. There is one best solution, and if it is spoiled, the worst payoff will be realised. That is why players are very cautious and do not act in uncertain circumstances, but wait for the other's action or their own certainty. However, after a while, the cost of passed time matters so the players will accept the second best solution This is a game without motivation for free riding. This game models e.g. the situation when small or less developed economies wait for large countries to initiate.

The chicken game is a useful framework to describe a situation when there are two (or more) opposite approaches, opinions, interests to be realized at any price by the players. The biggest damage (negative payoff) will be realized if all players insist on their own ideas, principles etc. and never give them up. The stubborn behaviour is motivated by the cost or loss caused by giving up their own preference. A climate related example is when, during the Bush era, the U.S. government insisted on a market approach of and market solutions to carbon emission damages, while the EU insisted on international regulations and quotas. The conflict could have been cancelled only by a change in the U.S. governance (democrats returned to majority in Congress and Obama became president).

The called bluff is the asymmetric game for free riding by a weaker/less developed/smaller player. There are cases when the weaker one can enforce the stronger one to choose the weaker one's preference and this way to avoid a bigger cost or loss. The weaker one's preferred bargaining position must be rooted in a difference of vulnerability or resource availability for the advantage of the weaker in the given case. General international examples: The German and Japanese states defeated in

[12] Briefly stag hunt; stag is a very valuable trophy for the successful hunter and good meat for everyone, but a missed shoot will threaten all other animals. That is why players are very cautious. But if a long time passes without shooting, any other type of meat will become good, and this will accept a second best solution: less valuable meat and less valuable trophy.

the World War II could use undervalued currency in the 1960s and this way gain higher growth financed by their export markets (Ravenhill et al., 2005). In the climate topic, the empirical example for the called bluff is the case when emerging countries like China or Brazil are asking compensation for participation in the Kyoto protocol for CO_2 reduction. This would mean extra costs and lower payoff for highly developed countries, but at least they could get closer to their objective, lower global carbon emission as a second best way. Meanwhile, the emission cut would be cheaper for the emerging countries, and they can also enjoy the benefits of less or zero global warming, thus they (i.e. the less developed) could reach their own first best outcome. The basis of the whole situation is that the highly developed countries are actually more vulnerable in this case, and emerging countries can blackmail them with ruining the mitigation plans by staying out of the carbon regulation.

The harmony and the suasion games are specified asymmetric games with communication between players. The aforementioned games assume no communication, only individual deductions about the partner's strategy. The harmony game is the case when cooperation is the best solution. For a climate example, without mitigation every big power of the Earth will lose costal territories as sea level would rise. Keohane (1984) understood the harmony situation as an automatic, invisible hand operating the international relations perfectly, because in that case there is no externality, so no motivation for free riding. Suasion (convincing) means a called bluff with communication, when one player can convince the other in negotiation to accept the second best payoff to secure the first best payoff for the first one. E.g. China refers to the cost of the change of outdated manufacturing technology as a reason to get financial compensation for its participation in the Kyoto protocol. A special case of suasion is the hegemonic stability, when there is one power enforcing its own first best payoff and convinces its allies to accept the second best payoff. In the global order of 21st century, non-hegemonic but post-hegemonic cooperation or multi-polar/non-polar systems can be mentioned (see Haass, 2008; Ikenberry, 2008). Obviously, a multiplayer model is also possible by using matrixes or vectors in formulating community or individual behaviour (see Owen, 2008; Osborne and Rubinstein, 1996; Forgó et al., 1999).

3.5 Negotiation games of climate change

Negotiation games are about the enforcement of bargaining positions, i.e. relative power. Enforcement demands two factors to be hand in hand: power and wealth. As Keohane (1984) cited the definition of wealth by Karl Polányi and the power definition by Hans Joachim Morgenthau, wealth is the mean of satisfying material want, and the exchange value of marketable goods and services; power is the control over others' minds and actions, or control over other actors' play in the process of satisfaction. The eternal question is how to use the power to increase wealth or how to use wealth to increase power?[13] Negotiation games can be used for modelling the process of carbon emission negotiations related to climate change. In literature, it practically means the modelling of strategies in the Kyoto process.

In negotiation games, the significance of vulnerability of the players and intensity of power competition is high. The determining factors of climate change negotiation games and the payoff of players are gathered by Hasson et al. (2010) as follows:

- Probability of warming or disaster, or expected change of temperature
- Marginal per capita cost of mitigation
- Marginal per capita cost of adaptation
- Share of cooperating partners from the total group of actors

> *"There has been a lot of research devoted to bringing together game theory and climate change negotiations. Simultaneous move non-cooperative (e.g. Nordhaus and Yang, 1996; Peck and Tijsberg, 1999) and classical cooperative models (e.g. Barrett, 1994; Carraro and Siniscalco, 1993; Chander and Tulkens, 1995) dominate the scene. Ciscar and Soria (2002) were the first to suggest the use of sequential (extensive form) games to describe and analyze the dynamics of the post-Kyoto negotiations in which reactions to previous moves of the players are taken into account at any decision point.*" (Forgó et al., 2003, p. 252.)

Since negotiation can be a finite or infinite game, trigger strategy must be taken into account whether it is competitive, contracting or long-term cooperative. The first note mentioned by Kandori (2006) according to folk theorem is that there could be multiple equilibria in repeatable games if there are subgames (Abreu et al., 1994; Dixit & Skeath, 1999, p. 156-162). The cost of mitigation can be distributed variously to prevent global warming. The second note is about the credibility of threat and penalty in the case of unilateral free riding. How serious and certain and perceptible are the damages for the players? The third note is about the horizon of negotiations. How far can countries postpone starting to take mitigation actions? Which countries are being increasingly abandoned by polluting industries and activities, and which ones are targeted in the relocation process of manufacturing? High-tech

[13] There are examples for both. The Nazi Germany in the 1930s or the USA in the cold war used their power for economic advantages. In the period from the 1960s to the 1980s, Japan and West Germany their economic wealth to have international power as they were forbidden to keep a strong military force.

energy production and declining manufacturing means a gradual exit from carbon emission activities by post-industrialized countries. Thus in an ultimate version, their strategies shall not be taken into account by the emerging countries.

In the development of negotiation game models, two directions can be discovered in literature. The first is a sequential modelling of multi-participant decision-making based on the Harsányi model and the Aumann model (Harsányi, 1967; Aumann, 1974). The second one is looking for the mapping of influence in negotiations.

Starting with sequential modelling, Forgó et al. (2003) gives a good summary of the Harsányi model, which takes incomplete information into account.

> *"The Harsanyi model calls for condensing all uncertainty a game might involve in defining different types of players, each characterized by a specific information (attribute) vector whose actual occurrence is governed by chance. Chance then determines which types of players will actually play the game. Each player knows his own type but has only a subjective probability distribution about the types of the rest of the players. Harsanyi's basic assumption (usually referred to as Harsanyi's doctrine) is that there is a common prior distribution defined over all possible types of all players whose conditional probabilities (conditioned on each player's own type) coincide with the posterior subjective probabilities of the players. Expected payoffs can then be defined in terms of the common prior (or as shown by Harsanyi, equivalently in terms of the posterior probabilities) and the game with incomplete information be reduced to a game with complete information in which the Nash equilibrium will provide the same solution we would have obtained in the original game (of incomplete information) if Bayesian rationality is assumed of the players each player to maximize his own expected payoff using his subjective (posterior) probabilities about the behaviour of the rest of the players."* Forgó et al. (2003, p. 255).

Myerson (1997, p. 75) demonstrated the incomplete information situation when there are no clear answer opportunities but players must figure out the possible answers from their limited knowledge. Uncertainty and the limited empirical experience on warming make the climate change problem such an incomplete information game, since there is no consensus about the optimum ways and forms of mitigation.

The Harsányi model was further developed and continued in the correlated equilibrium for two players by Aumann (1974) and for more than two players by Aumann (1987) with a bimatrix game. The correlated equilibrium is based on the normal form of a non-cooperative game. The complex version has critical point, as

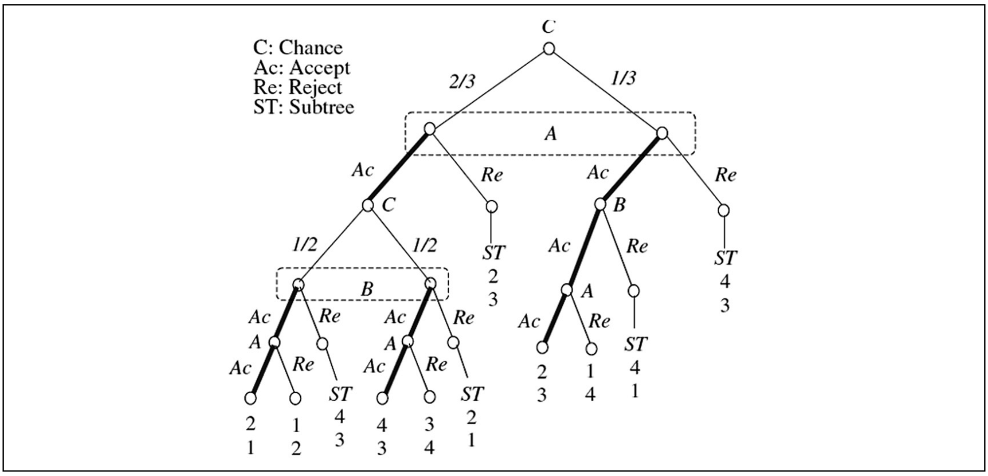
> *"when the game is originally defined in extensive form and is given by the game tree, then going from the extensive form to the normal form entails both a large growth in size and we also lose some of the direct, intuitive meaning of a CE since the basic idea gets across through the mediation of the very complex strategies used in the normal form."* (Forgó et al., 2003, p. 259)

Tree construction is a methodological instrument in simultaneous game theory to illustrate all possible alternatives that can be taken in an iteration process when players decide one by one after each other. The tree model can simultaneously represent all possible payoffs and more than two players, thus easing the decision in a repeated finite or infinite game. Trees are also useful to incorporate the uncertainty through the probability values of the individual branches of a tree. In parallel, the tree model can follow the repeated actions caused by one-by-one individual strategic choices, too, and detach the opponents' actions limited by a previous action in the iteration process (Dixit & Skeath, 1999, p. 45-54, 176-178).

In the correlated equilibrium model adapted by Forgó et al. (2003) from Aumann (1987), each player can make a single step in a given sequence before any other player acts in the next round. Thus, this assumption gives opportunity to draw the sequence of decision options as a tree. This results in a so called tree-correlated equilibrium model derived by Forgó et al. (2003) from the Aumann model. The Forgó-Fülöp-Prill model or tree-correlated equilibrium model (Figure 1) assumes that there is a game tree of an extensive game with perfect information and probability distributions assigned to every non-terminal node, and the probabilities are known for each player. There is a moderator in the game, and the players react blindly to the moderator's hidden proposals. The options are acceptance or rejection. Forgó et al. (2003) have two ways for the solution of the game: the Nash bargaining solution and the Kalai-Smorodinsky bargaining solution.

Similarly to the correlated equilibrium model, Rausser and Simon (1991) can be viewed as an extension of Rubinstein (1982), who developed the multilateral bargaining model in which there is no moderator but Player 1 makes an offer, which player 2 can accept or reject. In the case of rejection, game is repeated and bargaining can go on for an infinite number of times. This model has been used by Pinto & Harrison (2003), where the players are the seven regions/countries constituting the OECD. The countries select from policy vectors and create collations. "*The policy vector consists of a specific emission cut and a specific year to attain it. The proposed coalition must be an admissible coalition as previously defined.*" (Pinto & Harrison, 2003p. 921) The model was specified for carbon regulation with and without quota trade.

Figure 1 Example of a tree-correlated equilibrium model



Source: Forgó et al. (2003, p. 260, Figure 3)

Table 3 TCCF model

Objective function of the model

$$\mathrm{Max}\,\Pi_{i,t} = \sum_t \frac{U_{i,t}}{(1+\delta_t)^t} \quad \text{with } U_{i,t} = L_{i,t}\log\left(\frac{C_{i,t}}{L_{i,t}}\right) \qquad \text{(a)}$$

Socioeconomic module

Production function

$$Y_{i,t} = f(K_{i,t}, L_{i,t}, ES_{i,t}) - c^E_{i,t} ES_{i,t} \qquad \text{(b)}$$

$$Q_{i,t} = \frac{Y_{i,t}}{1+\mathrm{imp}_{i,t}} \qquad \text{(c)}$$

$$\text{with, } \mathrm{imp}_{i,t} = (Y_{i,t}/Y_{i,1990})^{\beta}[\theta_{1,t}T_i + \theta_{2,t}T_i^2] \qquad \text{(d)}$$

$$ES_{i,t} = \upsilon_{i,t}E_{i,t} \qquad \text{(e)}$$

$$c^E_{i,t} = \varepsilon_t + \mathrm{mkp}^E_i \qquad \text{(f)}$$

Equilibrium output-final demand

$$Q_{i,t} = C_{i,t} + I_{i,t} \qquad \text{(g)}$$

Capital accumulation dynamics

$$K_{i,t} = (1-\delta)^{\alpha} K_{i,t-1} + \alpha I_{i,t} \qquad \text{(h)}$$

Geophysical module

Greenhouse gas emissions

$$\mathrm{Cum}\,C_t = \mathrm{Cum}\,C_{t-1} + 10E_t \qquad \text{(i)}$$

$$\varepsilon_t = \xi_1 + \xi_2\left(\frac{\mathrm{Cum}\,C_t}{\mathrm{Cum}\,C^*}\right)^{\xi_3} \qquad \text{(j)}$$

Carbon cycle

$$M^{AT}_t = h(M^{AT}_{t-1}, M^{UT}_{t-1}, E_t, LU_{i,t}) \qquad \text{(k)}$$

$$F_t = g(M^{AT}_t) \qquad \text{(l)}$$

Climate change

$$T_t = T_{t-1} + l(F_t, T_{t-1}) \qquad \text{(m)}$$

Output of the model

Optimal path for capital accumulation and emission level

Source: Courtois & Tazdaďt (2007, p. 303)

Influence in climate change negotiations is modelled by the Tóth-Ciscar-Courtois-Forgó stochastic model (TCCF) by Tóth et al. (2001), and used for simulation by Courtois & Tazdaďt (2007) based on RICE model. RICE is the acronym for Regional Integrated model of Climate and the Economy, developed by Nordhaus & Yang (1996) and Nordhaus & Boyer (1999). Incidentally, Yang (2003) made a coalition simulation based on the RICE model of climate change negotiations, and modelled the behaviour of big powers like China, USA etc. In the case of influence modelling, the methodological study of Courtois (2002) can be mentioned as an early mapping of climate change negotiations by vector and matrix analysis.[14]

The TCCF model is built on an equilibrium framework using traditional economic concepts regarding optimization and capital accumulation. It is a parameterized formulation of a problem, and allows the evaluation of countries' payoffs on the basis of key policy variables such as capital accumulation and carbon emission control rates. Players optimize their economic welfare taking into consideration the trade-off that the emission of greenhouse gases means production and damage together, both expressible in economic terms. The model has a built-in carbon-energy variable related to the energy intensity by carbon emissions. The geophysical module of the TCCF model contains three groups of equations describing the causal chain: emission – concentration – global change, Courtois & Tazdaďt (2007, p. 303).

3.6 Conclusions

The game theory offers a broad background for the modelling and examination of stakeholders' behaviour affected by climate change challenges and damages. However, the high number of actors, variables, and the high level of uncertainty lim-

[14] Courtois & Tazdaďt (2007) illustrated the climate change negotiation games with the following situation: "Each country sends a delegate to a negotiation round. Each delegate knows to which coalition his country belongs. He knows also his country's payoff in any action profile. Consider pair wise interactions. The two countries' delegates meet each other and interact. We distinguish four types of interactions. The ones leading to imitation, to persuasion, to dissuasion and to avoidance. They can be grouped into two categories. First category is the tendency for a country to follow the action of another. A country's delegate can persuade another to adopt a similar policy. He can call for another country to follow his example or dissuade another from playing differently. For instance, an environmentalist country can persuade others to cooperate. On the other hand, this same country can prefer to defect if confronted with a majority of countries who want to defect. Second category is the tendency for a country to adopt the opposite action from the one adopted by another. This is fight or avoidance. For example, a country who is aware of the formation of a large cooperative agreement can decide to defect although he initially wanted to cooperate. Also, a country can decide to cooperate if another defects in order to avoid irreversible damages. Finally, one can conceive of a situation in which a country fights with another and decides to adopt an action which is the opposite of the one played by his opponent."

its the opportunities of game theory modelling. Through the game theory, it is possible to illustrate the dilemmas and strategic options of a group of actors, thus making the very complex relationship of industrial activity, carbon emission, climate change, ecological and economic damages transparent for decision-makers at the levels of economic diplomacy, public policy, or private business.

We can conclude that the carbon emission and the climate can be surveyed in the most efficient way if we consider them as a common pool resource for international relations. By this approach and the well-developed general theories and empirical experience on CPR problem, we can create adequate strategies, recommendations, conclusions for the appropriate mitigation and adaptation to global warming.

The negation games applied for climate negotiations provide opportunities to quantify and compare the varied and diversified interests, cost, damages, benefits represented by hundreds of countries and an uncountable number of businesses, households, NGOs etc. as actors. Besides, the negotiation games provide an opportunity to discover how to convince reluctant players to participate in mitigation and adaptation.

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4. Cost-benefit analysis of climate change – A methodological overview of recent studies

4.1 Introduction[15]

Global warming[16] has already begun. Climate change has become a self-propelling and self-reinforcing process as a result of the externality associated with greenhouse-gas (GHG) emissions. Although it is an externality related to humankind, according to a number of unique features we should distinguish it from other externalities. Climate change is a global phenomenon in its causes and consequences. The long-term and persistent impacts of climate change will likely continue over centuries without further anthropogenic mechanism. The preindustrial (equilibrium) level of GHG concentration in the atmosphere cannot be restored since it is irreversible, but if we do not stabilise the actual level of atmospheric concentration, the situation will become much worse than it is now. Assessing the impacts of climate change requires careful considerations because of the pervasive uncertainties and risks associated with it.

Climate change threatens the most fundamental elements of life for people and makes no difference between people wherever they live from Asia to Northern America. Each individual and each economy both developed and developing are affected by the impacts of global warming. On current trends, average global temperatures could rise by 2 – 3 °C within the next fifty years as compared to preindustrial level average global temperatures. This phenomenon leads to a constrained access to water, food, health and use of land and environment and this phenomenon intensifies extreme events mediated by water and wind, including droughts and floods, hurricanes, tornadoes, typhoons and blizzards. According to Stern et al. (2006) the most frequent results anticipated are the following: increase in average global temperatures, rising sea levels, melting or collapse of ice sheets, declining crop yields, melting glaciers, ocean acidification, increasing number of deaths from malnutrition and

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[16] In this paper 'global warming' and 'climate change' are used as interchangeable terms.

heat stress, increasing migration pressure due to extreme environmental events, extinction of species in the ecosystem and sudden shifts in regional weather patterns.

With rising temperatures, impacts in many sectors will become disproportionately more serious. Examining the relationship between the impacts of climate change and increasing global temperature, Hitz and Smith (2004) found that impacts for several climate-sensitive sectors were linear or exponential, even though they were unable to accurately determine the shape of the real functional relationship. Agricultural production, for example is depicted as an inverse parabolic function: a low level of warming may improve conditions for agricultural production in cooler regions, but further warming will have harmful effects principally in tropical (warmer) regions. All climate-sensitive sectors have their own functional form.[17]

People, through consumption and production, emit GHGs. As a consequence of emission, GHGs accumulate in the atmosphere where they trap heat and effect global warming. The related policy challenge is twofold. The first is to minimize the costs of adaptation, mitigation and that of the residual climate change damage. The second challenge is to distribute the related intertemporal and intratemporal burdens and gains in an equitable way. To carry out an economic analysis a reference point or a baseline is needed which allows us to fulfil the cost-benefit analysis of adaptation and mitigation. The reference point used in the literature on climate change is a hypothetical future no-policy scenario. Recently another term, the "cost of inaction" has become popular amongst scholars.

Total damage costs represent the sum of adaptation costs and residual damages. It is usually expressed in per cent of GDP. The marginal cost of climate change damage, sometimes referred to as the Social Costs of Carbon (SCC), is expressed in emission of metric tons of carbon dioxide (tCO_2). It is difficult to implement an appropriate assessment measure because both the total and marginal damage costs of environment change are characterized by large scale uncertainty and risks that have a hindering effect on the analysis, especially in connection with extreme events and low-probability high-impact scenarios. The physical impacts need to be assessed in monetary terms involving market and non-market goods and services, covering health, economical, environmental and social values. On one hand, it is generally accepted that some kind of equity manner is inevitable between generations as the notion of "sustainable development" suggests. On the other hand, it is also generally accepted that advanced countries are responsible for the bigger part of CO_2 emission still are less vulnerable to the effects thereof, while developing countries are less responsible for CO_2 emission but more vulnerable to the effects of

[17] See The Stern Review page 71-72 for more information on proposed functional form.

them.[18] If we would like to cope with the complexity of the cost and benefit assessment of climate change, we have to take into consideration a number of crucial dimensions from market and non-market valuation, through uncertainty and risks, to equity and discounting.

In this chapter we would like to provide a summary of recent studies on cost-benefit analysis of climate change. Reviewing the significant relating literature we would like to address the essential factors that have to be included in a comprehensive economic analysis and also address the neglected considerations. In the next chapter we briefly demonstrate what were and what are the typical studies and we differentiate the literature by impacts, geographical area and attempts to assess total and/or marginal damage costs. Then we turn to methodological aspects representing scenarios and modelling of climate change studies. Section 4 discusses the valuation and estimation approaches and then section 5 shows the landmarks of intertemporal and spatial aggregation. Section 6 deals with factors often ruled out of researches and section 7 concludes.

According to our interpretation, methodology and probability (probabilities and considerations for the future, scenarios, equity manners and discounting methods, aggregation over distant times and transformation into present value) are inseparable during the examination of climate change.

4.2 Overview of recent studies on cost-benefit analysis of climate change

Prior to the 1990s, scientific research in the field of global warming was limited to natural scientist.[19] More than twenty years have passed, and the majority of research still comes from natural scientist, despite the fact that social and economic consequences become more and more important. So we can say that the number of social and economic studies is limited. After an overlook on the given literature we conclude that there are few complex and comprehensive studies in the field of the possible impacts induced by climate change. Most studies either only apply to a specific sector – e. g. agriculture – or to a limited geograpchical area – the United States or the European Union. Furthermore, when taking into account the possible impacts,

[18] At the same time, the level of GHG emission by emerging or BRIC countries is growing rapidly, while in numerous advanced countries GHG emission is constrained by institutional authorities (e.g. in the case of the European Union (EU)).

[19] The first international negotiations related to climate change took place in 1985. The Intergovernmental Panel on Climate Change was established in 1988 by the World Meteorological Organization and the United Nations Environment Programme.

most studies only deal with total or marginal damage costs. Tol (2005) only counted 22 new studies in the 1990s and then Tol (2008) repeated his summary and increased the numbers of new studies to 47 until 2006.

It is difficult to provide a comprehensive synthesis of this field of research. First of all a reference point should be defined but the no policy choice in itself entails a contradiction because of its complexity and of the numerous different ways it can be interpreted. Our objective is to give a summary of methodological consideration by assumptions, choices and methods. Different studies and different methods used in studies make very hard to implement a summary of a very wide range of estimates.

4.3 Methodological aspects – scenarios and modelling

Scenarios

The International Panel on Climate Change (IPCC) makes a distinction between climate scenarios and non-climate scenarios. Kuik et al. (2008) make a short presentation of climate scenarios, addressing factors like static or dynamic modelling, spatial aggregation and weights. Climate scenarios differ from each other in that there are models that compare two equilibrium states of the climate and there are models that dynamically follow changes in climate variables. Spatial aggregation is also a crucial issue as working with a simple statistical mean for the global change in temperature may lead to a bias. In climate scenarios extreme weather events and low probability high impact events are emphasised more as they get higher weights.

IPCC (2007) makes a distinction between four essential socio-economical climate scenarios. A1 storyline (market-oriented) is characterised by a low population growth that peaks at 2050 then declines, and a high GDP growth. Strong regional interactions make a high degree of convergence possible between rich and poor countries. Three different scenario groups can be discriminated: fossil-intensive, non-fossil and balanced. A2 storyline (differentiated) is described by a high population growth and a modest GDP growth. Regional and local governance and self-reliance rule this scenario so the lack of equalisation in terms of GDP and the continuing fragmentation of technology determine this future scenario. B2 storyline (local solutions) disposes with intermediate population and GDP growth. The pattern of environmental protection appears while regional and local authorities still play an important role. This initial environmentalism couples with more rapid technology development (though slower than in A1/B1). B1 storyline (convergent) is characterised by a low population growth but a high GDP growth. A services and information based economy allows firm convergence between poor and rich countries and eventuates clean and resource-efficient technology. Table 1 depicts the four socio-economic scenarios.

Table 1 Four different storyline exerted by IPCC

Economic emphasis →

Global integration ↑

Regional emphasis ↓

A1 storyline World: market-oriented Economy: fastest per capita growth Population: 2050 peak, then decline Governance: strong regional interactions; income convergence Technology: three scenario groups: • **A1FI**: fossil intensive • **A1T**: non-fossil energy sources • **A1B**: balanced across all sources	**A2 storyline** World: differentiated Economy: regionally oriented; lowest per capita growth Population: continuously increasing Governance: self-reliance with preservation of local identities Technology: slowest and most fragmented development
B1 storyline World: convergent Economy: service and information based; lower growth than A1 Population: same as A1 Governance: global solutions to economic, social and environmental sustainability Technology: clean and resource-efficient	**B2 storyline** World: local solutions Economy: intermediate growth Population: continuously increasing at lower rate than A2 Governance: local and regional solutions to environmental protection and social equity Technology: more rapid than A2; less rapid, more diverse than A1/B1

← Environmental emphasis

Source: IPCC (2007)

These four socio-economic scenarios determine the quantity of emissions. Emission levels in A1 storyline depend on the choice of technology. It is not hard to see that the fossil-intensive technology emit the most CO_2. A2 is characterised by medium high, B1 by low and B2 by medium low emissions. If we take a short look at Table 1 movement from one scenario to another corresponds to no other than a choice between emphases. Environment, integration, economy or regionalism should be considered the main factors and choosing an emphasis means that we completely neglect another and we can partially include the remaining two emphases.

Modelling

Non-climate scenarios are important because they determine the vulnerability of social and economic systems to climate change over time. They are capable of determining the development of global greenhouse gas emissions by designing a range of emissions scenarios. Simple models use climate change variables (e.g., sea level rise, mean temperature etc.) at a point in time and independent variables like present population and economy to assess the estimation studies on the damage cost of carbon. More advanced studies make a distinction between studies that use exogenous scenarios and studies that employ Integrated Assessment Models (IAM) to establish scenario values. Kuik et al. (2008) argue that recent studies lack the use of dynamic IAMs therefore complex analysis of the long-term and dynamic modelling climate change are highly needed to create better estimations and valuations.

Even though fully dynamic models are scarce, a few had also been developed in the early phase of climate change research before they became popular amongst specialists, at the beginning of the 1990s. Hope and Maul (1996) compared two very different approaches, the PAGE and Intera models. Both these models treat uncertainty but from a different view. In order to calculate marginal costs for CO_2, the Intera approach takes into consideration small perturbations to the global system. The reason for calculating the costs for CO_2 discharges is twofold: first, modelling the environmental effects of discharges and second, estimating the impacts of the resulting environmental change. To address the environmental impact they use simple linear models derived from Nordhaus (1991). Four key parameters are represented in the model:

1. the fraction of CO_2 which is rapidly removed from the atmosphere;
2. the long-term rate of removal of CO_2 from the atmosphere;
3. the rise of global mean equilibrium temperature due to a given increase in atmospheric CO_2, levels;
4. a constant rate for global mean temperature changes in response to changes in atmospheric CO_2 levels.

Assumptions on impact costs are consistent with the convention employed in the United Kingdom nuclear industry for the calculation of long-term liability. They use this approach in order to give an acceptable and plausible comparison between fossil and nuclear power. The four most important assumptions of the approach are as follows:

1. Any international cooperation required to adapt to global warming will take place, therefore major social upheavals are not considered.
2. The cost to the polluter should not vary according to where the damage occurs. In particular, the value of a statistical life (VOSL) is taken to be the same, no matter where the risk of death is incurred.
3. The discount rate employed is 2% per year.
4. No consideration is given to economic growth.

The Intera analysis takes into account both economic and non-economic impacts. Economic impacts can easily be monetised as losses are counted in GDP. At the same time non-economic impacts do not appear in GDP measures. It is very hard to monetise certain parts of the ecosystem or to give accurate estimate to a value of statistical life. Hope and Maul (1996) calculated US$24 per tC as a reference discounted cost.[20]

The "PAGE" abbreviation stands for policy analysis of the greenhouse effect. The PAGE model was developed in 1991 to provide an integrated assessment of global warming policies. It calculates the costs of implemented policies and the impacts of any global warming process. Hope et al. (1993) describe the model in detailed version and Hope and Maul (1996) briefly depict it. PAGE contains equations that cover:

1. The EU and the whole World. The PAGE model was first developed for the European Union. It was later adjusted for greenhouse effect is a global problem, even if the EU is only responsible for 13% of the emission of $CO_2$2.
2. All major greenhouse gases. CFCs and HCFCs are also included.
3. The impacts of global warming. Ten sectors of the economy are handled as global mean temperature changes
4. The effects of uncertainty.

The PAGE model applies a wide range of inputs. 200 years horizon for calculating impacts facilitates allow long time lags in the natural and socio-economic systems, while the base year is 1990. The reference point is the business as usual emission path. The model includes economic as well as non-economic impacts. Economic aspects appear and non-economic impacts do not appear in GDP measures. The adaptation of the developed is endogenous which can reduce the impacts of global warming. The PAGE model operates with an exogenously defined 2% growth rate per year. With the 2% discount rate Hope and Maul (1996) reached a far lower result, namely US$5 per tC for the marginal impacts of CO2 emission.

The United Nations Framework Convention on Climate Change (UNFCCC) employs a version of PAGE models called PAGE2002, described as follows: "The model calculates regional and global impacts of climate change, and social costs of different greenhouse gases. It also calculates the costs of abatement and adaptation. It is an Integrated Assessment Model starting from emission projections, and carrying uncertainties throughout the calculations" (homepage of the UNFCCC).[21]

[20] For more details see Hope and Maul (1996) Tables 1 to 3.
[21] PAGE2002 (Policy Analysis for the Greenhouse Effect) – http://unfccc.int/adaptation/nairobi work_programme/knowledge_resources_and_publications/items/5447.php

The Dynamic Integrated model of Climate and the Economy (DICE) was developed by William Nordhaus. This model aims to “integrate in an end-to-end fashion the economics, carbon cycle, climate science, and impacts in a highly aggregated model that allows a weighing of the costs and benefits of taking steps to slow greenhouse warming” (Nordhaus and Boyer 2000: 5).

Nordhaus (1991) first developed a long-run model of the global economy that involves both the abatement costs of $CO_2$2 emission estimates and long-term climate change impacts. Cost-benefit analyses made by applying both factors allow the determining of the optimal level of control. Then he finalized the DICE model (Nordhaus, 1992), which can be described as a fully dynamic Ramsey-type optimal growth model. From the DICE model emerged an optimal time path of emission reduction and related carbon tax system.

In the DICE model the atmospheric $CO_2$2 concentration has a negative effect on the economic output, influencing the global average temperature. The DICE model is formed by the following factors:

1. Labour and total factor productivity grow exogenously over time.
2. The carbon dioxide intensity of production and the cost of carbon dioxide emissions decrease over time.
3. The output in each period is divided between consumption, investment and expenditure on emission reduction. In each period a fraction of output is lost because of the climate change damage function.
4. The discounted sum of all future utilities from consumption has to be maximised, and utilities are discounted at a fixed pure rate of time preference.

The DICE model, besides being a fully dynamic approach of climate change and optimal CO_2 emission estimates, deals with different sectors of the economy and integrates non-economic categories as well. The potential damages from climate change are divided into seven categories: agriculture, sea level rise, other market sectors, human health, non-market amenity impacts, human settlements and ecosystems, and catastrophes. Nordhaus and Yang (1996) establish a modified version of the DICE model in which all global regions are represented. This modified version (RICE - regional integrated model of climate and the economy) distinguishes between the regions therefore makes it easier to determine the possible losers and winners of climate change.

Table 2 below shows the sector-specific results with optimal calibrating of the RICE model when average global temperature elevates by 2,5°C above pre-industrial level. Catastrophes and low-probability high impacts are responsible more than 50% of damages.

Table 2 Damages as a percentage for global output at 2.5°C of warming

	output weighted	**population weighted**
agriculture	0,13	0,17
sea level rise	0,32	0,12
other market sectors	0,05	0,23
health	0,10	0,56
non-market amenities	-0,29	-0,03
human settlements and ecosystems	0,17	0,10
Catastrophes	1,02	1,05
Total	**1,50**	**1,88**

Source: Nordhaus and Boyer 2000, pp. 91.

4.4 Valuation and estimation approaches

There is a wide range of techniques for the monetary and financial valuation of the impacts of climate change. These techniques are often divided into two main groups: some impact estimates can be directly based on market observations while other impacts cannot be directly measured on market prices. The challenge appears when one would like to find appropriate future market prices for the monetary valuation of direct and especially for that of indirect impacts.

The economic valuation is based on the principles of willingness to pay (WTP and willingness to accept compensation (WTA)). The majority of recent studies estimate – by definition – "how much we are willing to pay to purchase a better climate for our children and our grandchildren" (Kuik et al. 2008: 23). However, few studies rather estimate "how much our children and grandchildren are willing to accept" (Kuik et al. 2008: 23). Current studies use a mix of the above-mentioned valuation methods. There are no studies taking alternative methods into account. Furthermore, Frankhauser et al. (1997) argue that while WTP and WTA values depend on income, they reflect the unfairness of the current income distribution therefore a question of equity emerges. Rich people expect a higher compensation or are willing to pay more for a given change in environment quality, if the substitution between income and environmental services is decreasing with increasing income.

A further problem can be mentioned when a comparison between WTP and WTA is addressed. The two values are often not equal with each other; Brown (2006) insists that the difference between WTP and WTA can be substantial. Li et al. (2005) analyze American citizens' willingness to pay and find that an average American citizen is willing to pay \$15/tC.

The economic impacts of climate change can also be divided into direct and indirect impacts. Direct impacts principally deal with the effects of climate change on production and consumption. Indirect impacts handle the indirect effects of changes in production and consumption. Direct cost studies are considered more common and usually ignore indirect costs while their valuation is unsolvable. Only a limited number of studies, mainly related to impacts on agriculture, forestry and fishery have received attention so far. Moreover, the inter-linkages between direct and indirect effects of climate change impacts remain unclear. Indirect cost can both enlarge and diminish the direct economic impacts of climate change.

Economy-wide estimates of climate change induced impact on a certain scope are very rare. Bosello et al. (2006) examine the effects of climate change on health through changes in labour productivity and public and private demand for health care. They point out that the impacts of climate change on human health are numerous and complex and global warming would increase heat-related health problems, which would mostly affect people. Their interesting assumption is that cold-related health problems are reduced by global warming, which diminishes direct costs. But on the other hand serious diseases, for instance malaria, in particular, are to increase because of climate change, which increases the direct costs. In another study Bosello et al. (2004) conclude that the rise of sea-level implies large-scale additional costs aggravating coastal zones and increase direct costs of climate change impacts. As a consequence they emphasise that direct costs are underestimated and needed to be adjusted by determining the true costs of impacts.

4.5 Aggregation – temporal, geographical and their results

Climate change possesses a very long time horizon. Today's emission will affect climate for decades or even centuries. As we can separate causes and effects, we can separate costs and benefits. If we try to create a commensurable value of costs and benefits at a certain point in time we need to proceed to discounting. Since climate change is a large-scale problem the discount rate has to be transformed into a social discount rate. Discounting implies that events that occur in the far future are less important than those in the near future or at present. As Kuik et el. (2008) summarise, two kinds of discounting processes are used in the literature. The first one is built up by the intertemporal allocation of resources of individuals. The other one is exponential discounting.[22]

There is no agreement yet in the literature on which discount rate should be chosen. Most of the climate change studies apply different discount rates, usually between 1 to 3 percent. In the Stern Review, Stern et al. (2006) took an extremely low pure rate of time preference – that is why the costs of inaction or costs of business as usual are much higher than in other studies. Discounting is the only process to convert future values to present values, although this method also has some controversies as pointed out by Pearce et al. (2003).

Since climate change is a global problem, most of the impacts of a country's emission have an effect on other countries. Geographical or spatial aggregation is not as common as needed. For the US and EU, a large-scale of studies has been conducted, but for developing countries the same amount of studies are yet to be conducted. Equity weighting is the most common form of aggregation in the literature. Considering an aggregation without equity weighting means that a death in a rich country has greater weight than a death in a poor country. Anthoff et al. (2006) state that equity weighted estimates of the marginal damage costs of carbon dioxide emissions is significantly higher than estimates without equity-weights.

Azar (1999) applies a simple welfare optimisation model and he sheds light on how the introduction of weight factors affects the aggregation of cost-benefit analysis of climate change. He concludes that on the one hand the introduction of weight factors significantly reduces rich region's and the global optimal emissions, on the other hand, in a couple of decades the introduction of weight factors will significantly affect the rich region's emission, but the global emission will not decrease. A welfare theoretic approach is used by Tol (2001) where three alternatives are presented. The first alternative is inspired by Kant and Rawls – "do not to others what you do not want them to do to you" (Tol 2001: 72). The second alternative is based on the assumption that the sum costs of emission reduction is and the costs of climate change should be equal. In the third one a global welfare function includes distaste for inequity.

In the following we would like to provide some useful evaluates in connection with climate change induced costs and likelihoods. Table 3 represents some essential studies assessing the impacts of climate change. This table shows six different aspects through which we can compare and evaluate recent studies. Sub-Saharan African countries are the most affected negatively by climate change but Eastern Europe, Commonwealth of Independent States and especially Russia may benefit

[22] Discount rate is often called pure rate of time preference

from climate change. Stern et al. (2006) deal with a more pessimistic scenario – 20 percent decrease in the worst-off region and huge 5 percent fall in the best-off region – thus, it is better to take into consideration as an outlier.

The stabilisation of CO_2 concentration in the atmosphere at 450 ppm CO_2 equivalent (CO_2e) has a 90 percent probability to occur between 1 C to 3,8 C average temperature change and 10 percent to add other value outside the range. Figure 1 depicts the CO_2e thresholds with 90 percent probability to happen in a tighter range and 10 percent to happen in a wider range including no temperature rise.

Table 3 Estimates of the Welfare Impact of Climate Change (expressed as an equivalent income gain or loss in percent GDP)

study	warming (°C)	impact (% of GDP)	Worst-off region		Best-off region	
			(% of GDP)	(name)	(% of GDP)	(name)
Frankhauser (1995)	2,5	-1,4	-4,7	China	-0,7	Eastern Europe and CIS
Tol (1995)	2,5	-1,9	-8,7	Africa	-0,3	Eastern Europe and CIS
Nordhaus and Yang (1996)	2,5	-1,7	-2,1	Developing countries	0,9	CIS
Plambeck and Hope (1996)	2,5	2,5	-8,6	Asia (China)	0,0	Eastern Europe and CIS
Mendelsohn et al. (200)	2,5	0,0	-3,6	Africa	4,0	Eastern Europe and CIS
Nordhaus and Boyer (2000)	2,5	-1,5	-3,9	Africa	0,7	Russia
Tol (2002)	1,0	2,3	-4,1	Africa	3,7	Western Europe
Maddison (2003)	2,5	-0,1	-14,6	South-America	2,5	Western Europe
Rehdanz and Maddison (2005)	1,0	-0,4	-23,5	Sub-Saharan Africa	12,9	South Asia
Hope (2006)	2,5	0,9	-2,6	Asia (China)	0,3	Eastern Europe and CIS
Stern et al. (2006)	> 2,5	~ -8,0	-20,0	Africa	-5,0	Eastern Europe and CIS

Source: own table based on Tol (2009)

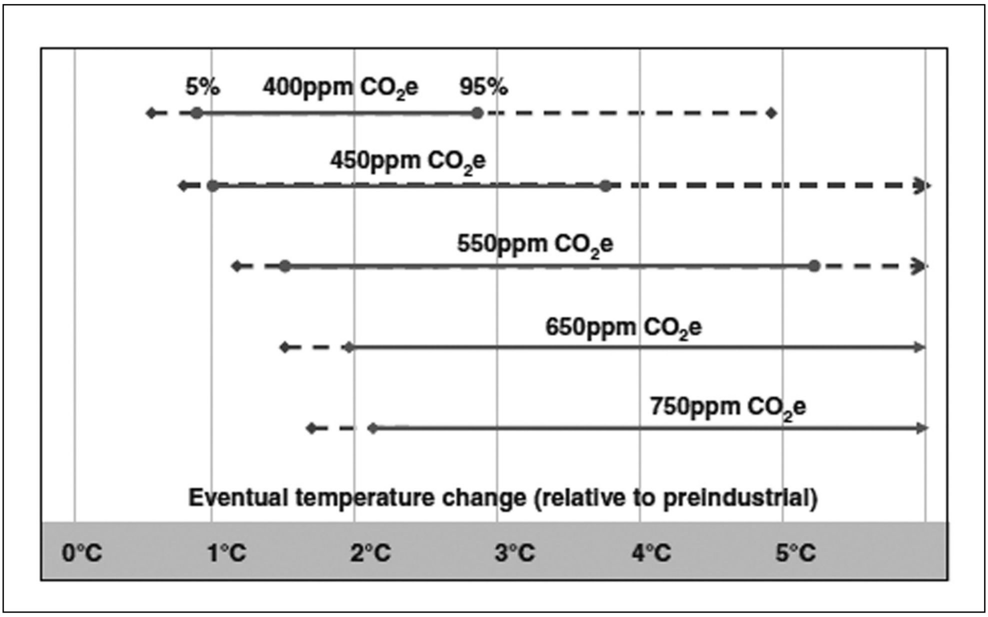
Table 4 demonstrates the likelihood of exceeding a temperature increase at equilibrium. If we choose 550 ppm CO_2e, the likelihood of exceeding 2 C is 99 percent, 69 percent is that of 3 C and 1 percent that of 7 C.

Table 4 Likelihood (in percentage) of Exceeding a Temperature Increase at Equilibrium

Stabilization level (in ppm CO_2e)	**2°C**	**3°C**	**4°C**	**5°C**	**6°C**	**7°C**
450	78	18	3	1	0	0
500	96	44	11	3	1	0
550	99	69	24	7	2	1
650	100	94	58	24	9	4
750	100	99	82	47	22	9

Source: Stern Review, Stern et al. (2006)

Figure 1 Stabilization and Eventual Change in Temperature



Source: Stern Review, Stern et al. (2006)

4.6 Often missed factors

Recent papers abound in assumptions stating that the effects on developing countries can be more serious than on developed countries. The field of game theory can present the current situation of climate change regime. For some countries it is worth staying out of global GHGs emission reduction plans because their sovereign nation-state will is more important than to participate in a comprehensive global regime.

Climate change related studies always ask the question how much it costs to prevent climate change, how much are the total or marginal damage costs of emissions. We believe that the latter questions are not the correct ones. One needs to address the question how we can save the most people, how we can prevent climate change in order not to cause human death or how we can ease the effects of climate change on individuals. The cost-oriented question is evident because of politicians' attitudes in decision-making positions, who are interested in minimising costs but not in maximising the number of saved people. The companies which are mostly responsible for harmful emissions have too much lobbying power to influence the mitigation and adaptation policy of a country and thus have an adverse effect on GHGs emission reduction. The political economy of climate change is often ruled out of research because it often does not rely on hard facts, but it can address some controversial questions. The political economy approach may determine some useful implications to climate change economics. The syntheses of the two approaches may give a more complex research path.

Climate change is a global problem and therefore a global solution is needed. Neither a single country nor a region alone can give an appropriate response, because one only country is capable of risking the whole ecosystem. A collective answer is needed in the framework of a stronger and more effective international institution, which can use its coercive power on each country, as the actual climate change related international regime is inappropriate to meet its duties. An international institution is needed to provide a public good, namely healthy life for present humankind and for subsequent generations in the notion of sustainability.

4.7 Conclusions

In this chapter we briefly summarized the methodological aspects of climate change. If one aims to achieve a comprehensive and worthwhile analysis on the impacts, cost and damages induced by climate change, many factors need to be considered. Some aspects, which cannot be monetised – e.g. indirect costs, political decisions and moral questions –, make it hard to execute a damage cost assessment and to reach appropriate measures. In any case, more and more research is needed; first, to address new research paths and take into consideration a wider range of essential factors and second, to compare them and last, to give more thorough conclusions combating climate change.

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5. Mitigation and adaptation to climate change

5.1 Introduction[23]

Climate change produces significant social and economic impacts in most parts of the world, thus global action is needed to address climate change.

In this chapter, the different possibilities of mitigation are explored from different points of view, and analyse the possibilities of adaptation to climate change. First, substantial reduction of GHG emission is needed, on the other hand adaptation action must deal with the inevitable impacts. According to the assessment of the chapter, it is essential that coordinated actions be taken at an EU level. In our argumentation, a macroeconomic model is used for the cost- benefit analysis of GHG gas emissions reduction. The GHG emission structure is analysed on European and global level.

Even in the case of a successful mitigation strategy there rest the long-term effects of climate change which will need a coherent adaptation strategy to be dealt with. Although certain adaptation measures already have been taken, these initiatives are still very modest, and insufficient to deal with the economic effects of climate change properly.

5.2 Why should we deal with climate change?

According to the Intergovernmental Panel on Climate Change Assessment Report the increase observed in global temperatures is very likely to be a consequence of the increase of greenhouse gas concentrations. Therefore, on a larger scale, human actions have an effect on on the ocean warming, continental average temperatures and wind patterns (IPCC, 2007). According to cited report, a further increase of 1.8 to 4 şC of global expected average surface temperature can be expected. (There are different scenarios but they all coincide in that temperatures will keep rising.)

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If we would like to assess the damages caused by climate change and the benefits of mitigation, we must take into consideration market and non-market damages as well. In the case of market damages, welfare impacts should be studied. As a result of the rise of temperature and the scarcity of goods, there will be significant changes in price structures and the quantity of certain goods.

Some sectors such as agriculture, forestry, water supply, energy supply are particularly affected by climate change. Such impact is quite difficult to be quantified. For instance, in agriculture land prices or rent can be good indicators. However in the case of products, substitution effect must be taken into account. So-called non-market damages are lot more difficult to estimate. There are considerable welfare costs from lost biodiversity and harmed ecosystems and there are utility losses from the less favourable weather (Nordhaus, 2007).

The following flowchart represents the contribution of the different sectors to climate change. According to the data of the World Resources Institute the most important contributors to GHG emission are the energy sector, transport, agriculture, and land use, including forestry.

A rise in prices will result in lower demand and in a decrease in GDP. Climate change produces substantial costs to the world economy. According to the key study, the Stern Report elaborated in 2007, the costs of climate change sum up to the 5% of the global GDP.

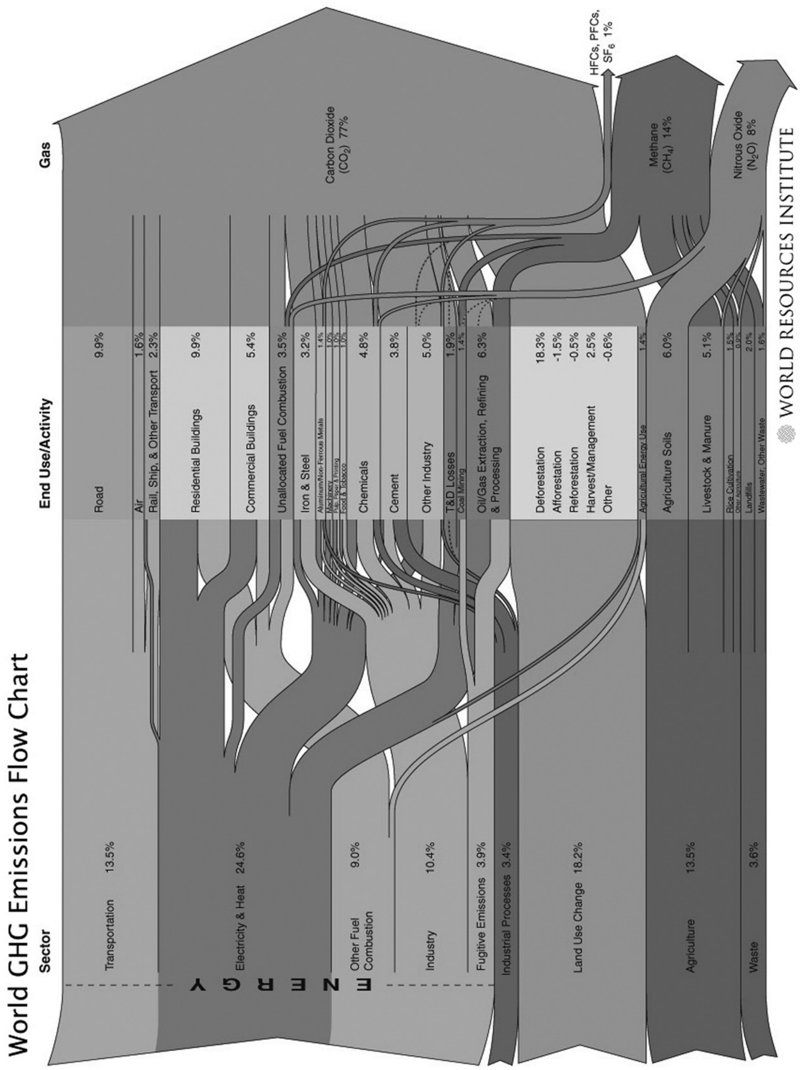
There are various commitments of the states. The first and the most important is the Kyoto Protocol. The EU has committed itself to a reduction of 8% of the emissions from 2008 to 2012 compared to the 1990 levels.

The EU made an ambitious plan of reducing emissions by 20% up to 2020, in the future, an alleged post-Kyoto agreement would project a reduction of 30% whereas on the long run, a reduction of 50% would be necessary by 2050.

How to achieve these ambitious plans? There are different policy options to take for governments. Possible economic instruments are with regard to market-conform government measures: the introduction of energy/emissions taxes, setting up of GHG emissions trading schemes. Other, rather redistributive options are the adoption and the diffusion of low-carbon technologies, and the introduction of efficiency standards and labelling systems.

Each of these measures aim at changing the incentives of the economic actors, which is very hard, even impossible on the short run. Therefore, these policies must set such market conditions that give motivations for companies to comply with the environmental regulations.

Figure 1 Wolrd GHG Emission Glow Chart



Source: WRI, http://cait.wri.org/figures.php?page=/World-FlowChart

Moreover, the public good nature of climate (Nordhaus, 2002) must be emphasized, which implies per se the free rider problem (Tulkens, 1998). This circumstance makes it difficult to a great extent to build a policy framework that would be effective, i.e. that would cover all emitters. The consequence is that if policy makers would like to increase the efficiency of these instruments, they should apply efficient monitoring systems, which would result in enormous monitoring costs but which, at the same time as a consequence of information problems, could never be effective enough to prevent free riders. The existing policy instruments assessed below suppose the existence of a perfect financial market, where price functions as a perfect indicator.

All mitigation policy instruments must meet the following objectives: be cost-efficient, promote and facilitate innovation, diffuse GHG emission reducing technologies and be flexible to be able to respond to changes in the economy.

5.3 Building a macroeconomic model

When policy makers would like to choose between different policy instruments, they should base their choice on impact studies of each measure. When modelling climate change mitigation, we must get the proper indicators to measure the impacts.

As an overall indicator, we can study changes in GDP, which however can be distorted. GDP does not reflect changes in externalalities, cannot capture the increase in the security of supply and other secondary benefits that cannot be quantified. Non-market evaluated activities are also out of the focus of an analysis that considers only changes in GDP.

Changes in employment are even more difficult to assess. On one hand a shift in technology, and the reduction of the production results in the decrease of real wages, and possibly in employment.

On the other hand, from carbon intensive sectors, there can be a shift of the labour to the green economy where there are new potentials of investment and growth. The possibilities of the expansion of green employment depend on many things and must be further analysed in detail.

There are two main factors to be studied: Cost effects and innovation promotion.

Price and cost effects

Below, it will bedescribed a model argued by Lintz (Lintz 1992. pp 34-38), which is based on neoclassical assumptions. It is assumed that quantitative restrictions on GHG emissions are applied. Therefore the use of fossil fuels must be reduced. This will change the cost structure of companies, increasing the cost burden. This will result in lower real wages and a substitution effect to other input products. The potential output is reduced if we consider that companies are profit maximizers. According to this approach, a new equilibrium can be reached with full employment in the case of flexible labour market. This model has some preconceptions that are rather simplifying. A clear distinction must be made between short, medium and long term effects.

A possible but not necessary decrease on the short run can be attributed to higher input costs, however on the long run, after a technological change was made, the initial production will be changed, thus production can even rise compared to the ex ante state. In Lintz's analysis it is also assumed that the starting point is Pareto optimal. However, if we assume that the starting point is suboptimal, the introduction of a climate change mitigation instrument will not result in the reduction of the GDP.

Hence, we should state that current production schemes are not efficient enough, and efficiency can be ameliorated. In the case of the economics of climate change, the free lunch hypothesis of Michael Porter can be used (Porter, 1990). There are so called No-Regret Potentials i.e. economic actors can find cost-efficient saving potentials. If companies, as a result of an increased cost burden caused by GHG emissions restrictions, are obliged to look for and activate unused efficiency potentials, or innovate to reduce costs, and as a result, achieve competitive advantage, then mitigation policy has reached its objective (Porter, 1995). A well-directed environmental protection policy can therefore encourage innovation, investment in R&D and the diffusion of low-carbon technologies (Ambec & Lanoie, 2008).

"The notion is that the imposition of regulations impels firms to reconsider their processes and hence to discover innovative approaches to reduce pollution and decrease costs or increase output." (Berg and Holtbrügge, 1997. p.200)

Nevertheless the picture is not quite clear, yet there are many factors to be considered. The former model represents companies as rational economic agents; however, decision making processes are rather complex to be able to decide easily how companies will act in such circumstances. As it was mentioned before, a distinction must be made between short and long term. We must refer here to the principal-agent problem. Investing in new technologies needs high R&D costs therefore it only turns to be positive, beneficiary after a while (as suggested in product life cycle theory). As a consequence, there is a trade-off between short-term and long-term objectives. Innovate and be more competitive on the long run or pay dividends, get a higher profit on the short term.

Company decisions are, to a great extent, affected by former experiences, sunk investments in green economy, environment-friendly production or they are distorted by future uncertainties.

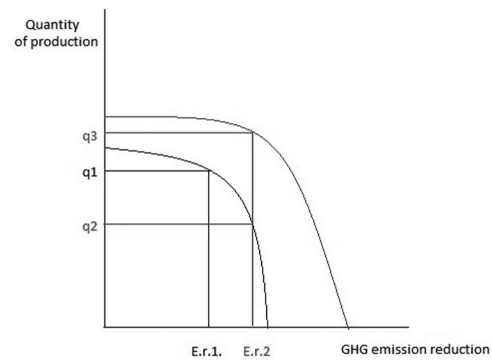
Innovation promotion

As the aforementioned Lintz model suggests, GHG emission taxes will increase costs for companies, thus will result in a decrease in the GDP. On the contrary, we assume that additional, well-selected financial burdens are expected to foster a swift in technologies, promote investments in new technologies, innovation. Therefore, it will result in a shift of the production frontier curve.

In the following figure it can be seen that on the short run, further reduction of GHG emissions will result in a decrease of production (q2), while on the long run, motivated by profit maximization, the company will invest in R&D and develop new production techniques. Technological changes will move the production frontier right, and extend production capacities. Production, with the same amount of GHG emission will increase significantly.

In theory, this can be an impressive model that proves the legitimacy of GHG emission reduction policies. Empirical studies, however, do not agree totally with these assumptions.

Figure 2 The shift of the transition curve as a result of climate investments and technological change



Source: Author

If an increase in investment volume and an increase in economic growth can be observed, it does not necessarily mean that investments in GHG emission reduction contributed to experimented growth.

According to empirical studies, an increase in green investments when it is about end-of-pipe systems will not result in economic growth, while production-integrated environmental protection may contribute to growth.

Below, a detailed assessment is given on four policy instruments.

Table 1 Policy instruments addressing climate change

Policy instrument	Cost-efficiency	Promotion of innovation	Technology diffusion	Flexibility	Address market imperfections
GHG emission taxes	Relatively High monitoring costs and tax collection costs income for the states	YES Gives incentives to invest in R&D to reduce emissions	YES Foster diffusion of low-carbon technologies	YES Easily implemented, can be adjusted to economic changes possibility of harmonization	NO Rests the information problem which entails monitoring difficulties
Emission trading schemes	NO large transaction and monitoring costs, no perfect permit market	Partly high price volatility, uncertainties	Partly high price volatility, uncertainties	Partly differentiation can be made, difficulties in choosing price cap, difficulties in incorporating new countries.	NO asymmetric information, monitoring is difficult, transaction costs
CAC approaches	NO, lag in cost and result costs are not immediately visible	Low does not give innovation and adoption incentives	Low no incentive to introduce more efficient technology than obliged	NO do not accommodate to changes	Partly cover segments not address by market instruments
Technology-support policies	NO market distortion, large initial R&D spending	YES corrects innovation failures	YES corrects technology diffusion failure	NO do not accommodate to changes	Partly addresses innovation failures

Source: author

GHG emission taxes

From the point of view of cost-efficiency, there exists a double dividend from introducing CO_2 emission taxes. The income generated by the tax can be "recycled" and reinvested in CO_2 reducing technologies. This might be the most cost-efficient, and market-conform instrument of mitigation action (Parry, 2000).

On one hand, it gives strong incentives for companies to introduce new technologies that would reduce GHG emissions and increase productivity at the same time. On the other hand tax revenues can be used to finance green investments.

Other advantage of this instrument is its flexibility. Flexibility can be considered at a national level: taxes can be adjusted to economic cycles, or changes in demand. At an international level, it is easy to introduce and harmonise emission taxes in two countries or in a group of countries. Tax schemes and rates can be adjusted, and thus, climate policy can be more effective. Nevertheless, at a European level it is rather controversial that a unique carbon tax could be introduced, considering that tax schemes are not identical at all, and although the same GHG emission tax would be introduced in all EU countries, the effect of this measure would vary from country to country in function of the existing tax scheme and interaction with other policies.

Policy makers can opt for a swift form taxes on labour to ecological tax. That would diminish the costs of GHG reductions and would be less distortive; however, its success would depend on existing tax system (Parry et al., 2000)

However, there are some circumstances that influence its applicability. First it is hard to build up public support for a tax. And the application of a tax in itself cannot assure that companies invest in new low-carbon technologies if they can shift increased costs on consumers. In many cases emitters have monopolistic power therefore they are able to adjust prices to maximize their profits. As in the case of all taxes, monitoring and tax collection costs must be taken into account, which means that transaction costs are quite high.

According to an empirical research by Blackman and Harrington (2000), GHG emission taxes can be applied in developed countries, however in lower income countries institutional capacities are not ensured to enforce an emission tax (Routledge, 2004). Therefore transaction costs are higher than the possible revenues from such taxes. The fact of high carbon intensity would mean huge costs for the private sector in developing countries, what deters them from introducing such taxes. This entails the problem of the internationalization of GHM emission taxes.

It is also true that for the time being there is no strong need for a large international harmonization of emission taxes or to set up a new international institution. We also have to distinguish between public and private companies, yet the former does not have profit maximization as priority, they have laxer budget constraints, and as a consequence, they do not have enough motivation to invest in R&D, innovations, and technological changes. In private companies there are more incentives to reduce costs and to compete with quality standards.

Emissions trading schemes

The introduction of this measure reflects an administrative approach to address climate change. A central authority introduces a ceiling for the amount that can be emitted. Companies, usually willing to overstep this limit, are obliged to obtain more permits.

The cost-efficiency of this instrument is less proven. Permits should be fully auctioned, and there should be no uncertainty with regard to emissions trade. If a perfect emission permit market existed, emission trading would perhaps do better, however we are quite far from this. Transaction costs are much higher than in the case of emission taxes, and pricing is a lot more difficult. Implementation and monitoring, due to the absence of yet existing infrastructure, will produce much higher costs for states.

It also distorts market dynamics: modifies entry and exit circumstances, and provides monopolistic benefit for emitters, whose emission is financed by consumers.

Internationalization could be a solution to achieve higher cost-effectiveness, but existing schemes do not allow being optimistic about it. It is not as flexible as a tax, which can be easily moved to an international level, or even to incorporate new participant countries.

Political support can be achieved by “grandfathering”, i.e. by granting permits for free to some existing emitters (Böhringer – Lange, 2008).

This is a supported instrument in the EU because it is ideal to deal with international competitiveness and also has a distributive effect. The implementation of this measure favours subsidiarity to some extent.

From the point of view of fostering innovation, it is less effective than GHG emission taxes. If we accept the assumption that perfect permit markets do not exist, it is evident that price volatility will be considerable, which could only be reduced if a price floor as well as a price cap would be set. This would contribute to the moderation of price volatility and there would create a more favourable climate for investments in R&D. For the same reason emission trading policy should be predictable, and stable, to don't deter investments.

Command-and-control (CAC) approaches

The market instruments described above cannot address market failures as they are unable to handle information problems and their monitoring is rather difficult. They strongly depend on the institutional capacities of a country. Therefore, there are many segments that are not covered by these instruments. CAC approaches can be efficiently used as a complement.

This instrument aims to set up environmental standards to oblige abatement decisions on companies. These standards can be technology related ones, which dictate companies to use certain low-carbon technology to reduce emissions. Performance standards can also be set up, i.e. an emission target defined with regard to the unit (OECD, 2009).

This is a regulatory and not a market instrument therefore it is inevitable that it would cause certain distortions. It is not flexible, yet it cannot be adapted to different emission and production structures of the companies. It is not able to differentiate the function of the cost structure. (Bourniaux et. al., 2009)

On the other hand, it can address market failures better, and in the case of the inefficiency of market instruments, it can also be a better solution. It is ideal to address information problems. While price elasticity can affect the success of market instrument, CAC approaches can be applied in all situations.

Technological minimum standards are set to be achieved by companies. This measure gives not only an incentive, but also an obligation for emitters to reduce their GHG emission significantly. However in the case of a company that already meets this requirement, it gives no motivation to invest in new, more efficient technologies. A possible hazard is that these standards, by giving no incentives for companies that are already more developed technologically for further innovations, could freeze the current technological level and as a consequence, they are counterproductive. A more adaptive and flexible instrument would be needed, i.e. it would be essential that these standards be revised frequently, and be shaped to the different technological possibilities of firms.

In the case of performance standards, there are more incentives for new innovations. It this case, firms cannot react for emission reduction by reducing production, yet an emission per unit is set. The goal of companies would be to find the ideal technology to increase production without increasing environmental costs.

This instrument can be studied from the point of view of behavioural economics. A motivation map can be elaborated from the drives of companies. Companies are profit-oriented therefore they prefer to take measures that increase benefits. Emitters do not get direct financial benefit from adopting abatement technologies or reducing emission per unit. Indirectly, however, they can gain a lot from being first movers, and get competitive advantages. Another factor can be that standards, to a great extent, depend from the average performance of companies. Thus, they are not motivated to invent new, more environmentally friendly technologies, because this would make standards increasingly stricter.

For policy makers it contributes to its popularity that no special institutions are needed to introduce it, and it can be easily implemented. However it is difficult to choose appropriate standards on a national level and even more on an international level. Too lax standards will not make a change; too tight ones, however, would be unenforceable.

On an international level, technology standards could be negotiated; however, national interests would be very different and it would be almost impossible to find the smallest sum, and as a result, this would not be efficient enough and would not result in fundamental changes.

Considering European cooperation with third countries, this instrument could be built into these projects and conciliated with technology transfers to developing countries (which are, as we stated above, less willing to introduce emission tax and cannot incorporate to emission trading schemes).

Technology support policies

These policies are designed to address innovation failures and to reduce GDP losses attributed to mitigation policy. Implemented as transfers, they would be far from being cost-effective, yet subsidies would distort market and would not necessarily contribute to a substantial reduction of GHG emission while causing high monitoring costs.

For the same reason, contrary to the suggestions of the OECD report (OECD, 2009), we question the efficiency of an international fund rewarding innovation. Doubted is the thing that any "grandfathering" would be efficient in economy, and in this case a lot of definition problem would arise, and historically such funds cannot be considered as a success.

In the beginning, R&D investments would mean high initial costs for companies, while the gains will come only later, and they are quite precarious. Policy makers can use fiscal instruments or direct subsidies to promote innovation and foster R&D spending; however these initiatives are not so efficient because innovation necessities do not come from an internal need of the company but it is an obligation from the outside. Therefore, an information problem will arise.

It can be a good complement to carbon pricing, because if there is a price on GHG emission, technology support would canalize innovation in low-carbon, emission-reducing technologies. Otherwise it cannot be assured that companies invest in such technologies and not in energy-efficiency. By spending R&D funds on energy-efficiency, firms will be more competitive, production costs will decrease, and thus, it will be totally beneficiary and rational for them. Nevertheless, an increased energy-efficiency will result in lower carbon prices, and in an increased demand on a global scale.

Another hazard of this policy is the asymmetric costs for developed countries, which are supposed to cover most of the spending, and offer these technologies as a transfer, for developing countries. At a national level, the whole population will finance R&D investment, while only few inventors will get the benefits. Spread costs, however can be interpreted as an advantage from the point of view of the introduction of this policy.

To sum up, we can say that it is a complementary instrument to carbon pricing, which helps boost innovation and growth and contributes to addressing innovation failures. As a whole, it must only be a secondary measure.

5.4 What an ideal policy mix would be to address climate change?

Pricing GHG emission is inevitable; however, to address its inefficiencies, other, softer policies should be applied. CAC approaches address information problems and technology-support policies to mitigate the production decrease from emission reduction.

A stronger cooperation between the government and companies would be ideal to deepen the relations between the public and the private sector, and also to involve universities and higher education in research activities more explicitly.

The efficiency of a mitigation policy does not depend only on the selection of the convenient instrument, but to a great extent on its integration into other policy areas. For example, a production-supporting agriculture policy would result in greater emission levels, while a favourable trade policy could promote the diffusion of low-carbon technologies (Mattoo et al., 2009).

Probably some institutional changes would also be necessary to enable the implementation of mitigation policies. Stronger legal framework could better enforce emission reduction and could make it easier to monitor compliance with GHG emission-reducing regulations.

5.5 The legitimacy of a European mitigation and adaptation policy

Recent OECD analysis concluded that a particular EU mitigation policy would have, at a world level, negative effects on a global mitigation policy (OECD, 2009) According to the argument of the OECD report, as a consequence of carbon leakages, a separate EU policy could reduce the efficiency of global climate policy.

It can be easily proved that if a smaller group of countries applies emission cuts, it will not result in a decrease of emission levels globally because these effects are eliminated by increasing emissions in other regions. Moreover, it may cause larger mitigation costs for the global community.

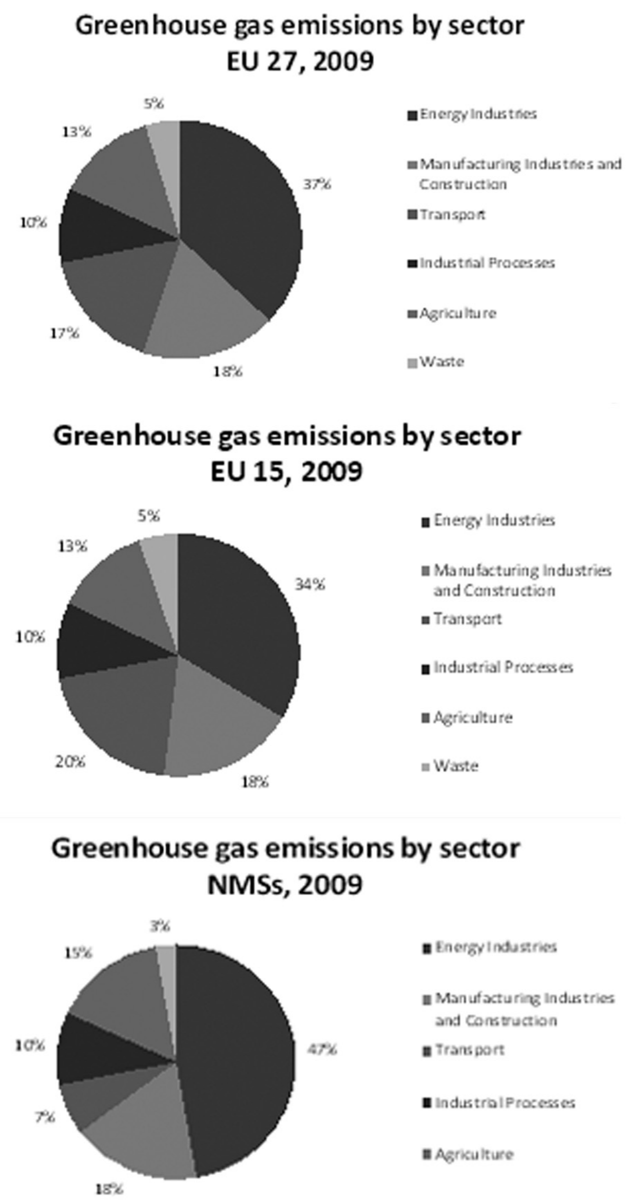
If restrictive measures on GHG emission are applied only on some countries, the producers of these countries will lose competitive advantages at an international level compared to their foreign competitors. Therefore, if it is possible, they will outsource production or some phases of production to non-participant countries. This means that although in the region where emissions-reducing policy is implemented, GHG emission will decrease, globally there will be no change in emission levels.

The same policy would entail a decrease in the demand for fossil fuels in the region and therefore a fall in prices, which would make these energy sources cheaper, and thus more fossil fuel would be used in non-participant countries. Below, the OECD simulation analysis is used to describe a possible scenario (OECD,2010).

Table 2 Carbon leakage rates

		2020	**2050**
EU acting alone	CO_2 only	13.0%	16%
	All GHG	6.3%	11.5%
Region acting	EU acting alone	6.3%	11.5%
	Annex I	0.7%	1.7%
	Annex I + Brazil, India, China	0.2%	0.7%

Figure 3 Greenhouse gas emissions by sector



Source: Eurostat statistical database

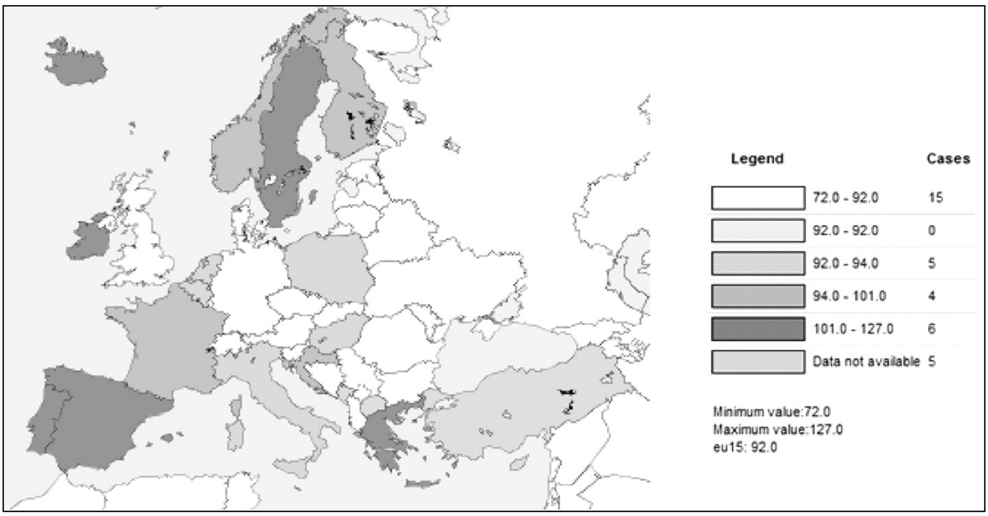
According to this model, in the case of a unilateral 50% reduction of emissions compared to 2005, leakage would be 11.5% of the achieved reduction achieved by the EU. If emission reduction was the same with larger country coverage, carbon leakage would be between 1 and 2% (COM 2010).

However, we argue that policy incentives must rise, and it is not surprising that the first changes can only be implemented in a group of countries and later on, a global institution can be set up. Therefore, an alternative scenario can be conceptualized where GHG reductions are first made in the EU but then global trends follow these initiatives. In this case, although carbon leakages will appear, they will be lower.

Considering the EU's competitiveness in the world, although a unilateral GHG restriction policy would affect production costs negatively, it is still necessary. In this section, we are arguing that, despite undoubted negative consequences, a European climate mitigation and adaptation policy is needed. Climate change affects the different common policy areas in which the EU acts. What is more, mitigation policies are more enforceable through the EU framework.

Other factor can be that GHG emission structures are very similar in European Union Member States. Analysing the Eurostat data on GHG emissions, we can say that there are no significant differences between the EU 15, and new Member States.

Figure 4 GHG emission compared to Kyoto 1990



Source: Eurostat

The lack of significant differences in emission structures suggests that a common European emission-reducing climate policy might have legitimacy, and should be canalized into common energy, agriculture, and transport policies.

A three-level approach is needed to assess the European climate policy. Carbon pricing, namely GHG emission taxes, may interfere with national taxation. Currently fiscal policy is not part of the common policies and we are far from the existence of a European Economic Governance. However, a stronger European economic coordination would be necessary to have an efficient climate policy.

The first level is the national one. Due to the aforementioned reasons, national policy will rest the dominant one, and European is only a complement. European states have their own targets to meet Kyoto goals, and they also have their own measures. As a whole, they are not wrong, however there is a long way to go.

Second is the EU level. In the traditional EU arguments we can read that, due to "regional variability and severity of climate change" (COM(2009) 147/4) a coordinated EU action is needed to face regional and sectoral disparities and to spread the best practices. The European Union can enforce climate change mitigation measures through common European policies. A broader framework has been elaborated in 2009 in a White Paper on Adapting to Climate Change. The roadmap laid down an ambitious project to harmonize EU Climate Policy, but it seems to be rather a political incentive than a pragmatic Action Plan. A comprehensive strategy is needed, which would include the Transport, Energy Efficiency Action Plans, as well as the reform of the CAP. It is necessary to enhance the EU's resilience to the impacts of climate change, and to develop well-elaborated plans to promote energy-efficiency, foster innovations in the green economy, facilitate the spread of the use of renewable energy sources, keep up with changes in the global economy, and diffuse low-carbon technologies.

Third, the EU must think globally. To be competitive on the global market, the EU must take advantage of its capacities, and invest in green economy and low-carbon technologies (Berndes - Hansson, 2007).

The actions suggested in the White Paper (COM(2009) 147/4) are the following. First, it would be necessary to raise awareness and to build a knowledge base of the impacts of climate change. A Commission Staff Working Document (SEC (2008) 3104.) set up an European Institute of Innovation and Technology with the task to quantify costs and benefits of adaptation. Within this institution, Knowledge Innovation Communities (KICs – Climate-KIC, KIC InnoEnergy) and EIT ICTLabs have been created, which link higher education, research and business sectors. Then adaptation should be integrated into other policy areas. To successfully integrate adaptation action into sectoral policies it is fundamental to assess interaction with other policy instruments. This is the case with the Common Agricultural Policy, where fundamental reforms are taking place. The most important priorities are to enhance the competitiveness of the EU and to contribute to the development of rural areas.

CAP, as a whole, is far from being cost-effective. The sustainable production scheme would mean that the whole financing of the agricultural policy should be changed and focused on investments and making production and export structure of the Member States more competitive.

In a post-2013 CAP, a knowledge and invention-based agriculture should be targeted and connected to rural development, which should be separated from social policy, i.e. transfers should be based on investment capacities, technology diffusion.

Nevertheless, plans are only plans if there is no financing behind. According to the Stern Review (Stern Review, 2006) financial constraints are the main barriers to adaptation.

How can the EU handle this problem? In the 2007-2013 Financial Framework (EU Council, 15915/05), adaptation to climate change is one of the most important priorities. In the European Economic Recovery Plan (COM(2008) 800 final) there is a special emphasis on climate change adaptation policy, i.e. the promotion of energy efficiency, fostering the production of green energy and the modernization of the European infrastructure.

An interesting proposition of this paper is the coverage of certain strategic public or private investments by weather-related insurances. This suggestion should be further analysed in the future. The PES (Payment for Ecosystem Services) would be designed to build public-private partnerships to share investments, risks and it would recycle the revenue generated from auctioning allowances (COM(2009) 147/4).

5.6 Conclusion

In this chapter we assessed, that a mitigation and adaptation policy is needed to address climate change. Policy instruments should be selected very carefully, yet they have substantial impact on the real economy, on the GDP, and they have employment effects. Therefore, market-based instruments and complementary, innovation-promoting instruments should be applied to reach a sustainable growth. New motors of economic growth could be detected in the green economy and renewable energy sources, which could foster innovation, contribute to production growth and create employment.

The EU has published many action plans to face climate change, but lacks the appropriate financial instruments and coherence with other common policies. In the future, a more pronounced competitiveness-promoting and innovation-based adaptation policy should be elaborated, together with market-based financial instruments.

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6. Carbon pricing: theory and practice

6.1 Introduction

Carbon pricing policy is a fundamental humanly devised theoretical and practical cornerstone in the fight against climate change. It involves short term and long term policies, theoretical and practical considerations. A quantitative global stabilisation target range for the stock of greenhouse gases in the atmosphere is needed, because it is an important and useful foundation in the shaping of a comprehensive climate pricing policy. A global stabilisation target range is obviously a long term policy to control climate change and events ensuing excessive increase in temperature.

Setting long term objectives in the fight against climate change are substantial in avoiding catastrophic consequences therefore short term policies, which aim advances in emission reductions, have to be consistent with the pre-defined long term stabilisation goals. Short term policy reaction means using price-driven instruments like taxes and tradable quotas. These instruments allow broad flexibility in the parameters of emission reduction, and provide opportunities and incentives wherewith the cost of mitigation and abatement can be kept down. Taxes and tradable quotas give the flexibility in how, where and when emission reduction can be accomplished thereby reaching agreements between states and companies may result an appropriate and environment-conscious emission scheme, that can fit into the long term objectives.

In defining price-driven instruments one major problem emerges even: How to define an applicable price for carbon emissions? A significantly lower price can be resulted by excessive emission so it is ineffective, and a significantly higher price can also be ineffective because it hinders the development of industrial production imposing substantial cost on companies. That is why the price signal should reflect the marginal damage that caused by emissions. Over time if the damages caused by emission increase as the stock of greenhouse gases in the atmosphere grow, the paid price should also rise along with it.

In theory, price-driven instruments as prices and tradable quotas could establish a common price signal across countries, sectors and industries. As from the above mentioned thought reveals setting an implicit price and leave market-base mechanism to operate alone can be misleading. There can also be a role for regulation aware of the misleading phenomenon of price signals. In practice, tradable quota systems may be the best way of creating a common price signal across countries. Both taxes and tradable quotas have a favourable characteristic that they have the potential to raise public revenues.

Towards the end of the introduction we have to focus on another critical issue. The global distribution of emitted greenhouse gases is fairly unequal among countries and sectors. Equity should have to play a central role to securing a global agreement on carbon emission pricing. In compliance with the Kyoto Protocol, participating developed countries have committed to reduce emissions but this reduction in emissions is not necessarily sufficient. A comprehensive company-level multilateral trading scheme only exists in the European Union, which makes cost-effective the emission reductions.

In the following we would like to demonstrate some theoretical considerations in connection with carbon pricing policy. We start with a short description of the greenhouse-gas externality because it is obviously elemental part of the pricing problem. Then we focus on the carbon pricing policy in theory and in practice. We discuss the debate on how to choose between prices versus quantities and then we continue with tradable allowances.

6.2 Greenhouse-gas externality

Describing the climate change as a negative externality is more complicated than a simple pollution. Varian (2005) in his well-known microeconomic book partly mentions an environmental problem, exactly the pollution vouchers problem, in the chapter of externalities. "*Everyone wants a clean environment …as long as someone else pays for it. Even if we reach a consensus on how much we should reduce pollution, there is still the problem of determining the most cost-effective way to achieve the targeted reduction*" (Varian 2005, pp. 636). This quotation highlights some crucial consideration with the negative externalities of the environment. First of all a very hard-to-answer question: who wants to pay for it? According to the standard microeconomic argumentation nobody wants to pay for it because the economic rational behaviour of a human is a profit maximising, so nobody wants to pay for it. Secondly, a better question is that who should pay for it. The principle is unequivocal, the emitter pays always. Thirdly, how can we determine the most cost-effective way? And last but not least who determines the target that we should achieve?

So many questions evolve when we are thinking about a simple microeconomic problem. When the whole climate change is in the focus a far more greenhouse-gas externality features have to be addressed, Stern (2009) gathered the most important ones:[24]

- Climate change is a global externality, as the damage from emissions is broadly the same regardless of where they emitted, but the impacts are likely to fell very unevenly around the world;
- The impacts of climate change are not immediately tangible, but are likely to be felt some way into the future. There are significant differences in the short-run and long-run implications of greenhouse gas emissions. It is the stock of carbon in the atmosphere that drives climate change, rather than the annual flow of emissions. Once released, carbon dioxide remains in the atmosphere of up to 100 years;
- There is uncertainty around the scale and timing of the impacts of climate change and about when irreversible damage from emission concentrations will occur;
- The effects are potentially on a massive scale.

The above mentioned characteristics have to be involved into an appropriate policy response to climate change. Stern (2009) mentions four ways in which negative externalities can be approached taking into consideration the standard theory:

- A tax can be introduced so that emitters face the full social cost of their emissions so a carbon price can be established that reflects the damage caused by emissions;
- Quantity restrictions can limit the volume of emissions, using a "command and control" approach;
- A full set of property rights can be allocated among those causing the externality and/or those affected (in this case including further generations), which can underpin bargaining or trading;
- A single organisation can be created which brings those causing the externality together with all those affected.

The first approach reflects a kind of Pigouvian tax. Pigou (1920) wrote that taxes can establish a marginal cost to polluters which is equal with the marginal damage caused by the pollution. A Pigouvian tax can be a good solution for climate change externality if we know the optimal level of pollution. If we do not know the optimal level the tax cannot be appropriate. But if we knew the optimal level of pollution we could just tell the companies involved in the system to produce exactly and not have to care about the taxation scheme at all.

[24] The list of the key features of greenhouse-gas externality is made upon the list of Stern (2009, pp 352-354.) with some own supplements.

The third approach refers to the Coase-thesis. The state intervention is unnecessary because the markets always reach the social optimum. And this is independent from the fact who disposes with the property rights.

The fourth implication is also worth for mentioning it. Meade (1951) brought into public awareness his idea to create a single organisation that deals with the opposition of those who cause the externalities and who suffer damages from it. The present situation of the climate change emission reduction lacks of a globally institutionalised form, but in the near future a global regime may be established to fairly control the global greenhouse gases emissions.

6.3 Carbon pricing policy in theory

Theoretical assumptions relating carbon pricing policy can be separate into two different groups. The first group is the command-and-control approach of the problem which does not provide enough flexibility to meet objectives. The second policy is a market-based one which is enough flexible to meet objectives and contains incentives for companies to create more effective and sustainable instruments contributing to the evolution of environment. Beyond these two policy Fazekas (2009) mentions a third policy that refers to decentralised regulation. Table 1 shows the three different environmental policy instruments: direct regulations (command-and-control policy), indirect regulations (taxes and tradable quotas) and decentralised regulation instruments.

The command-and-control policy measures for reducing the emissions are prescribed by the government. These obligatory regulations do not provide enough flexibility for other policy measures. In general, the direct regulations limit the amount of greenhouse gases emissions into the environment. Examining the companies: the command-and-control regulations are independent from the costs of a single company thus the costs are shared equally among companies. Usually it applies common norms or particularly performance or technology-based ones. Stavins (2001) called the command-and-control approach to conventional regulation approach. Stavins particularly criticised that holding all firms to the same target costs can be too expensive and counterproductive.

Table 1 Environmental policy instruments

direct regulation	indirect regulation	decentralised regulation
normatives	taxes	voluntary agreements
ban	charges	environment marketing
licensing process	subvention	ISO, EMAS and environmental standardisations
monitoring	tax allowance	eco-audit
sanctions	tax exemption	eco-label
fines	public loans	BAT[25]
standards	credits	BATNEC[26]
	tradable quotas	implementation incentives
		environmental insurance
		information-based measures

Source: Kerekes – Szlávik (2001)

Indirect regulations are managing price-driven instruments and as we above mentioned these can be determined by a market-based way. Stavins (2001, pp 5.) pointed out a definition: "*Market-based instruments are regulations that encourage behaviour through market signals rather than through explicit directives regarding pollution control levels or methods*." and he continued his consideration "*tradable permits or pollution charges, are often described as "harnessing market forces" because if they are well designed and implemented, they encourage firms (and/or individuals) to undertake pollution control efforts that are in their own interests and that collectively meet policy goals*." Stavins broadly expressed in his definition the fundamental benefits of the market-based instruments against the old-fashioned command-and-control regulations. The most significant advantage of the indirect regulations is that the emissions reductions can be achieved in the least burdensome way from the perspective of the society. Price-driven instruments can be divided into two different groups – the first one is quantity-based instruments, for example tradable quotas or norms, the second one is price-based instruments, for example taxes, state subventions and other charges. The most widespread instruments are the taxes and tradable quotas.

The decentralised instruments are the third group of carbon pricing, what is described by Fazekas (2009) in a compact form. Decentralised approaches allow to

[25] BAT: Best Available Technology
[26] BATNEC: Best Available Technology not Entailing Excessive Cost

the stakeholders of the carbon dioxide emissions in general, the stakeholders to the pollution to solve each situation in an individual and unique way. This issue mainly covers those situations when the government has not set regulations or the results cannot be explained by the market. The participants undertake voluntary commitments to improve their environmental performance and they voluntary over fulfil mandatory requirements.

In theory, there are three different carbon pricing policy from which the market-based or indirect regulations seem to be far more effective and flexible. If we merge the market-based policy measures with the decentralised approach we get to a well-functioning system. This system at the same time applies price signals and incorporates voluntary commitments to exceed mandatory requirements in order to improve the environmental performance. This mixed approach can be a long term solution in reducing greenhouse gases emissions.

6.4 Prices versus quantities[27]

Since market-based regulations seem to be more applicable in the real world and more favourable for countries and sectors that is why we continue this consideration. If we take a brief look on Table 1, there are several forms of indirect regulations from taxes through subventions to tradable allowances. So the next question is how we can choose the most effective form of market-based regulations. The debate on choosing between taxes and quantities goes back to decades.

In an idealistic world with ideal economic conditions like perfectly competitive markets, perfect information without uncertainty, and no transaction costs, both taxes and tradable quotas can reach the goal of efficient reduction of greenhouse gases emission. Taxes can determine the price of greenhouse gases thus emitters can choose the appropriate scale of emission. And alternatively a quota for global emission can be useful while tradable quotas can originate effective market prices. But the real world is not idealistic there are a lot of impediments which make less effective the two measures. Therefore emerged a debate on whether prices or quantities are optimal in terms of emission reductions.

Hepburn (2006) created five different approaches regarding the aforementioned instruments. The first group emphasise the simple but essential symmetry between prices and quantities. In an idealistic world using quantity or tax measures to control emissions regulations are the same.

[27] The heading is based on Weitzman (1974) famous article.

Quantity regulation is the second approach. This is the most common form of regulation and it is often used as command-and-control quantities. Quotas, targets, or specific commands are included. However, there is an important disadvantage of the quantity instruments. We cannot address an appropriate quantity because the appropriate quantity can vary between different countries or companies. Perfect information needed to determine the optimum allocation of quantities which are often unavailable. Hepburn (2006, pp. 230.) emphasised that "*creating a legal scheme involves at least three elements: (i) an aggregate quantity is fixed; (ii) licences are allocated between individuals and firms*[28]*; and (iii) a mechanism is established for enforcing compliance with scheme*."

Price instrument based policy scheme is the third approach. Price instruments can also ensure the efficient allocation between companies and can indeed use to achieve policy objectives. Price instruments have the same problem as quantities, when conditions are uncertain they do not provide that a price target will be achieved. In connection with this problem Hepburn (2006, pp. 230.) mentioned that "simply because a target is expressed as a price (quantity) does not mean that a price (quantity) instrument has to be employed to achieve it. The last two paragraphs predict some kind of combination of the price and quantity instrument reaching a set of objectives.

Hepburn presented two different kind of mixed approaches, these approaches constitutes the fourth and fifth ones. Weitzman (1974) noted that why we have to use a single a single instrument when there is a wide range of mixed instruments. A hybrid instrument is a combination of price and quantity instruments which can be characterised by complexity. The more complex approach of the problem was to ignore these schemes. The most important hybrid instrument is a trading scheme with a price ceiling. The function of this hybrid approach is very simple "*the government can implement a price ceiling by committing to sell licences at the ceiling price, and a price floor can be implemented by a commitment to buy licences at the floor price*" (Hepburn 2006, pp. 230.). Non-compliance is penalised in a tradable-permit scheme. Jacoby and Ellerman (2004) examining a hybrid approach the cap-and-trade system of emissions regulation in the United States, they found when the payment of the penalty is an alternative to compliance, the penalty is equal with the price ceiling.

Multiple instruments compose the last approach. This approach brings another problem. When a country or an authority try to internalise the externalities they do not take into account that one instrument is needed to internalise one externality. An excessive use of a single instrument does not solve the whole problem and if we

[28] Hepburn (2006) used individuals and firms in his paper, but it can be easily applicable for climate change with using countries and companies in the scheme.

focus on climate change, a single policy like emission trading system does not reverse the process of global warming. That is why when multiple market failures evolve, single policy measure is not and will not be able sufficient to solve them. Multiple approaches are needed but sometimes these approaches become problematic when they are inconsistent with each other.

The price versus quantity debate can continue whit short term and long term considerations. Stern (2009) and Hepburn (2006) both applied the illustration of Weitzman (1974) in the climate change case. Both of them called this situation 'efficiency under uncertainty' when substantial uncertainty emerges regarding the timing and scale of climate change impacts. Under such circumstances, price and quantity instruments are no longer equivalent – as in the idealistic state – therefore policy instruments needed to be chosen.

Weitzman's (1974) analysis, applying to climate change particularly to greenhouse gases reduction, stated:

If the benefits of making further reductions in pollution change less with the level of pollution than do the costs of reductions, prices are preferable. In this situation the marginal damage curve is relatively flat, compared with the marginal abatement cost curve.

I• If benefits of further reductions increase more with the level of pollution than do the costs of reductions, quantity measures are preferable than price instruments. With the increase of pollution costs are rising sharply.
- Summarizing Weitzman analysis and completing it with time horizon we get to a more complex solution. This approach claims that in short term time horizon, when the marginal benefits of abatement curve is relatively flat, it is preferable to use prices and in the other case in the long term, when the marginal benefits of abatement curve is steep, it is preferable to use quantity measures.

Figure 1 (a) depicts the case when the marginal benefits of abatement curve is relatively flat and Figure 2 (b) depicts the case when the curve is relatively steep. In the first case the efficiency loss of taxes () is smaller than in the second case therefore in the first case it worth using taxes and in the second case it worth changing to quantity measures.

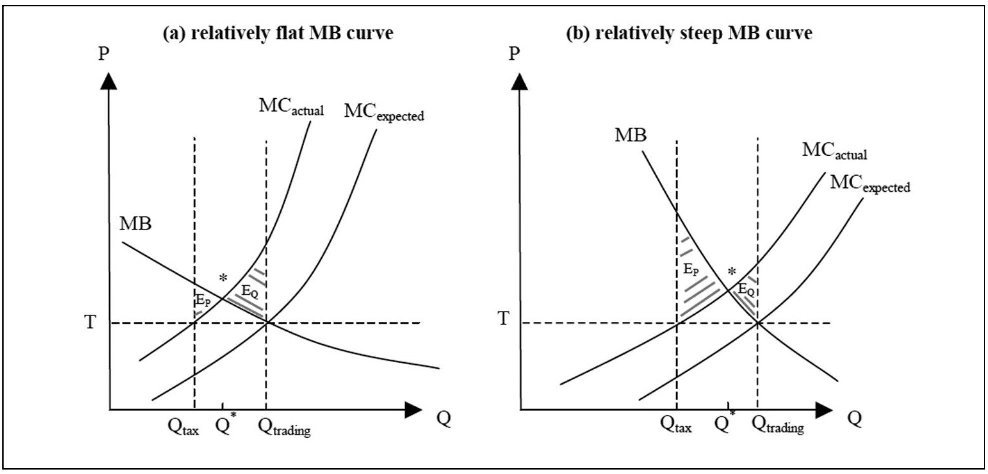
According to Stern (2009), the most efficient instrument in the case of climate change will depend on three assumptions:

- The change of the total costs of abatement
- The change of the total benefits of abatement
- And the degree of uncertainty about the aforementioned two features

As we can make distinction between the impacts of the short term and long term measures in emissions reduction we can set a credible policy goal. Hepburn (2006) and Stern (2009) also emphasise the question of credibility because it is essential to achieve a policy goal. Therefore short term policy outcomes should be consistent with long term policy goals. The short term policy measures should be coherently embedded into a long term policy. In climate change the long term policy goal is to stabilise the concentration of greenhouse gases in the atmosphere. And lastly short term policies provide flexibility in achieving long term policy goals.

Helm et al (2003), also, highlighted the importance of credibility but their approach can be reached by the solution to the time-inconsistency problem. Their options that could solve this problem in carbon policy are the followings: reducing the number of objectives, increasing the number of instruments, establishing an international body within a contractual framework or establishing a national body within a contractual framework.

Figure 1 Illustration of Weitzman results



Source: Hepburn (2006), and the original from Weitzman (1974)

6.5 Carbon pricing in practice, the tradable allowances

Emission trading schemes have several benefits. Emissions reduction can occur wherever they are the cheapest. A key benefit of the emission trading system is that it generates transfers between countries automatically because the emission reductions start where the costs are the lowest. Tax harmonisation across several countries is difficult to achieve especially comparing with the much easier introduction of a trading scheme. And last but not least, emission trading is a very powerful tool in the framework for addressing climate change at an international level.

If we use the Coase-thesis, the polluters always reach the optimum control level of emission. In the emission trading system the main objective of tradable allowances is to equalise the marginal abatement cost of the participants. Marginal abatement cost denotes the cost to decrease the emission with a ton of CO_2. In theory, every participants decrease their CO_2 emissions till the marginal abatement cost will be equal with the unit cost of tradable emission allowances. In practice, there can be differences in the individual marginal abatement cost thus the participants can only reach the optimum with trading instead of decreasing CO_2 emission.

We can made distinction between several types of tradable emission allowances. Sorrel and Skea (1999) emphasised two different systems. The first one is the emission trading system and the second one is the project-based system. Table 2 describes the main characteristics of the two systems. A project-based system can be applied when the authority tries to decrease the emission below a baseline thus only emission reductions can be traded. In practice, this system is embodied in credits to participants to achieve some emission reductions. In the emission trading system all emissions can be traded under strict regulation and participation in the program is mandatory.

Table 2 Tradable emission allowances

Project-based system	**Emission trading**
Emission reduction credit	Emission allowance
Scheme: 'Baseline and credit'	Scheme: 'Cap and trade'
Applies to emission reductions below defined baseline	Applies to all emissions
Only emission reductions can be traded	All emissions can be traded
Credits are generated when a source reduces its emissions below an agreed baseline	Allowances are allocated by the regulatory authority
May develop incrementally as a means of introducing flexibility into existing regulatory structure	Trading must be built into the regulatory structure from the beginning
Participation in the credit market is voluntary - sources can just meet existing standards	Participation in the program is mandatory - the overall emission cap still applies even if sourves do not trade

Source: Sorrel and Skea (1999)

Tradable allowances are not a new feature to environmental policy. Tradable allowances were in practice first used in the United States in the 1970s (Fazekas 2009). Then trading in emissions has been used in the United States since 1995 to reduce emissions causing acid rain (Stern 2009). To meet the Kyoto target emission reduction became more difficult that is why the European Union started to use trading. A 'Green Paper' made by the European Commission was the first comprehensive official document that proposed the use of emission trading system. The EU Emission Trading System[29] was launched in 2005, which works on the 'cap and trade' principle, is a landmark of the European Union's policy to fight against climate change and it is a key tool for reducing greenhouse gas emissions. Beyond CO2 emissions from industrial installations – power plants, combustion plants, oil refineries and iron and steel works, as well as factories making cement, glass, lime, bricks, ceramics, pulp, paper and board – airlines join the scheme in this year and petrochemicals, ammonia and aluminium industries will join the scheme in 2013, when the third period of emission trading launch.[30]

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[29] The EU Emission Trading System operates in 30 countries (the EU 27 plus Iceland, Liechtenstein and Norway).

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7. Climate change impacts on migration and labour market

7.1 Introduction[31]

Floods, droughts and monsoons have always disturbed human settlements, but there are more settlements now and more people in the world. Therefore, if a natural disaster happens, more will suffer than ever before. Moreover, climate in the past several decades has been greatly degraded by anthropogenic activity. In some cases, the chain of causality of human influence on the climate is direct and unambiguous (e.g. the effects of irrigation on local humidity), though there are instances where it is less clear. Presently, the scientific consensus (IPCC, 2007) on climate change is that human activity is very likely the cause for the rapid increase of global average temperatures, more generally known as global warming (see Appendix 1).

The thorough climate change report of the Intergovernmental Panel on Climate Change[32] (IPCC, 2007) points out that in the last few years, the increase in global average air and ocean temperatures, the widespread melting of snow and ice, and the rising global average sea level was noticed (see Appendix 2). According to the IPCC study, human influences have *very likely* contributed to the rise of sea level during the latter half of the 20th century; have *likely* increased temperatures of extreme hot nights, cold nights and cold days; have *more likely than not* increased risk of heat waves, areas affected by drought since the 1970s and the frequency of heavy precipitation events.

Winds have changed in both hemispheres – especially those blowing from the west. This ominous sign means that weather fronts and weather patterns are less stable, which points to the unknown risks involved. Since scientists are not able to determine the "elasticity" of such weather patterns or winds, it is hard to predict where the border line lies for the global wind system, or how much change it could

[31] The author was supported by TAMOP-4.2.1.B-09/1/KMR-2010-0005 project in the research for this paper.

[32] The Intergovernmental Panel on Climate Change (IPCC) was jointly established by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) to assess the scientific, technical and socio-economic information relevant for the understanding of the risk of human-induced climate change.

tolerate until it suffers irreversible damage. To my very best knowledge, scientists are not investigating the possible consequences of a change in the global wind system or the Thermohaline circulation (i.e. the redistribution of heat by carrying out a very slow and extremely deep movement of water in the oceans of the world).

According to a reader's letter sent to the editor of The New York Times online[33], there are two physical findings that stand out from climate change facts: firstly, in the last 50 years the world ocean has accumulated 22 times as much heat as has the atmosphere (data provided by the National Oceanic and Atmospheric Administration of the Department of Commerce). Secondly, it is this repository of heat — through processes like evaporation and ocean overturning — that drives the changes in weather we are experiencing: heavier precipitation events, sequences of large storms, bitter cold spells, and prolonged droughts in some regions. If the environment degrading human activity does not take a radical turn toward a greatly eco-friendly way of production, the number of natural disasters and nature-related problems are very likely to increase.

For the next two decades, a warming of about 0.2°C per decade is projected for a range of emission scenarios created by the IPCC. Even if the concentration of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected (IPCC, 2007). The Copenhagen Climate Summit of the United Nations, held in December 2009, was a failure. It was considered by the press a "disarray"[34] with a "weak" and "wishy-washy" declaration[35]. The developed and developing countries could not form a strong political cooperation to decrease the pollution of the environment and to initiate the transformation of present economies into sustainable ones. It is improbable that in the near future a climate agreement will be formed partly because of the economic crisis. As a consequence, the concentration of greenhouse gases cannot be held constant at year 2000 levels. Continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would *very likely* be larger than those observed during the 20th century (IPCC, 2007).

[33] Paul R. Epstein wrote the letter to the editor titled *Climate Change Facts*, as a reaction to article of The New York Times online. He is a doctor and an associate director at the Center for Health and the Global Environment, Harvard Medical School. The letter was published on February 13, 2010. Available online at http://www.nytimes.com/2010/02/14/opinion/l14climate.html.

[34] John Vidal (December 8, 2009), *Copenhagen climate summit in disarray after 'Danish text' leak*, guardian.co.uk. Available online at http://www.guardian.co.uk/environment/2009/dec/08/copenhagen-climate-summit-disarray-danish-text.

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7.2 The scenarios

The long-term nature and uncertainty of climate change and its driving forces require scenarios that extend to the end of the 21st century. **Scenarios are alternative images of how the future might unfold.** They are appropriate tools to analyze the influence of driving forces of, for example, future emission outcomes, and they help us assess the associated uncertainties. Scenarios assist climate change analysis, too, including climate modelling and the assessment of impacts, adaptation, and mitigation. In 2000, the Intergovernmental Panel on Climate Change accepted a new Special Report on Emissions Scenarios (SRES scenarios), which cover most of the main driving forces of future emissions, from demographic to technological developments and international cooperation. In the next chapter, these complex SRES scenarios will be developed further and their migration implications discussed. This subsection, on the other hand, only introduces a short description of each of the four SRES scenarios and demonstrates their forecasts of average global temperature and sea level rise. However, the possibility that any single emissions path will occur as described in the scenarios is highly uncertain.

The set of SRES emissions scenarios is based on an extensive assessment of the literature, several alternative modelling approaches, and an "open process" that was solicited by the wide participation and feedbacks of several environment groups and individuals. None of the scenarios in the set includes any future policies that explicitly address climate change, although all scenarios necessarily encompass various policies of other types (IPCC, 2000).

Four different narrative storylines were developed from the four scenario families to consistently describe the relationship between emission driving forces and their evolution and add context to scenario quantification. Each storyline represents different demographic, social, economic, technological, and environmental developments, which may be viewed positively by some people and negatively by others. The description of the four SRES scenario families[36] is the following:

- **A1[37] – A more integrated world:** characterized by rapid economic growth and quick spread of new and efficient technologies. It represents a convergent world where income and way of life converge between regions and where there are

[36] The Special Report on Emissions Scenarios (2000) consists of four scenario families. Only the A1 scenario family has subgroups. All in all, there are 40 alternative SRES scenarios within the four scenario families. It is not the intention of the author to go into such detail, thus this paper only deals with the four basic SRES family scenarios even when mentioning "scenario" instead of "scenario family".
[37] Only the A1 scenario has subgroups. They are the following: A1FI with an emphasis on fossil-fuels; A1B with a balanced emphasis on all energy sources; and A1T with an emphasis on non-fossil energy sources.

extensive social and cultural interactions worldwide. The global population will reach 9 billion in 2050 and then gradually decline.

- **A2 – A more divided world:** characterized by independently operating, self-reliant nations, regionally oriented economic development, and continuously increasing population. There are slower and more fragmented technological changes and improvements to per capita income.
- **B1 – A more integrated and more ecologically friendly world:** represents the emphasis on global solutions to economic, social and environmental stability. In this scenario, economic growth is rapid as in A1, but with rapid changes towards a service and information economy. Its population is rising to 9 billion in 2050 and then declining as in A1. There are reductions in material intensity and an introduction of clean and resource efficient technologies.
- **B2 – A more divided but more ecologically friendly world:** there is an emphasis on local rather than global solutions to economic, social and environmental stability. It has a continuously increasing population, but at a slower rate than in A2. This scenario has intermediate levels of economic development and it is characterized by a less rapid and a more fragmented technological change than in A1 and B1.

Table 1 Projected global average surface warming and sea level rise at the end of the 21st century

Case	Temperature change (°C at 2090-2099 relative to 1980-1999)[a), b)]		Sea level rise (m at 2090-2099 relative to 1980-1999)
	Best estimate	*Likely* range	Model-based range excluding future rapid dynamical changes in ice flow
Constant year 2000 Concentration[b)]	0.6	0.3 - 0.9	Not available
B1 scenario	1.8	1.1 - 2.9	0.18 - 0.38
A1T scenario	2.4	1.4 - 3.8	0.20 - 0.45
B2 scenario	2.4	1.4 - 3.8	0.20 - 0.43
A1B scenario	2.8	1.7 - 4.4	0.21 - 0.48
A2 scenario	3.4	2.0 - 5.4	0.23 - 0.51
A1Fl scenario	4.0	2.4 - 6.4	0.26 - 0.59

Notes: a) Temperatures are assessed best estimates and likely uncertain from a hierarchy of models of varying complexity as well as observation constraints.b) Year 2000 constant composition is derived from Atmosphere-Ocean General Circulation Models (AOGCMs) only. c) All scenarios above are six SRES marker scenarios. Approximately CO2-eq concentrations corresponding to the computed radiative forcing due to anthropogeric GHGs and aerosols in 2010 for the SRES B1, A1T, B2, A1B, A2 and A1Fl illustrative marker scenarios are about 600, 700, 800, 850, 1250 and 1550ppm, respectively. d) Temperature changes are expressed as the difference from the period 1990-1999. To express the change relative to the period 1850-1899 add 0.5°C.

Source: (IPCC, 2007)

It is important to note that the SRES scenarios are intended to exclude catastrophic futures, though such catastrophic futures feature prominently in the literature. They typically involve large-scale environmental or economic collapses, and extrapolate current unfavorable conditions and trends in many regions (IPCC, 2000).

The above table summarizes the global average surface warming and sea level rise projected by the four SRES scenarios (A1B, A2, B1, and B2). It shows that **climate change in the 21st century largely depends on the main energy resources people will be consuming until than and the level of international political cooperation.** In a more integrated and ecologically friendly world (B1), global average surface temperature is supposed to increase only by 1.8°C and the sea level is forecasted to rise by 28 centimeters on average between 2090 and 2099 relative to 1980-1999. This is the best case scenario from environmental perspectives. The worst case scenario is the more divided world, A2. Here, global average surface temperature is supposed to increase by as much as 3.4°C and the sea level is forecasted to rise by 37 centimeters on average between 2090 and 2099 relative to 1980-1999.

These numbers are serious if we consider the results of an environmental study (McGranahan, 2007) published in the Environment and Urbanization journal. The study states that **there are about 634 million people living in low-elevation areas**[38] and two-thirds of the world's largest cities[39] are at least partially in these low areas. The number of people under the threat of possible floods is expected to rise further due to the growth of population and increasing urbanization. The ten countries having the most people in low coastal areas are China, India, Bangladesh, Vietnam, Indonesia, Japan, Egypt, United States, Thailand, and the Philippines. The countries with the largest share of their populations living in low-elevation areas are the Bahamas, Suriname, the Netherlands, Vietnam, Guyana, Bangladesh, Djibouti, Belize, Egypt, and Gambia. These are the biggest source countries for future (environmental) migration.

The Special Report on Emissions Scenarios excluded future rapid dynamical changes in the ice flow. Internalizing the fact that global warming may cause large parts of the ice sheets of Greenland and Antarctica (holding the world's largest reservoirs of fresh water) to melt, the future seems even darker. Water expands as it warms, and even a temperature rise of a few degrees can raise sea levels and produce changes in ocean currents and acidity. This way global warming might destroy entire ecosystems and island communities. Furthermore, since the snow that fell in Antarctica has

[38] In this particular study, low-elevation areas were defined as places along the coast that are less than 10 meters above sea level. Overall, this zone covers 2% of the world's land area but contains 10% of the world's population and 13% of the world's urban population. On average, the Least Developed Countries have a higher share of their population living in the zone (14%) than do OECD countries (10%).

[39] In the study all the cities with more than five million people are considered to be among the world's largest cities.

never melted for millions of years, the melting ice will probably set free air bubbles containing different chemicals that were trapped in the layers of ice for many years.

In 2000, the Intergovernmental Panel on Climate Change (IPCC) published its Third Assessment Report with a new set of emissions scenarios, called the Special Report on Emissions Scenarios (SRES). These scenarios project emissions for the major greenhouse gases, ozone precursor gases, and sulfate aerosol emissions, as well as land-use changes for the 21st century. The IPCC Special Report on Emissions Scenarios (IPCC, 2000) was issued by GRID-Arendal, an official collaborator of the United Nations Environment Program (UNEP). The report overviews the scenario literature, analyses different demographic, technological, social and economic driving forces, and describes the four scenario families in detail. Six different modelling groups volunteered to participate in the formation and development of the scenarios from three different continents (Europe, North America, and Japan) ensuring the diversity of methodological approaches. Also, due to open process, scientists worldwide had access to the research in progress and sent their feedbacks which contributed to the professionalism of the final outcome. The SRES framework has become a reference document for modelling the human dimensions component of impacts assessment (Gewin, 2002).

The main aim of the report was to describe the range of possible future emissions by 2100, but its scenarios are also based on concrete demographic, economic, and technological calculus, thus they truly describe the possible future alternatives of humanity in the next century. The scenarios are so detailed and multidimensional that they can be easily treated as global scenarios. Nevertheless, the environment together with available energy sources certainly shapes our future, so it should not be a doubted basis for individual scenario building.[40]

The beginning of the report highlights the large uncertainty in the scenario literature. These uncertainties range from inadequate scientific understanding of the problems, data gaps or lack of data, and inherent uncertainties of future events in general. As a consequence, not one or two but more alternative scenarios had to be developed. The final scenarios cover a wide range of driving forces from demographic to social and economic developments, and they encompass a wide range of future greenhouse gas (GHG) emissions. They are representative of a broad range of scenarios found in the scenario literature, but they are not directly based on any particular published scenario taxonomy or set of scenarios (IPCC, 2000).

[40] The Special Report on Emissions Scenarios (2000) consists of four scenario families. Only the A1 scenario family has subgroups. All in all, there are 40 alternative SRES scenarios within the four scenario families. The author does not intend to go into too much detail, thus this paper only uses the main characteristics of the four scenario families. For the sake of simplicity, “scenario families” mean the same as “scenarios” in this paper.

The four SRES scenarios differ in how global regions interrelate, how new technologies diffuse, how regional economic activities evolve, how protection of local and regional environments is implemented, and how demographic structure changes. The Special Report on Emissions Scenarios (IPCC, 2000) has a "quantitative" storyline which includes various political, social, cultural, and educational conditions (e.g. type of governance, social structure, and educational level) though often these conditions are hard to be defined in strictly quantitative terms. Nevertheless, they participate in complex cause-and-effect relationships with quantitative emission drivers (e.g. economic activities, population levels, energy consumption). Their explicit inclusion in the scenario development process made scenarios more "plausible" and "believable".

Each of the four SRES scenario families includes a descriptive part ("storyline") and a number of alternative interpretations and quantifications of each storyline. The storylines describe a demographic, social, economic, technological, and policy future; consequently, they occupy a multidimensional space. All of them describe dynamic changes and transitions in generally different directions. They have features that can be interpreted as positive or negative, and their assumptions should be viewed with an "open mind". The storylines do not include specific climate-change policies, but they do include numerous other socio-economic developments and non-climate environmental policies (IPCC, 2000).

The authors of the Special Report on Emissions Scenarios have not given "normal" names to the SRES scenarios in order to avoid unintentional connotations that could have breached their neutrality – they have named them: A1, A2, B1 and B2. It is easy to remember the basic characteristics of the four scenarios if the two most important dimensions of the scenarios are remembered. One is the global/regional dimension, and the other the economic/environmental dimension. The next table demonstrates that if we join "economic" with "A" and "global" with "1", we get the A1 scenario which describes a highly globalised future with economic performance in its focus. This logic eases the understanding of further scenario comparisons.

Table 2 Summary of the two main dimensions of the four SRES scenario families

	Economic	**Environmental**
Global	A1	B1
Regional	A2	B2

Source: IPCC, (2000)

Initially, all scenarios were characterized by two quantitative “targets”, namely global population and global gross domestic product (GDP) by 2100. These quantitative targets were harmonized data not projected by the IPCC but a result of a consensus process among the SRES authors (Gaffin, 2004). The targets guided the subsequent quantification of the SRES scenarios with different model approaches. The following table shows an overview on the specific numbers:

Table 3 The quantitative targets of the SRES scenarios by 2100

	A1	A2	B1	B2
Global population target	7 billion	15 billion	7 billion	10 billion
Global GDP target in 1990 US dollars	US$ 550 trillion	US$ 250 trillion	US$ 350 trillion	US$ 250 trillion

Source: IPCC (2000)

We can see from the table above that while the globalised and economic performance focused scenario A1 predicts the highest global GDP target and the lowest global population target by 2100, the regionally divided and economic performance focused scenario A2 foresees the lowest global GDP target with the highest global population target. Scenarios B1 and B2, both representing eco-friendly futures, are in between these two “extremities”. Appendix 13 demonstrates the characteristics of each storyline briefly by presenting them in the form of hexagons that portray, among other things, the values for the two main driving forces (population and economic growth). Furthermore, the following table summarizes the main driving forces of the different scenarios:

Table 4 Summary of the driving forces of the four SRES scenario families

	A1	A2	B1	B2
Population growth	low	high	low	medium
GDP growth	very high	medium	high	medium
Energy use	very high	high	low	medium
Technology change	rapid	slow	medium	medium
Technology base	A1C – coal A1G – oil, gas A1B – balanced A1T – non-fossils	regional	efficiency and demateri-alization	“dynamics as usual”

Source: IPCC (2000)

The *Climate of the future* subsection of this chapter has already advanced a brief overview on the basic characteristics of the four SRES scenario families, and it is this chapter that deals with the different SRES scenarios in detail. The following sections first describe the SRES scenarios one by one, according to the report they were published, and then the scenarios are reconstructed through the author's additional trains of thought, which concentrate on the implications of the scenario on the future migration of people. The latter will be summarized in the end of this chapter.

7.3 Scenario A1 – A more integrated world

The storyline of the first scenario shows a highly globalised world focusing on economic performance in the first place. Firstly, the scenario will be illustrated according to its original description in the IPCC Special Report on Emissions Scenarios (2000). Secondly, parallel to its further development, the migration implications of the scenario in question will be expounded.

Description of scenario A1

This scenario undergoes a rapid and successful economic development where regional average income per capita converges. The transition to economic convergence results from progress in communication technology and transport, shifts in national policies on immigration and education, as well as firm international cooperation in the field of national and international development of institutions, which enhance productivity growth and technology diffusion. The current distinctions between "poor" and "rich" countries will eventually dissolve.

The primary dynamics of scenario A1 is market-based solutions and high rates of investment, especially in education, technology and innovation both at national and international levels. Business is dominated by American/European entrepreneurial culture with progress-oriented perspective. In some examples of this type of scenario, high economic growth leads to shifts of economic power from traditional core countries to the current economic "periphery". In that case, Chinese and Indian entrepreneurial will be dominant. Households pile up savings and develop a commitment to education and lifelong learning. High mobility of people, goods, technology and ideas, as well as liberalized trade markets, and rising income levels characterize this globalised world. High incomes also precipitate into high car ownership, expansive suburbia, and dense national and international transport networks.

Low mortality and low fertility in the A1 scenario family shows how demographic and economic trends are closely linked, since affluence is correlated with longevity and small families. Global population grows to some 9 billion by 2050 and declines to about 7 billion by 2100. Though average age increases, economic needs of retired people will be met by private pension systems.

The global economy expands at an average annual rate of about 3 % to 2100, reaching around US$ 550 trillion[41], whilst global average income per capita reaches about US$ 21,000 by 2050. Despite this world being far from problem free (e.g. wealthy communities might face problems of social exclusion), we can conclude that the high average level of income per capita contributes to an improvement in the overall health and social conditions of the people.

In this scenario, family energy and mineral resources are abundant. This is so thanks to the rapid technical progress reducing the resources needed to produce a certain level of output and increasing the economically recoverable reserves. The energy use per unit of GDP (final energy intensity) will decrease at an average annual rate of 1.3 %. Technological development "releases" natural resources currently devoted to supplying human needs for other purposes. The idea of environmental quality changes in this storyline from the emphasis on "conservation" of nature to active "management" of natural and environmental services. This increases ecologic "flexibility".

The several subgroups of the A1 scenario family reveal the uncertainty regarding the type of the possible ruling energy source. In this rapidly changing world, some scenarios evolve along a carbon-intensive energy path consistent with the present development strategy of countries with abundant domestic coal resources. Other scenario groups build up their economy on oil and natural-gas resources in the long run. The third group predicts a shift toward renewable and nuclear energy sources. Finally, the fourth group assumes a balanced mix of technologies and supply sources with technology improvements. The latter scenario assumes no single source of energy as overly dominant.

Description of scenario A1 and the analysis of its implications on migration

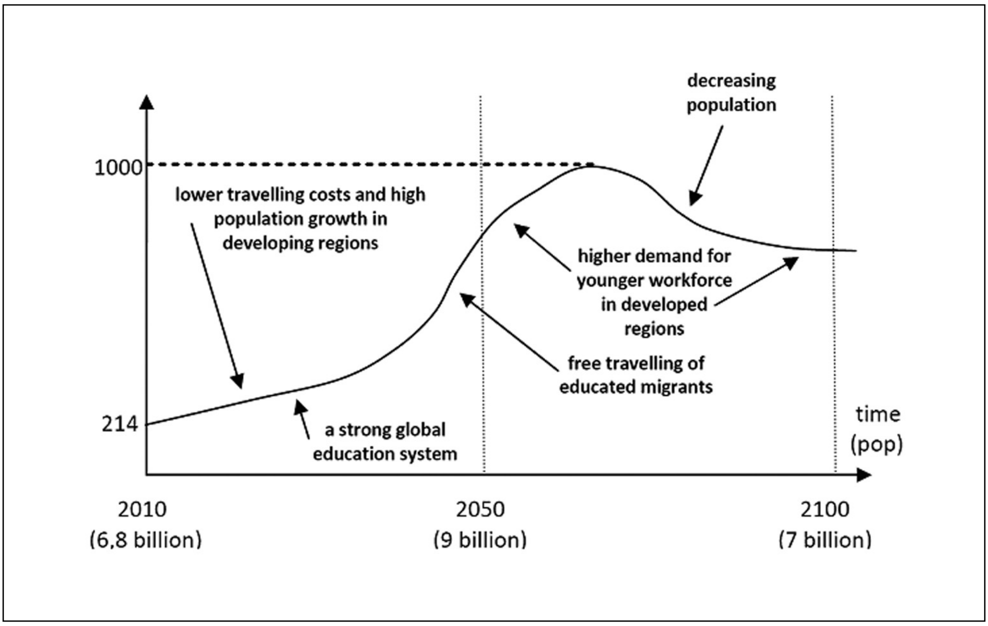
The economic performance focused scenario A1 projects the highest global GDP target by 2100. Its development is mostly based on advances in transport and communication technology. The globalized world further strengthens and develops international institutions, enlarging their scope of authority. It is possible that by

[41] All dollar amounts herein are expressed in 1990 dollars, unless stated otherwise

2100 nation states lose their territory-based sovereignty; due to the high mobility of masses citizenship loses its value; and a global government is established to deal with the greater international issues.

Everyday people live in large urbanized areas with dense national and international transport routes. They live in a market-base economy and a globalized society. They are aware of the fact that every human being is equal and their only way to live a decent life is to achieve high level education. This way they can earn enough and put aside for their elder years. Due to advanced technology in health care and developed medical science, patients are easily cured and are able to live a longer and healthier life than today. Small families with one or no children are common, as government policies favor a decreasing global population trend. People are surrounded by an individualistic global culture, where ones family roots do not matter only the person's capabilities and educational background. The different languages slowly disappear and only one remains: English or Chinese.

Figure 1 Dynamics of migration in scenario A1



Source: author

In the beginning, as population increases mostly in developing regions and the price of travelling starts to drop, masses of people will start migrating: first to the closest urbanized cities, then to developed regions. As local national and political tensions tone down and local infrastructure is built up, there will be few obstacles left for companies to erect factories, and invest in local agriculture (more people with bigger budget demand more healthy food for which new territories need to be cultivated). The bigger urbanized world requires more energy and no matter which will be used in great majority (coal, oil and gas, renewable with nuclear energy, or a balanced mix of these), the developing countries rich in energy will obtain the attention of energy producing companies, thus earning external investments for the country's development and the increase in the domestic average level of per capita income.

The mobility of people increases greatly due to advanced and dense transport facilities. Just as governments and international institutions realize that the best way to decrease the gap between the affluent and the poor of the world is to enhance local education and create a strong international educational net which arms each student with enough opportunities to find a good job and live a decent life. Asylum applications and illegal migration will decline globally, and legal migration will change in character. A typical migrant will have a good educational background, capable of speaking English or Chinese, and will represent a good workforce for companies all over the world. It might as well happen, that the global government later orders all the basic telecommunication and traveling services to be free of charge, this way, too, contributing to higher economic performance.

The global government will support and sponsor primary, secondary and higher education and research in less developed countries until the community develops to a level where no additional support will be needed. As a consequence, the current distinctions between "poor" and "rich" countries will eventually dissolve and less people will strive for leaving as they find enough opportunities in their home region, too. Nevertheless, the slowly aging population of the western world will create a great demand for young employees coming from the developing world. This too, contributes to higher migration in the world.

7.4 Scenario A2 - A more divided world

The storyline of scenario A2 shows a divided world, where the different regions concentrate on the substantiation of a self-reliant economy with their own energy and food resources. Firstly, the scenario will be illustrated according to its original description in the IPCC Special Report on Emissions Scenarios (2000). Secondly, parallel to its further development, the migration implications of the scenario in question will be expounded.

Description of scenario A2

The A2 scenario family represents a heterogeneous world. Compared to the A1 storyline, it is characterized by lower trade flows, relatively slow capital stock turnover, and slower technological change. It consolidates into a number of economic regions which are self-sustainable in terms of resources. Economic growth is irregular. The income gap between developing and presently industrialized parts of the world does not narrow, unlike in scenarios A1 and B1.

The A2 world has less international cooperation. Technology diffuses more slowly because people, ideas, and capital are less mobile. International disparities in efficiency, as well as income per capita are for the most part maintained or increased in absolute terms. Fertility rates decline relatively slowly due to the emphasis on family and community life, which makes the A2 population the largest among the storylines (15 billion by 2100).

Relative to other storylines, global average per capita income is low in this scenario, reaching about US$ 7200 per capita by 2050 and US$ 16,000 in 2100. Global GDP reaches about US$ 250 trillion by 2100. Technological change in scenario A2 is also more diverse than that in A1. It is faster than average in some regions and slower in others, as the industry adjusts to local resource endowments, culture, and education levels. Resource intensive economies will be only developed in regions with abundant energy and mineral resources. Countries poor in resources through technological innovation improve resource efficiency and make use of substitute inputs. They place a priority on minimizing import dependence. High-income but resource-poor regions orient toward advanced renewable or nuclear technologies, while resource-rich regions with low-income generally rely on older fossil technologies. In this scenario, final energy intensities decline with a pace of 0.5 to 0.7 % per year.

Social and political structures diversify in the A2 world, with some regions moving toward stronger welfare systems and reduced income inequality, and others towards a more diverse income distribution and leaner government. Due to substantial food requirements, research and innovation in the A2 world is mainly directed toward agricultural output. The attention given to potential environmental damage is not uniform across regions and global environmental concerns are relatively weak. Strengthening protectionist trade blocks could slow down economic growth and there is a likelihood that regional spheres of influence will develop.

The authors of the IPCC report (2000) emphasize the neutrality of each storyline, involving scenario A2. All can have their positive and negative sides. Scenario A2, for example, has an increasing tendency toward cultural pluralism and the acceptance of diversity and basic differences.

Description of scenario A2 and the analysis of its implications on migration

Though the second scenario is focused mostly on economic performance, because it is regionally divided, it can only accomplish one of the lowest global GDP targets by 2100. The division of the world is so deep-rooted in this scenario that the different regions concentrate on self-sustainability only. This already predicts that in this scenario global mobility will be much lower than in the previous one.

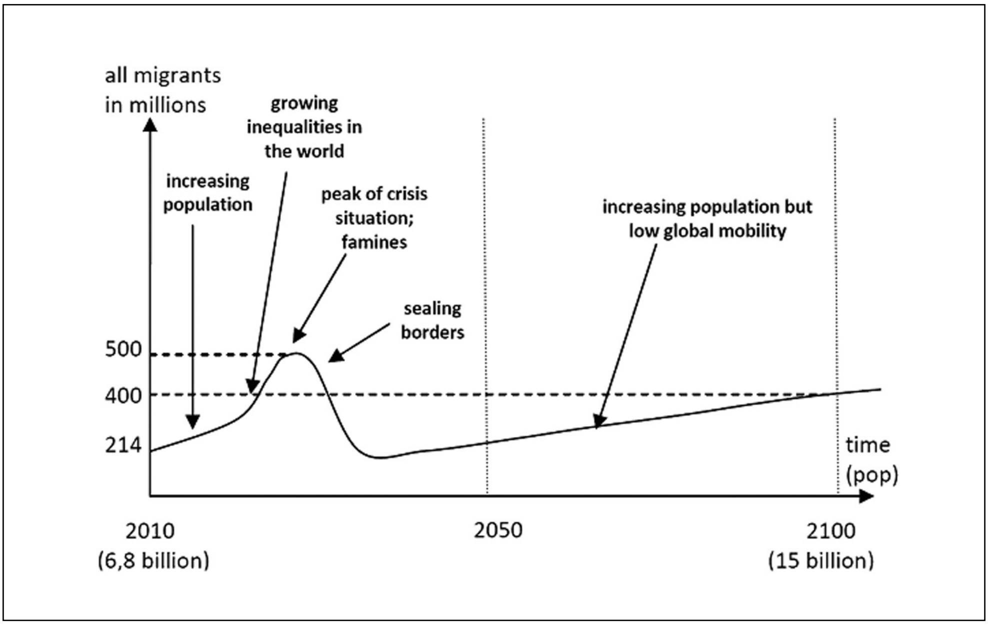
The fraction of different regions in the future, according to this scenario, can be triggered off by several possible causes. The most likely cause is the inflammation of the present division between the developed and the developing world parallel with the strong isolation and protectionist policy of the affluent part of the world. If the developed countries continue to exploit the environmental resources and human capital of the developing world without investing in local economies and infrastructure, and they refuse to admit the growing number of refugees and migrants from these parts of the world (as another way of alleviating poverty in developing countries), it is possible that the world will be divided into two parts: the "rich" and the "poor".

The population of the South rises sharply and there will be more and more migrants moving to the North. Due to intensifying conflicts within the population of the developed world between the newcomer immigrants and the locals, the developing world might take over and/or destroy the valuable assets of Western multinational companies on its territory to put an end to the exploitation of its resources. As a response, the developed world might totally seal its borders not letting anything or anybody through. A strong and deep-rooted conflict arises that is unlikely to result in war, but which creates two different worlds in one.

The reason why this cause of division is the most probable is that being a developed country or a developing/underdeveloped country is easily connected to a larger territory or continent. For instance, North America and Europe would represent the North and all the others the South which could naturally further divide into subgroups according to sub-dimensions, too. Other causes of division could be religion and culture, or according to Huntington (1996), conflicts between civilizations may as well determine the geo-political future of the world.

The main dimension of scenario A2 is that it is about a divided world, though the reason for this division is rather marginal. It is about a closed world where communication between the different regions is undesirable and rare. As the previously well functioning system of global division of labor ceases to exist, nation states might fall in a crisis; they fail to fulfill their original roles as a state. These roles are taken over by local communities in developing regions and other forms of organizations, such as city-states in developed regions. International cooperation transforms into inter-territorial or interregional cooperation. International institutions disappear. Possibly global cyberspace will devolve into several regional internet networks accessible only from the actual region.

Figure 2 Dynamics of migration in scenario A2



Source: author

Regions and countries will self-organize and local communities will be the main, most basic and cohesive cell of less developed regions. People might as well be organized into modern clans as they realize that cooperation with the group is their only chance for survival. Family and social relationships bare great value for the individual in this scenario. Clans or groups of people will cooperate and organize the life of the community. Through division of labor, these communities would coordinate and rationalize food and energy production, infrastructure building, health care, education, and so on. Since family connections are of great importance for the people, there might be a possibility for the clans or groups of people in less developed regions to take up matriarchy. The priority of a woman led community is the security of the offspring and the group. It is less likely for women to engage in a conflict or war than for men, so for the sake of peace between groups of people who all share harsh survival life conditions it is healthier to let women decide about politics.

Developed regions have many cities and urbanized areas. These regions will supposedly have a serious crisis when food disappears from the shelves of shops and supermarkets and urban citizens massively migrate from big cities to the suburbs and villages where they might find food. This chaos will be dealt with by the government or the military but it should not last long. Through serious research and technology development, people will find new ways to feed the urban population. With the establishment of a complex control system, order and discipline can be sustained in cities, too; however, it is more probable that the urban population of the world will migrate to yet unpopulated areas close to other communities. Once equilibrium is reached after the transition, global peace will be self-sustained thanks to the family-oriented local communities.

Technology development is the slowest in A2 compared to other scenarios, but it is a priority. Efficiency is weak because people, ideas and capital are almost immobile in this world, thus the fruitful cooperation of scientists coming from different cultures and circumstances is missing. On the other hand, population is rising (especially in developing regions) and all people have to be fed properly. There is a great urge in local communities to survive, thus they need to find ways to provide enough for all members. Food production is one of the main driving forces of technology development, but people also need to find ways to develop high-tech agriculture (if they have little territory as Japan), new energy sources or technology (if the territory is weak in natural energy sources or the contamination of the air or sea is too high), and strong infrastructure (if natural disasters are common in the region). Local communities living in territories with abundant natural resources will obviously evolve more resource-intensive economies, while those with less will find alternative ways and methods to compensate for it.

Scenario A2 envisages a great transformation of the world as we know now. Regional division creates a heterogenic world with many local communities and city-states which are characterized by different mixes of religion, culture, races and language. First, regional borderlines will be prohibited to cross and international transport will cease to exist. Second, masses of people will migrate until they settle down and form self-sustainable local communities.

7.5 Scenario B1 - A more integrated and more ecologically friendly world

The storyline of scenario B1 represents an eco-friendly future and an integrated and convergent global world. International cooperation and sustainable development are key features of this future. Firstly, the scenario will be illustrated according to its original description in the IPCC Special Report on Emissions Scenarios (2000). Secondly, parallel to its further development, the migration implications of the scenario in question will be expounded.

Description of the B1 scenario

The primary characteristics of scenario B1 are a high level of environmental and social consciousness and a globally consistent approach to sustainable development. Governments, businesses, the media, and the public pay increased attention to the environmental and social aspects of development. Simultaneously, technological change plays an important role.

Economic development is balanced in the scenario and income distribution is more and more equitable through time. It describes a fast-changing and convergent world; nevertheless, the priorities differ from the ones found in A1. Whereas the A1 world invests its gains primarily in economic growth, the B1 world invests a large part of its gains in improving the effectiveness of resource use, social institutions, equity, and environmental protection.

Social exclusion on the basis of poverty is prevented by a strong welfare net. However, in some regions people may not conform to the main environmental and social intentions of the majority. World markets and economic efficiency may be adversely affected by high taxation levels and massive income redistribution.

An increase in resource efficiency is a major factor in achieving the goals stated above. Incentive systems and advances in international institutions promote the diffusion of cleaner technology. New organizational measures are adopted to reduce material wastage by maximizing reuse and recycling. This, together with technical and other organizational changes contributes to high levels of energy saving, and reductions in pollution. As a by-product, labor productivity improves.

Global population reaches 9 billion by 2050 and declines to about 7 billion by 2100. Though demographic transition to low mortality and fertility occurs at the same pace as in the A1 scenario, it happens for a different reason: it is motivated environmental and social concerns. This world has high levels of economic activity, and makes significant progress toward international and national income equality. Global income per capita averages US$ 13,000 in 2050 and global GDP reaches about US$ 350 trillion by 2100. As the emphasis on material goods is less and resource prices are increased by environmental taxation, more income is spent on services than on material goods. Quality becomes more important than quantity.

The B1 storyline sees a relatively flexible transition to alternative energy systems as conventional oil and gas resources decline. There is an extensive use of natural and unconventional gas during transition period, but the major push is toward post-fossil technologies, driven in large part by environmental concerns. Environmental quality is high due to high environmental consciousness and institutional effectiveness. Most potentially negative environmental aspects of rapid development are effectively dealt with on local, national, and international levels. Cities are compact, suburban developments controlled. Infrastructure is designed for public and non-motorized transport. Low-input and low-impact agriculture contributes to high food prices with less daily meat consumption per person than in scenario A1.

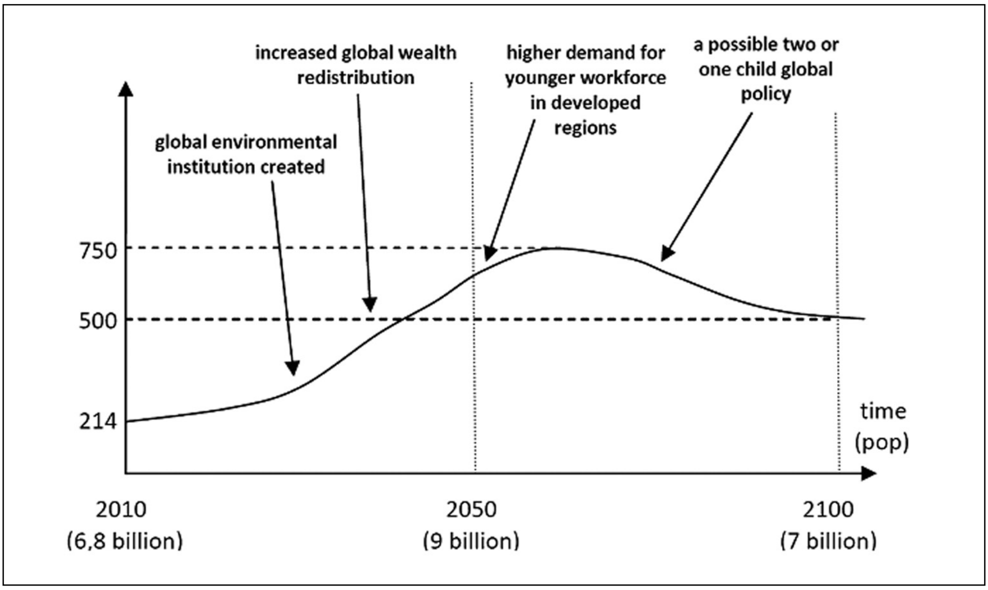
Description of scenario B1 and the analysis of its implications on migration

The trigger of scenario B1 is the awakening communal responsibility of humans. People start seeing the evidence of accelerated environment depletion around them (e.g. deforestation, soil depletion, over-fishing, and global and regional pollution) and they decide not to follow the same path. They kickoff local civil movements to promote an eco-friendly economy and lifestyle and they engage in the work of international environmental organizations, such as Greenpeace. The internet and the media contribute to the quick spread of this eco-movement and in the end it becomes a global priority to restore and preserve natural resources.

The popularity of national green parties start to grow in an increased scale among locals and they start to gain majority in national parliaments. For the purpose of conducting such a world-changing mission, serious political, social, and financial support is needed. The strengthened social awareness of environmental problems and the strong will to take action grows, and finally it appears on the global "circus floor". First, politicians and capitalists are forced to take action by the public, than they simply realize their potential individual gains in this trend that greatly stimulates economic growth.

As this issue represents a possible threat to the future of humanity (because the final degradation of nature can seriously damage the quality of life on Earth) the national governments within the institutional framework of the United Nations decide that stronger international cooperation is needed in order to achieve specific results. A global institution is established with supranational authority to decide upon a global environmental policy. It builds up a complex plan to transform the world into an eco-friendly and sustainable one. It will levy a global tax on every person in the world, the amount of which will depend on the assigned development level of the country they are residents of. It will be the task of national governments to collect this tax together with the traditional national taxes. This way the capital needed to finance the transformation process will be secured step by step. The global institution will create ways to restore depleted natural resources and to save species that are on the verge of extinction; furthermore, it will command the public sector and urge big multinational companies to invest in technology development in order to find new and environment friendly ways of human lifestyle. Creating this new eco-friendly and sustainable world economy becomes a task that will unite people from all over the world. A new global economic "order" will be created.

Figure 3 Dynamics of migration in scenario B1



Source: author

Conventional cities will be transformed into compact smaller ones designed for public and non-motorized transport, with suburban developments tightly controlled. Traditional means of transport will be replaced by new technology based no-emission vehicles, motorcycles and airplanes (powered by electricity, hydrogen, or nuclear energy etc).

Economic growth will be fuelled by new green technologies entering the market and the push of their obligatory usage in both public and private sphere. As a consequence, this world will undergo rapid changes in global economic structures. People will get accustomed to the new lifestyle where quality is more important than quantity, where natural resources are distributed in a more egalitarian way, where the basic needs of each person are fulfilled and children get free and compulsory education. The B1 storyline is the opposite of the A1 storyline, which foresees a materialistic consumer society where the individual is in the centre of attention.

The storyline of scenario B1 is characterized by high taxes and an increased level of global wealth redistribution. As fast population growth, especially in the developing and underdeveloped regions, represent a threat to the sustainable capacity of the environment, the supranational global institution might introduce a two or one-child policy in the world parallel to providing the basic needs for those in need. This also explains the low population growth of this scenario. A reformed primary education system, which is the same all over the world, represents one of the milestone projects of this global institution because it plans to educate the future generations in a right way so that after the few decades of transition, the created eco-friendly world order will be sustained.

Since this storyline is about a highly globalized world, the migration and the movement of people will be common through border lines and it will reach a medium level compared to other scenarios. As the reformed educational background will provide the migrants with the most important capabilities and language knowledge (English), they will not represent a heavy weight on the receiving community's social system. The development of infrastructure and travelling system based on green technology will further enhance global migration. Furthermore, the slowly aging population of the western world will create a great demand for young employees coming from the developing world. This too, contributes to higher migration in the world.

7.6 Scenario B2 - A more divided but more ecologically friendly world

The storyline of scenario B2 represents an eco-friendly future in a regionally divided and fragmented global world. Environmentally aware citizens and community-based solutions are the key features of this storyline. Firstly, the scenario will be illustrated according to its original description in the IPCC Special Report on Emissions Scenarios (2000). Secondly, parallel to its further development, the migration implications of the scenario in question will be expounded.

Description of scenario B2

The B2 storyline represents a world which is one of increased concern for environmental, social and economic sustainability. Government policies and business strategies at the national and local levels are increasingly influenced by environmentally aware citizens, with a trend toward local self-reliance and stronger communities. International institutions lose their importance. Local and regional decision-making institutions take the lead instead. Community-based social solutions and technical successes endorse the priorities of this storyline: human welfare, equality, and environmental protection. The storyline of scenario B2 appears to be consistent with current institutional frameworks in the world and current technology dynamics. However, it is characterized by a relatively slow rate of development.

The widely pursued education and welfare programs reduce mortality and fertility to a lesser extent. The population reaches about 10 billion people by 2100 which is consistent with the United Nations projections. Income per capita grows at an intermediate rate, and it reaches about US$ 12,000 by 2050. By 2100 the global economy might expand to reach US$ 250 trillion. Income differences decrease internationally, although not as rapidly as in more globalized storylines. Through the development of stronger community-support networks, local inequities are reduced considerably.

Educational levels rise in average and they promote development and environmental protection – the latter being the only truly international common priority in the B2 storyline. Nevertheless, people do not intend to address global environmental challenges in the first place. They prefer to create strategies to address environmental challenges at the local and regional levels, thus these being more successful, too. It is difficult for governments to design and implement agreements that combine global environmental protection, even when this could be associated with mutual economic benefits.

The B2 storyline represents an especially prosperous climate for community initiative and social innovation – particularly in view of high educational levels. Technological frontiers are pushed less than they are in A1 and B1 scenarios, and innovations are also regionally more heterogeneous. Investment in research and development about energy declines globally. Regions with high economic growth and limited natural sources place an emphasis on technology development and bilateral cooperation, while regions that are abundant in natural resources do not engage in technology development at such a scale. Therefore, technical change is uneven. The energy intensity of GDP declines at about 1 % per year, in line with the average historical experience since 1800.

Community innovation puts a particular emphasis on urban and transport infrastructure and it decreases the level of car dependence and urban sprawl. People aim at food self-reliance so they try to consume more and more local products. Countries with high population densities have dietary patterns with less meat.

Depending on the availability of natural resources, energy systems differ from region to region. In some, the need to use energy more efficiently (due to the lack of natural resources) spurs the development of less carbon-intensive technologies. A gradual transition occurs towards non-fossil energy resources in world energy supply, though the energy system remains a predominantly hydrocarbon-based system until 2100.

Description of scenario B2 and the analysis of its implications on migration

The trigger of the B2 storyline is the same as of B1: people realize the high level of environment depletion locally and they start off community initiatives to deal with the problems locally. The great difference between the two scenarios is that while in the B1 world this bottom up initiative grows into a supranational global institution dealing with environmental sustainability, the B2 world remains fragmented and its citizens and international politics do not seek a global solution. The B2 storyline is the continuation of the present. It is characterized by the cooperation of (nation) states and a weak international framework. The slowest economic growth compared to other scenarios and its medium level yet uneven population growth ensures that countries evade stronger forms of international cooperation. Substantial steps towards economic, social and environmental sustainability are taken at community level.

The more a territory is hit by the effects of global warming (e.g. deforestation, soil depletion, over-fishing, and global and regional pollution), the more the people living there will become concerned about their environment and about the future of their children. It can be foreseen that the citizens of small coastal and island countries, economies dependent on fishing or on agriculture will be the first to seriously deal with the environmental issue. It is unlikely that now developed countries will take their share of responsibility for the effects of global warming, but it is possible that the developed private sector will step by step realize the potential profit in eco-friendly products due to the growing demand of the global market. Nevertheless, big multinational companies are likely to use their lobby force in the public sector to slow down the introduction of eco-friendly measures. The reason for this is that not letting the (former) product life cycles to evolve in the market and reach the maturity and decline phase[42], and the reorganization of the production lines for the new

[42] The phases of product life cycle are the following: development, introduction, growth, maturity and decline. The development of a product is considered profitable if it goes through all the five life cycles.

products based on different technologies both represent a great financial burden for multinational companies. Thus it will not be the private sector to lead environmental friendly technological change but community initiatives.

The B2 storyline has a weak international institutional framework which is more like a camouflage as these institutions are not given sufficient power and authority to implement decrees at national levels. Representatives from mostly all governments around the world do not reach a compromise due to their stubborn attitude and will not give in. As the uncooperative attitude becomes the attitude of most countries on the global political arena, the groups of issues the international institutions engage in decrease to a single one: environmental protection. This theme remains the one which loosely but surely keeps alive international political cooperation.

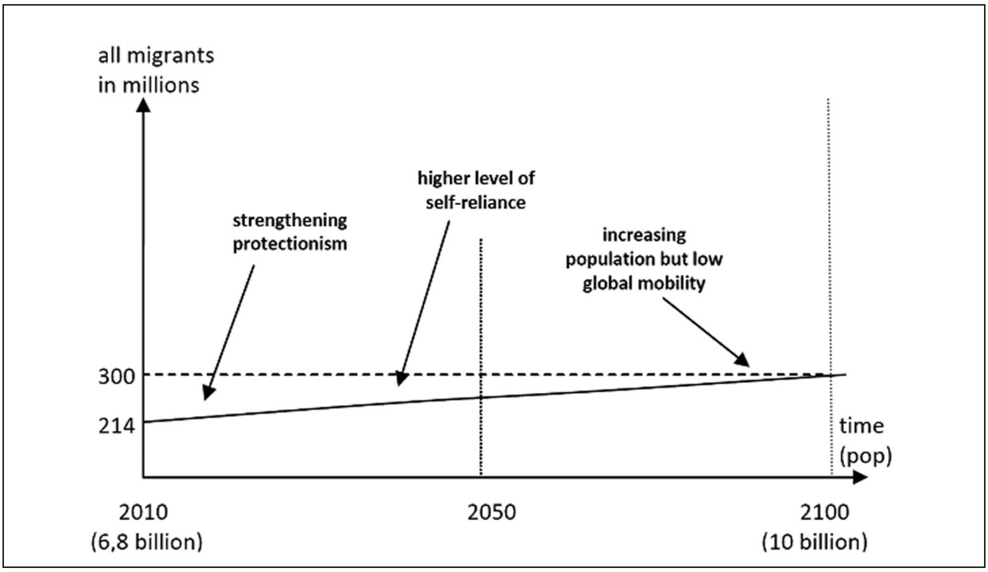
The regionally divided world of scenario B2 is based upon the strong and cohesive communities of environmentally aware citizens. The aging/growing population, health care, pension system etc. begin to represent a growing burden for governments all over the world and the welfare system might fall in crisis as well. Not only international cooperation but also problem-solving ambitions at a national level fail, too, due to weak economic ambient. This is the reason why local communities become the basis of this scenario.

Ideas, innovation, capital, and people will become less mobile globally because of the divided nature of this scenario. The globally slower economic growth and the failure of international cooperation result in countries closing up their borders towards most migrants and asylum seekers. It is probable that illegal migration will increase and more and more environmental migrants will appear due to the more frequent environmental disasters.

The uncooperative and sometimes violent global environment forces countries to create self-reliant economies and minimize import dependency. Technology improvement is slow due to ideas, innovation, capital, and people being less mobile globally. Local communities adopt a proactive approach to their unique local problems: in the beginning, -small-step innovations mostly come from the society and not the public or private sector. Bigger communities (cities) mostly in now developed countries are transformed as urban transport is modernized to be more eco-friendly and sustainable. Communities realize their vulnerability and dependence so they determine to reform themselves to be self-reliant (on food and energy) in an environmentally friendly way, if possible. The education system gets a lot of attention everywhere.

This divided world can evolve in positive and negative ways: it can be a world where governments are able to implement reforms to fight the economic, social and environmental problems coming in the future, or it can be a world where governments turn out to be inadequate as they postpone cardinal reforms and decisions too much. Naturally, the outcome depends on how each country will handle the problems in a bad economic situation.

Figure 4 Dynamics of migration in scenario B2



Source: author

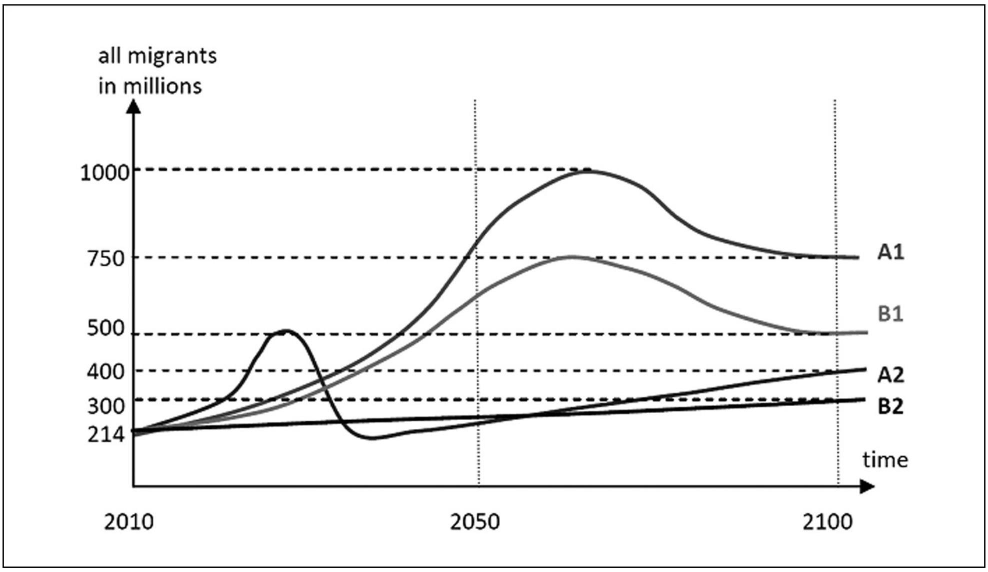
7.7 Scenario summaries

We can lay down the following observations: both of the two globalized worlds (A1 and B1) are having high economic and low population growth; the two fragmented worlds (A2 and B2) are characterized only by slow or medium technology change; the first scenario (A1) has the highest economic growth together with rapid technology change but one of the lowest population growth rates. Moreover, even an environmentally friendly world (B1) can reach high economic growth.

This section demonstrates a comparison between the different migration trends of each scenario. It disregards migration within countries and it pays attention only to international migration (both legal and illegal) with all asylum seekers, economic migrants, environmental migrants, tourists etc. – as long as they cross borders. The international migration identified here are not quantified because of (1) the high uncertainty that lies behind forecasting for the next 100 years, (2) the complexity of the six models used in the original scenario building (apart from them being unavailable for the author), and (3) because sometimes less information is more useful.

The comparison of the different migration trends is based on four elements: the two main dimensions of the scenarios mentioned in the beginning of this chapter, the respective population growth rates, and the author's reconstructed storylines. The two main dimensions of the scenarios are the global-regional dimension, and the economic-environmental dimension. The following figure represents the international migration forecast for each of the four scenarios.

Figure 5 Dynamics of migration in all scenarios



Source: author

Scenarios A1 and B1 reach higher migration levels in the long run because they represent a globalized world with less international barriers and more international mobility possibilities for people. Though both have low population growth levels and they reach a target of 7 billion people by 2100, their migration trend is different. According to the storyline of A1, it reaches the highest economic growth level from all scenarios based on rapid technology change. Furthermore, in both cases, the advanced and dense transport facilities allow travelling costs to decrease greatly. The globally but gradually introduced modern education system in scenario A1– which puts an emphasis on the international exchange of students – also contributes to higher migration levels. Scenario B1 has a high GDP growth rate but because it characterizes a more environmental friendly world (which means that the prices of natural resources are increased artificially to a high level), it can accomplish only a medium rate of technology change. However, after the global economy "greens out" totally (it runs on unlimited natural resources, for example wind or solar energy), and this green technology slowly diffuses to all regions in the world, the growth rate of international migration will decrease. Due to population decrease after 2050, the levels of migration will fall in both scenarios. Also, we could suppose that an aging population is less mobile compared to a young population.

Scenarios A2 and B2 reach lower migration levels in the long run because they represent a regionally divided world with limited or sometimes "forbidden" international movement. Thus, international mobility possibilities are small. However, these two scenarios, too, have different migration trend lines. While the total number of migrating people in scenario A2 reaches a peak very fast compared to other scenarios, the migration trend of scenario B2 shows the same trend of slow international mobility in the long run. The answer to this difference can be found by studying their storylines. Scenario B2 is the one most similar to the world today: the level of international cooperation is low and international migration is restricted. If this migration policy remains the general policy for most of the countries, than even with 10 billion people by 2100, migration patterns will not change much – i.e. international migrants as a percentage of the global population will decrease, which is in line with the divided and protectionist nature of this scenario. What is more, with more people in the world who can afford overseas transport, migration policies will also have to be stricter than they are today. It is probable that illegal migration will increase and that more and more environmental migrants will appear due to the more frequent environmental problems and disasters.

The migration trend line of scenario A2 shows a steep pump out in the beginning of the period studied. It portrays the "crisis" between the developed and the developing world caused by the protectionist policies of the affluent part of the world. The exploited developing world bans natural resource allocation and trade with the dependent developed world. Due to this, a chaos situation evolves detailed in the storyline. Later, this mass movement of people will level off and the average level of global migration will be fuelled just as in scenario B2. The only difference being that scenario B2 will hold two thirds of the population of scenario A2 by 2100 (10 billion and 15 billion respectively). This explains that there are more migrants foreseen in the latter storyline.

The possibility of these four scenarios has not yet been discussed. Globalization is a far reaching trend in history; we could even say that apart from some exceptions, globalization characterized the last few centuries of humanity and it grows at an accelerated pace. This is the reason why this chapter claims that the two globalized versions of the scenarios, A1 and B1, have a higher possibility of coming true than the two other scenarios about regionally divided and heterogeneous worlds, A2 and B2. Unless, a disturbing and trend-breaking event happens that has a bigger impact than the two world wars –since even after the world wars the political segmentation of the world was able to dissolve.

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Gergely Rezessy

8. Weather derivative markets

8.1 The beginning of weather derivatives trading[43]

The main use of weather derivatives is to hedge against weather related risks for a period shorter than one year. The over-the-counter (OTC) market of weather derivatives dates back only to 1997, when the first deal was struck between the now notorious Enron Corporation and Koch Industries (Brockett et. al., 2007). The exceptionally cool winter in 1997/98, due to the strong El Nino effect that year, pointed to the fact that weather risk is a real threat to the revenue and profits of enterprises and gave momentum to the development of the weather derivatives market. Before that, the only way to hedge against weather risk was to purchase insurance policies from insurers. However, as a logical consequence of the convergence between the insurance and the securities markets, the general trend of securitization and increasing counterparty risk the trading of weather derivatives started on the Chicago Board of Trade – which is now a part of the Chicago Mercantile Exchange (CME) – in 1999 (Considine, 2000). According to the estimate of the U.S. Department of Commerce, 30% of the United States' economy but at least US$ 1 trillion of revenues is exposed to weather risks.[44] CME estimates that about one third of the US economy is affected by weather risk (CME, 2009), which translates into more than US$ 4 trillion calculating with the US annual GDP number in 2010. Compared to these numbers, the traded volume of weather derivatives is still relatively low, meaning that there is significant space for market growth in spite that the weather market grew considerably since the second part of the nineties. According to a survey of the Weather Risk Management Association (WRMA), the annual volume of weather derivatives was US$ 19.2 billion in 2007 (USA Today, 2008), which means a sharp decrease after the US$ 45.2 billion peak volume in 2006. However, it is still considerably higher than the US$ 9.7 billion in 2005 and the US$ 4.7 billion in 2004. According to WRMA data, the sharp rise from the 2006 volume is due to the busier trading on the CME, while the value of deals on the OTC market slumped somewhat (WRMA, 2008). The lower volume in 2007 was a result of less extraordinary weather events

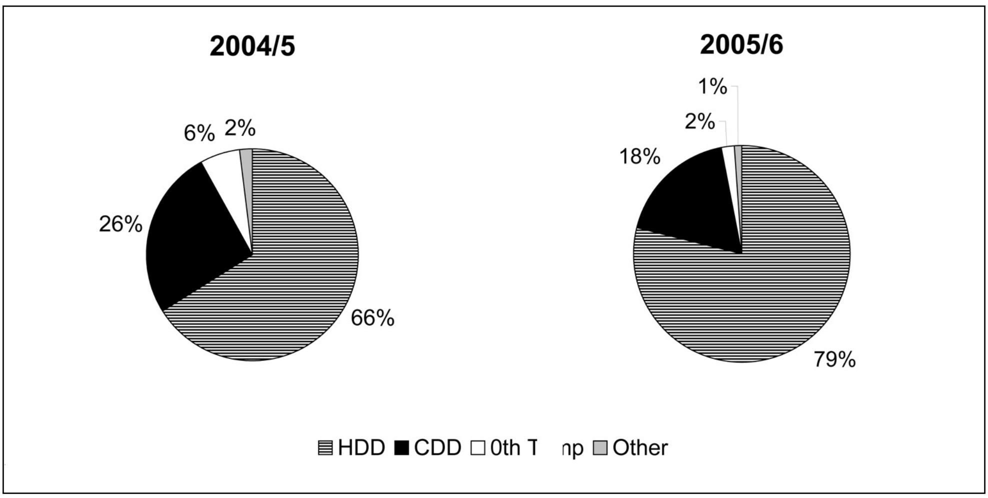
[43] The author was supported by TAMOP-4.2.1.B-09/1/KMR-2010-0005 project in the research for this paper.

[44] Source: http://www.guaranteedweather.com/WeatherRisk.aspx, downloaded on 13 March 2011

than during the preceding years, however, this temporary pullback did not affect the longer uptrend in the volume of weather derivatives. A big part of the trading activity was transferred, however, from the OTC market to Chicago attracted by the liquidity on the CME created by speculators and other market players. As trading became more intense on the weather market, the composition and the relative weight of market players changed as well. It will be discussed in more detail in the third section.

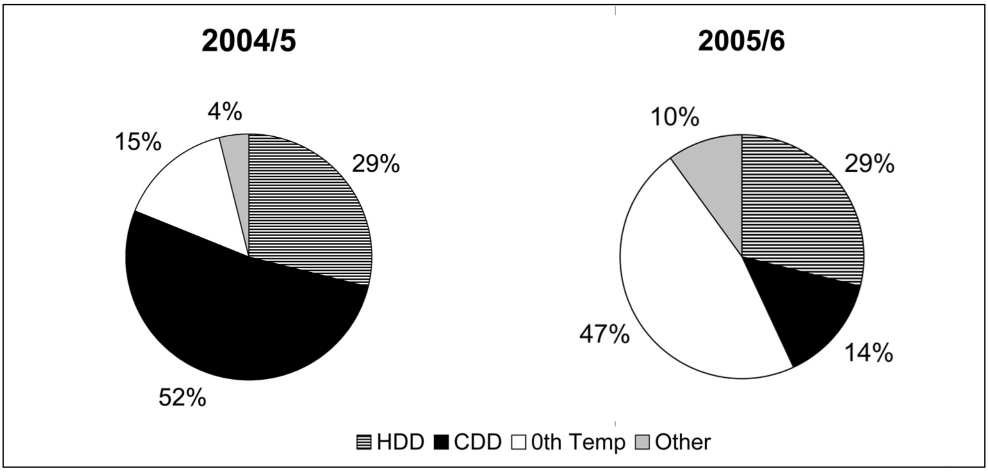
As it was mentioned, the bulk of the trading volume is on the CME, where only standard products are traded. Among them, the most important weather products are the temperature derivatives. Traders have access also to hurricane, frost, snowfall and rainfall contracts. Around 98-99% of the trading volume, however, is generated by temperature contracts (Garman et al., 2000), so we will concentrate mainly on these products when talking about the pricing of weather derivatives. Figure 1 shows the composition of the traded volume on the CME and the OTC market combined by product types; figure 2 shows the same composition for the OTC market alone. Both figures show data taken from a survey conducted by PricewaterhouseCoopers in 2006. It can be seen quite clearly from the figures that on the CME the share of temperature products is overwhelming, while on the OTC market temperature products are the most heavily traded product category, however other products also have a significant proportion. Other products, however, still had only a 10% share in the OTC market in 2005/6.

Figure 1 Total notional value of weather risk contracts by product types



Source: PricewaterhouseCoopers, 2006, http://www.wrma.org/members_survey.html

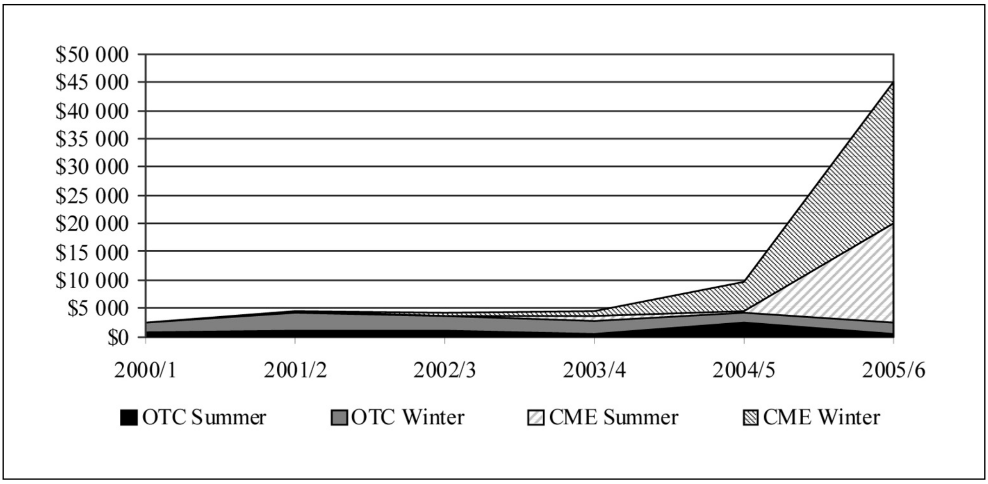
Figure 2 Notional value of weather risk contracts by product types on the OTC market



Source: PricewaterhouseCoopers, 2006, http://www.wrma.org/members_survey.html
Note: On both Figure 1&2 HDD stands for heating degree days, while CDD stands for cooling degree days. Both represent standard temperature products based on HDD and CDD indices. These will be explained in more detail at the pricing of weather products in section 5.

The increasing liquidity on the CME (see Figure 3) also attracted hedge funds to the market. According to big market players, hedge funds nowadays have a key role in the weather market. In practice they act as market makers, meaning that they guarantee liquidity if anyone wants tobuy or sell large quantities at the market price, so big trades will not change the market conditions if no other event occurs at the same time. A considerable part of the volume is generated by hedgers who intend to eliminate weather related risk, stemming from their natural exposure to commodities (e.g. mining and energy companies), as weather has an impact on the price of a wide range of commodities from agricultural products to energy products like heating oil, natural gas and electricity. This kind of trade is called cross-commodity hedging (Cundy, 2007). Another part of cross-commodity trading is done by speculators who look for temporary discrepancies between the two markets which can provide trading opportunities for them. As most players are active on both the weather and the commodity markets we can assume that the increasing volume on weather markets is at least partly due to heavier trading of some commodities.

Figure 3 Total Notional Value of weather risk contracts (in millions of U.S. dollars)



Source: PricewaterhouseCoopers, 2006, http://www.wrma.org/members_survey.html

8.2 Directions for further development of the weather market

The first factor which is likely to spur the growth of the weather derivative market is global climate change, which is supposed to increase weather related risks worldwide. While the increasing emission of greenhouse gases and global warming are the first to come to our mind when we talk about global climate change, it also seems to make extreme weather events more frequent, alter precipitation patterns in space and time and weather could also become harder to predict as a result. All that would make it more important companies to hedge their weather related risks.

Another factor behind the increasing volume of the weather derivative markets is the growth of the alternative energy sector which is expected to accelerate in the future as conventional energy sources will become increasingly scarce and expensive and as safety concerns regarding nuclear energy will be more serious. While both the conventional and the alternative energy sector is affected by weather, the latter is much more exposed to it as in its case not only energy demand but also energy supply is influenced by weather. We should just think about wind energy for example, which is very dependent on wind conditions, solar energy which is dependent on the amount of sunny hours per year or hydropower which depends on precipitation levels (Cundy, 2007). As a result the spread of alternative energy production will also increase the demand for hedging against weather related risks.

Another source of growth could be the involvement of the developing world in the trading of weather products. That would be an absolutely rational mve as agriculture has a much higher share in the economy of developing countries, so these countries face much more weather risk proportionally to the size of their own economies than developed countries. Yet these risks remain mostly uninsured today in the developing world. Consequently these countries could reap tremendous gains by starting to hedge against weather risk faced by their agricultural sectors. Moreover, that would not only mean pure economic gains but could save many lives in a lot of cases. The main reason why these risks remain unhedged is of course the lack of sufficient funds and technical expertise to be able to buy such policies or contracts on weather markets. These countries are not only poor and heavily dependent on agriculture, but their agricultural sector is underdeveloped. First of all land sizes are generally small as a high proportion of the population works in the agricultural sector, each owning a relatively small agricultural property. Therefore, owners of small pieces of land using outdated production techniques cannot pay for insurance at all. This serious problem can be alleviated by the action of international organizations; one possible way to help could be to use weather products. This will be discussed in section 7 in more detail. At the same time private insurance companies also have a strong interest to enter the market of developing countries to increase their global market share and their profitability. When these companies start to take on more and more risks in these countries, eventually they will want to pass on a part of it, which can be done through reinsurance but also can – above a certain market size and favorable market conditions – create the demand for standard weather products tracking weather events in certain regions of developing countries. These standard products can be traded on exchanges. An example for the growing importance of developing countries is the acquisition of the Indian Yes Bank by Swiss Re in 2006. The goal of the deal was to provide insurance products for small Indian farmers by combining the good local customer relations of Yes Bank and Swiss Re's expertise on the weather markets. Other companies with a good knowledge about the market also report the growing geographical reach of the market, mentioning Africa, South-America and other developing regions besides Asia (Cundy, 2007).

Another way to alleviate weather risk – which has not been discussed so far – is to sell catastrophe bonds. Such bonds were first issued by insurance companies to reduce their risk exposure by spreading it to others who are willing to take it for compensation. So catastrophe bonds were an alternative of reinsurance policies, a way to securitize risks by insurance companies. The most important difference between the two is that reinsurance can be bought only from reinsurance firms, while catastrophe bonds can be sold to a much wider public. Those who buy the bonds agree that in the case of a certain catastrophic event they will lose their investment or a part of it, or even the annual yield of that year. In exchange, however, they can reap higher than normal returns in those years when there is no extraordinary event. More developed catastrophe bonds combine several regions' risks. In this way, they reduce the risk of investors by forming a portfolio from regional catastrophe risks. Governments and international organizations have also issued catastrophe bonds. Mexico for example financed the foundation of a catastrophe fund by issuing such bonds; the fund is used to alleviate losses in case of earthquakes, floods and tropical storms. The World Bank started the "MultiCat" program in 2009, which makes it possible to bundle many countries and many catastrophe types together in a single bond program to further diversify risks and to reduce the cost of financing of the program this way (ICLEI, 2011).

8.3 Players of the weather market

Players of the weather market have different roles in the operation of the market and different motivations to enter it. Market makers are those big players who guarantee fair prices on the market at all times, even when the liquidity is relatively lower and as a result prices could significantly differ from the fair value or it would be hard to trade in larger quantities. These large players use their own sophisticated pricing models and proprietary long-term weather forecasts, which come in varying qualities (Considine, 2000). Brokers serve as intermediaries between the exchanges and market players, they execute trade orders given by their clients. Insurance and reinsurance companies hedge a part of their risk exposure on the market so they can be called the financial end-users of the market. These companies can also act as market makers on the market. Non-financial end-users are those companies which want to hedge their weather related risks; they can come from a wide range of industries (Garman et al., 2000). Currently the biggest volumes are traded by energy companies and utilities, but farmers, retailers, entertainment companies and the tourism sector are also significant players on the market (CME, 2009). A part of these companies – mainly energy traders – use hedge fund-type strategies. International organizations like the UN's World Food Programme and the alternative energy sector also have to be mentioned. A good example for the involvement of the latter sector is the former Merrill Lynch investment bank's wind product which was used during the financing of wind farms. The use of the wind product was beneficial for developers because if they had insurance against unsatisfactory wind speed, they could finance their projects at a lower interest rate (Cundy, 2007). Hedge funds also play an increasingly important role in the market as they try to seek out market discrepancies and profit from those situations. Active individual traders can also be found among market players (CME, 2009).

8.4 Risks associated with weather products

Weather markets are characterized by two types of risks: counterparty risk and basis risk. The first is the risk that the other party becomes insolvent so it cannot fulfill its payment obligation. For example an insurance company cannot pay the insurance proceedings after an unprecedented and unexpected catastrophic event, because its funds are not sufficient to meet its obligations. Another reason behind insolvency could be when an insurance company loses a massive amount of money on its derivative positions. That happened with AIG, the biggest insurance company of the world of the time in 2008. AIG sold insurance against certain bonds' default on the OTC market – in the form of credit default swaps (CDSs) and collateralized debt obligations (CDOs) –, but it was not required to deposit any collateral on this market because it had the highest credit rating. When the company, however, was downgraded it suddenly had to post the collateral. That was well beyond the means of the company, so a government bailout was needed to be able to meet its obligation. It can therefore be seen that those positions were different from positions taken on exchanges as initially it was not backed by any collateral. It was, however, also different from conventional insurance policies which pay only when a certain trigger event occurs. CDSs and CDOs are tradable on the secondary market, so their prices are always changing reflecting the risk associated with each bonds' default. As a result, these contracts are acting like derivatives (futures), not like insurances (or options) and AIG could lose a lot on those derivative positions even when no bond default happened, only the investors' expectations changed dramatically. Therefore, counterparty risk arises when an end-user enters a contract with an insurance company. When trading on exchanges, however, that type of risk does not exist as exchanges have margin requirements (collateral must be deposited for every position) and investors' positions are marked-to-market every day which guarantee that each party's payment obligations are fulfilled regardless of their current liquidity position. The recent crises started in 2007 also proved that deals made on exchanges are much safer than OTC and other non-exchange deals as the fulfillment of those trades was never in question during the crisis. While the world's biggest insurance company, AIG, nearly went bust in 2008 only a government bailout could save it, no exchange had any insolvency issue during the crisis.

The other type of risk similar to exchange traded weather products is basis risk. This stems from the fact that in case of exchange traded products payout depends on weather conditions at a certain geographical location, which can significantly differ from weather conditions at the location where it matters for the buyer. This difference is due to the geographical distance between the two. In case of CME's, temperature product payouts are calculated using the temperature measured at a certain data collection point. Currently CME provides temperature products in case of twenty-four U.S., six Canadian, ten European and three Japanese cities.[45] Other data providers, however, use different methods to produce data, Risk Management Solutions (RMS), a consulting and data provider company, for example calculates ten regional temperature indexes in the U.S., all of which are average temperature data of ten major cities in the region. Temperature products can be constructed also with the use of RMS's regional indices, which can be used more efficiently to hedge weather risks according to Brockett et al. (2007). As these indices are based on data measured in several locations, basis risk is lower than in case of data gathered in a single measurement location. Basis risk can be mitigated entirely by buying a tailor made insurance policy; in this case, however, one has to calculate with a counterparty risk. To reduce both types of risk, exchange traded weather contracts can be combined with insurance policies. Exchange traded contracts should be used to hedge against the bulk of the weather risk while a separate insurance policy can be purchased to mitigate basis risk. This combination can be very useful because, if the company can find an exchange traded product which correlates well with its weather exposure, and the geographical location of the weather products data collection point is not very far from the company's place of exposure, the bigger part of its risk can be hedged with the exchange traded product without taking on any counterparty risk. The remaining basis risk can be mitigated with an insurance which covers only the basis risk, which is considerably lower than the original weather exposure. In this case the entire weather risk is hedged with taking on only a minimal counterparty risk and no basis risk.

8.5 Pricing weather products

On the CME, futures contracts and options on futures are traded. However the pricing of weather options is different from that of ordinary stock options, as the price changes of their underlying products is different that of the stocks. As a result, the Black-Scholes model cannot be applied to the pricing of weather options (Garman et al., 2000). We will discuss below the pricing of temperature options which gives 98-99% of the total weather market volume, however first the calculation and the workings of temperature indices are described.

[45] Source: http://www.cmegroup.com/product-codes-listing/weather-codes.html, downloaded on 13 March 2011

Temperature products

The goal of temperature products is to help mitigate the risk stemming from the unpredictable energy demand due to the uncertainty of temperature during the winter heating and the summer cooling season. Winter temperature conditions (which strongly affect the heating demand during winter months) is quantified by calculating Heating Degree Days (HDD), while temperature conditions during the summer months (which also affect summer energy demand) is grabbed by Cooling Degree Days (CDD). Heating degree days are those days when the actual daily temperature is lower than a base temperature value, so most households and businesses are supposed to use some energy for heating. Cooling degree days are those when the daily temperature is higher than the base value, so air-conditioners are heavily used. This base temperature is 65 Fahrenheit in most cases which equals about 18.33 Celsius; however it can be higher in warmer climates.

Daily HDD and CDD values are calculated as follows (Garman et al., 2000):

Daily HDD = Max (0, base temperature – daily average temperature)

Daily CDD = Max (0, daily average temperature – base temperature)

It can be seen that daily HDD and CDD values can never be negative, so cumulative HDD and CDD values' lower bound is also zero. The daily values are cumulated for a certain period, which is normally one month or a heating/cooling season, e.g. from November in a given year until March in the next year.

Other indicators can also be calculated besides the two aforementioned ones. One can calculate for example the energy degree days, which is the sum of the HDD and CDD values. In agriculture, growing degree days are defined as those when temperature is in a range favorable for the growing of crops.

In case of simple options, payouts are calculated by multiplying the difference between the strike HDD/CDD value and the cumulated HDD/CDD value for a certain period with a dollar value representing the size of the contract. Payouts are often capped to maximize the risks taken by the seller. From these simple options other more complex hedge or speculative instruments can be created.

Pricing models of temperature products

Some pricing methods purely model the movement of HDD or CDD values, while others predict temperature levels and calculate the HDD/CDD values from them. The latter method seems to be more effective (Garman et al., 2000), as those models which ignore temperature data do not use our knowledge about temperature. For example, they disregard the fact that HDD/CDD values cannot be lower than zero;

temperature values are mean reverting and can be predicted with certain precision by physical models.

The Black-Scholes model and the pricing of temperature products

The Black-Scholes model which is used for pricing stock options cannot be used for the pricing of weather options for the following reasons:

- Temperature events do not walk randomly like stock prices, as they are mean reverting. This means that temperature always stays near an average and cannot go very far from it, while stock prices does not necessarily obey such rule. Historical data shows that temperature returns back to normal levels every 2 or 3 days.
- In case of the Black-Scholes model, the value of the option is calculated from the price of the underlying product at the time when the option is exercised, while in the case of weather options, payout is usually determined by the average temperature of a period, so they are more similar to Asian options than European or American ones.
- Weather options are also frequently capped, meaning that profit is maximized for the holder of the option and loss is also maximized for the seller.

For the above reasons, in the case of weather options, alternative pricing methods shall be used instead of the Black-Scholes model.

The "Burn analysis"

One of the simplest pricing models is the "Burn analysis", which is based on historical data. This method calculates the cumulated HDD/CDD values for the past couple of years and based on that it is possible to calculate the hypothetical payout of the option in those previous years. Next the payout of each past year is averaged, which will give the option's fair value.

Monte Carlo based models

In case of the Monte Carlo based pricing models, many possible weather scenarios are ran on a computer, for which the corresponding HDD/CDD values are calculated. Based on the calculated HDD/CDD values, the payout of the option can be determined for each scenario and the option's fair price will be the average of the payouts, possibly weighted by the probability of each weather scenario. The advantage of this method is that a lot of model parameters can be defined before running the predictions. It is easy for example to build in price caps, the average difference in temperature can also be included between the data collection point and the relevant locations for the company, which are taken into account by the computer when calculating the fair price of the option.

8.6 Weather forecast using weather derivatives

The public trading of weather derivatives on exchanges means that information relating to expected weather embedded in the pricing of weather derivatives became accessible through the use of simple models for everybody. Several companies and other organizations with large weather exposure have their own proprietary weather forecasting models of varying precision. These organizations use their own forecasts to decide when and at what price to buy or sell certain weather products, so they influence the market with these trades and at the same time reveal their insights regarding expected weather. Before weather products started to be traded on exchanges this information was accessible only for big OTC market players. Today, however, smaller market players can also use prices for weather forecasting. This information is especially valuable because it contains the outcome of several weather forecasting methods, so using this information is supposed to be less risky than picking just one model to forecast weather. How can market players create forecasts from public prices of the exchange traded weather products? A good example is natural gas market, where consumption strongly depends on temperature, so a given month's cumulated HDD value is strongly related to natural gas consumption in the same period. This is true, however, not only retrospectively, as HDD futures and option prices show correlation with the next couple of day's or week's consumption. Even with the use of a simple model, it was demonstrated by an analyst at the CME with the use of one month's HDD prices for the period between the fall of 2001 and the spring of 2003[46], natural gas consumption can be very well predicted for the next 20 or 30 days. This is a longer forecast period than the usual 2-week weather forecasts. It is not surprising, however, that 20-day forecasts prove to be more accurate than the longer 30-day forecasts, as in the latter case, the first temperature data for the first 10 days were facts, thus one third of the monthly HDD data was given. That also means that the uncertainty was considerably lower with for the monthly consumption, as consumption data were also facts for that 10-day period. 30-day forecasts explained more than 50% of the variance in natural gas consumption both for New York State's regional consumption and for the national data; 20-day forecasts were considerably more accurate by explaining roughly 80% of the consumption's variance. Forecast was, of course, a little more accurate in the regional case than for the national consumption data, however the difference in accuracy was lower for the 30-day than for the 20-day forecast. The forecasting power of HDD futures prices regarding natural gas consumption data shows that a considerable part of weather

[46] Kulkarni, Vishu: „Using weather futures as weather forecasts", Chicago Mercantile Exchange, Weather Risk & Return, Sponsored series: http://www.cmegroup.com/trading/weather/files/WEA_wtfutures_as_wtforecast.pdf, downloaded on 9 August 2011

market players has useful weather forecasting models and the information drawn from these models is reflected in HDD futures prices. This information in turn, as discussed before, can be extracted from market prices and can serve as a relatively accurate and cheap prediction of temperature conditions.

8.7 Weather derivatives and the public sector

Using weather derivatives to avoid humanitarian catastrophes

Weather derivatives can also be a useful tool for governments and international organizations. So these products can not only be used to hedge weather related risks in the private sector. A transaction by the UN's World Food Programme received considerable publicity and thanks to that a lot of technical details are available unlike in the case of most transactions by governmental organizations, so this transaction can be cited as an example. The World Food Programme purchased a precipitation contract from Axa Re, a big reinsurance company.[47] The aim of the transaction was to ensure funds for a relief effort by the World Food Programme should the previous years' drought in Ethiopia continue into 2006. The deal covered the Ethiopian agricultural season, which is the period between March and October. Precipitation was measured in 26 locations throughout the country and precipitation levels on each data collection point were converted into crop water-stress indices, which were then combined into a national basket of indices. If this national index would have been higher than a certain trigger level, the option would have had a payout. That high level of the index meant very low precipitation levels associated with a very low crop yield. The option premium paid by the World Food Programme was US$ 0.93 million, while the payout of the option was capped at US$ 7.1 million. The biggest advantage of ensuring relief funds with the purchase of a weather derivative product versus the conventional way of collecting aid from different donors in case of emergency is that in the former case, funds are available quicker, as the insurer pays immediately when the crop-water stress index goes higher than the trigger level. It takes, however, several months to collect aids after a severe crisis has struck. This rapid availability considerably reduces the scale of the humanitarian catastrophe. According to evaluations the donor's money was used effectively when the above instrument was bought, as a US$ 7.1 million fund was purchased for the case of a severe drought for less than US$ 1 million. Eventually precipitation levels in 2006 were above average in Ethiopia, so the option was not triggered. It

[47] Source: http://www.wrma.org/risk_transactions.html, downloaded on 11 July 2011

was proved, however, by the transaction that international organizations could supplement funds coming from donor countries with the use of the weather market. Axa Re demonstrated that it is possible to make deals on the weather market amid complex technical circumstances and data processing challenges. Naturally weather products relating to developing countries can be purchased only on the OTC market, as exchanges offer standard products only for regions in developed countries which attract a lot of businesses and have the potential to generate considerable volume. As a consequence, for OTC deals in the developing world, governmental organizations have to calculate with counterparty risk, which can be reduced however by for example the use of syndicated instruments in case of larger payouts.

Financing resilience upgrading projects

The financing of city and regional infrastructure upgrade projects is the other important field in the public sector where weather derivatives could play a role. Proper infrastructure upgrades can considerably contribute to alleviate damage caused by extreme weather events. In other words, they result in urban areas that are more resilient against climate change impacts. For example a modern water drainage system can reduce losses due to exceptionally heavy raining, or the building of escapements can prevent flooding. High risk of damage due to extreme weather events is considerably drawing back the economic development of a city or a region. As a result, low quality infrastructure reduces the income of local businesses, local authorities and national governments. An infrastructure upgrade that improves resilience against climate change impacts will mean lower expenditure for the public sector first of all, and boosts the region's growth potential by reducing investment risk for private businesses and attracting qualified workforce by providing higher living standards. This higher private sector growth also means more jobs and higher tax revenues. So this kind of infrastructure upgrading does not only results in lower expenses in the case of extreme weather events, but it can generate extra revenues in both the private and the public sector as well.

Such resilience upgrading projects, however, need considerable financing, which is perhaps one of the main impediments of these developments. Funds are usually the scarcest in those developing regions where infrastructure upgrading would generate the highest marginal return. Resilience upgrading projects can be financed in several ways. Conventional financing solutions can be used when a part of the cost saving, increased revenue or increased real estate value generated by the development accrues to investors. This situation is similar to when in the private sector, some kind of energy efficiency project is financed by a loan which is guaranteed by the increased value of the real estate, the cost reduction or the higher rental revenue associated with higher service quality the property can provide as a result of the development project. We can call that the mainstreaming of the development program financing (ICLEI, 2011). A typical example of such mainstreaming in the public sector is when the government makes conventional private sector financing feasible by guaranteeing set future profit margins for the utility which finances and operates the infrastructure, when the price what the utility can apply is regulated by the authorities. Other possibility is to use development loans drawn down and guaranteed by the national governments or the issuance of bonds by local governments for project financing, guaranteed by the increased revenue of the local government as a result of the upgrading project. Any risk of a catastrophic damage that could destroy a part or the entire infrastructure can be covered on the weather market e.g. by purchasing an insurance policy or can be securitized by the issuance of a catastrophe bond. Financing costs can be reduced also by structured financing which spreads investment risks.

Financing is the most difficult for those projects where mainstream financing methods do not work. They are those cases when a large share of the cost reduction or the additional revenues do not accrue to the investor company or to the local governments (ICLEI, 2011). In these cases, non-conventional financial instruments must be used: innovative, in some cases tailor-made financial products which can provide financing for those development projects. Such an innovation could be the introduction of a new generation of catastrophe bonds. Conventional catastrophe bonds were discussed earlier in section 2. In the case of conventional catastrophe bonds the advances are used to alleviate losses so the instrument is used passively. However, in the case of new generation catastrophe bonds, a part of the revenue would be used to finance resilience enhancing development projects. These developments would aim to strengthen the protection of the area against the adverse effects of weather related and other types of catastrophe. This way, the risk of bond investors will be lower and as a result the risk adjusted expected return on their investments could become higher given the same nominal payouts. There are examples for such use of bond advances in the healthcare sector, where bond revenues are not exclusively used to cover the cost of treatment, but also for the prevention of certain diseases. The same method could be used to finance infrastructure upgrading projects.

Another possible invention would be the issue of bonds working in a way similar to the so-called social impact bonds. In the case of social impact bonds, an agency or another organization undertakes to take measures to decrease the costs arising from a certain social problem, a part of which is returned back to the agency. From this revenue the agency is able to cover the interest and principal payment of the bond program. The program itself is financed by the advances of the bond issuance. There are, however, two important prerequisites of the issuance of such bonds, (1) an agency capable to lower the costs of a detrimental social issue, (2) and a saving bigger than the cost of operating the program. In this case there is an opportunity to negotiate how to distribute the revenue coming from the cost reductions among the government, the investors and the agency. Resilience upgrading projects could be financed by the issuance of such bonds, where the upgrade project creates an immediate saving for the community, like in the case of building better roads, which are more resilient against heavy rain or freezing, and in this way reparation costs can be reduced.

8.8 Summary

There are various types of markets where weather related products can be traded. These are the insurance market, the OTC market, the bond market and exchanges. All of these markets have different characteristics; however, all of those can help cope with weather related risks. This chapter described the main fields where weather products can have an impact on the economy and current and future living standards. First, it shall be mentioned that weather products can be used to avoid serious humanitarian disasters in developing countries, where unfavorable weather can still cause starvation and a spread of different diseases.

Second, climate change could increase the extent of weather related risks by making weather less predictable, more extreme and causing increasingly uneven rain patterns. While the permanent solution for these problems would be to stop climate change by reducing the current emission of greenhouse gases, a bigger financial reserve rendered to alleviate weather risk through weather derivative markets can provide protection against the loss stemming from unpredictable weather events. It also have to be noted that not all effects of climate change can be tackled by these additional funds. Permanent effects, like desertification and rising sea levels are problems which cannot be alleviated by weather products.

Third, as it was demonstrated, weather products, however, have also a direct effect on climate change by supporting the financing of renewable energy projects and by contributing to the financing of infrastructure upgrading projects which increase the resilience of cities against weather caused damages.

Finally, exchange traded weather products provide cheap and easy access for all market players to the information provided by sophisticated proprietary weather forecasting models used by big energy companies, hedge funds and other market players. The low-cost access to this information for smaller enterprises can intensify competition by creating a more level playing field, so could provide for a cheaper access to energy or other products for consumers.

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II

COUNTRY- AND SECTOR-SPECIFIC ANALYSES RELATED TO CLIMATE CHANGE

Gábor Kutasi

9. Fiscal impacts of climate change and practices for carbon taxation

"A forward-looking perspective is always useful in policymaking, and it is especially useful for fiscal planners."

Peter S. Heller (2003:10)

9.1 Introduction[48]

In most industrialized countries, there are many factors that could ruin fiscal sustainability before any mentioning of the cost of climate change. The aging population, the welfare state reform, the recovery from global crisis, the tax competition, the rigidities of labour markets already have resulted robust debt levels.[49] The determining debt level warns for an important constraint in the beginning: The fiscal cost of mitigation and adaptation can not be financed simply from public debt. Even a new type of taxes is not risk free in a very bounded fiscal room for manoeuvre.

It is preferable to examine the impacts of climate in the fiscal environment drafted above. Nevertheless, the climate change is an expected occurrence in the future of the 21st century, which depends on many factors. This uncertainty or probability creates a more complex challenge for fiscal strategy. The regional variability of extent of warming or frequency and intensity of extreme weather events (cyclones, hurricanes, storms) or importance of coastal rise in the sea level still increases the complexity of fiscal analysis.

The mitigation and adaptation to climate change means any private or public action to prevent the change of temperature or adjust to a changed climate. Aaheim & Aasen (2008) distinguish autonomous and planned ways. The autonomous adaptation is the case, when private individuals do something for adjustment in uncoor-

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[49] The approximately debt to GDP ratios have been the followings in 2011: USA 100%, Japan 225%, France. 80%, Germany 75%, Britain 70% etc. source: Eurostat)

dinated way. This could have been a cheap way for public finances, but also results suboptimal solution because of bias for individual free riding, emergence of common pool resource problem, or uncertainty. That is why planned adjustment, namely fiscal adaptation is necessary, too, to motivate the private sector for (pro-)action. Nevertheless, the autonomous adjustment also has impact on tax revenues and public transfers. E.g., energy saving means less pollution-related tax payment, or direct investments in renewable energy equipment can create right to get public subsidy.

To adopt the debt sustainability aspect into the frame of climate change aspects, the long-term solvency, the budget constraint, the primary gap indicator has been applied. Besides indebtedness, refocusing fiscal spending and resetting the extent of public budget invoke the Keynesian fiscal crowding out impact.

The chapter overviews the public finances aspects of climate change. The sustainability is in focus, but this time the fiscal one and not the development aspect. The purpose is to gather the practices and to model the impacts of climate change on fiscal spending and revenues, responsibilities and opportunities, balance and debt related to climate change. It contains also a survey on application opportunities of carbon tax. The purpose is to estimate the impacts of introduction of carbon emission taxation in EU countries, implied by climate change mitigation and adaptation. The chapter overview the practices of EU countries, and refer to theoretical models of optimum taxation to create a possible framework for green taxation for EU members. By the gathered knowledge of practices on green taxation, it is possible to reply for fiscal challenge from climate change, and give a guide for policy makers by warning for difficulties and giving solutions.

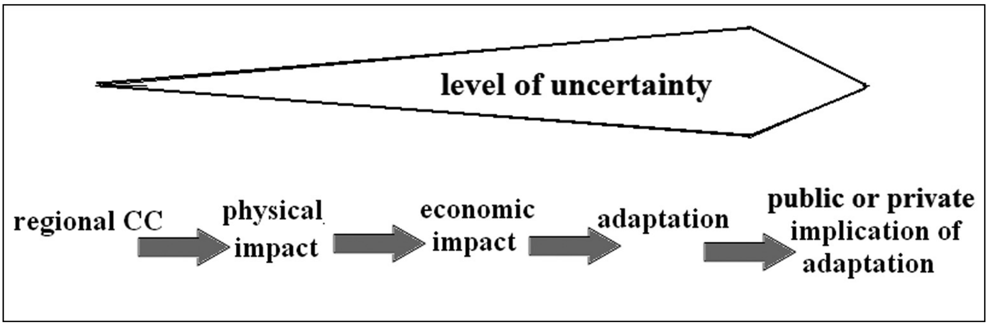
9.2 Methodology of climate change in public finances relevance

As a methodological simplification, the climate change can be translated as significant shift in average temperature, thus there is a variable or factor for calculations.[50] The modelling of fiscal impacts shall be examined in the frame of temperature change causing damages or benefits, and cost of mitigation or adaptation. If climate change got realized globally, it does not mean a generally same extent of change of temperature in every region and territory of the Earth. (It is possible more or less warming in temperature or even cooling is a likely outcome in certain regions.) As warming may be so different, the physical impact can be various. In some region, the rise of sea might will take costal territories, in some region the hart illnesses

[50] The estimation of global and regional probability, extent and direction of temperature change is a natural science question, thus in public finances study, it will be treated as an external factor

might will rise by warmer climate, in other territories the agricultural lands will dry out, somewhere else the disappearance of ice and snow create land cultivation opportunities or ruin the winter tourism etc. But what is the likelihood in a continent, a country, a county or a city/village level? If there are more scenarios, what are the effective mitigation and adaptation actions? What is the critical mass or scale of action? Will the actors wait for each other to act? Who should act first? Should the state intervene, motivate, initiate? And so on. If such uncertain probabilities are accumulated (namely multiplied), finally the likelihood of effective actions can be low. (See fig. 1 and fig. 2.)

Figure 1 Increasing uncertainty in climate change (CC)



Source: Simplified adaptation from Stern (2007) and O'Hara (2009)

Heller (2003:19) refers to the IPCC (2001) projections on expectable change of temperature in 100 years term horizon, which forecasts 1.9 – 5.8 Celsius (3 – 10 Fahrenheit) gradual warming by the concentration of greenhouse gases in the atmosphere. The uncertainty of temperature change can be illustrated in a fan chart of probable further future expectations.

Besides high uncertainty, the economic actors should agree in the distribution of financing between public and private players. The economic motivation for participation can be established, if the participants can get at least so much benefit from mitigation and adaptation actions as much cost they invest. Nevertheless, there are private actors (or maybe even state actors in the international relations), who are not able to finance themselves the adaptation. Thus, the public decision makers must determine the extent of equity toward poor economic actors (CEPS & ZEW 2010).This aspect raises the equity vs. efficiency trade-off dilemma, whether the fiscal resources should be used for subsidizing rich or poor actors (by direct spending or tax refunding). To resolve the dilemma, the economic theory knows the utilitarian approach and the Rawls approach. In case of climate change mitigation, the specific carbon emission per household of different social groups can guide the balancing between equity and efficiency. However, equity is not just a dilemma in social class dimension, but in geographical view, too. Which are the populated and industrial areas deserving protection against higher sea level or other natural damages? See the bad practice case of New Orleans in 2005. How well developed hurricane warning system has it done worth to be financed? How big efforts and how quickly has it done worth to save people right after the catastrophe? Or see the Dutch agricultural lands under the sea level. How far should they be protected? Do these lands produce enough income to protect them from the sea?

The policy making – in relation to market motivation – must decide another dilemma between short-term profit and long-term supply what can be called supply security dilemma (CEPS & ZEW 2010). In which territories should the state sustain the supply of energy, food, transportation, safe water and sewage system, pipelines? The prices and the (in)elasticity of the (network) service markets, the intensity of destructive competition[51], will decide the short-term profit. When the profit is negative, the state may force the service companies to supply – or maybe not.

In case of climate change, the likelihood of irreversibility is important determinant. Although an early mitigation action can look like unworthy because of high uncertainty and low probability of occurrence of damages far before the forecasted warming or disasters, an overdue mitigation can not reverse the natural, environmental changes. In this case, only adaptation remains as option (CEPS & ZEW 2010). The economics of decision theory suppose to use the net present value (NPV) to choose the more worthy option. In climate change relation, the comparable options are the NPV of an earlier mitigation or the NPV of a later adaptation.

To estimate the fiscal costs, the market capacity, propensity and perfection is preferable to be examined. It should be estimated, how far can the government levy the burden of adaptation on the private sector (solvency, marginal proactive propensity etc.), and can the market manage the risk to have demand and supply to meet and avoid the market failures. In climate disasters, first of all, the insurance sector should be helped to be able to manage the risk as far as possible.

To treat the impacts of climate change, it is possible to mitigate, what – according to Heller (2003:25) – means much effort *devoted to reducing emissions of greenhouse gases*.

[51] Destructive competition: In such service markets, (1) where the fix cost (exit cost) is high, (2) the competiton is intensive and presses the price to low level and (3) the demand is very volatile (some times much, some times few), the three characteristics together cause frequent bankruptcy what endangers the supply security.

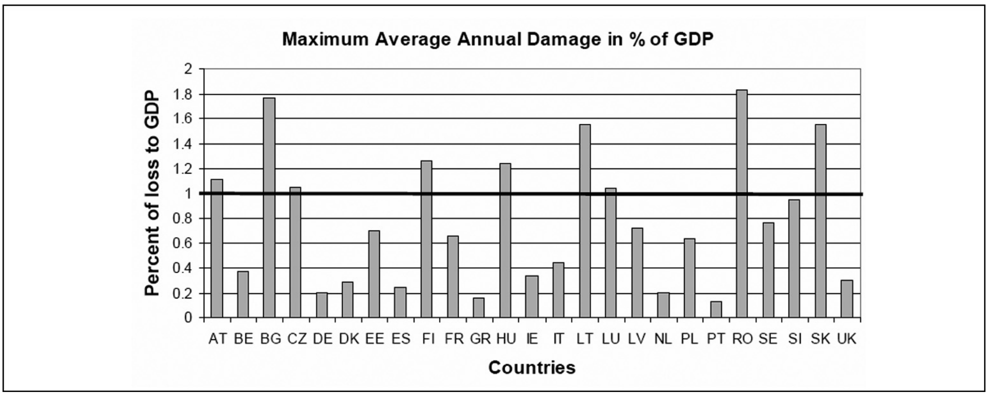
> *Here public sector involvement may involve replacing existing taxes with new ones that promote reduced emission. Or there may be more active use of regulation, whether of the command-and-control or the market-based type (...), in which case the fiscal consequences are likely to be more limited.* Heller (2003:25)

If mitigation is too late, or it is too expensive for preventing a not too likely event, the adaptation to new/changed circumstances can be another response. According to Heller (2003:23), the extent and cost of adaptation is regional or country specific, as it depends on the intensity of climate change, the embodiment of environmental or geographic changes, and the side effects on economy and physical assets. Heller thinks the followings:

> *Although much of the burden of relocating resources and financing new investment will undoubtedly fall on the private sector, it is unlikely that the public sector will remain unscathed, especially in countries, such as many developing countries, where the net economic impact of climate change is expected to negative. Areas of potential public sector involvement include outlays on infrastructure (...), other public goods in the areas of disease prevention and agricultural extension and research (...), and subsidies (to facilitate the resettlement of population*). Heller (2003:23)

As the significant warming is forecasted for century long, the public fiscal intervention is far more necessary in case of produced capital stocks, buildings, physical infrastructure with lifetime over 50. Especially, if unexpected or unlikely, radically destructive disasters or abrupt changes cause high scale of short-term cost.

Figure 2 Example for uncertainty: does it worth to have protection against flood?



Source: CEPS & ZEW (2010:55, fig.3.4)

The methodology on surveying fiscal impacts by climate change distinguishes fiscal cost of mitigation and adaptation, besides direct and indirect costs. It also introduces cost benefit analyses to evaluate the propensity of policy makers for action or passivity. Scenarios shall be drafted to see the different outcomes. The scenarios shall contain the possible losses in the natural and artificial environment and resources. Impacts on public budget are based on damage of income opportunities and capital/wealth/natural assets. In the followings, there is a composed list of actions when the fiscal correction of market failures is be necessary.

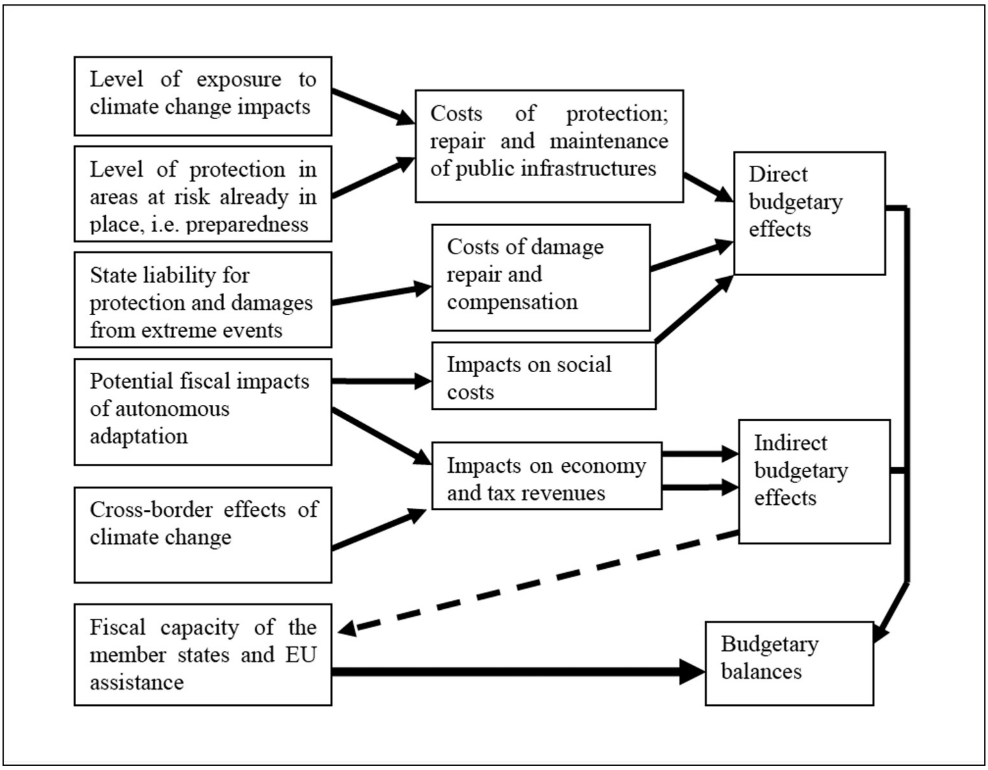
When fiscal cost of climate change is under survey, two main type of cost, the direct and the indirect costs can be distinguished. The direct costs are easily identifiable, however it is assumed to be smaller part of total costs. The difficulties with the identification of indirect costs alert for efficiency challenges, because the transparency of total cost of adaptation gets deteriorated. If costs are not transparent, economic participants will not be willing to finance it or support it, thus, the absent funding ruins the efficiency of any actions. The mechanism of direct and indirect costs can be described by the model on drivers of fiscal impacts.

9.3 Modelling the fiscal impacts

In the model on drivers, the CEPS & ZEW (2010) gathered the fiscal implication of climate change and identified six drivers that determine the size and importance of the fiscal implications. These are the followings: (1) the degree of exposure to gradual and extreme climate events; (2) the level of protection already in place in areas at risk, i.e. preparedness; (3) the state's liability for damages; (4) the potential and impacts of autonomous adaptation and remedial actions; (5) the cross-border effects of climate change; and (6) the fiscal capacity of the member states and the role of the EU.

The mechanism of drivers is illustrated in Figure 3, below. Direct fiscal costs are the construction and maintenance of protective infrastructures, the additional maintenance of public infrastructures affected by climate change, the changes in social expenditures mainly from potential repercussions on employment or alterations in health expenditures. A certain type of direct "cost" can be the revenue changes of the budget because of shifts in the economic and trade structure or in the consumption. The indirect fiscal costs appears as impacts on fiscal capacity to deal with very long-term challenges, like climate change, by definition of CEPS & ZEW (2010:52).

Figure 3 Drivers of impacts, various national concerns



Source: CEPS & ZEW (2010:52, Fig.3.2)

The degree of exposure means the above mentioned region-specific characteristics related to local geography, climate and location in climatic belt. (E.g. average temperature, rainfall, coastal facilities etc.) The level of protection means the existing infrastructure for protecting or monitoring and early warning systems against natural disasters endangering lives and economic values, extreme weather conditions endangering human health. High level of existing protection saves a lot of investments for the budgets in the future. However, it has been meaning a high level of permanent operating cost to keep the condition of systems and edifices. Early mitigating investments and intensive technological developments can reduce such type of cost factors. State liabilities for damages are any type of promise of state or expectable aid and help from the state which are paid or financed for victims of natural catastrophes, or financing the natural disaster relief. To reduce the scale of such liabilities, sophisticated and well developed private insurance sector is necessary, and thus the public support for its development is recommended.

Autonomous adaptation as driver of fiscal impacts represents the cooperative, initiative and supportive propensity of the private sector individuals. The actual occurrence of autonomous adaptation is the result of private utility-maximization objectives and their assessment of risks. The cross-border effects as impact drivers include two types of cost factors. One is the residual costs from actions in another country, the other type is the aid transfers for developing countries to adapt to climate change, or technology transfer to mitigate. Fiscal capacity as determinant of scale of spending for mitigation and adaptation shall be understood in dynamic approach. Not only the given balance of revenues and expenditure matters, but the potential changes of them do, too. This is called fiscal flexibility what means the taxation and spending room for maneuver of the fiscal government, the realizable potential scale of change of tax burden and expenditure by discretionary decisions. Standard & Poor's rating agency has even developed an indicator, the Fiscal Flexibility Index with sub-indices such as Expenditure Flexibility Index and Revenue Flexibility Index. (See Standard & Poor's 2007a and Standard & Poor's 2007b.) The fiscal flexibility can be extended through – first of all – the minimized indebtedness, the economic growth friendly economic policy and the lower scale of public finances, namely, lower total tax burden and public spending intensity with same balance (Benczes & Kutasi 2010:95).

Generally, the cost impact of the drivers can be reduced by technological (R&D) investments, supranational provision and assistance, internationally integrated financial and technological resources, expansion of insurance market, regulation of land and water use, information provision for awareness, direct fiscal incentives to help individual actors for autonomous mitigation, review of state liabilities (CEPS & ZEW 2010:59-62).

As mentioned above, fiscal impacts can be derived from the economic impacts which are preferable to be anticipated by the economic actors. Such general impacts are the average temperature in the seasons, along with an expected rise in temperature extremes; precipitation patterns; snow cover; water systems – particularly river flows (flood and drought risks) and groundwater levels; and coastal regions – with sea level rise and flood risks.

The following economic and natural impacts are expectable, what might demand autonomous and/or planned adaptation (UNFCCC 2007, World Bank 2009, Fischer et al. 2007, Bosello et al. 2009, Bräuer et al. 2009).

- In the agriculture, change in cultivation to more thermophile plants, redesigning drainage systems, building and reconstruction droughts, rethinking short land tenancy period, earlier seeding, potentially an additional crop rotation, expanding variety of crops and plants, developing of new crop types, increased use of

fertilization and plant protection; water-saving cultivation; development of plant and animal disease and pest monitoring; new insurance regulation;
- In the forestry, the needful actions: control of pests and diseases; enhance resistance of forest by mixed stands; earlier evacuation of trees after pests damage; forest fire and related monitoring system; rapid harvesting after wind damages; forest transformation to higher diversification of tree types;
- In health sector, the heat stress, vector-born diseases, increasing use of the health service capacity.
- Water related factors are the floods, heavy rains, coastal sea level, droughts, ice accidents, fertilizer in water reservoirs.
- Tourism related impacts: less snow for winter sport, algal blooms, sea level, hotter or longer summer periods.
- Energy sector related impacts are less heating, more cooling, unreliable water transport, limited water cooling, better temperature for biomass, increase in precipitation, power cable damages, changes in wind velocity, research demand.
- Transportation related impacts: drainage, resisting capability of infrastructure, risk of accidents by hot weather, erosion and flood damages, shorter ice and snow period, dried canals.

According to CEPS & ZEW (2010) the following type of fiscal cost impacts can be derived from the economic and natural impacts of climate change:

– Incentives for innovation and technological development
– Agricultural subsidies for guiding to new climate, and compensation for loss of agri-lands by desertification or higher sea level
– Relocation of infrastructure in coastal areas and building protective infrastructure (e.g. dykes)
– Restructuring tourism and energy sector and related transportation systems
– Compensation for lost real estates taken by the sea or nationalized territories for relocated infrastructure
– Adaptation cost of public buildings
– Cost of monitoring and providing early warning information
– Cost of health problems caused by changed climate
– Restructuring of employment
– Damages by natural disasters
– Compensation of poor part of society

The tax impacts can realize in the tax revenues depending on income and energy consumption. The transparency of carbon pricing in taxation will also determine the energy consumption propensity, thus the energy related tax revenues.

9.4 Climate change as one of the fiscal sustainability factors

As it was written by Heller (2003), the public finances are challenged by long-term structural problems like aging population, sharp increase of population in emerging and the least developed countries, health and disease problems, technological change, globalization of capital, labour and consumer markets, and of course last but not least the climate change.

Before mentioning any practical issues of public financing, there is a theoretical frame what must be taken into any account. Namely, sooner or later any public expenditure must be covered, otherwise debt crisis is expectable. To avoid the default, budget constraint is guiding principle, which means that the present value of future expenditures and revenues and the liabilities accumulated in the past should be in balance (Benczes and Kutasi 2010).

$$PV\text{ (debt + future expenditures)} = PV\text{(future revenues)}$$

If the budget constraint is continued through the findings of Fatás et al. (2003), Grauwe (2000), Buiter and Grafe (2004), Chalk and Hemming (2000), the affordable deficit can be concluded from the budget constraint:

$$\Delta b = g - \tau + (r-n)b - m,$$

where Δb is the change of debt in % of GDP (namely, the budget balance), g is the public sending in % of GDP, τ is the tax revenue in % of GDP, r is the real interest rate, n is the growth rate of GDP, b is the debt to GDP ratio, and m is the seigniorage revenue. This constraint still can be fined with overlapping generation aspects (see Zee 1988) and with crowding out impact (see Tobin and Buiter 1976, Bagnai 2004).

To evaluate the fiscal room for maneuver – e.g. before raising the green spending, – there is opportunity to form sustainability indicators from the budget constraint. A generally used one is the primary gap indicator by Blanchard (1990).

$$\tilde{d} = (n_t - r_t)^* b_t \qquad \text{and}$$
$$\tilde{d} - d_t = (n_t - r_t)^* b_t - d_t$$

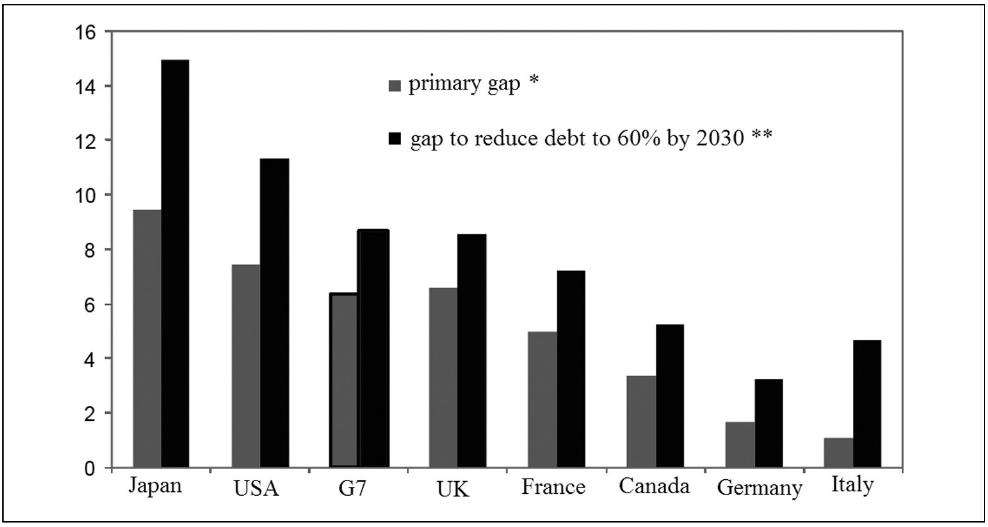
where $\tilde{d}$ is the primary deficit, d_t is the realized general budget deficit, , r is the real interest rate, n is the growth rate of GDP, t is a given year. If d? < d_t , there is excessive budget deficit which destabilize the public financing. Real interest rate is calculated from the Fisher equation:

$$1 + i = (1 + r) * (1 + \pi),$$

where i is the nominal interest rate, π is inflation.

$$r = ((1+ i) / (1 + \pi)) - 1$$

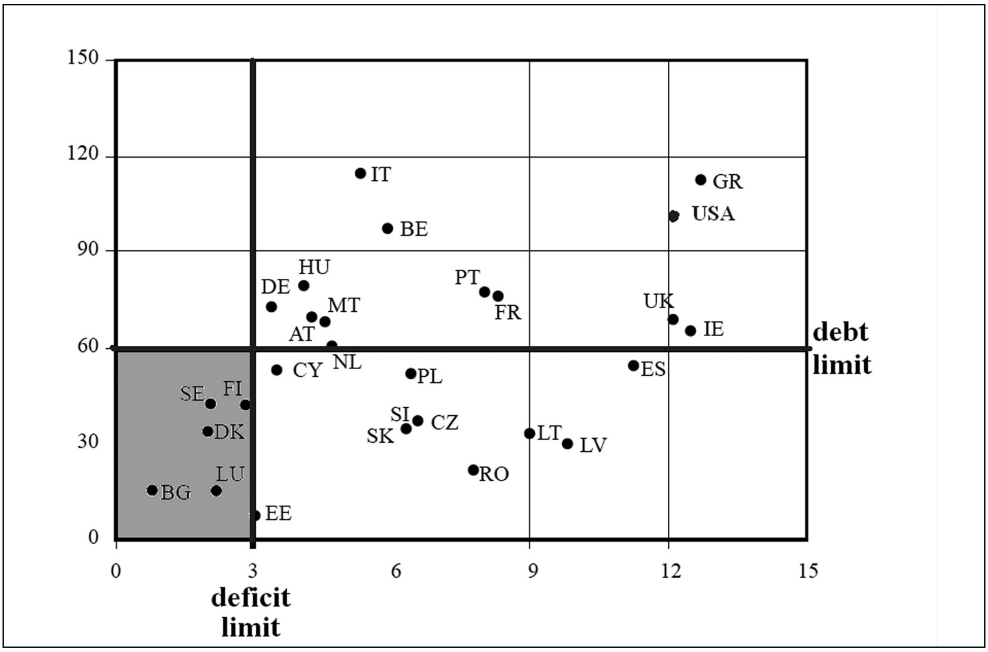
Figure 4 Primary gap in G7 countries, 2010, %



Source: IMF *Staff Position Note* SPN/10/13 (Long-Term Trends in Public Finances in the G-7 Economies) Fig. 7., p. 14, based on IMF *Fiscal Monitor* May 2010, IMF *World Economic Outlook* July 2010 Update, and IMF staff calculations and estimates.
* The primary gap is the difference between the primary balance for 2011 that is needed to maintain the 2010 debt-to-GDP ratio and the cyclically adjusted primary balance (CAPB) in 2010.
** The scenario assumes that the CAPB improves gradually from 2011 to 2020; thereafter, the CAPB is maintained constant until 2030. The CAPB path is set to reduce the debt-to-GDP ratio to 60 percent by 2030. For Japan, a gross debt target of 200 percent of GDP (net target of 80 percent of GDP) is assumed. The scenario uses country-specific interest rate–growth differentials.

As it is clear from the crude data of figure 5, and the primary gap indicator in figure 4, most of the high developed countries have trouble with the general budget balance. Besides, the primary gap indicator even represents a longer term fiscal adjustment period necessity for these countries. Especially the big key economies (USA, Japan, Germany, France, UK) must face to drastic return to balance during decades after many years of fiscal stimuli. The global crisis of 2008-2010 caused a serious turmoil in many EU states' public finances. Only six EU countries could keep the deficit criterion in 2009 (see graph 1.), four of them (Sweden, Denmark, Estonia, Bulgaria) have not introduced the euro. The other countries have diverged both in debt and deficit. Since 2010, during one and a half year many euro zone countries had difficulties in debt financing (Greece, Portugal, Ireland, Spain). Some euro zone members also have got closer to non-credible indebtedness (Italy, France). In USA, the solvency gets also questionable in the middle of 2011 because of political disputes on debt ceiling. Big countries budgetary troubles spill over to their economies and to partner economies, thus causing them fiscal troubles, too. Such a global situation is not favourable for quick fiscal adjustment to the challenge by climate change.

Figure 5 Fiscal sustainability problem of EU and USA. Fiscal impact of crisis on debt (vertical axis) and deficit (horizontal axis) in 2009, % of GDP



Source: Eurostat

In case of a new type of spending forced by external natural factors, just like the prevention or damages from climate change, the sustainability question can be composed also as a dilemma of hard or soft budget constraint. Hard constraint means budget balance beside restructuring of expenditures or tax revenues increasing together with spending. Soft constraint means unilateral rise of spending what results higher overall deficit (Kopits 2000). The hard constraint is not attractive for political deals. The soft constraint causes increasing default risk. If sustainability is a primary objective, soft budget constraint is not an option, however political deals can frequently overwrite the economic rationale.[52]

Besides, any case of increasing scale of public budget, also because of green spending or taxes, raises another policy dilemma. Namely, does it worth to strengthen the fiscal crowding out impact? (Tobin & Buiter 1976) The increasing spending (indifferent whether form tax revenues or debt) results higher market interest rate as

[52] About political factors of fiscal decisions see the literature represented by A. Alesina, R. Perotti, G. Tabellini, T Persson, J. von Hagen, etc.

cost of credit. The increasing public spending turns the private investments and consumption to be declining. This crowding out impact will be important, also, to explain why the private sector becomes more and more passive in mitigation and adjustment when high government activity is observable. So not only free riding is behind the passivity of the private sector, but crowding out can be another explaining factor. The extent of any crowding out will be determined by the elasticity of money demand, the capital income to total income ratio, the wealth to out-put ratio, the level of taxation and interest rate and the speed of growth.

9.5 Fiscal policy dilemmas related to climate change

Through the recognition of indebtedness of highly developed (and climate sensitive) countries, the climate dilemmas of public finances can be worded. The first dilemma is the following: As there is no satisfying room for issuing more debt to cover the fiscal climate adaptation, the two options for fiscal policy are the redistribution among the items of taxes and spending or levy as much cost as possible on the private sector through perfect markets, like a sophisticated insurance sector. However, the two horns of the dilemma demand challenging balancing. If the private sector with limited time horizon got no fiscal (public) impulse at all, the private perception on net present value of adaptation will be considered to be negative, as individuals of the private sector can not optimize for the endless future, or more then a few generation. (See the paradox of Ricardian equivalence.[53]) In the contrary case, getting excessive fiscal subsidies, the community of individuals of the private sector will expect any adaptation from the state, thus remain passive.

The second dilemma rooted also in the limited room for issuing debt. The fiscal decision makers are forced by indebtedness to select among private actors, and create preference lists. Who should be compensated for damages, and who not? If rising sea level swallows coastal real estates, should the owners get subsidies, and how

[53] In the economics models, it is a reasonable assumption, that the states as actors are immortal, so they should be considered as infinite ones. That is why, the Ricardian equivalence can presume, that it is indifferent for the state to finance a new item of spending either from raising tax or from public debt. If it was true, this aspect gives opportunity for infinite Ponzi game for states, and just always accumulate higher and higher debt by promising higher and higher future tax revenues. However, O'Conell & Zeldes (1988) and also Buiter (2004) emphasized, that it is not possible because of the finite or limited horizon of individual households as buyer of public bonds. As the buyers are thinking in finite future and they are in limited number, the assumption of public bonds with infinite maturity is unrealistic. Besides, the imperfection of capital markets can not treat perfectly the uncertainty of the future. That is why it is expectable from the state to pay all the debts in the unseen future, namely what is expressed in the form of PV (debt + future expenditures) = PV(future revenues).

much? If productivity of agricultural lands were ruined by desertification, should the state bother with ensuring alternative income for rural workers and entrepreneurs? Should the ski parks get public or EU subsidies for snow guns if climate warming means too high temperature for snowing? etc.

The increasing green tax burden, bond issue and funding for mitigation and adaptation raises the dilemma whether does it worth to increase the fiscal crowding-out effect in the capital markets or not. This effect is very regional market specific because of the interest rate elasticity and marginal propensity of saving and investment. Of course, less investment can mean less carbon emitting production growth, but also slower technological development in carbon reduction, too.

Heller (2003:120-150) recommends conceptual aspects for long-term fiscal planning to finance long term mitigation and adaptation to any sustainability problem. Certain aspects are the limits or "stop sign" for certain ways of adaptation. First of all, the public financing has social welfare function, namely, the support for more vulnerable groups in the society. The climate change enlightens, too, that decisions makers should take into account the interest of the future generations as one of the most vulnerable group. Thus, the aims of policy making shall contain the objective of achieving fairness across generations, what means excluding Ponzi games[54] in budgeting, counter-weighting short-term political interest and eventually a kind of self-limitation in long-term borrowing for financing current outlays. The necessity of self-limitation rotted in the political economy recognition that there are individual interests behind the decisions, the principal-agent problem is an existing occurrence in public policy, and short-term interests are overweight, long-term interests are underscored in discretionary decisions. Institutional solutions, like fiscal rules, fiscal councils can improve the transparency and suppress political myopia, thus, treat the political obstacles.

Besides, the government must be able to assess correctly and ensure the financial sustainability, namely, the long-term public solvency. Sustainability means not only focusing on budget balance, but also, the sustainability of the tax burden, the adequate risk management on fiscal threats and weaknesses, the sustainable institutional mechanisms to ensure the far future balance, and the limitation on future policy makers' discretionary decisions. The decision makers must preserve the scope for stabilization measures, even though they prefer to use the fiscal policy as an instrument for having influence on the economy. The efficiency of allocation for Pareto efficient income production means practically the elimination of distorting effects in tax system, the distribution of spending in optimal structure referring to the equity

[54] About Ponzi game in budgeting see more in Buiter & Kletzer (1992)

vs. efficiency trade-off, and the suppression on red tape concerning the public finances. Of course, not just the present, but the legacy of fiscal policy will disperse the position of countries or regions. Simply, the fiscal legacy can be expressed in the current scale of public debt. And not only the extent of debt, but its structure will matter, since in dynamic view, it can be the root of suddenly intensifying side effects. For example, indebtedness in foreign currency can modify significantly the solvency of debtors in a foreign exchange rate shock without short term risk management instruments. (Such impacts are called nonlinearities by Heller (2003:149).)

According to Heller (2003), state must be ready to anticipate market reactions driven by short-sighted interest. Private sector's propensity for funding or resource saving can determine crucially the effectiveness and scope of public policy actions for adaptation. The governments must think about market side effects of the structure of realizing the long-term sustainability. Will the market help or weaken certain stimulating or restricting actions? What will be, for example, the effect of lower or higher risk premium on private savings and investments? E.g., it is well known about debt crisis impacts, that when the direct danger of collapse get milder the private interest groups get less devoted to public finances reforms, so, the politicians will ease the previous restrictions and deteriorate the previously improved fiscal balance or balancing program.

The items mentioned in the followings and serving the green adaptation causes structural changes in public finances. This aspect supposes to treat the green reform, also, as a structural fiscal reform together with balancing. The simplest way to move toward fiscal balance is, when the incomes grow faster than the expenditures in absolute share. Thus, at once, the collapse of economic growth dynamics can be avoided.

That means, the absolute growth of tax burden should be lower than the GDP-growth, and comparing even to tax increase, the growth of public expenditures should be much lower. However, this demands the public green spending not to be automatic, because the rigid expenditure types insensitive for business cycles will make the adjustment of spending unmanageable to the governmental solvency. Nevertheless, the tax incomes can not be decreased until the expenditures will not decline at least in the same scale. Besides, the expansion possibility of state debt means also limit in the play of tax reduction (Tomkiewitz 2005).

The green reform basically is making an attempt to increase the net present value achievable through the fiscal policy, explained with the instruments of cost-benefit analysis is the following:

$$\max \text{PV} \{\text{benefit of society} - \text{cost of society}\}$$

However, this cost-benefit analysis is fairly complex, that is why the results must be treated carefully to avoid misleading understandings. First of all, it is hard to measure any side effects of public expenditures and absorption. During the estimation of benefits the experts must face the comparison problem, how commensurable are the individuals' subjective utility. Wildawsky (1997) guess, the appraisal methods used in practice are very uncertain – at least in case of public services. The net present value calculation is uncertain in dynamics, as the costs can vary in the future (Kutasi 2006).

The structural green reform of public finances is not simple corner-cutting or spare of expenditure targets. Any kind of efficiency-seeking restructuring related to revenues or expenditures can be mentioned under this category that will have a positive long-term impact for years or decades. In certain circumstances, the previous level of expenditures can be held. The essence of reform of public finances is, that the previous financing mechanisms get changed or reorganized to create more efficient structure independently form the current budget deficit or surplus.

In Drazen's (1998) approach, the fiscal reform is a common pool. Everyone consider this common pool to be made, but everyone wants it to be financed by others. This way, the possible utility created by a possible reform for everyone is in vain if there is high probability for burdening the cost on the certain individuals. This will be a 'war of attrition' impact on the reform, as most of the individuals will not support it. Moreover, the distribution of costs means actually a dispute on distribution of tax burden in the planning stage of restructuring, what will impede more the execution. Besides, the support of reform will be ruined much more in case of uncertainty of individual benefits. Many researches were made to find relation between the success of reform execution and the political institutional system. (See e.g. Strauch & von Hagen 2000, von Hagen, Hughes-Hallett & Strauch 2002, Alesina & Perotti 1999, Poterba & von Hagen 1999, Benczes 2004, Benczes 2008 etc.) These surveys concluded that mostly the plurality of decision makers, the pressure for consensus or the multi-party government usually weaken the fiscal discipline as well the not transparent budgeting procedures or the strong bargaining power of spending ministers against financial minister. Although, the political and multi-party system can not be question of restructuring, making efforts for transparency of budgeting procedure and dealing can do a lot for disciplined public finances (Kutasi 2006).

9.6 Fiscal risk management of climate change

The general risk management of sustainable budgeting has broad range of instruments with many experience of practical implementation. The fiscal rules have became often used since the 1990s. (See Kopits 2001, Kopits & Symansky 1998, Kumar et al. 2009, Benczes 2008, Benczes & Kutasi 2010:122-144.) The different types of rules are the balanced budget rule[55], the public debt rule[56], the golden rule[57], the expenditure rule[58]. These rules are useful to restrict the short-sighted political decision makers in discretionary decision enforcement.

Besides rules, revising bodies can be established, which are typically called fiscal councils or fiscal boards with right to publish opinion, or, maybe, to veto on fiscal related decisions. Numerous example can be mentioned: the U.S. *Congressional Budget Office*, Dutch *Budget Inspectorate, Budget Directorate* (Blöndal & Kristensen 2002) and *Centraal Planbureau* (Debets 2007), the Belgian federal *High Council of Finance* (Buti et al. 2002, Stienlet 2000) , the Spanish *Consejo de Politica Fiscal y Financiera Financial* (Quintana & Torrecillas 2008) the German *Finanzplanungsrat* (Lübke 2005), the Portuguese *Program Financing Committee* and the *Unidade Técnica de Apoio Orçamental*, the British *Office for Budget Responsibility* etc.

In financing the very long-term impacts, just like the adaptation to climate change, the efficient solution for smooth, gradual accumulation is the fiscal funding (if the private insurance services can not create opportunity to shift the cost toward the private sector). Its weakness is that mostly those countries can easily establish such funds who have any way fiscal surplus typically from natural resource (oil) export. Such row material export based funds are e.g. the Norwegian and Russian oil funds for future pensions. Nevertheless, some member states of USA has also stability funds, or Australia has the *Future Fund* for public and military officers pension, the *Higher Education Endowment Fund* for college and university infrastructure development etc. (Blöndal et al. 2008).

The funding specified for climate change is called financing by green funding. In national level, it would be possible to select a certain type of fiscal revenue (just like the oil exporting countries do with oil trade revenues), and indicate it as a source of a fund. In high developed countries, year by year, there are specified items in the annual budget for subsidizing the modernization of carbon emission related technologies. But such spending frames are result of discretionary annual decisions

[55] Limitation on general government balance or primary balance.
[56] Limitation on public debt level.
[57] Debt financing is allowed only in case of public capital investment, infrastructure investment.
[58] Limitation on overall spending scale.

made by the current government. This does not ensure the long-term financing of mitigation and adaptation. An automatic fund could not only ensure the current scale of subsidy, but also the security of long-term financing by accumulating the revenues.[59] Unfortunately, as it was already mentioned, the public budget has other long-term challenges related to demography, demanding funding for the future.

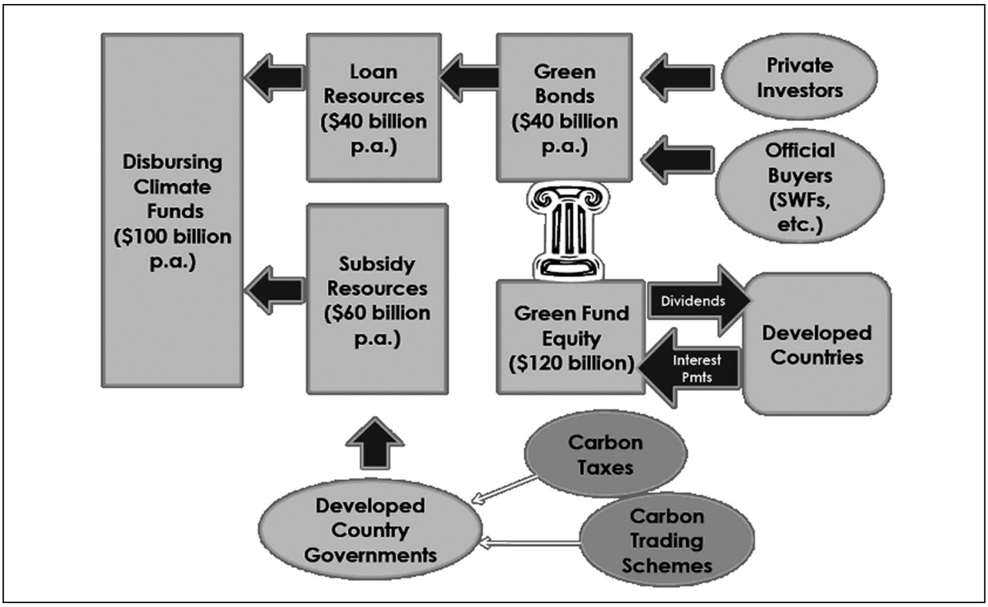
Especially in the developing countries, the national accumulation of green fund has no source. Besides, eventually the climate change is a global problem, so national, unilateral adaptation does not seem to be the most efficient. Alternative option is the international funding, where national budgets contribute as their quota prescribes. Its advantages are cooperation of low income and high income countries, and the stronger governmental commitment to the long-term objective as giving up an international membership has more transaction cost (diplomacy damage) for a country than splitting a national fund. International green fund can be a mixture of national quotas, green tax revenue as direct income of the fund and market bonds financed by Sovereign Wealth Funds and other private investors. (See Fig.6.)

Such operating fund is the Caribbean Catastrophe Risk Insurance Facility (CCRIF) in the CARICOM, described by IMF (2008a:31). CCRIF is multi-country risk pool and also insurance instrument backed by both public finances and capital markets. It was set to help CARICOM countries mitigate the short-term cash flow problems in disaster situations. It is a regional catastrophe fund for Caribbean governments, CCRIF operates as a public-private partnership, and is set up as a non-profit 'mutual' insurance entity. The CCRIF pays out in the event of parametric trigger points being exceeded. It provides rapid payment if disaster strikes. The CCRIF has coverage for hurricane, earthquake and excess rainfall. The facility is a fund operating particularly like insurance. There is plan to involve the agricultural sector and the energy companies.[60]

Similar international green fund is in the period of formation. According to the Copenhagen Accord issued at the 2009 United Nations Climate Change Conference in Copenhagen, international Green Fund shall be ready in 2020 to ensure financial aid for developing countries. The design of the exact financing is illustrated by Figure 6 (Bredenkamp & Pattillo 2010). It seems, it is possible to capitalize a climate change adaptation from the private sector. The international Green Fund will stand on private and public pillars. The public pillar is composed from national contribution quotas, national carbon tax incomes and national revenue from CO2 quota trade. The private pillar means issuing market bonds for private investors.

[59] Of course, ultimately the law-makers can reintegrate any fund back to the annual budget, if that is the will of the significant political majority. So national level green funding is neither the absolute solution for financing the long-term objectives.
[60] For more see www.ccrif.org

Figure 6 Financing by green funding



Source: Bredenkamp & Pattillo (2010:10)

However, any public funding raises the dilemma of crowding-out mentioned above, as the CCRIF and Green Fund backed by states pumps the financial resources from private investments. Moreover, as a general international aiding problem, appearing also in critics on ODA (Official Development Aid) operation, that international organizations (funds) are not able to achieve critical mass of capital to swing off the developing countries from the problem of undercapitalized position blocking the efficient risk management. The credibility of such funds will be decided on its operation, the effective commitment of the members and the realized results.

To share the financing between public and private actors, namely planned and autonomous adaptation, beside the funding, there is an other item have been already mentioned in this chapter, the insurance. However, simply private insurance is not enough to have efficient mitigation or adaptation. Phaup & Kirschner (2010) assume that public risk management is more efficient than individual, especially if it is preventive. On the other hand, it can become very expansive for the state, if private sector individuals see that they can get every protection from the state. The only state financed actions are called *ex post* budgeting, as it does not motivate the individuals to be preventive. That is why the optimum is the *ex ante* budgeting which accumulate reserves for the cost of catastrophe in the future, both from tax revenue and private income. The following options can be combined in the insurance sector for *ex ante* budgeting:

(1) The state makes market transactions by purchasing insurance service from insurance companies. Its advantage is that government can secure insurance for anything considered to be necessary. The disadvantage is that the insurance sector may will not be able to pay the compensation for all the damages.
(2) The state prescribes mandated purchase of insurance for the private asset owners. The advantage will be that the market will evaluate every object to be or not to be worthy for insurance. The disadvantage is that the private risk premium is very likely higher than the public risk premium.
(3) The government-provided insurance means that the state establish a state insurance company, e.g. New Zealand Earthquake Commission. In this case, the state can control the whole process of insurance, but the possibility of political intervention is very likely, that is why the efficiency of this option is questionable.
(4) Contingency Fund is the forth option, which is actually the government saving fund or green fund mentioned above.

Johns & Keen (2009) based their recommendations on situation of broadly afflicting heavy indebtedness and high deficit problems. They suppose to charge the CO2 emission with green tax to mitigate the warming and to avoid the higher deficit. Of course, introduction of a green tax has many side effects. If it hits the emission target, and CO2 pollution decreases, the tax revenue on CO2 scale will also decrease. If the green tax automatically increases the tax burden (tax wedge) on the economy, it can have the economic growth to slow down.

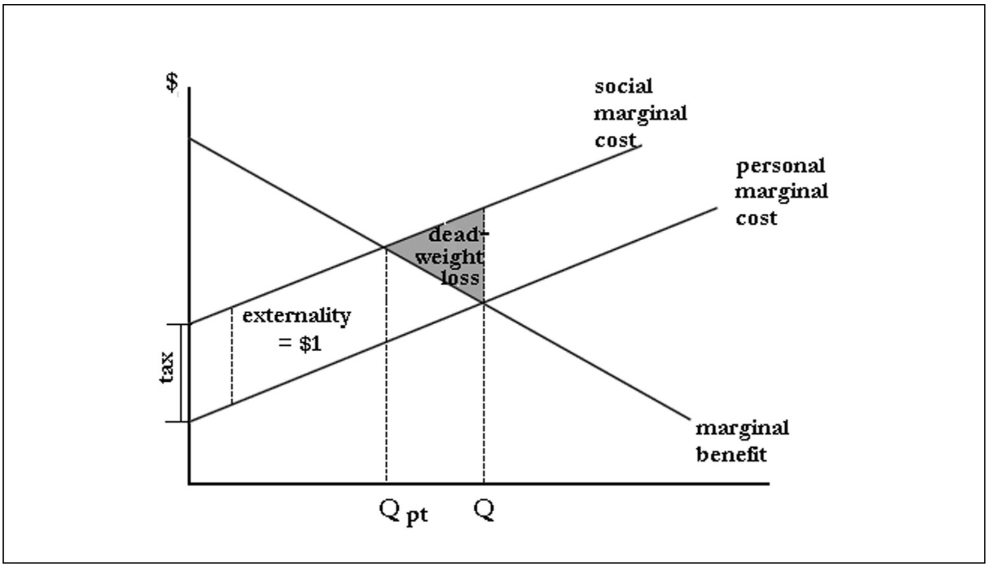
To manage the growth risk of crowding out and to cope with the crisis and recession of 2008, Jones & Keen (2009) proposed “green recovery”, namely state investment into green energy sector and CO2 saving technologies. Anyway, because of recovery, governments have been spending on stimulus packages. Such green stimuli could serve both the objectives of recovery and the mitigation through the multiplying impact of fiscal spending. This green recovery can be associated with employment objectives which are especially a sensitive field of economic policy, nevertheless in USA where the after crisis 2008 level of unemployment got up to 9.5-10%. Bossier & Bréchet (1995) has already recommended in the middle of 1990s that carbon tax can be connected to the cost problems of employment in Europe. As much scale of green tax burden would have been levied on the economy, so much scale of social contribution (or any other labour-related employer cost) should be eased by labour tax cut.

Even though it sounds simple, many side effects must be taken into account. How does the carbon emission tax raise the price of energy and fuels? If CO2 emission decreases, it means lower tax base, thus lower tax revenue. How to sustain the financing of social service systems if social contribution (health and pension contribution) has got decreased? Would labour tax really an incentive for more employment for companies? Is the tax cut critically enough to be effectively cheaper than foreign rivals? If companies do not see more demand, a tax cut will not motivate to hire more workers. Bossier & Bréchet (1995) warned for the risk of uncertainty and the necessity for simulation before policy actions. For example the E3ME (energy-environment-economy model of EU) by Barker (1998) was an econometric attempt to simulate effect of carbon tax on emission, GDP, competitiveness and employment.

9.7 Green taxation for climate mitigation

Carbon tax is a practical version of the theoretical Pigou tax (or Pigovian tax). The Pigou tax is a solution for internalization of externalities. Pigou (1920) recognized that the market mechanism had failed to include external costs into market prices, which was why he recommended the implementation of a tax to solve this market failure. Baumol & Oates (1971) proved that tax is an efficient instrument to realize environmental goals, even in the case of unquantifiable externalities. The Pigou tax can be levied on the market activities creating negative externalities. The role of the tax is to correct the market outcome. In the case of CO_2 emission, the externality is the global warming and its geographical, social, health, economic, fiscal etc. impacts. The externality distort the economy from the Pareto optimum, while the Pigou tax can have the economy return to the optimum. The tax should be equal to the marginal externality (Pigou externality) for the expected effect. The challenge of the tax – just as general taxation – is its fine calibration for the wanted impact, in the case of green tax to counterweight the externality of CO_2 emission. Wrong setting, institutional failures in legislation and execution, or the polluters' political lobby can ruin the real efficacy of Pigovian type taxes. As the Pigou tax does not pursue fiscal revenue purposes, fiscal charges are to be regarded as small as the enterprises as possible. However, putting a tax into practice always demand the analysis of marginal tax burden impacts on the business. (See fig. 7.)

Figure 7 Microeconomic externality and the Pigou Tax



Source: Nye (2008), Qpt = production with tax, Q = production without tax

In the criticisms of Pigovian type taxes, there can be found an ignorance of whether the market structure is competitive or monopolistic, as in case of monopoly, the price is above and the quantity is below the competitive equilibrium. Thus, estimating optimum Pigou taxes ignoring the market structure could overestimate the rate of tax to impose. Buchanan (1969) and Nye (2008), for example, refer to the oil and gasoline market where suppliers can limit the production, and the impact of restriction on oil drilling or the impact of the alternative energy supply on oil based energy market price, which makes it difficult to calculate the exact tax. Nye (2008) also refers to the doubts written by Edlin & Karaca-Mandic (2006) on the case of heterogeneity. As for carbon tax, heterogeneity can mean different technological levels of production or different productivity levels and various value added, not just in the sense of geographical disparities, but also in small versus big companies or inter-industrial aspect, too. One percent or one dollar tax will burden less an industry with high profit margin than another with low return.

As any type of tax, Pigou tax has a deadweight loss impact, too, on consumers' benefit. (See figure 7.) The question is whether this deadweight loss or the damage from warming is bigger. The calculation of deadweight demands the knowledge of the price elasticity, and the estimation of damage by warming needs the very uncertain probabilities of climate change. Thus, it is not simple to match the alternative losses.

Another critic on green tax is called the "green paradox" by Sinn (2008), who suggested that increasing emission taxes accelerate global warming because resource owners start to fear of higher future taxation and for this reason they start to increase near-term extraction. Edenhofer & Kalkuhl (2011) tested Sinn's model for increasing unit taxes on emission, and found that an accelerated resource extraction due to increasing carbon taxes (namely, the green paradox) is limited to the following specific conditions: "*The initial tax level has to be lower than a certain threshold and the tax has to grow permanently at a rate higher than the discount rate of resource owners*." (Edenhofer & Kalkuhl 2011:2211). This means that most ranges of carbon taxes for warming mitigation is not risky for the green paradox. They suggest "quantity instruments" to avoid any risk of the paradox.

The expectation from implementation of carbon tax is to mitigate carbon emission by pricing the cost of future damage and thus enforcing emission efficiency. The function of carbon tax is to raise the price of CO_2 emission. However, to identify the real tax impacts on energy demand and CO_2 emission is a serious challenge for policy-makers. As it was established by IMF (2008b), the conditions of success in mitigation policy are complex.

As any mitigation policies, the carbon taxation must be flexible, robust and enforceable. According to Kim et al (2011), carbon tax has an important advantage over other mitigation measures, namely, that they create a common price for emissions, which makes polluters more efficient in emission reduction. Efficiency of green tax can be understood as how much CO_2 emission can be reduced in energy use and production or in transportation, if a carbon tax is adopted in the mentioned industries.

In comparison to command and control, the advantages of carbon tax can be summarized in lower compliance costs, and a continuous incentive to adapt in the technology of energy use and conservation (Cooper 1998, Pizer 1997).

The main advantages of market-based carbon taxation are the following according to Cooper (1998), Pizer (1997) Pearce (1991) Nordhaus (2007) and Kim et al. (2011):

- Creating a common price for emission taxation makes firms with lower abatement costs emit more. The carbon tax fixes the price of emissions effectively.
- The cost for CO_2 emission encourages a switch to low-emission technologies and activities, and the development of emission-reducing technologies.
- Carbon-tax systems can make use of existing tax collection mechanisms and require less intensive emission monitoring efforts.
- Carbon tax provides for greater flexibility and adjustment capability for both firms and public finances in case of changing economic conditions, allowing

firms to reduce emissions more during the periods of slow demand growth, and providing opportunity for tax easing.
- The carbon tax can induce a technological change to avoid higher cost, which results in lower emission and at the same time technological shift toward better productivity or cost efficiency (Gerlagh & Lise 2005).

The disadvantages are as follows:
- The new type of tax generates administrative and transaction costs.
    - Without other tax easing, the higher tax burden results a crowding out impact by government.
    - Under carbon tax, the quantity of emission reductions is uncertain. Impact of tax is very dependent on non-constant price elasticity and income elasticity.
- Taxes may be politically difficult to implement (Kim et al. 2011).

Market structure and energy consumers' heterogeneity is not treatable in a homogenous tax system (Edlin & Karaca-Mandic 2006).

The range of applicable green tax is limited by the existing total tax burden on economy, or, from contrary view, the level of green tax determines the necessity of tax cuts in other types of tax burden (Bossier & Bréchet 1995).

Some literature estimation on tax elasticity expresses a very skeptic view on carbon tax efficiency. Sipes & Mendelsohn (2001) made the evaluation of the effectiveness of gasoline taxation as an air pollution management. Their conclusion was that an environmental surcharge added to gasoline taxes can decrease gasoline consumption only with very low price elasticity of demand. The estimation of Davis & Kilian (2009) confirmed this inelastic behavior, as their result showed that a 10 percent tax increase could decrease carbon emission of the transportation sector by about 1.5 percent and reduce the total carbon emission by about 0.5% in the USA. (See Kim et al. 2011.)

The impact of carbon taxes on international competitiveness of energy intensive industries is determined to a certain extent, because additional cost factor appears in the countries devoted to mitigation, meanwhile free riders of international relations try to avoid the implementation of green taxes. However, the empirical econometric survey of Zhao (2011) concluded that empirics do not support this hypothesis. As it is established in the analysis, when only the importing countries have carbon tax, it exerts negative influence on exporters' competitiveness in energy-intensive industries. If only the exporters use carbon tax, impact on competitiveness is insignificant. When every trade partner countries harmonize the carbon taxation, the impact on competition is still not completely cancelled mutually, but there remain some net negative impact on exporting countries.

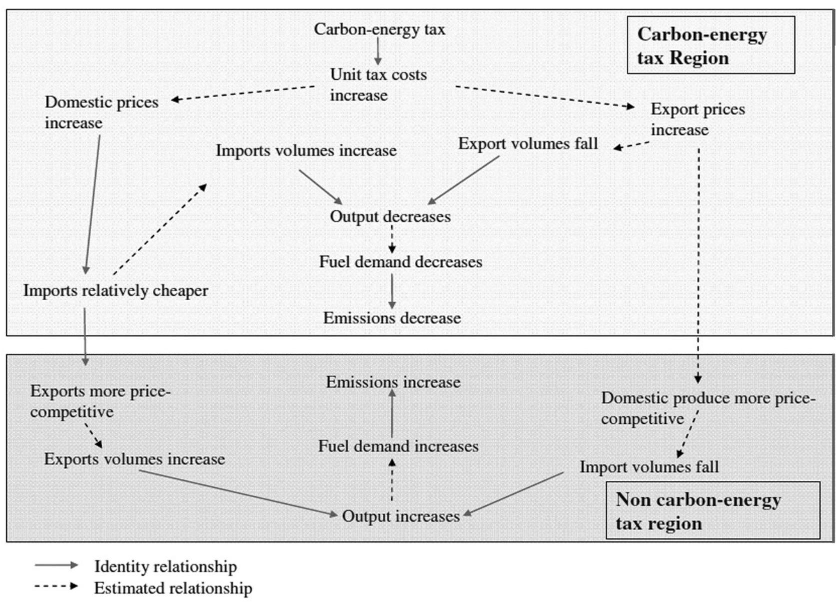
Baranzini et al. (2000) and later Zhang & Baranzini (2004) shed light on the relation of green tax introduction to fiscal reform necessity, as introduction of a new type of tax has impacts on competitiveness, distribution and environment, at least at the same time. Galinato & Yoder (2010) experiences that, environmental taxes on energy are politically unpopular, especially in the USA, particularly because it is hard to accept increasing energy prices any way. That is why they suggest the implementation of a combined tax and subsidy system, because subsidies on alternative energy and fuel are financed by general budget from already existing taxes. However, these types of indirect subsidies are found to be weak in their efficiency to reduce carbon emission. The model contained a tax-subsidy mix for political boundaries. The essence of this model is that revenues from emission taxes finance the subsidies alternative energy.

9.8 European practices and experience

Bossier and Bréchet (1995) described the first European Community initiation on harmonized green tax as follows: *"As it was defined by the European Commission (EC1992), the tax considered in this study is a mixed tax. One of the basic arguments lying behind the proposal was to improve energy efficiency and to curb carbon emissions at a European level. A mixed tax meets both of these purposes since it is based both on the energy and on the carbon content of the different types of fuels (for a discussion of the use of a mixed tax. (See Hoornaert, 1992; Manne and Richels, 1993.) The tax is imposed at a level of 17.75 ECUs/toe the first year which is roughly equivalent to a tax of US$3 per barrel of oil. The energy and carbon components represent 50% of the tax each. The energy component (0.21 ECU/GJ) is levied on all fuels while the carbon component (2.81 ECUs per tonne of CO2) depends on the carbon content of each energy product."*

The global "early birds" in carbon taxation have been the North-European countries such as Norway, Sweden, Denmark, Finland, and the Netherlands, who introduced green taxes in the early 1990s. In other European economies, around the millennium, the carbon charges and taxes were only topic of disputes (Baranzini et al. 2000).

Figure 8 Carbon leakage in the energy-environment-economy model of the EU



Source: Barker et al (2007:6286, fig.1)

Barker et al. (2007) warned the community of European countries that unilateral environmental tax reforms leads to imperfection when participation is particular. It is called carbon leakage, when the efforts made by unilaterally green reforming countries are ruined by the non-reforming countries in two ways. First, the sustained emission level of non-reforming countries ruins the mitigation of reforming ones. Second, the reforming countries suffer from unilateral degradation in their competitiveness since their additional tax. However, very similarly to the weakness of green paradox, Barker et al (2007:6291) found very few proof for carbon linkage: "*Only in a highly competitive, export-driven market does the small industry price increase lead to a decrease in output, namely the UK and German basic metals industries. The absence of strong evidence for carbon leakage is most likely due to the fact that the ETR* (environmental tax reform) *energy taxes are relatively small and so they do not have a large enough effect on unit costs to justify the cost of relocation.*" That might be explained by the generally weak impact of green taxes on economy and emission.

There are several studies assessing national industrial impact of tax burden on carbon emission. Most of them found weak impacts of carbon tax on European national markets in price elasticity and demand structure. In the case of reduction of emission, the studies recognize significant contraction, however, it is not sure, whether the change was enforced by the green tax or a natural part of the technological development cycle, or other regulation. Floros & Vlachou (2005) investigates the carbon tax impact on Greek manufacturing. Their findings showed that energy demand is inelastic, and the diesel demand exhibited the highest price responsiveness. €50 tax per ton of carbon, with no independently initiated electricity restructuring, resulted in an overall reduction of 17.6% in CO_2 emissions between 1998 and 2004. Their sensitivity analysis revealed that this reduction falls within the interval from 11.4% to 26.5%.

Giblin & McNabola (2009) examined the vehicle tax related to carbon emission in Ireland. They estimated a reduction of 3.6 to 3.8% in CO_2 emissions intensity, perpetuated by a shift in purchase patterns to smaller vehicles and diesel engines and amounting to a 3% reduction in total CO_2 emissions from private transport. The price or tax of fuel was measured to be relatively ineffective in influencing car purchase decisions. This resulted little change in the carbon emissions intensity of vehicles. Besides, Wissema & Dellink (2007) analyzed the Irish carbon related energy tax. The Irish economy decreased its carbon emission by 25.8% in the period from 1998 to 2006. Substitution possibilities made it possible to achieve this with relatively lower tax level. The welfare impact of Irish carbon tax was very slightly negative, by -1%, as the tax resulted in adjustment in the form of shift in demand structure. The biggest welfare damage was caused among the poorest households.

Bureau (2011) estimated the impacts of French carbon tax on car fuels. The conclusion on the French regime was that the 7-8 Euro cent / liter tax caused income loss for households, where the poor suffered more. The poorest households lose 6.3‰ of their income, as compared to 1.9‰ for the wealthiest. This actually means regressive taxation. However, the recycling of tax revenues toward the poorer households has been measured to be more intensive than toward the wealthiest. Despite the latter gross trend, the net loss of poorer households still exceeded the loss of richer ones.

Bruvoll & Larsen (2004) were interested in the functionality of Norwegian carbon taxes on CO_2 and N_2O gases. In Norway, carbon taxes were implemented in 1991. The Norwegian emission of CO_2 increased by 19% in the period from 1990 to 1999. The authors understood this growth to be lower than the 35% GDP growth; namely, GDP was reduced by 12% by emission cuts. The energy intensity and structure created particularly a 14% reduction of emission in the surveyed period. However, it could happen because the carbon taxes in Norway have been dominated by the national oil and gas industry. In case of non-oil producing industries, the carbon tax effect on emissions was measured only as 1.5%. The competitiveness related exemptions weaken the impacts very much in a broad range of fossil fuel intensive industries. The existence of zero-tax industries such as metal and industrial chemicals explain why there has been close to zero effect by green taxes.

9.9 Green taxation for growth and employment

Kohlhaas (2000) described the green tax reform concept as follows*: "A core concept of ecological tax reform is to levy environmental taxes (or charges) and use the subsequent revenue to reduce other existing taxes by an equivalent amount. This revenue-neutral approach ensures that the business sector and private households, taken as a whole, will not face a higher overall tax burden. Ideally, this method enables policymakers to reduce economic distortions that the tax system currently causes by reducing taxes that are considered harmful to the economy."* According to the findings by Bossier & Bréchet (1995), carbon pricing (e.g. through green tax) can be connected to employment problems, especially in developed European countries. Their recommendation toward policy makers is to pay attention on the total tax burden. Although the primary purpose of green tax is not to secure government revenues, it is eventually a budget resource. Thus the volume of carbon tax revenues can be redistributed through cuts of other duties, especially if this results in growth impacts. Europe suffers mostly by relative low employment causing high social fiscal costs. So, it seems reasonable to ease the burden on labour cost.

The simple version of tax compensation means only a redistribution of the funds in social service systems. In this case, green tax must finance the loss of revenues from the easing of social security contribution. Of course, in a complex social security reform (pension reform and health care funding reform), the tax easing anticipating the green tax can be broader. The latter approach indicated by "green tax for employment" slogan sets the carbon taxation issue in a complex economics model. The efficiency of this policy instrument will be indicated not only by carbon reduction, but also by its impact on employment, energy use efficiency, prices, wages and ultimately on global competitiveness and external balance (Bossier & Bréchet 1995).

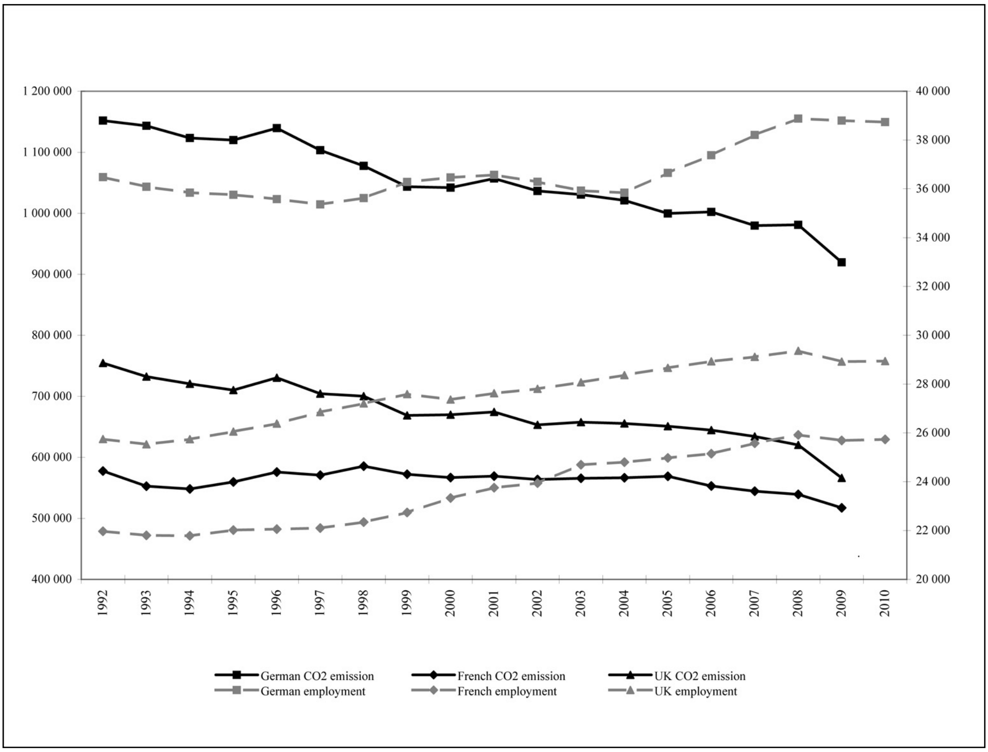
In European relevance, two ways of so-called targeted cuts in social security contribution have proved to be practical. The targeted cuts in contribution paid either by sectors exposed to international competition or by sheltered sectors like single market services. The other way, recommended by Drčze et al (1994), means targeted cuts in contribution paid by sectors employing low-skilled workers. The latter one can help a serious problem caused by the quickly growing value added by technological development, which excluded about 10% of the European society from the labour market (Bossier & Bréchet 1995).

There is a good practice on green tax reform combined with employment objectives in Germany. The *Gesetz zum Einstieg in die ökologische Steuerreform* (First Step toward an Ecological Tax Reform Act) took effect in 1999. Green tax was levied on primary energy consumption, in parallel with cuts on the employers labour-related cost. (Bach et al. 2002) As it is described by Kohlhaas (2005), Knigge & Görlach (2005) and Kohlhaas (2000), the ecological tax reform was started in 1999, and finalized by a later modification in 2003. This tax reform gradually raised the tax burden on petroleum and gas and introduced the electricity tax. Parallel, the wage cost was decreased in public budget revenue in a neutral way. The modification in 2003 was simply differentiation between renewable and non-renewable energy use, as the Act introduced the subsidies for renewable energy and for energy saving reconstructions of buildings.

The German green tax revenue rose up to 18.7 billion EUR in 2003, but the emission reduction impact stabilized later the green revenue around 16 billion EUR in the following years. This financial room created opportunity to lower the total volume of public pension insurance contribution by 1.7%. In wage cost, this made possible to lower the social insurance rate from 42.3% to 40% of gross wage (Kohlhaas 2000, Kohlhaas 2005, Knigge & Görlach 2005).

As shown in table 1, the reduction of emission speeded up exponentially from the start-up year 1999. The -2.39% change of CO_2 emission in 2003 meant 20 million tons less carbon air pollution. In parallel, employment grew by approximately 250 thousand people until 2003 which already meant an employment ratio of +0.75%. However, the impact of reform on GDP growth was measured to be insignificant, close to zero. Among the sectors of national economy, the private sector felt lower social security cost and higher energy and fuel prices, the government balance was not affected, the investments were diverted toward energy saving technologies, which resulted high fluctuation among industries. Thus, the industrial level impacts proved to be very various. (See Table 2.) The current account impact is negative, the higher cost of import energy ruined the export competitiveness of German industries; thus, export sank and import grew. Especially the transportation and the construction sector suffered from the highest increase of cost as they have been the most energy intensive sectors, at the same time the agriculture suffered the biggest contraction by higher energy price for being more price elastic than former industries (Kohlhaas 2005, Knigge & Görlach 2005).

Figure 9 Emission (left axis, 1000 tons/year) and employment (right axis, 1000 persons) in Germany, France, United Kingdom.



Source: Eurostat, data download in June, 2011.

Table 1 Annual changes in emission, employment and GDP as impact of German ecological tax reform, %

Change in	1999	2000	2001	2002	2003	2004	2005	2010f
CO2 emission	-0.55	-1.33	-1.75	-1.95	-2.39	-2.47	-2.61	-3.1
Employment	0.64	0.76	0.67	0.41	0.76	0.63	0.52	0.46
GDP	0.39	0.47	0.44	0.29	0.45	0.38	0.3	0.13

Source: Kohlhaas (2005:13, Tabelle 3-1), f = forecast

Table 2 Effects of the ecological tax reform on the real production output of industries, Deviations from the reference growth values, %

Industries	1999	2000	2001	2002	2003	2004	2005	2010f
Agriculture	-0.08	-0.31	-0.27	-0.37	-0.41	-0.33	-0.31	-0.57
Energy	-0.41	-1.19	-1.79	-1.94	-2.31	-2.52	-2.66	-3.37
Raw material and chemical	0.02	-0.13	-0.25	-0.27	-0.11	-0.09	-0.01	-0.19
Investment goods	0.24	0.18	-0.10	-0.07	0.18	0.11	0.11	-0.02
Consumer goods	0.06	-0.06	-0.09	-0.10	0.11	0.06	0.10	-0.06
Construction	0.82	1.06	0.87	0.19	0.52	0.24	-0.02	-0.18
Transport	0.20	0.07	0.05	-0.12	0.02	-0.03	-0.06	-0.15
Services	0.44	0.43	0.40	0.32	0.43	0.34	0.25	0.07
Government	0.16	0.50	0.67	0.67	0.62	0.73	0.64	0.48

Source: Kohlhaas (2005:13, Tabelle 3-2), f = forecast

Kohlhaas (2005) created *ex post* and *ex ante* model to estimate the effect of German green tax reform on GDP and employment. The German green employment shows effective characteristics, as during the global recession the German unemployment could have decreased from 10% to 7%, in period of 2008-2011. (See Fig. 9.)

9.10 Conclusions

It can be established, that climate change has introduced a new aspect into the structure of public finances both in expenditure and in revenue side. The exact fiscal impact in a given country is very uncertain since neither the exact regional natural impact is unsure, nor the unilateral national/regional mitigation could be enough and efficient without global cooperation. The fiscal impacts can be mapped by calculating with direct spending related to damages caused by climate change, and with indirect impacts in revenues and new expenditure themes caused through climate impacts on the economic growth, health condition, social relations and energy demand.

It is clear, that the multi-year fiscal stimuli to anticipate the global crisis started in 2008 created unfavourable fiscal rigidity for new types of spending, like climate change related mitigation and adaptation. It is not an easy task to enforce the political decision makers to prefer a 50-100 year-long problem to their short term interest related to political cycles, either. However, there are good practices how to build-in automatisms into the budget by funding, how to keep the balanced budget by restructuring of spending and tax systems, how to involve the private (autonomous) financial resources through insurance and funding. The government must find the optimum distribution of adaptation cost between public (planned) and private (autonomous) adapting actors and the adequate structure of incentives to motivate the private individuals for cooperation and participation in mitigation and adaptation to climate change.

The efficient policy should treat with the factors or drivers of climate change cost, just like the degree of exposure to gradual and extreme climate events, the level of existing protection, the state's liability for damages, the potential and impacts of autonomous adaptation, the cross-border effects, and the fiscal capacity.

The public budget must be the reserve for mitigation with complex structure. Either infrastructural or social or health or industrial or employment etc. aspects can connect to the climate problem. It is not simple to introduce any fiscal item or action for mitigation and adaptation since fiscal crowding-out and multiplier effects must be simulated on savings, investments, carbon emission, economic growth, competitiveness, external balance and employment. The simulation in the same time means testing the policy risk, namely the potential failure of green budget reform, and the political risk, namely loosing the next elections because unwanted side effects.

The ideal fiscal policy affected by climate change would be a green stimulus combining spending and green tax, meanwhile keeping the scale and balance of the budget, but restructuring the fiscal preferences, thus, cutting the wage related cost of employment and improving the international competitiveness of the national economy.

As climate change is global problem, international/global cooperation is likely to be the most efficient also in fiscal aspect. International cooperation can give solution for risk distribution, low income insolvency, credible funding with private investors, technological cooperation and access to knowledge, efficiency of early warning and reserving sustainable national budgets, all together.

A carbon tax could be one of the most effective policies to mitigate carbon emissions. The implementation of green tax is expected to price the externalities cost-effectively, thus, really enforce the mitigation of the private sector. However, there are some limits of the policy making by taxation. The carbon tax impact is not absolutely certain if price and income elasticity can not be empirically forecasted. The flat tax rate can have various impacts on industries or different size of companies having various productivity or profitability.

A multilateral ecological tax reform seemed to be more effective than a unilateral one, however, the assumption that the impact on competitiveness would be smaller if more countries participated or took equivalent measures was not proved by empirical studies. Anyway, after the proposal of the German government, the EU accepted tax rate minimum limits for ecological taxes like environmental protection product fee, environmental charges, and energy taxes on electricity, natural gas and coal. (See Directive 2003/96/EEC.) However, a EU-wide counter tax easing was not harmonized for higher employment.

In the case of complex environmental tax reform, the extent of increase and cuts on tax rates will be cautious and prudent since the impact of green tax on medium or long term emission reduction will result a fall in tax revenues, too.

The European experience from green tax shows small impact on emission, welfare and competitiveness. Because substitution opportunities on carbon-related fuel and energy are income dependent, households with lower income take relatively more burden. This means that the theoretically flat carbon tax actually works as a regressive tax.

The empirical studies measure low efficiency and low elasticity in the case of green tax implementation, which can be explained with a broad range of exemptions in energy use and rigid, inelastic demand in gasoline consumption.

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10. The Europe 2020 Strategy as a response

10.1 Introduction

Climate change, without going into academic debates, can be regarded as a scientific fact. The anthropogenic phenomenon is a global problem; it may even be *the* threat of the present century that jeopardises practically all regions of the world. Therefore in a theoretical ideal case the actions taken in order to avoid the detrimental effects of the anthropogenic greenhouse effect should have to be global as well. However, mainly due to the different (primarily diverging economic) interests of the most influential and polluting international actors (prisoners' dilemma), a true global action and international cooperation against climate change is still to be achieved. As a result of the lacking international cooperation (regardless of the operative but not efficient Kyoto Protocol), the main international players possess their own climate strategies that, of course, can no way possess the same efficiency on an aggregate level as a global action would do.

The same applies for the European Union. In order to combat climate change, the partly supranational cooperation of 27 European states possesses a climate strategy that primarily intends to reduce the greenhouse gas emissions of member states since the first community strategy of 1991. Furthermore, the EU, as a forerunner, enhances its programme combating climate change with other actions and often emphasises that its climate change programme is the most ambitious worldwide. However, the intra-European cooperation that emerged basically in the last past years still cannot be perceived as a complex policy since, due to the structure of the union and despite ambitious goals, the implementation of the EU policies is still happening basically on a member state-level.

This chapter concentrates on the current climate change policy of the European Union with regard to the Europe 2020 Strategy and takes the climate related actions of the strategy into account. The short study does not elaborate on all climate change related activities of the European Union. It does not specify the main duties of European Commission Directorate-General for Climate Action, neither does it analyse the EU's long term emission reducing strategy called Roadmap 2050, nor does it go into policy specific details as the EU's greenhouse gas monitoring and reporting system. The main purpose of this chapter is to provide an introduction to the topic and make the reader acquainted with the Europe 2020 strategy's climate related measures. Consequently, due to the review nature of this chapter, it primarily relies on official EU documents, sources (legislative proposals, studies, and statistics).

Moreover, it also has to be emphasised that the climate related measures of the Europe 2020 strategy cannot be perceived as sole climate related measures, but rather as an integrated climate and energy package. Given that energy production and use are the main sources for greenhouse gas emissions, climate policy is closely linked to energy policy.

The primary reason why this chapter focuses exclusively on the climate related measures of the Europe 2020 strategy is due to the fact that EU 2020 is the buzzword in current EU politics. This growth strategy sets various economic, social, and environmental goals with a deadline for 2020, which ought to trigger economic growth. It is this strategy, which should transfer the EU into a smart, sustainable, and inclusive economy. Whatever the outcome of the EU 2020 (climate change related) strategy may be years later, it is this strategy that will stand in the foreground of European politics in the upcoming years.

10.2 The birth of the integrated climate and energy package – an overview of the climate related goals of the Europe 2020 framework

To begin with, it is noteworthy that the so called "energy and climate package" of the European Union – that is now an essential and coherent part of the Europe 2020 strategy – already emerged in 2007, long before the birth of the Europe 2020 strategy. The forerunner of the agreement reached in 2007 is the so-called Green Paper (2006) issued by the European Commission. The green paper covering the topics of energy sustainability, energy security, and energy efficiency already indicated that the European Union simply needs a coherent, new energy strategy in order to face the challenges of the 21st century. The new strategy should be arranged around the following cornerstones according to the Commission's document: establishment of an internal electricity market, enhancement of solidarity among Member States, shift to a sustainable energy structure, an integrated approach to mitigate climate change, encouragement of innovation, unification of the energy related foreign policies (Green Paper, 2006).

The intention of the Commission was clear: starting a Europe-wide discussion on the future energy and climate policy of the European Union. The cornerstones of the green paper envisaged the future focal points of an emerging strategy and – not of minor importance – triggered the member states to make thoughts about the possible ways of future cooperation regarding energy policy. Not surprisingly the European Commission released the official document “An energy policy for Europe” only one year after the publication of the green paper. It was this document that can be regarded as the first important step of the emergence of an integrated energy policy that already contained the main elements of the present Europe 2020 climate and energy package. Interestingly, the document enumerates the threats and primary reasons why the EU should act and finds the following arguments as important: combating climate change, limiting the EU's external vulnerability to imported hydrocarbons, furthermore promoting growth and jobs, thereby providing secure and affordable energy to consumers.

The document also underlines the vital importance of creating a real internal energy market that relies on competitiveness, sustainability, and security of supply. The Commission document also stresses the importance of solidarity among the member states regarding energy related issues. However, apart from the general observations, the document also describes the future actions and policies that the EU should take in order to combat the well known difficulties and threats. The Commission’s first proposal is an action on the limitation of greenhouse gases (GHG). The action on GHG is crucial due to the facts that:

- CO2 emissions from energy make up 80% of EU GHG emissions, reducing emissions means using less energy and using more clean, locally produced energy,
- an integrated action may limit the EU's growing exposure to increased volatility and prices for oil and gas,
- reducing GHG emissions may potentially bring about a more competitive EU energy market, stimulating innovation technology and jobs.

(Communication from the Commission to the European Council and the European Parliament – An energy policy for Europe, 2007)

Therefore it is no surprise that the Commission proposed the EU to have an objective of 30% reduction in greenhouse gas emissions by developed countries by 2020 compared to 1990 – should an agreement be reached on the international negotiations. In addition, global GHG emissions must be reduced by up to 50% compared to 1990, implying reductions in industrialised countries of 60-80% by 2050. Should no international agreement on greenhouse gas reduction be reached on the international negotiations, an *EU commitment of a 20% reduction of greenhouse gases by 2020 compared to 1990* should still be valid. (Communication from the

Commission to the European Council and the European Parliament – An energy policy for Europe, 2007) Moreover, the Commission also pledged to review the EU ETS (EU Emissions Trading System) in order to create the necessary incentives needed to stimulate changes in how Europe generates and uses its energy.

The second measure affects the energy efficiency of the European Union. According to the document, improved energy efficiency has the potential to make the most decisive contribution to achieving sustainability, competitiveness and security of supply. Therefore, increasing energy is efficiency is crucial; the measures already established in 2006 by the so-called Energy Efficiency Action Plan are to be fulfilled. The Energy Efficiency Action Plan already contains measures that would put the EU on the path to achieving a key goal of *reducing its global primary energy use by 20% by 2020*. The Commission intends to reach this goal primarily by accelerating the use of fuel-efficient vehicles, by establishing stricter standards and better labelling on appliances, by rapidly improving the energy performance of the EU's existing buildings etc. (Communication from the Commission to the European Council and the European Parliament – An energy policy for Europe, 2007).

Finally, the last provision of the legislative proposal consists of the future regulation regarding renewable energy sources. According to the Commission document, the use of renewable energy sources is vital for the future economies, due to the facts that:

- Using renewable energy today is generally more expensive than using hydrocarbons, but the gap is narrowing – particularly when the costs of climate change are taken into account;
- Economies of scale can reduce the costs for renewables, but this needs major investments;
- Renewable energy helps to improve the EU's security of energy supply by increasing the share of domestically produced energy, diversifying the fuel mix and the sources of energy imports and increasing the proportion of energy from politically stable regions as well as creating new jobs in Europe;
- Renewable energies emit few or no greenhouse gases, and most of them bring significant air quality benefits.

The Commission therefore proposed a binding target of *increasing the level of renewable energy in the EU's overall mix from less than 7% today to 20% by 2020*. The necessary measures are detailed in the Commission documents entitled "Renewable Energy Roadmap" and "Renewable Energy Directive". Since achieving a 20% share for renewables will most likely result in an additional average annual cost of approximately € 18 billion, this measure can be maybe regarded as the most important among the 2020 related goals.

On the whole, the Commission proposed the following measures that can be regarded as the spinal cord of an emerging European climate and energy package:

1. 20% reduction of greenhouse gases until 2020
2. reducing primary energy use by 20% until 2020
3. increasing the average level of renewable energy sources to 20% by 2020

The publication of the Commission document was followed by the usual legislative procedure: the (European) Council and the European Parliament also discussed the legislative proposal and made the necessary amendments, changes. The outcome of the procedure was unveiled already in 2007, when the Council of the European Union approved the strategic points of the Commission's proposal. Accordingly, the Council document emphasises that the climate related challenges have to be tackled urgently and effectively and calls upon the creation of an integrated approach to climate and energy policy. The document also underlines that an emerging energy and climate package should fully respect the member states' choice of energy mix and sovereignty over primary energy choices (N.B. Germany's energy policy actions following the Fukushima-catastrophe). However, it is also stressed that solidarity has to be achieved among the member states regarding the increasing security of energy supply, regarding the coverage and the availability of affordable energy, and regarding the promotion of environmental sustainability and combating climate change.

In general the Council was committed to maintaining international leadership on climate change and energy. It praised the GHG emission declining actions proposed by the Commission and stressed the importance of the establishment of a renewed ETS regulation. Moreover, the Council underlined that an effective, fully-functioning and interconnected internal energy market is an essential condition for a secure, sustainable and competitive supply of energy in Europe. It furthermore stressed the importance of energy efficiency and the advanced use of renewable energy sources and positively acknowledged the Commission's commitment proposals. So on the whole the Council reaffirmed the general observations made by the European Commission, endorsed the specific goals of the legislative proposal, and gave green light to the realisation of the integrated climate and energy package, to the ambitious package of proposals proposed by the Commission (Council of the European Union: Presidency Conclusions, 2007).

Keeping in mind that the integrated climate and energy package dates back to 2007/2008, the accompanying legislation, legislative proposals were also established in the upcoming months and years, e.g.:

- Proposal for a directive of the European Parliament and of the Council on the geological storage of carbon dioxide (2008)
- Proposal for a directive of the European Parliament and of the Council on the improvement and extension of the emissions trading system of the Community (2008)
- Proposal for a directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (2008)

As the legislative procedures regarding the integrated climate and energy package came to an end, the new energy and climate policy of the EU was established. This was a remarkable step of the EU due to the fact that such an integrated climate- and energy package, those actions are mandatory for all member states, is a totally new phenomenon in the history of the European integration. However, it has to be underlined that the package itself does not exist anymore. The climate and energy related actions were integrated into (amended to the actions of) the ten-year strategy called “Europe 2020” proposed by the European Commission in 2010. The strategy intends to be the adequate response to the current economic crisis by aiming to transfer the EU into a smart, sustainable, and inclusive economy.

10.3 The actions of the Europe 2020 climate strategy in detail

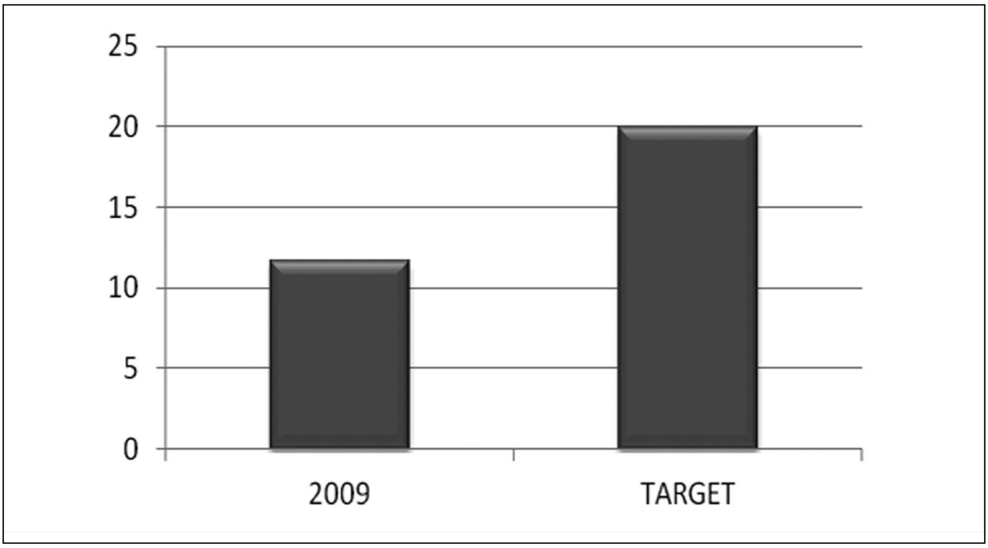
The actions of the integrated climate and energy package that form an essential part of the Europe 2020 Strategy have already been briefly introduced. The following sub-paragraphs elaborate on the specific measures that are pursued by describing the current situation and the specific legal background/regulation of each policy action.

Increasing the share of renewable energy sources up to 20%

Renewable energy sources can be generally regarded as those clean energy sources that may be an effective alternative to substitute traditional fossil energy sources producing greenhouse gases. So renewable energy sources (namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas, and biogases) in the end can help combating climate change – one may cut the consumption of fossil fuels by some hundred million tonnes a year, reduce CO2 emissions by many hundred million tonnes a year. Additionally, renewable energy sources may also provide a secure and clean supply of energy, whereby the dependence on external energy supplies could be reduced significantly. Moreover, keeping the economic aspect in mind, renewable energy sources may also be regarded as opportunity for the national economies as well, due to the fact that job generation and R&D expenditure in the industries related to renewable energy sources have an effect on the national economies as well. By today it is already evident that economic growth can be established through innovation and a sustainable competitive economic policy.

However, besides the positive effects of the clean energy sources, the European Union as a whole does not currently possess figures good enough in terms of the usage of renewable energy sources. There are some member states that do have a relatively high amount of energy production deriving from renewable energy sources; however, the general situation of the EU regarding the usage of renewable energy sources is not that glorious. According to the latest Eurostat figures, the share of renewable energy in the gross final energy consumption was 11% in 2009 in the European Union, so should the member states want to achieve the 2020 targets by the original deadline, an increase of more than 10 percentage points has to be achieved in the upcoming ten years.

Diagram 1 The share of renewable energy in gross final energy consumption (%) – EU27



Data source: Eurostat (own diagram)

The goal of the European integrated climate and energy package, namely to increase the share of renewable energy sources to 20% until 2020, is formulated explicitly in the directive nr 2009/28/EC of the European Parliament and of the Council. This directive approved in 2009 established a common framework for the promotion of energy from renewable energy sources and set the binding national targets for all member countries for 2020. Moreover, the future share of renewable energy sources is not only regulated regarding the gross final energy consumption, but also regarding the share in transport: a fixed 10% of transport fuel should be covered by biofuels – or other fuels from renewable energy sources – in each member state of the European Union.

Regarding the mandatory national overall targets set by the directive, the legal document underlined that each member state has to ensure the reach of the legally binding target by 2020 in their energy mix, but did not implement any sanctions, should the target not be reached by 2020. The most important aspect of the directive is without doubt the introduction of the national targets that were calculated according to a rather specific and complex formula detailed in the directive, but apart from the emerging targets it is also noteworthy to mention the so-called national renewable energy action plans. These action plans set out the member states' national targets for the share of energy from renewable sources, taking into account the effects of the necessary policy measures, the necessary measures to be taken to achieve the national overall targets (Directive 2009/28/EC). In other words, these action plans can be regarded as roadmaps of how a member state plans to reach its national target. According to the directive, all member states should have sent their national action plans to the European Commission by the 30 June 2010; however, some member states (e.g. Hungary) only did so with a significant delay.

The national targets for each member state are the following (the first column depicts the share of renewable energy sources in 2005; this figure was used as a basis for the calculation of the 2020 target):

The table demonstrates that various member states possess different positions regarding the share of their renewable energy sources, so the target for 2020 also differs for (nearly) each member state. The member states also have reporting obligations, since they have to submit reports to the European Commission on their progress in the promotion and use of energy from renewable sources in every two years. The member states' reports are complemented by the monitoring activity of the Commission, since the Commission also analyses the activity of the member states regarding the promotion of renewable energy sources (especially the origin of biofuels and the impact of their production) and shall, if appropriate, propose corrective action (Directive 2009/28/EC).

Table 1 Renewable energy targets (%)

	2005	2020 target		2005	2020 target
Austria	23,3	34	**Latvia**	32,6	40
Belgium	2,2	13	**Lithuania**	15,0	23
Bulgaria	9,4	16	**Luxembourg**	0,9	11
Cyprus	2,9	13	**Malta**	0	10
Czech Rep	6,1	13	**Netherlands**	2,4	14
Denmark	17,0	30	**Poland**	7,2	15
Estonia	18,0	25	**Portugal**	20,5	31
Finland	28,5	38	**Romania**	17,8	24
France	10,3	23	**Slovak Rep**	6,7	14
Germany	5,8	18	**Slovenia**	16,0	25
Greece	6,9	18	**Spain**	8,7	20
Hungary	4,3	13	**Sweden**	39,8	49
Ireland	3,1	16	**UK**	1,3	15
Italy	5,2	17	**EU27**	8,5	20

Source: Directive 2009/28/EC; (own diagram)

Increasing energy efficiency by 20%

The goal of increasing energy efficiency is three-fold: to decrease the greenhouse gas emissions, to increase energy security and sustainability, and to achieve significant savings in energy consumption. Energy efficiency is key to achieve economic growth and establishing more jobs while it decreases the energy costs of enterprises and households. In many ways, energy efficiency can be seen as Europe's biggest energy resource. By saving 20% of energy consumption by 2020, the EU hopes to cut emissions by almost 800m tonnes a year and save as much as €100bn (2020 Vision: Saving our energy (2007)).

The main opportunity to achieve the goal of increasing energy efficiency lies in the development, improvement and diffusion of energy efficient technologies, products and services especially in the fields most prone to energy savings. Question is, whether regulation enhances or discourages investment in research by EU industry? There is no consensus among environmental economists whether environmental regulation causes a positive or a negative impact on firm behaviour. The exact impact of regulation is relatively unknown, however, results from previous EU experiences indicate that in general, regulation tends to encourage more investment, but if restrictions are too tight investment levels can start to fall (Leiter et al. (2010)). The relationships between environmental regulation and investment indicate that European industries appear to focus on the comparative advantages resulting from an efficient and sustainable resource management, i.e. increased availability of resources (input factors) or enhanced quality due to a decrease in pollution. Alternatively, industry could recognise the advantage of investing in innovative technologies to improve efficiency or to sell technology as a product. Thus finding the right balance between regulations, environmental taxation (pollution taxes) and investment into environmental research (R&D) is essential for the future of the environmental policy (and the increase of energy efficiency) of the European Union.

As for energy efficiency, the greatest energy saving potential can be attributed to buildings, transport and manufacturing. Accounting for about 40% of the EU's needs of energy and 36% of CO_2 emissions, buildings come top of this list of areas where energy efficiency can be enhanced. According to certain estimations, energy consumption of buildings could be cut by up to a third. It is seen as no surprise that the EU has made several steps to take certain aspects of energy efficiency into account in planning and designing new buildings to encourage the use of more efficient lighting, heating, cooling and hot-water systems, since the Directive on energy performance of buildings (2010/31/EU) makes it mandatory for the Member States to apply minimum requirements as regards the energy performance of new and existing buildings, ensure the certification of their energy performance and require the regular inspection of boilers and air conditioning systems in buildings. (For more information on building efficiency, see: Energy-efficient homes and buildings: The beauty of efficiency 2008).

Table 2 Energy saving potential in the European Union as of sectors

Sector	Energy consumption 2005 (Mtoe)	Energy saving potential 2020 (Mtoe)	Energy saving potential 2020 (%)
Households (residential)	280	91	27
Commercial buildings (tertiary)	157	63	30
Transport	332	105	26
Manufacturing industry	297	95	25

Source: 2020 Vision: Saving our energy (2007); (own diagram)

The second most energy-consuming sector is transport (approx. 25% of EU energy requirements). The main measure to be taken here directly affects car production as in order to make the most optimal use of energy efficiency potential, car emissions are to be capped at 120g of CO_2/km by 2012. This legally bounding directive (Directive 98/70/EC) assures a significant decrease in the emission of substances harmful to the environment by car industry. Energy-efficient vehicles should be promoted through clearer labelling as well as public and non-motorised transport. Finally there are several opportunities to increase energy efficiency in manufacturing as well, which accounts for another 25% of EU energy requirements and has an energy saving potential of 25%. The energy performance of products has been studied and eco-design standards will be applied to certain products such as boilers, televisions and lighting products to improve their performance. The eco-label tells consumers which product or service is kinder to the environment and saves the most energy. This can be seen in practice for example at the labelling of electronic household equipments, which are ranked from A++ energy class to G energy class (A++ being the most eco-friendly) by their energy consumption. Labelling that is regulated by Directive 2010/30/EU is another way to encourage conscious consumer for “green shopping”.

Nonetheless, recent European Commission estimates suggest that the EU is on course to achieve only half of the 20% objective (European Commission Communication: Energy Efficiency Plan 2011). Responding to the call of the European Council of 4 February 2011 to take 'determined action to tap the considerable potential for higher energy savings of buildings, transport and products and processes', the Commission has therefore developed a comprehensive new Energy Efficiency Plan, which was adopted on 8 March 2011. This Plan sets out that the public sector should lead by example in energy efficiency as public spending accounts for 17% of EU GDP and publicly owned or occupied buildings represent about 12% by area of the EU building stock. Hence achieving the goals in the public sphere would bring a substantial change in energy expenses.

Following the adoption of the plan a new set of measures for increased Energy Efficiency was proposed by the European Commission to fill the gap and put back the EU on track. The new directive (COM(2011) 370) proposed in June 2011 by the Commission would bring forward measures to accelerate Member States efforts to use energy more efficiently at all stages of the energy chain – from the transformation of energy and its distribution to its final consumption. Apart from setting a common framework for promoting energy efficiency, the directive draws up three ambitious measures:

1. a legal obligation to establish energy saving schemes in all Member States
2. the public sector to lead by example (in line with the Energy Efficiency Plan) and
3. major energy savings for consumers.

Apart from many noteworthy elements contained in the legal proposal, the future regulation also recommends that public bodies should buy energy-efficient buildings, products and services, and refurbish 3% of their buildings each year to drastically reduce their energy consumption.

The main target of the regulation from an end-consumer's point of view is to raise awareness and ensure better information. Consumers would be better able to manage their energy consumption thanks to better information provided on their meters and bills while energy utilities would have to encourage end users to cut their energy consumption through efficiency improvements such as the replacement of old boilers or insulation of their homes. National energy regulatory authorities would have to take energy efficiency into account when deciding how and at what costs energy is distributed to end users. However, not only energy utilities and consumers are to take serious measures but the industry as well. Industry would be expected to become more aware of energy-saving possibilities, with large companies required to undertake energy audits every 3 years. Having set the goals, it is important to keep in mind that progress made in achieving EU's 20% energy saving target in 2020 will be reviewed in 2014. In case the countries are lagging behind in achieving the target numbers, national energy efficiency targets will be proposed.

Cutting greenhouse gases by 20%

Today, it is clear that major reductions in emissions are needed to prevent global warming from reaching dangerous levels. The emission of the greenhouse gases is the number one reason for the anthropogenic greenhouse effect so the reduction of such emissions is vital for the future climate of the planet. Although the international climate negotiations did have some positive outcomes and agreements (UN Framework Convention on Climate Change (UNFCCC) in 1992 and the Kyoto Protocol in 1997), it can be generally stated that these international negotiations did not yet reach a breakthrough (the scope of the Kyoto Protocol is 2008-2012) so the future global emission reduction is at least regulated in an appropriate way. Anyhow, the aim of the European Union is to reduce the emission of greenhouse gases. The member states have committed themselves to reduce their greenhouse gas emissions by at least 20% from 1990 levels by 2020 and by 30% if a satisfactory international agreement is reached.

GHG emission reduction is a complex task that requires a multipronged attack. The basic action necessarily taken is the reduction of primary energy usage by increased energy efficiency and the substitution of fossil energy sources by renewable ones (see subparagraphs 2.1. and 2.2. for more detail). Apart from these initiatives, the European Union gives special attention to two other mechanisms that may directly reduce GHG emissions in the long-term: the EU Emissions Trading System and the so-called 'carbon capture and geological storage' mechanism. Since an essential part of the Europe 2020 strategy's GHG reduction action comprises of these two latter mechanisms, it is necessary to elaborate on these two latter mechanisms in the following.

The EU Emissions Trading System (EU ETS) was the world's first international company-level 'cap-and trade' system of allowances for emitting carbon dioxide (CO2) and other greenhouse gases. The system was launched in 2005 and is considered as a key tool for a market-based and cost-effective reduction of industrial greenhouse gas emissions. The basic principle of the mechanism that covers some 11.000 power stations and industrial plants in 30 (!) countries functions on the cap and trade principle. The principle means that a cap is allocated on the total amount of certain greenhouse gases that can be emitted by the factories, power plants and other installations that are part of the EU ETS. Within this limit, companies receive emission allowances which is tradable: companies that are in need of more emission quotas then they received may buy from others and vice versa. The limit on the total number of allowances available ensures that they have a value. The essence of the EU ETS is that at the end of each year each participating company must surrender enough allowances to cover all its emissions. Should this not be the case, heavy fines are to be imposed on the violation company. The market-philosophy of the EU ETS in ensured by the fact that those companies that reduced their emissions can keep the spare allowances to cover their future needs or sell them to another company that is short of allowances. This market-based approach combined with flexibility ensures that GHG emissions are cut. One also has to mention the declining number of allowances that keeps the system in movement. According to various forecasts, by 2020 the GHG emissions will be by 21% lower than in 2005 as a result of the EU ETS (The EU Emissions Trading Scheme (2008)). Moreover, by putting a price on each tonne of carbon emitted, the EU ETS is driving investment in low-carbon technologies.

Although the EU ETS relies on several directives and cannot be perceived as a simple construction, the mechanism is constantly developed. Interestingly, its geographical scope is not just the European Union, but other countries outside the EU are full members of the EU ETS as well (Iceland, Lichtenstein, Norway) that explains there are 30 members within the system. Moreover, it is officially confirmed that the EU ETS is open to establishing links with compatible mandatory cap-and-trade systems for greenhouse gases in other parts of the world in order to enlarge the international emissions trading market further (The EU Emissions Trading Scheme (2008)). Apart from the geographical scope, the EU ETS currently covers around 11.000 installations in power generation and manufacturing. According to the upgrade of the EU ETS, its scope will be expanded to include emissions from air flights to and from European airports and to the petrochemicals, ammonia and aluminium industries. These modifications regarding the participating industry sectors will be in force from 2013, when the third trading period (running from 1 January 2013 to 31 December 2020) will be launched.

Besides the EU ETS, the European Union dedicates a special role to the cutting edge technologies that also make a contribution to curbing the GHG emissions. One of these technologies is the so-called 'carbon capture and storage' (CCS) that can be perceived as a technique for trapping carbon dioxide as it is emitted from large point sources, compressing it, and transporting it to a suitable storage site where it is injected into the ground (Directive 2009/31/EC is the basic regulation regarding CCS). Experts expect CCS to be a great asset in the combat against climate change since the technology has significant potential as a mitigation technique for climate change, both within Europe and internationally, particularly in those countries with large reserves of fossil fuels and a fast-increasing energy demand. In the EU the CO_2 emissions avoided through CCS in 2030 could account for some 15% of the reductions required (Directive 2009/31/EC). The role of carbon capture and storage is also reflected in the newly published 'Roadmap 2050' document as well which targets a reduction of the European emissions of 80-95% by 2050.

The principle of the CCS is to capture carbon dioxide as a relatively pure gas. This is not a new technology since CO_2 is routinely separated and captured as a by-product from industrial processes. After capturing, CO_2 needs to be stored exclusively in compressed form and transported to the place of sequestration. After the transportation process, CO_2 can be sequestered directly in geological formations including oil and gas reservoirs, and deep saline reservoirs. According to the experiences, the security of sequestration depends on the site characteristics and management. However, environmental integrity remains a concern. CCS is a relatively new technology, and one has to ensure that the captured and stored CO_2 do not pose any risks to the nature. The novelty of the CCS technology is in fact the reason the relating integrated systems are new, and a clear regulatory framework must be still developed. Last, but not least, one also has to mention the cost-effects of the carbon capture and geological storage. Capture in particular is an expensive component due to the fact that flue gas from coal- or gas-fired power plants contains relatively low concentrations of CO_2 (10-12% for coal, and around 3-6% for gas), and the energy needed to capture at such low concentrations imposes a significant efficiency penalty and thus additional cost (2009/31/EC). The opposing voices that question the legitimacy of such a new technology regarding the fulfilment of the important European integrated climate and energy package may be justified keeping the cost effects and environmental concerns of CCS in mind.

10.4 Concluding remarks

“What is not started today is never finished tomorrow” said Goethe, and 180 years after his death the European Union may claim that his advice is being followed. The climate and energy package of the European Union, which had been integrated into the framework of the Europe 2020 strategy, is a milestone in the EU’s climate policy. This is the first package that has an integrated approach regarding the climate related challenges of the European Union and that sets binding obligations and special targets for the member states. No other climate related activity of the European Union had been so carefully prepared and regulated before. Moreover, should we set our sights on the global scene the goals of the European Union appear to be far more ambitious than the climate related commitments of the other global players. Putting the necessary weaknesses and policy shortages aside, one can really agree with the European Union’s slogan regarding its climate related policies: the EU is the forerunner in combating climate change.

However, apart from the ambitious goals, an analytic eye has to underline that the present conditions are far from optimal in terms of the realisation of the climate related goals. As these concluding sentences are written, the EU is forced to cope with severe economic challenges; the euro zone faces a possible breakup. In the middle of the economic crisis, when Europe can be characterised by political and economic instability, when no jobs are generated, when deteriorating macroeconomic figures force the European governments to introduce austerity measures, when the whole future of the euro zone and of the European Union itself is being questioned, then climate policy obligations are not perceived as top priority by any government.

But even though the European Union faces the biggest challenge and threat in its history, one should never forget life outside economy. Climate change is a global threat that jeopardises the future of our planet, so should necessary action be postponed due to the various economic or political crises, we all will face the inevitable negative effects. The EU and the member states will have to stay focused regarding the climate related obligations in the upcoming period, even when bigger problems may emerge. Actions mitigating climate change should be started and carried out in the upcoming decade, otherwise the integrated climate and energy package will have the same fate as the Lisbon Strategy.

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Krisztina Hegedüs

11. Changes in the russian climate and its consequences

11.1 Introduction[61]

Like any country in the world, the Russian Federation perceives the consequences of climate change as well. Maybe even more, because for once, Russia has the largest territory and the climate change affects Russian regions differently as well. In addition, air temperature warming is well above the global average. However, the climate change has positive and negative outcomes. This puts Russia in a difficult situation. Obviously, Russia would like to avoid the negative consequences of warming, so developing some green technology would help. On the other hand, Russia owns huge fossil fuel reserves; what's more, about 67% of the Russian export revenue comes from mineral product export. So it does not seem to be Russia's best interest if the partner countries adopt greener, more sustainable or renewable technologies. At the same time, global warming could damage the transportation system of these fossil energy resources. Therefore, Russia faces a complex problem. While its whole economy basically depends on the consumption of the fossil energy resources, they have to create a more sustainable development, and slow down global warming.

In this chapter, we analyze the Russian climate change, and the situation that Russia faces. How will global warming change Russia's climate system? What are the consequences both in Russia's environment and in the Russian economic system? Is it possible that, along with the many negative environmental and economical effects, there could be some economic advantage? How does Russia try to avoid the unfavorable climate changes? Does the Russian Government have some plan, or did Russia join the international community?

To answer these questions, at first we have to see what Russian climate is like today. Then in the second chapter, we will see how Russia contributes to the climate change with greenhouse gas emission, and how they try to reduce it, and how they

[61] The author was supported by TAMOP-4.2.1.B-09/1/KMR-2010-0005 project in the research for this paper.

took part of the Kyoto Protocol. Next we discuss the changes in the Russian environmental system: they way surface air temperature increased, the permafrost zone melted, and whether there are more extreme climatic events than a few decades ago, and how these changes will possibly continue. So there have to be some consequences for the environmental changes in the economy, and in fact there are. In the following chapter, we examine the changes in the agricultural system and the most important question for Russia: the changes in the energy production and the transportation system. At last, before the conclusions, we look at the Russian environmental regulation method, especially how Russia tries to minimize the negative factors of climate change.

11.2 Russia's climate

The Russian Federation, with its 17,075,200 square kms, is the single largest country in the world. Therefore its climate differs greatly. For example, in northern Siberia, there is a cold arctic climate, while near the Black Sea, there is a sub-tropical hot climate. We can find moderate continental climate in the northern part of Russia, which is formed by the western wind rose. Besides, the Gulf Stream influence can be felt in the Murmansk region. Furthermore, the central part of Russia, such as Siberia and the Ural Mountains, has continental climate with moderately warm summers and really cold winters. Sub-tropical climate can also be found in the southern territory of the Russian Federation, like Sochi and its region. Thus we can find wholly different landscapes in one country, like grassy steppes in the south or frosty tundra in the north, as well as Russia has the deepest lake in the world (Lake Baikal) and Europe's highest mountain (Mount Elbrus in the Caucasus) (NIC 2009).

Russia has a 37,653 km long coastline along the Arctic, the Pacific Ocean and several seas. It also has thousand of rivers (approx. 100,000), and with Lake Baikal, Russia possesses more than one fifth of world's fresh surface water reserves, although these reserves are not equally distributed in the territory of Russia. Moreover, the area where 80% of the population and the industry are concentrated possesses only 8% of the water resources (WWF 2008).

Therefore, climate change will affect Russia in many different ways, but some argue that Russia already feels the consequences of global warming. From that, some questions emerge. How does Russia contribute to the climate change, and what can we say about its GHG emission? More importantly: What can Russia do to avoid global warming, or, as it seems unavoidable, how will Russia reduce the negative consequences of climate change?

11.3 Russia and the World

Russia's contribution to GHG emission

Russia seems to play a big role in the debates on climate change. First and foremost, Russia has a significant share in the world's fossil fuel stock. Russia has a 5.6% share from the World's known oil stock, which is enough for the second place after OPEC. Its share in oil consumption is even bigger than its share in reserves: 12.9%. As for natural gas reserves, Russia leads with a 23.7% share in the world's known natural gas reserves. Russia is responsible for 17.6% of the world's natural gas consumption (BP 2010). It also has a big export share in both the oil and the gas sector. Furthermore, about 67% of Russia's export revenue comes from the export of mineral products (including fossil fuels) (gks.ru 2011). With these data, it is clear that the Russian economy depends greatly on the fossil fuel trade. Therefore, we can see that it is not in Russia's best interest for the world to "go green", and stop using the fossil fuels, which does not seem to happen in the near future. But it could be beneficial for Russia to reduce its own fossil fuel consumption and its dependence on these energy sources. According to the latest data, with 1532.6 Mt CO_2 (in 2009), Russia is the world's fourth largest emitter of CO_2 after China, the USA and India (IEA 2011). It is an almost 30% reduction since 1990, but we have to add that the collapse of the Soviet Union with its heavy industry in 1991 played a significant role in it. Previously, the USSR was the second largest emitter, and because of its industrial development, the emission growth was pretty fast (Lioubimtseva 2010). The bottom year for the CO_2 emission was 1998, after that the Russian economy started to recover from the crisis and so the emission slowly started to grow by app 2-3% per year. The top growth was in 2006 with 4% CO_2 emission expansion, then it seemed constant for a few years, when in 2009 decreased by 4% largely due to the global financial crisis (see Table 1). Although Russia's emission looks good in the light of the Kyoto Protocols emission reduction plan (see Table 2) the per capita emission is pretty high, almost four times higher that China's per capita emission)

Table 1 Annual greenhouse gas (GHG) emissions for Russian Federation, in Gg CO_2 equivalent[62]

Category	Base year (1990)	1998	2000	2006	2009
1 Energy	2,717,153.69	1,643,915.25	1,665,849.48	1,792,463.13	1,782,606.65
2 Industrial Processes	257,523.35	134,165.68	166,705.98	187,703.55	158,358.79
3 Solvent and Other Product Use	561.61	517.34	522.89	531.96	544.94
4 Agriculture	317,286.52	158,379.02	149,062.33	133,851.01	142,374.66
6 Waste	58,651.10	51,442.81	56,366.59	68,942.05	75,385.15
Total	3,351,176.28	1,988,420.10	2,038,507.26	2,183,491.70	2,159,270.18

Source: UNFCCC Data Interface

Russia and the Kyoto Protocol

The Russian Federation joined the UN Climate Convention in 1994, and played a significant role in the Kyoto Protocol's existence in 2004. For the Kyoto Protocol to enter into force, Annex B Parties[63] had to ratify it, accounting for 55% of 1990 carbon emissions (UNFCCC 2010). As we know, the USA did not ratify it, although it had 34% of 1990 global carbon emissions. Other large countries/groups have already ratified it (like EU, Japan etc.), therefore Russia's 16.4% share in the 1990 carbon emission was a game changer, and Russia ratified it in 2004. Why did it ratify it so late, when signed in 1999? For Russia, it was not an easy decision to ratify such a document like the Kyoto Protocol. As already mentioned, Russia has a large amount of the world's fossil fuel resources, and Russia does not belong to the most developed countries, so it needs a great amount of energy (and with that GHG emission) to develop. Therefore, it is natural that Russia uses these resources. So why even consider ratifying such documents? Even though we could think that signing

[62] The reporting and review requirements for GHG inventories are different for Annex I and non-Annex I Parties. The definition format of data for emissions/removals from the forestry sector is different for Annex I and non-Annex I Parties.

[63] Parties that have accepted targets for limiting or reducing emissions under the Kyoto Protocol are listed in Annex B to the Protocol. These Parties are known as Annex B Parties, mostly industrialized countries and economies in transition.

and ratifying the Kyoto Protocol is not beneficial for Russia, it did ratify the Protocol. So there has to be some positive effects on Russia. What were the reasons of the Russian yes to the Protocol? The original plan was the global reduction of GHG emissions by 5% until 2012 from the 1990 levels, and the Russian commitment was to keep the emission at the 1990 level (UNFCCC 2011). These aims were easy to reach for Russia, and also for some Eastern European countries, because for them the 1990 emission was already high, and after the end of the Soviet era (and with that many industrial projects), the GHG emission automatically reduced. Although there has been a slightly increase in the level of the greenhouse gas emission since 1998, Russia can still easily meet the criteria's of the Kyoto protocol; moreover, Russia has a great surplus of carbon credits for the first commitment period from 2008 to 2012. Thus Russia could trade with these unused emission units. We have to mention that Russia has not made any commitment yet for the further periods. Also Russia could benefit from some modernization of its industry, even better if it means some GHG emission along the process.

The countries that joined the Kyoto Protocol have to reduce their GHG emissions trough national measures. The Protocol offers three market-based mechanisms as an opportunity for cooperation between the countries, thus creating a "carbon market" (UNFCCC 2011).

The three mechanisms are the following[64]:

- Emission trading
- The Clean Development Mechanism (CDM)
- Joint Implementation (JI)

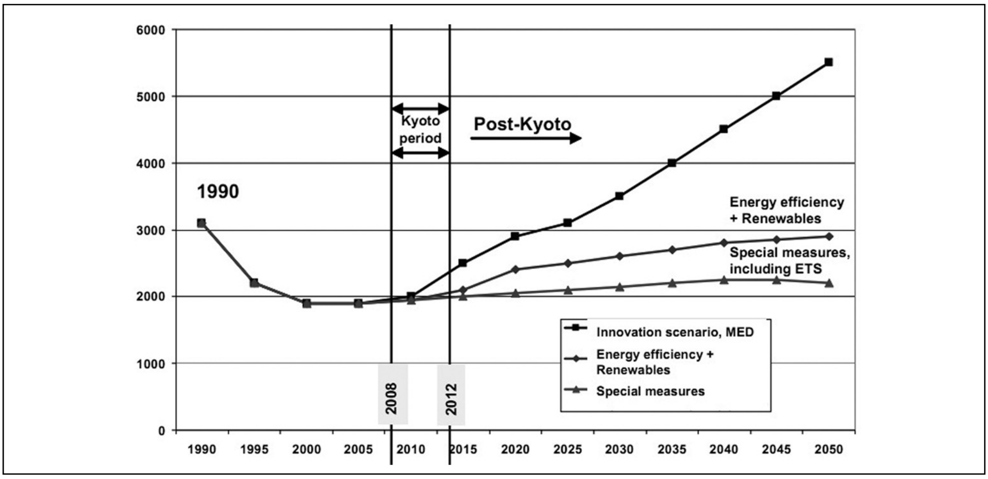
It seems that Russia has a serious amount of carbon credits to trade with (some estimates $US 40 billion to $US 60 billion), and it also has the greatest GHG reduc-

[64] Emissions trading, as set out in Article 17 of the Kyoto Protocol, allows countries that have emission units to spare (emissions permitted for them but not "used up") to sell this excess capacity to countries that are over their quota.
The Clean Development Mechanism (CDM), as defined in Article 12 of the Protocol, allows a country with an emission reduction or emission limitation commitment under the Kyoto Protocol (Annex B Party) to implement an emission reduction project in developing countries. Such projects can earn saleable certified emission reduction (CER) credits, each equivalent to one ton of CO_2, which can be counted in meeting the Kyoto targets.
The mechanism known as "joint implementation," as defined in Article 6 of the Kyoto Protocol, allows a country with an emission reduction or limitation commitment under the Kyoto Protocol (Annex B Party) to earn emission reduction units (ERUs) from an emission-reduction or emission removal project in another Annex B Party, each equivalent to one ton of CO_2, which can be counted in meeting its Kyoto target.
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.
(For more information visit http://unfccc.int/kyoto_protocol/mechanisms)

tion potential with over 150 Mt CO_2, which is about 58% of the global JI market (Lioubimtseva 2010). This creates an uncertainty in the global carbon market, as the cooperation set by Kyoto Protocol expires in 2012, and the Copenhagen Accord was not successful and did not put any further cooperation into motion after 2012, just simply extended all existing negotiating mandates. So now it seems that Russia has a potential to control the future of the trade system with its huge surplus of unused emission permits. Once Russia puts these emission permits on the global carbon market, it would likely lead to the collapse of the price of carbon (Lioubimtseva 2010). Another issue is that after the Kyoto Protocol's duration and in lack of a new legally binding international treaty, Russia's emission is likely to grow as shown in Figure 1. As mentioned above, Russia has a massive potential to reduce GHG by JI projects, but that does not mean that Russia will exploit all of it. Also, in 2008 in Poznan the Russian delegation declared that Russia will make quantitative commitments for the period following the expiration of the Protocol in 2012. There has not been any such commitment ever since, and now it seems that Russia will not make any commitment until 2017. "Considering the progress of the talks, the composition of negotiating teams, the attitude of the United States, we can assume with a great share of probability that no new agreement will be adopted in the next four to five years after the expiry of the Kyoto Protocol," said Oleg Pluzhnikov, an official with Russia's Ministry of Economy (Point Carbon 2011). So what could happen with the Russian emission after 2012? In Figure 1, there are three scenarios for the Post-Kyoto period for Russia. As Michael Yulkin calculates in the Innovation scenario, Russia will reach 80% of its 1990 emission by 2020. In that scenario, Yulkin assumes that Russia will double its GDP in the period from 2012 to 2020. The other scenario will be likely if Russia reaches some of the figures the Russian Government has already declared: by 2020 the share of renewables in the electricity production will increase by up to 4,5%, and the energy intensity of GDP should be reduced to 40% below the 2007 level. The best scenario contains other special measures, such as the ones also declared by the Russian Government: APG flaring should be reduced to only 5% by 2012, which is highly unlikely at the moment. Also the Russian Federation could create an emission trading scheme (ETS) system similar to the EU ETS system.[65] (Yulkin 2009)

[65] For furher information see: Mikhail Yulkin: Russian Perspectives on Climate Change in the Lead up to a Post-Kyoto Agreement, *Environmental Investment Center*, May 2009 http://ccgs.ru/en/publications/presentations/_download/1.pdf

Figure 1 Russian GHG emission (Mt CO2)



Source: Yulkin 2009

We saw how Russia contributes to the climate change and how they take part in the international conventions against the climate change. What we have not analyzed is why Russia should bother about taking part in this kind of agreement, or asking the same question otherwise, how the climate change affects the Russian Federation.

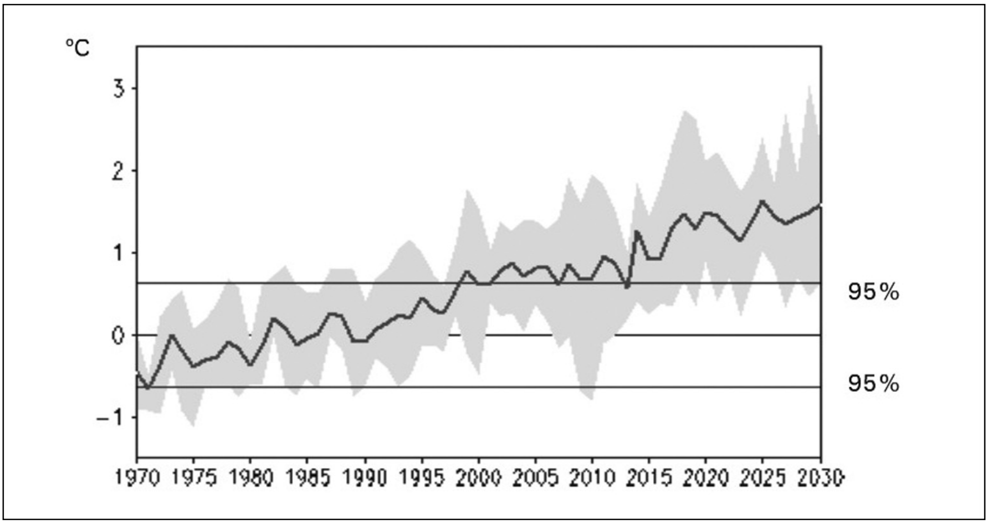
11.4 Climate Change in Russia

What can we say about the climate change of Asia or Russia in general? The Intergovernmental Panel on Climate Change (IPCC) has the most popular reports (the latest is published in 2007 under the title of Fourth Assessment Report) on the climate change. There has not been country report yet, but only a regional one. For Asia, the report predicts a warming above the global average in northern Asia, which is basically Russia. Also a very popular international organization, the World Wildlife Fund (WWF) compiled a report on the Russian climate change.

Surface air temperature:
This report stated that during the 20th century, Russia's average surface temperature rose by 1°C, which is 0.3°C above the average global temperature rise of the Earth. Between 1990 and 2000, the surface temperature rose by 0.4°C, which is extremely high, but in the beginning of the 21st century, this growth seemed to slow down, and

during the period from 2000 to 2010 it has hardly changed, but we should add that in the recent years Russia experienced plenty of "local records". The WWF adds that the climate change is not just a slow global warming process, but primarily amplifies the imbalances of the climate, such as the winters could be colder and summers hotter, so the average could stay put, with growing differences. The meteorological observatory of the Moscow State University collected data, and according to them, in the period from 1990 to 2000, the average surface air temperature rose by 3.7°C in January, 3.4°C in April, 1.3°C in July, 2 in October in comparison with the period 1901-1910. However the fluctuation of the temperature was even 3-5 times stronger (WWF 2008). By the middle of the XXI century, the temperature rise will be 2.6 ± 0.7°C, in winter even higher 3.4 ± 0.8°C (Roshydromet 2008)

Figure 2 Surface air temperature rise in Russia compared to 1971-2000[66]



Source: Roshydromet 2005

Figure 2 shows the average air temperature change in Russia, but as we already mentioned due to the great diversity of the Russian territory, the climate change affects Russia in many different ways and intensity.

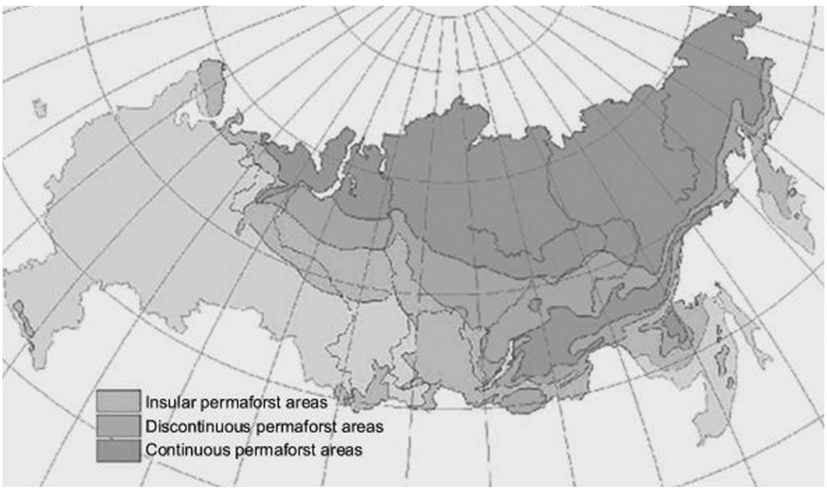
[66] Surface air temperature rise in Russia calculated using the ensemble of models for the period of up to 2030 relative to the reference values of 1971-2000 (based on the computations made by the Voeikov Main Geophysical Observatory). Dispersion of model assessments (assessments of different models included into the ensemble) is described by the gray region comprising 75% of average model values. A 95%-significance level of temperature changes averaged over the ensemble of models is specified by two horizontal lines.

The climate change affects the Arctic Region most, the rise of the surface temperature in the Arctic are almost double the rate of the global average (NIC 2009). Also in comparison with 2000 by 2015 could be huge warming in Western Siberia the temperature could rise by 3-4°C, by 2-3°C in Yakutia, by 1-2°C in the Far East and "only" by 0.5-1°C in Central Russia. The temperature rise differs not only by regions, but also by seasons. In winter there will be a higher temperature rise, by 1°C on average, and not more than 0.4°C during the summer (Kokorin – Gritsevich 2007).

Permafrost:[67]

Permafrost melting could be a huge problem in Russia, as the permafrost zone covers almost 63% of Russia's territory (it means about 10.8 million square km). Figure 3 shows that there are different kinds of permafrost areas, such as continuous permafrost zones which means that the permafrost covering more than 90% of the territory, discontinuous permafrost areas from 50% to 90% permafrost density and insular permafrost zones from 10% to 50% density.

Figure 3 Russia's permafrost areas



Source: Emerging Market Venue 2010

[67] "The term "permafrost" is often associated with massive ice buried under the ground and it does not imply the presence of the frozen water. Frozen ground may be "dry"; the term "permafrost" refers to any subsurface materials that remain below 0°C for at least two consecutive years – (Anisimov–Reneva; 2006 p.169)

The permafrost areas are melting massively due to the last decades' temperature increases in the top layer of the frozen ground. Calculation on the WWF study suggests that by 2030 the total permafrost area could shrink by 10-12%, by 2050 that shrink could reach 15-20%, so the borders shift by 150-200 km to North-East. The seasonal thawing may increase by 15-25%. The most affected area is the Arctic Region, since the beginning of satellite observations in 1979 the minimum seasonal sea ice area observed in September decreased by 9% in 10 years. The total ice-coveredd area was the lowest in 2007: it shrank from 7.5 million square km to 4.3 million square km. The WWF also predicts that in West Siberia (where gas and oil fields lie) the frozen ground temperature will rise by 1.5-2°C, from an average of -5°C or -6°C to -3°C or -4°C (WWF 2008). The problem is that this high frozen ground temperature is unstable for industrial use. The thawing of permafrost might cause another problem: the process could release huge amounts of methane (greenhouse gas) currently trapped in the frozen soil (Discovery News 2011).

Water resources:
As we already established, Russia has one fifth of world fresh water reserve, so it should mean that unlike some regions in the world, there will not be any problem with the water supply. However, water reserves are unevenly distributed within the country. Only 8% of the resources are in the most industrialized zone, where 80% of the population is concentrated. So there could be some shortage in some regions in Russia. Also another problem is that the surface and the underground waters are polluted significantly (WWF 2008). However, according to Roshydromet, the renewable water resources will increase in the next 30 years by 8-10%, but the regional supply will still be a problem, because a reduction of 5-15% is forecasted in the least provided areas, but to make the problem even more difficult, an increase expected in the demand or the use of water in that very same area. For example, in the Moscow Region there will be a decreased water supply by 2015, together with a significant demand for water resources due to the economic development and also because of the growth of the population in the area. So the main problems are the distribution, not matching the demand, and the water resources become more and more polluted (Roshydromet 2005).

Precipitation:
Precipitation changes are difficult to measure, and even more difficult to suggest that the changes are connected to global warming. However, it has certainly increased over the past 30 years (7.2 mm / 10 years), but not equally in every area and in every season. The highest increase occurred during spring in the western and northeastern regions of Siberia and in the European part of Russia (16,8 mm / 10 years), and even decrease was observed during winter in the north-eastern regions of Siberia. The dura-

tion of dry periods also decreased, and there has been a slightly increase in the numbers of extremely large precipitations. According to the forecasts of the Russian Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet), precipitation during winter will increase all over the country by 2050, depending on the regions in summer time. Precipitation most likely will decrease in the southern regions of European part of Russia and Southern Siberia, but that does not mean that high intensity precipitation will decrease as well (Roshydromet 2008).

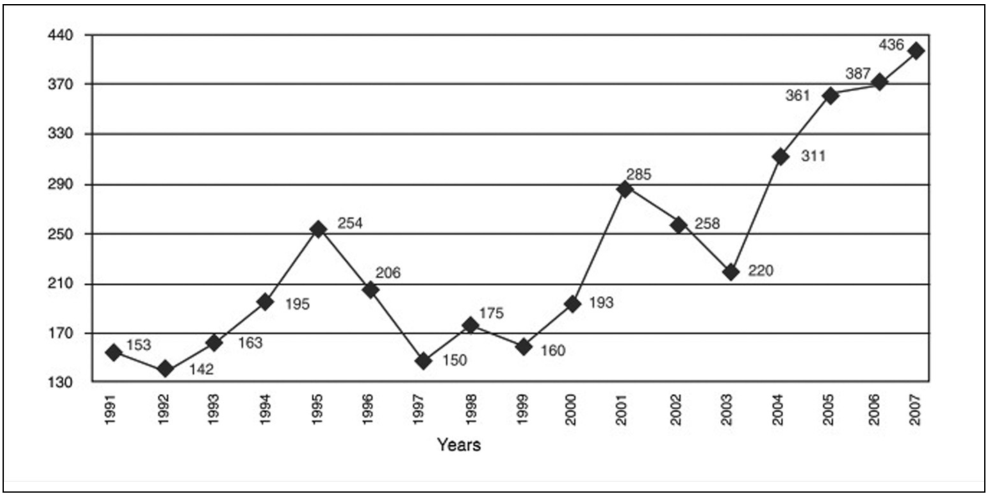
Snow cover:
Another consequence of the climate change is that the snow cover has shrunk significantly in spring and summer over the last 30 years, and also there is a decreasing tendency in snow depth. The main reason for these changes is that the rise of air temperature or the increase in precipitation. The forecasts predict an expected reduction of the snow cover during the next decades. This could lead to more frequent and extensive flooding (Roshydromet 2008).

River runoff:
The annual river runoff has increased by 15-40% over the last 30 years compared to the period from 1946 to 1977. The rate of the increase depends on regions. The biggest increase (20-40%) occurred in the Asian part of Russia (on the left-bank tributaries of the Tobol and the Irtysh rivers), and there was a 10-15% increase of the European part of Russia in rivers such as Dvina, Dnieper and Don, and more that 15% increase on the left bank of the Volga River. In the forecasts it seems that during the 21st century we can not foresee any significant changes in the river runoff, in some regions it might increase, but in other region even decrease is possible (Roshydromet 2008).

These phenomena are all connected and related to each other and amplify their effects. With higher air temperature, the permafrost zone will decrease and the arctic ice will melt. The increase in precipitation along with snow melt could cause the river runoff and so on just to mention a few examples.

As we mentioned, climate change is dangerous not only because the air temperature is rising, but the weather will also be increasingly unpredictable and climate change comes will result an increase in the number of extreme phenomena. These extreme phenomena called dangerous hydrometeorological events (DHE), include strong winds, hurricanes, tornados, whirlwinds, heavy rains or snow, continuous rains, downpours, hailstones, ground surface icing, heavy frogs, heavy sleet pickup, very hot or very cold periods, snow avalanches, mudflows, agro meteorological events (frosts, droughts, hot dry winds), floods, very high or very low level of the rivers, high risk of fire, etc. (WWF 2008). But just in Russia, more than 30 types of these events have been recorded (Roshydromet 2008).

Figure 4 The increase of dangerous hydrometeorological events, 1991-2007



Source: WWF 2008 p.13

Taking these WWF data into account, the most frequent of these DHE are strong winds, hurricanes, tornados, whirlwinds representing more than 25% of the all DHE, and another 21% are heavy rains or snow, continuous rains, downpours, and hailstones. Furthermore, seasonal allocation is not consistent either, as 70% of DHE occur from April to October.

These DHE increase in Russia by an annual 6.3%. According to the World Bank, the damages caused by DHE could reach as high as 30-60 billion rubles (1-2 billion dollars at the current exchange rate[68]). The prognoses also claim that this process is far from the end, and extreme weather events will continuously increase (WWF 2008).

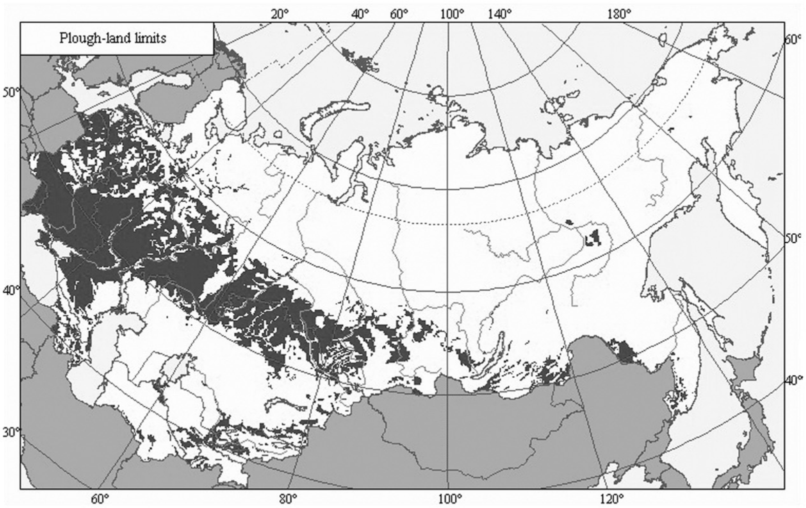
11.5 The economic aspects of climate change

Impact on agriculture

In a country where permafrost zone covers more than 60% of the territory, we can assume that global warming is favorable for agriculture. The agricultural area in Russia is a little more than 2,150,000 square km, which is about 13.2% of the total territory of Russia (Trading Economics 2007).

[68] 1 USD = 29.89 Rubel as of November 3, 2011

Figure 5 The area of arable land in the former Soviet Union[69]



Source: Agroatlas 2003

There is a popular presumption in Russia about the climate change, namely that the higher the temperature is, the more area there will be for agriculture. So global warming will affect agriculture positively, because the growing season will become longer, and the land, that was too north or far too cold, will become arable. Moreover, it will be possible to try new types of crops (NIC 2009). But in a study Dronin and Kirilenko demonstrate that it is not that simple, and global warming has negative effects as well along with the positives. Higher temperatures might be good for agriculture, but they showed that the warming could affect the yields negatively (Dronin – Kirilenko 2011). So first let us examine the favorable side of global warming to agriculture. In the past 30 years, the growing season has extended by 5-10 days on average, which means that the number of the days when temperature was above 5°C has increased. Also, very cold winters have decreased by 4 to 22%, the intensity of which depends highly on the regions: in the European part of Russia, it decreased by 18 to 22% while in the North Caucasus, the decrease is only 4 to 10%. Nonetheless, this is still improvement in the conditions for growing corn. In some part of Russia (mainly in the European part) it means that the warming related corn

[69] Arable land layers for the territory of the former USSR were obtained by carrying out an overlay reduction of the 1:4,000,000 land resources map to the scale of 1:20,000,000, setting off areas where a minimum of 10 % of lands are tilled.

yields has increased by 30% in the past few decades (Roshydromet 2005). Some study estimates a 50–100% potential increase in production, mostly due to the expansion of land suitable for agriculture. Also many kinds of plant could be moved further to the north, and if the warming continues, entirely new kinds of crops could be introduced in Russia. For example crops like cotton, grapes, tea, citrus, and other fruits and vegetables that are native in the south could be produced in the north Caucasus and the lower Volga regions (NIC 2009).

On the other hand, as already stated, there will be a lot of negative effects of global warming on agriculture. First, warmer weather could be a catalyst for plant diseases and pests, so this will be a serious challenge in many areas of Russia. In the coming years, as mild winters will become increasingly common, they are expected to spread. This could lead to decreased yields and more polluted lands, as more chemicals will be needed to destroy the pests (Dronin – Kirilenko 2011). Other problems the agricultural sector has to face due to the climate change are the changes in the weather. More dry periods and more extreme weather are expected in the future, which is undesired and harmful as well. Dry periods in the most important regions are expected to be 50-100 % more common by 2015, and this trend will most likely continue subsequently (NIC 2009). Therefore, the more frequent dry periods will result in another problem, namely that of water supply. To reduce the harm that dryness could cause to the plants, a highly developed water distribution system will be necessary, which Russia does not have at the moment. Along with that, the growth of the number of dangerous hydrometeorological events, such as hurricanes, tornados, floods, continuous rains, downpours, etc. will be also highly expensive, as they usually destroy the yield.

What could Russia do to avoid these undesired impacts? The key would be Russia's ability to adjust to the new conditions. The problem is that the Russian rural sector does not seem to be flexible. Moreover, supply, distribution, and management issues have historical difficulties. Dronin and Kirilenko argue in their paper that with imknown management, better yields, and increasing grain exports, Russia could avoid most of the negative effects. But for that, imknown investments and a higher level of governmental regulation would be needed. Roshydromet propose an early implementation of irrigation operations, along with investment in the water supply system (Roshydromet 2005).

Impact on energy sector

Considering that Russia has a huge share of the world's known fossil fuel reserves and the largest territory in the world, energy consumption and the operation of the energy system are key issues.

One of the first thought could be that with warming weather, the heating season will decrease, which is true. According to Roshydromet (2008) the heating season in Russia by 2015 will be 3 to 5 days shorter on average than in 2000. Also, winters could be warmer, so not only the heating season will shorten, but the lowest temperature in winter might increase, the same way as temperatures on the coldest day and during the coldest five-day period will increase by 20%, therefore the intensity of heating could be reduced, and it will be possible to keep the desired indoor temperature with lower fuel consumption. Therefore, the demand for energy will drop in winter time, but in warmer period of the year, it might increase due to the use of air conditioning (both private and industrial).

Another equally or even more important consequence of global warming is its effects on the oil and gas fields along with the transportation/pipeline system. As it is widely known, the main oil and natural gas extraction fields lie in Siberia, and for a trouble-free production, the soil needs to be frozen. However, with global warming and the permafrost zone melting, the period during the ground is frozen will be reduced. The problem is that the entire infrastructure (including roads, buildings, and industrial facilities) is designed for the frozen ground, and any of them not anchored to sufficiently strong foundations will be threatened as the shifting ground endangers their structural stability (Gotz 2007). High voltage power lines will also be vulnerable to damage as upper soil layers thaw and re-freeze. Not only the melting of permafrost is a huge difficulty for Russia, but also the pipeline system. The main problem is that most of the pipelines were constructed before 1980 – they are old and not well maintained and designed for steady climate. About 50 000-km oil pipelines and 150 000-km gas pipelines have been laid in Russia, and they cross many rivers. As we discussed earlier, an increased amount of annual and seasonal runoff and change in the ice condition could be predicted for many Russian rivers, and it most likely will cause a disruption or damage in the pipeline system. These damages could lead to oil spills and gas shows, which are considered as ecological disasters. To prevent these, new updated technology would be necessary by replacing the old and used river crossing pipelines to new ones, or at least monitoring the pipelines condition will be essential to avoid the disasters (Roshydromet 2005).

There also could be problems with oil shipping. In the Arctic Ocean, the danger of icebergs will increase, and dangerous hydrometeorological events as storms, high waves, strong winds, hurricanes, tornados will occur more often, which will impede shipping (Gotz 2007).

However there could be a positive implication of the melting of sea ice in the Arctic Ocean: it could provide an opportunity to the Russian Federation to explore and exploit more fossil fuel below the Arctic Ocean.

11.6 National policies to reduce the negative impacts of climate change

After joining the Kyoto Protocol in 2004, Russia published its first document about climate change and how to prepare for it in 2005. This document was made by the Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet) with the title "Strategic Prediction for the Period of up to 2010-2015 of Climate Change Expected in Russia and its Impact on Sectors of the Russian National Economy". This was the first paper that had some kind of strategic plan for the climate change; also we used it as a reference many times on our paper. It contains a prediction for the period 2010-2015 for many different sectors along with recommendations for the governance. This document suggests that Russia has to improve the National Early Warning System for Hazardous Hydrometeorological Events to be able to foresee extreme weather event and, if possible, prevent them or at least prepare to them and warn the citizens.

In 2009 Russia developed a climate doctrine. "The Doctrine represents an overview of the goal, principles, substance, and ways of implementation of a unified public policy of the Russian Federation, both within its borders and in the international arena, on the issues related to climate change and its consequences." – (Climate Doctrine of the Russian Federation 2009). The main goal of a climate policy is a wide-ranging consideration of the negative and positive effects of climate change, and obviously the planning and implementation of actions to protect the population, economy and the Government from the unfavorable effects of climate change. In this document, there are no concrete steps to reach the goals, but only the draw-up of the possible directions, such as the decrease of the GHG emission and increase its absorption by carbon sinks and receivers. The measures that should be introduced are to improve the energy efficiency, to expand renewable and alternative energy sources, to implement a financial and tax policy which will help reduce GHG emission, and to protect and improve carbon sinks and receivers (Climate Doctrine of the Russian Federation 2009).

In this year (2011) the president of the Russian Federation Dmitry Medvedev issued a number of instructions after the twenty-fifth meeting of the Commission for Modernization and Technological Development of Russia's Economy. The first project is to establish a "space-based environmental monitoring system", which could help have timely information not just about the weather but also to track down the changes (such as in the forest, permafrost zones, the state of glaciers, etc.). It would be expensive, but the government visualizes its funding from state and private investments also added to the project.

The second measure would be developing alternative/green energy. Russia has a huge drop behind in that field. As Russia own one of the biggest fossil fuel reserves it was not necessary to develop green energy in the past, as it is seen in the share of the production. The renewable energy sources share only 1% of the Russian energy production. Medvegyev said that they have the discussion, but developments stagnate at the ideas stage.

The third project what was discussed in that meeting is that in some regions the outdated public transport needs to be replaced with electric vehicles, and also develop the use of cars with hybrid engine. This is necessary because the air pollution is a serious problem in the big cities and this could help clean the air a bit (Russian Regional Environmental Centre 2011)

So Russia has already started the strategic planning to reduce the unwanted effects of the climate change, and it seems, that they are in the right way, but there is a question that is not it too late, as Russia has just begun to implement the plans into real action.

11.7 Conclusions

Due to the climate change Russia will face many changes in its climate. We can state that in Russia the air temperature will increase above the global average. Therefore the global warming affects will magnified. Along with the warmer weather the permafrost zones are melting, more river runoff expected and more extreme conditions are projected. With that come positive and negative consequences. The favorable effects of the warming are the decreased heating season, the possibility of the fossil fuel exploitation in the Arctic Ocean and the increased agricultural land area with more kind of crops that can grow now. The undesirable effects are the imbalances of the climate with increased amount of dangerous hydrometeorological events, which costs will be high. More dry periods could be expected that is harmful for the agriculture. With warming more plant diseases and pests are projected. Furthermore Russia's GHG emission is not likely to reduce for the future, as Russia has no legally binding international convention after the expiration of the Kyoto Protocol. Therefore further air, land and water pollution is expected in the country. Russia has already recognized that some steps need to be taken to reduce some of the undesirable effects of climate change, but the problem is that most of the plans have not taken into action yet, and it seems a slow process.

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Ágnes Tőrös

12. Balancing economic growth with climate change – the case of China

12.1 Introduction[70]

Climate change universally concerns every single country of the Earth; however, there are some regions that are more endangered than average. Southeast Asia is among them. According to forecasts, the stock of freshwater in the region will decrease to a great extent by 2050; the danger of inundation on the territories along the sea and the bigger rivers is increasing. The environmental change also affects the availability of natural resources and the health condition of people (disasters, feeding problems, epidemics) (IPCC, 2007).

Within the region, China's vulnerability is also significant: by the year of 2050 its average temperature will increase by about 1.7 % compared to the level in 2000. The danger that affects China is increased by the fact that it is the most populous country of the world and has a huge seaside. That is the reason why China has suffered natural disasters already in the past decades. During the period from 1971 to 2008, China was among the first countries as far as the average number of death per year is concerned caused by the droughts, high floods, and storms. During the period, these incidents affected more than 5% of the population (WB, 2010). Global warming weakens the country economically too and it causes serious economic damage.

According to the scientists who calculate with a warming of 2.5 °C (Nordhaus and Hope), China is belonging to those countries that suffer higher GDP loss than the world average because of the climate change. The opinion of Mendelsohn who calculates with a warming of 2 °C is that the loss of the country is on the same level as the world average. If we try to break it down after those that cause the GDP loss, then, in case of China, the increased number of disasters caused by the climate change contribute to it to the largest extent (IMF, 2008).

[70] The authors were supported by TAMOP-4.2.1.B-09/1/KMR-2010-0005 project in the research for this paper.

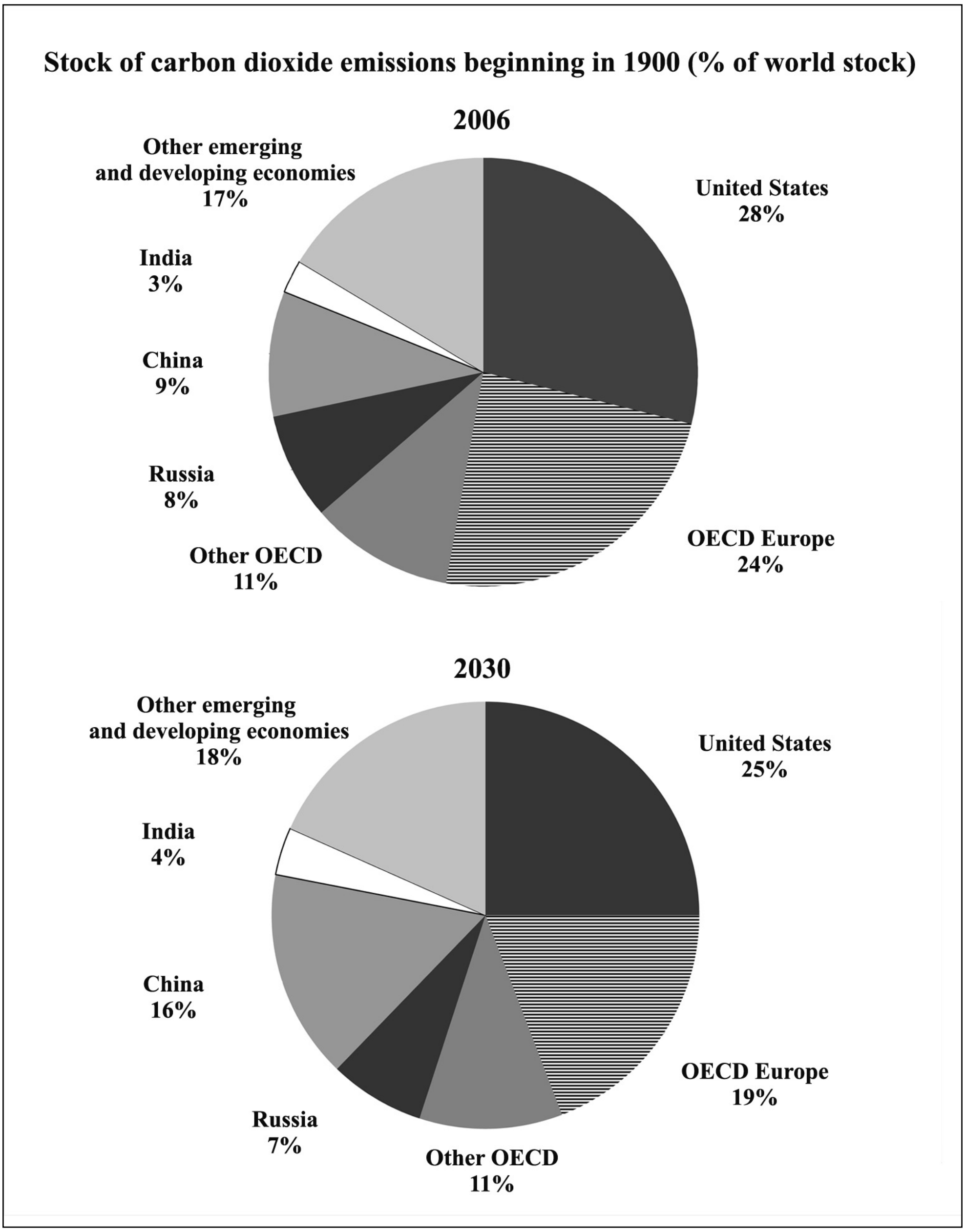
The handling of the climate change takes on a special character in China in relation to other countries. In the past years, a relative consensus has developed at international level in respect that the climate change has to be regarded as an issue of security policy. According to Freeman (2010), both the USA and the EU accepted that the climate change and international security are directly related but China is still showing some reluctance as yet. However, the statement can be questioned to some extent; it is a fact anyway that the country considers the fact from the viewpoint of its development and economic prosperity.

12.2 Beginning of a climate policy

China's climate policy does not have significant traditions; in the giant country of the Far East people have not been dealing with the questions of climate change for a long time at all. Since the opening in 1978, economic growth has appeared on the political agenda as the main target for a long time. As it is well known, the country can not only keep its target of growth but it has surpassed it considerably for many years. As a result, China started to develop rapidly and the crowds of Chinese people could break free from poverty. The spectacular change also required great sacrifices: as they covered the energy needed for speedy developments, industrialization and urbanisation by the use of fossil energy resources, the detrimental effects of pollution expanded radically. China's environmental problems became worsened by the fact that the global climate change also picked up a higher speed, which also increased the need of China's intervention.

The carbon dioxide emission of the world calculated from 1990 approached the 1,400 billion tons in 2006. The proportion of pollution was not steady, and after the year 2000, the rate of growth of the emission speeded up (Oberheitmann – Sternfeld, 2009). China's proportion still fell behind 10%. According to the prediction, this figure will increase significantly but the data of the USA will not be exceeded in 2030 either.

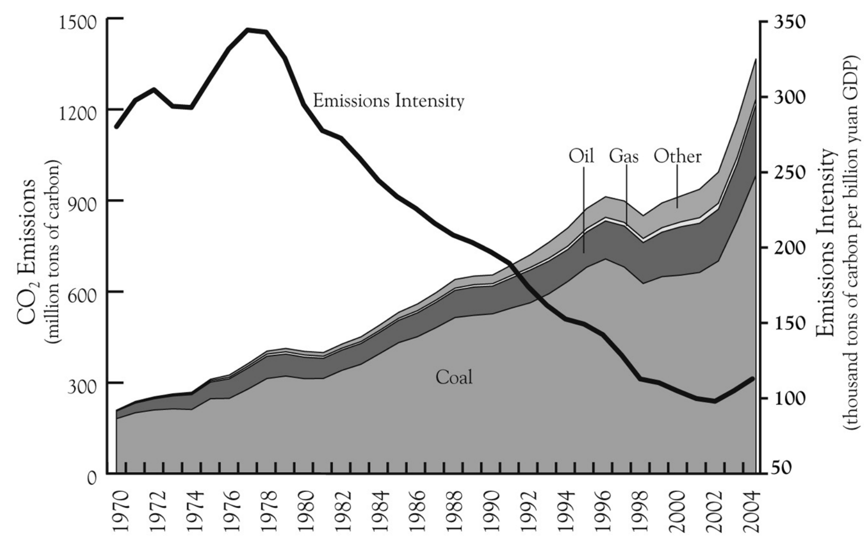
Figure 1 China's role in the global environmental pollution



Source: IMF, World Economic Outlook April 2008, Housing and the Business Cycle, Chapter 4. Climate change and the global economy pp. 4. downloaded 2011-04-12 http://www.imf.org/external/pubs/ft/weo/2008/01/

Thanks to the steps made by the country for the energy conservation, China's the environmental problems only spread after the turn of the millennium (Zhang, 2003). Contrary to other countries with similar advanced stage, in parallel with the spectacular miracle of growth (which meant a yearly average growth of 9.7% of the GDP between 1980 and 2000), China could cut on its energy consumption per unit of the GDP. At the same time, the income elasticity of the energy consumption of other developing countries on the same level of income as China was well above 1, which means that their energy consumption increased faster than their GDP. To put it another way, it means that during this period the energy intensity (the proportion of energy consumption to the GDP) and the intensity of emission (ratio of carbon dioxide – equivalent emissions to GDP) decreased. Without these trends, the country would have consumed much more energy even this time too. 2002 was a turning point because China's energy consumption speeded up and its rate exceeded the swing of the economic growth, which means that the tendency turned on its wrong side. This change radically influenced the China's greenhouse gas emission, which started to grow very fast. As the peak of the process, China became the biggest carbon dioxide emitter of the world in 2007.

Figure 2 Carbon dioxide emission from energy use according to source and emission intensity trends



Source: Lewis, J. (2007) China's Strategic Priorities in International Climate Change Negotiations, *THE WASHINGTON QUARTERLY*, Winter 2007-08, pp 157..

Today, as a result of outside and inside pressures, it became clear that China could not carry on its usual growth oriented economic policy it has pursued so far. In order not to deliver further growth at the price of environmental injuries, it is important to increase the role of renewable, green energies and to raise their energy efficiency. According to Zhang (2010), if China really determines itself to make steps to realize the aforementioned, it can achieve the decrease of its problems decrease and it can become a so-called low-carbon economy, which is capable for sustainable development in the long run.

12.3 Evolution of the institutions

The early development level of the institutions also provides some information about the fact that the country has not been dealing with the question of the environmental problems for a long time (Lewis, 2007). In the 1980's, the subject was assigned to the scope of the State Meteorological Administration. Pretty late, at the end of the 1990's, the question came to the National Development and Reform Commission (NDRC) after having realized that the subject needs further measurements. NDRC is one of the key organizations of the economic management of China, the strategies of the economic development, it develops the one-year, medium-term, and long-term plans, coordinates the policies and monitors the performance of the macro economy. Since the problem of climate change was assigned to an organization that is a main decision maker also on the field of energy policy, the management admitted that the problems of environment are not allowed to be handled only as a scientific issue.

From here on, the activity of the Government in connection with the subject became more intense step by step; then, from 2007 it became even faster: the central Government announced the establishment of the National Leading Group on Climate Change (NLGCC). The method was not recent because the State Council often establishes organizations in an ad-hoc manner in order to emphasize the importance of a case. Their duty is to coordinate the related policies and to make specific steps. They are usually led by the Vice President and in case of national questions of special importance (such as NLGCC) by the President (Qi et al, 2008). Regarding the climate change, the new organization significantly strengthened the capacity of the central government to make decisions. However, NLGCC also had a predecessor, and the set-up of the new institution can be considered as a positive message anyway because it clearly shows that Beijing is dealing with the fight against climate change as a key question.

Before 2007, local governmental bodies did not pay much attention to climate change either. However, by this time it became fully clear that it is a danger world-wide, local institutions still not felt the need to take actions against it. The main reason for that was that people felt on these levels, too, that any steps taken against the climate change would prejudice their interests: since, if they cut on their energy consumption and gas emission with greenhouse effect, the growth of the economy will come to a sudden stop. After all, in 2007, in line with the central policy, the approach of the majority of the local levels also changed and they worked out specific plans for research, mitigation and adaptation. In China's case, we cannot speak about a federal system; however, owing to the hierarchical structure of the state, the change in the line of policy on the lower levels depends on central expectations. On the other hand, it must also be admitted that the local answers for the central direction are strongly influenced by whether local people are concerned by the change or they have the capacity to it. According to Qi et al (2008), several factors had an influence on how much the provinces increased the level of their efforts against climate change. It was important to what extent they were conscious of the problem of climate change at all, how many capital and personnel they had available to work out a new system and how they recognized that the international cooperation also includes possibilities.

12.4 The frame of rules

For a long time, China's leadership has not even mentioned in its five-year economic plans (in which they usually set forth the main principles of their economic development) the importance of the fight against climate change. The period from 2006 to 2010 was the first time when Beijing included the question of sustainable development in its 11th five-year-plan. The appearance of the topic is clearly due to the fact that the former trend reversed in 2002 and from then on, the energy intensity of the economy started to increase (Lewis, 2011). The demonstration of the commitment to prevention developed a concrete reference indicator: they ordained the decrease of the energy intensity by 20% for the period 2005-2010. For the sake of the cause, the Government also launched a national campaign named "TOP 1000 Energy-Consuming Enterprises Program". After Price et al (2008), the program proved to be a success: participating companies contributed to the target, which was set at about 10-25%.

It is a milestone in China's climate policy that the State Council adopted the Chinese National Climate Change Programme in June 2007 to unify the former fragmented efforts. The main point of the event is that not only did they set forth in a document the general pieces of information in connection with the climate change and the early actions against it, which can also be called unimportant at the same time, but they also summarized the targets to be realised in the future as well. The document, which can be deemed as a self-defence, also mentions the main challenges that make the situation of the country difficult. According to this, China will be able to cut on the carbon intensity per unit of energy with more difficulty than other countries because the energy composition of the country is very concentrated: the proportion of the use of carbon in the country's primary energy consumption was nearly 70% in 2005, while the world's average was only 28% in the same period. It also has to face difficulties because it does not have the modern technologies suitable for efficient industrial production and energy exploitation, delivery and distribution. Its out-of-date technologies greatly contribute to the fact that the country's greenhouse gas emission is very high; its energy efficiency falls behind that of the developed countries by 10%. During its fast improvement, China performs large-scale infrastructure-developments and building projects these days. If these developments go together with the use of the old technologies in the future as well, it means that the country cannot switch to environmentally friendly technologies very soon and it will face more difficult problems. Moreover, it is also a challenge for the country that, as a result of climate change, meteorological disasters are very frequent and agriculture is not prepared for the defence against their detrimental effects; furthermore, another problem is that the density of population is the biggest in the seashore regions the most endangered because of the rise of sea level, since economic activity is concentrated here.

To demonstrate that China is ready to make efforts against climate change, in 2007 the decision makers set as a target that by the year of 2010:

- they will reduce the level of energy consumption per unit of the GDP by about 20%,
- they will increase the proportion of renewable energy to 10% in the primary energy supply.

Besides, they declared that they will increase the proportion of territories covered by forests, develop agriculture, increase the social dialogue to strengthen the fight against climate change and they will seek ways to modernize technologies (NDRC, 2007). However, it is important to emphasize that although China declares its targets explicitly and in the case of the most important ones it also determines a concrete value, it adds after all that in the course of history it was proved that an explicit positive connection could be identified between the per capita carbon dioxide emission and the level of the development of the economy. Taking it as a starting point that China still belongs to the states with relative low level of development, it is evident that during its catching up with developed countries, it will increase its per capita energy consumption. How far this process will be accompanied by an increased carbon dioxide emission will depend on the fact after how long time China will be able or will be ready to switch to the sustainable model of development.

In the 12th five-year-plan[71], Beijing confirmed that it seeks ways of sustainable development. They decided about the principles and targets for the period between 2011 and 2015 in the 4th Session of the 11th National People's Conference. One of the main messages of the document is that China feels even more that the growth and the development of economy must be differentiated. Its commitment to the latter is indicated by the fact that they are ready to cut on the target value of the annual growth of the economy by half a percentage to 7% for the next five years and, in parallel with this, to focus on the developments and the reorganisation of the structure of the economy. Handling sustainable growth as a priority has already appeared in the previous five-year plan too; the social interests and the conditions of the harmonious social life were emphasized more strongly, and the pressure of implementation seemed to be even smaller (see above). The essential element of the new strategy is that China increases its innovation performance in the future. According to the plans of the Government, the innovative sectors become the leading players of the economy in the future. Innovation can be a balm for several problems, too. The possession of more developed technologies decreases the dependency on foreign countries and results in competitive advantages. Environmental innovations can also help reduce the negative externals of production. Through modern procedures, dependency on energy gets into a different perspective as well.

The decision makers laid down serious undertakings in the latest five-year plan. In the 12th five-year plan they followed the targets of the previous 11th five-year plan and they built on the support programs that were created for its implementation. They targeted a decrease of the energy intensity by 16% (energy consumption per unit of GDP) before the end of 2015; they declared that within the entire energy consumption, they wanted to increase the proportion of non-fossil energy resources (including water, nuclear, and renewable energy) to 11.4% and they made a decision about a cut of 17% in carbon intensity, too. Considering the fact that in early 2011 Zhang Ping, chairman of the National Development and Reform Commission, announced that the country reached the decrease of 20% determined in the previous plan, the question arises why they want to reach a cut of only 16% for the second time. According to Lewis (2011), the target seems to be less ambitious, and in reality they have to face a bigger challenge in this case because earlier, in the frame of the TOP 1000 Program, bigger and less efficient companies performed the possible developments. Smaller companies and those with more problems remained in the

[71] Original text: http://news.xinhuanet.com/politics/2011-03/16/c_121193916.htm

second run. The plan also announced the introduction of new industrial policies. The main point of the achievement is that China is planning to change its old-fashioned strategic industrial branches. Instead of them, it wants to support those industrial branches that promote green transformation. This change means a modification in the context as well: traditional industrial branches were supported by the state, while they also want to include private capital in the financing of branches using renewing technology.

Table 1 Details of China's strategic shift

	The *old* pillar industries	**The *new* strategic and emerging industries**
1	National defense	Energy saving and environmental protection
2	Telecom	Next generation information technologv
3	Electricity	Biotechnology
4	Oil	High-end manufacturing (e.g. aeronautics, high speed rail)
5	Coal	New energy (nuclear, solar, wind, biomass)
6	Airlines	New materials (special and high performance composites)
7	Marine shipping	Clean energy vehicles (PHEVs and electric cars)

Source Lewis, J. (2011) Energy and Climate Goals of China's 12th Five-Year Plan, Pew Center on Global Climate Change, pp. 3. downloaded on 25.08.2011 from http://www.pewclimate.org/international/factsheet/energy-climate-goals-china-twelfth-five-year-plan

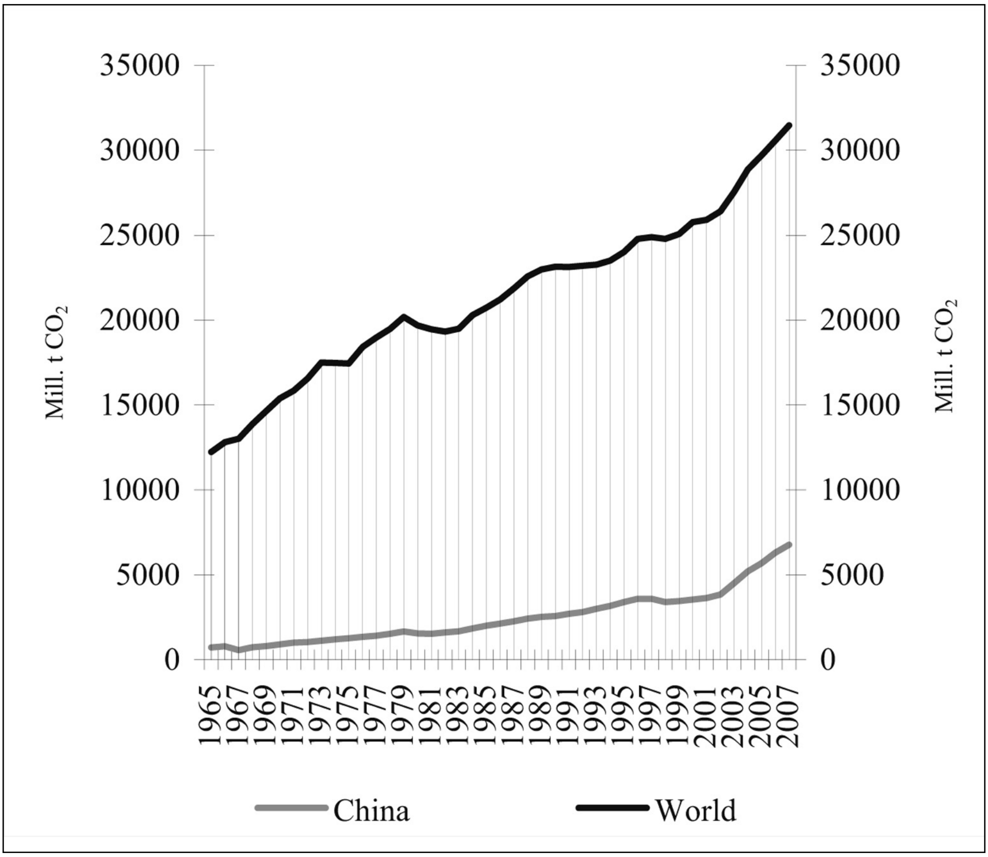
12.5 China's role in the international cooperation

China belongs to those countries that immediately signed the international environment protection agreement formulated on the United Nations Conference on Environment and Development (UNCED) held in June 1992. The country also ratified the document, which does not contain any responsibility and deadlines some months later. China did not delay to sign the Kyoto Protocol either, which was attached to the agreement, however not among the first ones: China also ratified it in 2002. For China, which belongs to the non-Annex I countries, the regulation that came into force in 2005 did not mean any quantitative restriction. This way China did not have the responsibility to restrain pollutant emission; it only received the duty to prepare regular reports at national level about the emission and to perform the kind of steps it is planning to introduce in order to stop climate change. With the Protocol coming into force, China acquired a right to implement projects under the Clean Development Mechanism (CDM). This device enables Annex I parties to perform the kind of investments in non-Annex I countries that promote a cut on pollution. Both parties can profit from this: the developed country (if the investments prove to be useful) receives an emission certification that will be included in its original undertaking, while the developing country obtains modern technology easier.

In the beginning, China did not play an important role in the Kyoto process. The main reason for this was that in 1998 they did not calculate with the fact that the country would boom very much. At this time, people assumed that China would overtake the USA only in about 2030 regarding emission. In reality, China has already become the biggest carbon dioxide emitter of the world in 2007. On the other hand, China fell well behind the other significant economies in the average per capita emission still in 2005: while the relevant figure for China was about 4 tons of CO_2 at this time, 19 tons for the USA, above 10 tons for Russia, 9 tons for Japan, and 8 tons for the Western European countries. According to predictions, it will catch up with the European countries by 2030, as expected, however it will still fall behind the other great powers (Oberheitmann – Sternfeld, 2009). In respect of the absolute emission data, it became obvious that in the interest of the climate change, China has to be forced to implement restrictions, otherwise the work of other countries is just for nothing. After the Turn of the Millennium, China made a more radical advance in the development, which was inevitably accompanied by an ever higher pollution. It became unquestionable that the regulation of the control of the emission has to be reorganized, but China was unwilling to admit it. Still today, it is arguing against its integration: if it was allowed for today's industrialized countries to achieve their present level of development with the use of fossil energy resources, by what right people want to forbid it for their country. The reasoning is rightful, but one has to see as well that the circumstances have changed significantly since then. The opposition of China is strongly influenced by the behaviour of the other responsible country, the USA, as well.

As the expiry date of the Protocol of Kyoto was approaching, international brushes were increasing on the negotiations. The annual climate summit meeting of the UN in 2007 was held on Bali in Indonesia, the central topic of the conference being the preparation of the new undertakings. At the meeting they laid down the course of further negotiations (Bali Roadmap). The experts considered the event successful, when the players agreed that the dialogue has to be continued, which actually happened in the frame of COP 15.

Figure 3 CO_2 emission in China and the rest of the world



Source: Oberheitmann, A. – Sternfeld, E. (2009) Climate Change in China – The Development of China's Climate Policy and Its Integration into a New International Post-Kyoto Climate Regime, *Journal of Current Chinese Affairs,* 3/2009, pp 138.

To illustrate its commitment to the cut on greenhouse gas emission, China announced shortly before the Climate Summit in Copenhagen that it is committed to limit the carbon intensity by 40-45 percent before the end of 2020, compared to the level of 2005. The country's energy saving target was received with mixed feelings all over the world. However, a lot of Western experts received the announcement with doubts. Zhang (2010) thinks that in this case it is not only about a shallow, high-sounding commitment. Notwithstanding, according to Zhang, if we want to get to know the real importance of this commitment, we have to take a lot of aspects into consideration. On the one hand, as China is the first carbon dioxide emitter of the world and its proportion in the whole emission of the world is increasing continuously, the reduction they undertook is not really significant compared to the world's entire emission. On the other hand, it is not entirely impossible to reach the target but it requires a hard and very meticulous work. Furthermore, even if China announces the fulfilment of its targets, it is also questionable whether we can believe the data published because the reality of the country's statistics can be questioned in many cases. In spite of the worries, the target is foreshadowing progress anyway. It is also positive that if the country really fulfils the reduction announced, its absolute emission will be close to the level advised by the IPCC. In contrary to the Chinese commitment, the United States declared only a 17 percent emission reduction plan before the conference.

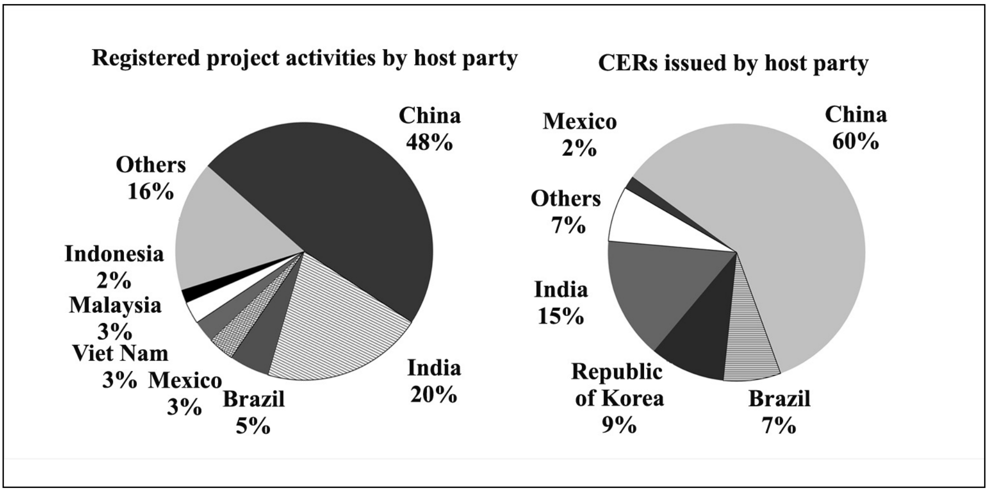
The COP 16 was anticipated very much, the target they set was the improvement of the protocol, however, the conference could be characterised by the inability of the main polluters to reach a compromise, the lack of success, and disappointment. The two big powers, China and the USA did not agree in several questions. The Americans criticized that China is authorized for an annual support of several billion dollars from the USA and Europe, the purpose of which is that developed countries help developing countries ever more to switch to the use of the clear energy resources. The USA wanted to achieve that China get out of the circle of the favoured countries in need, but China could not accept it. They also rejected that the reduction of their emission would be controlled internationally. The bad atmosphere between the two countries was also strengthened by the fact that they could not agree on other economic questions, besides the differences of opinions about the climate policy, either. Finally, a legally not binding agreement without any deadlines was drafted at the conference. Some pro forma advances happened in connection with the Climate Funds on the next meeting in Cancun; in reality, the problems remained unsolved.

12.6 The results of fight against climate change and the challenges for the future

The steps of China against the climate change can mostly be noticed in its activity in the Clean Development Mechanism. At first, China had doubts in connection with CDM and it also joined the carbon market only later. Partly, the reason for the sceptical approach was due to the fact that China has held protectionist views and it did not let the foreign investors into a number of sectors, particularly in branches of industry that were regarded as special because of the safety of its national economy. In the course of time, China's leaders realized that the mechanism contains an excellent possibility for the developing countries; this way the country became an active player of it. Having realized that it is worth joining both from economic and political reasons, CDM became the main engine to encourage the reduction of GHG emission in the country and to introduce the low-carbon technologies. Beyond the fact that they can obtain new technologies more cheaply, it is also an important view that China, with its activity on this field, presents a picture of itself on the international scene that reflects that it is concerned by the issue of climate change (Lewis, 2007).

China increased its role to the extent that it has become the first receiver country in the CDM projects by now. From the about 3,400 projects targeting the cut on the emission that were registered until summer of 2011, China was the host of about 1,500. Thanks to those investments that became successful, more than 700 million emission reduction credits were distributed in the world, from which the number of the CER-s emitted by China is the highest. The geographical distribution of emission is strongly concentrated: more than 40% can be connected to 3 provinces (Zhejiang, Jiangsu, Shandong). The most CER's emitted in China, on the basis of the distribution after scope, are related to the reduction of chemical pollutants (HFC-23) per year and on average (66 million t of CO_2e), followed by renewable energy (61 million t CO_2e). This covers 60% of the total CER. N_2O decomposition is still notable (21 million t CO_2e) in the category of "Afforestation and reforestation", there has not happened any emission yet.

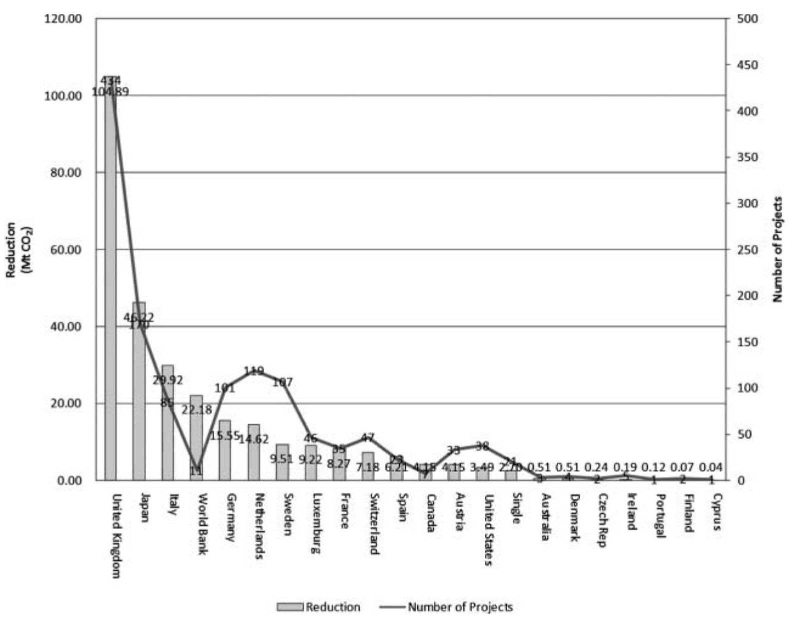
Figure 4 Chinese participation in CDM projects



Source: http://cdm.unfccc.int/ downloaded 24.04.2012

The United Kingdom is the first in the field of the climate political to conclude bilateral cooperation with China, but several other European countries have also made significant business with this emerging country. The fact that the European Union is China's main partner in this respect can be explained by several factors. On the one hand, the European Union is fully committed to the fight against climate change, it made very important steps in this issue, and, however without success, it usually recommends very radical responsibilities for the players of the climate conferences as well. On the other hand, China is the fastest growing low carbon product market of the world, which means that they complement each other very much. Otherwise, the EU is the second largest commercial partner of China, and vice versa. Beyond this commercial dependence, the significant FDI that arrives from Europe to China makes it self-evident that it is worth cooperating in the climate policy as well. Since the EU has been providing China with developed technology for a long time, it is logical that they are expanding their cooperation in low carbon technologies, too. Third, both China and the EU have to face serious duties, so their cooperation can lead to a win-win situation.

Figure 5 CDM Copartners with China and Their Estimated Annual Emission Reduction



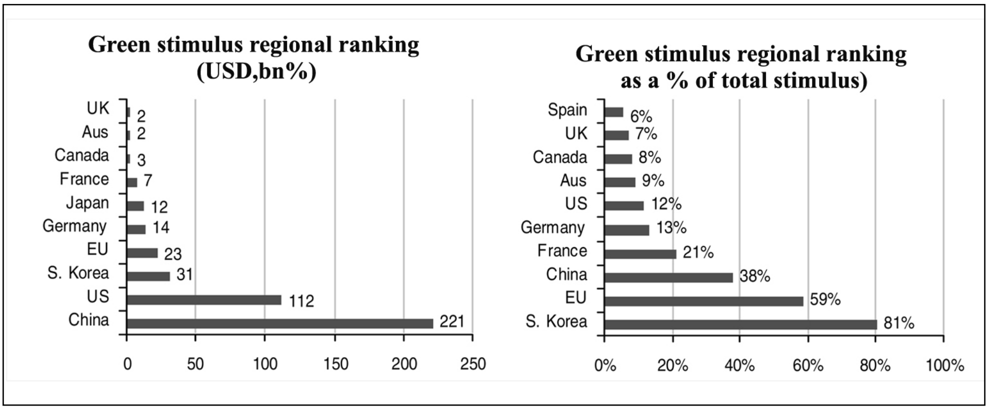
Source: Qi et al (2008) Translating a Global Issue Into Local Priority: China's Local Government Response to Climate Change, The Journal of Environment & Development, vol. 17, nr. 4. pp. 387.

From the number of the initiatives and the continuously increasing cooperation programs, one can assume that China set out to follow a new way, and it became open for the green revival. This is in conformity with the fact that the market of renewable energies, which was at first narrow all over the world, started to widen, and the value of the investments has increased by 630% globally since 2004, and the efficiency of this new energy is rising remarkably. Examining the geographical distribution of the investments, Europe continues to take the lead but, considering only the individual countries, it means that, disregarding the integrations, China has been the first in the world since 2009, when it preceded the USA. After the developments, increasingly more people speak of China as being among the winners of the new energy revolution (Cuttino, P. – Liebreich, M. 2011). In 2010, China received clean energy investments of a record volume, 54.4 billion dollar, which means an increase of 39 percent compared to the previous year. The main part of the investments in China is focusing on the use of wind power; however, the solar energy sector also became a well developing one. To be able to reach the targets for 2020 (installing 150 GW of wind) 17 GW of wind power plant was installed in China in 2010. In respect of the development of the wind energy, the country is considered to be a great power because about the half of the global wind energy investments (45 billion dollar) happens there. As far as the resources for the investments are concerned, the asset finance is predominant (PEW, 2011).

The increase in the quantity of these investments is a positive message to the world; however, one has to see too that not only quantity but quality counts as well. Of course, one cannot talk in generalities because of a number of flagrant cases; notwithstanding, it is worth becoming acquainted with an ambivalent example, namely the case of the Three Gorges Dam. The building is a huge hydroelectric dam, which was built on the river Yangtze and it counts for the biggest capacity power plant of the world. Its purpose it to generate electricity in the region using renewable technology, and it also serves flood-prevention purposes on the river. The project, which was originally developed to reduce pollution actually has a lot of negative effects, which is the reason why it is welcomed with mixed emotions both in China and all over the world. Its construction demanded the life of many people; more than one million people had to leave their homes because of the construction of the water-basin. The investment also influenced local fauna and flora: it caused loss of agricultural lands and also serious environmental problems (floods, earthquakes). However, blocking the water brought some advantages as well; however many consider the changes induced as an ecological disaster anyway (Ponseti - López-Pujol, 2006).

The responsible attitude of China towards the climate change is also reflected by the behaviour of the country demonstrated in the recession broken out in 2007. As the countries had to develop recovery plans to solve not only the economic recession but the shortage of energy supply as well, a lot of countries built the so-called green dimension into their encouraging plans. As a result, the proportion of the green elements amounted to 15% within the total of the plans published globally. The leaders were China and the USA, the sum of the stimulus (and within this, the proportion of the funds directed to climate change too) were the highest in these two countries. The proportion of the green new deals amounts to 38% of the package of 584 billion dollar of China.

Figure 6 Climate change investment dimension of economic stimulus plans 2009-2010



Source: HSBC (2009) A Climate for Recovery The colour of stimulus goes green, HSBC Climate Change,pp. 3. downloaded 2011-09-01 http://www.globaldashboard.org/wp-content/uploads/2009/HSBC_Green_New_Deal.pdf

In the frame of the high-growth and low-carbon strategies, China subsidized investments that resulted in savings and improved efficiency. To cut on transaction costs, China subsidized the development of the network infrastructure of renewable energy resources, and it also encouraged the building of roads and railways. From the total sum devoted to recovery, China set aside 50 billion dollar for biological conservation and environmental protection. To encourage the use of environmentally friendly cars, it reduced the sales tax for cars with engines smaller than 1.6 litres from 10% to 5%. Furthermore, China increased the tax on fuel oil and diesel several times (HSBC, 2009).

In the past years, China has multiplied its efforts related to climate change: it has determined self-limiting targets in the interest of the energy efficiency and the reduction of GHG emission; it has taken an active role on the carbon markets; furthermore, it has committed itself to the use of renewable energy sources to a larger extent. Notwithstanding, it still faces a lot of challenges. According to the prediction of the International Energy Agency (IEA), the energy consumption of the world will rise to 25.3 billion tonnes of coal equivalent (TCE) by 2030, which means that it will double compared to 1990. Within this, by 2030, China's proportion will increase to

21.6%. The increase is sharp; in 1990, this figure was only 10% in the China's case. According to calculations, the world's total carbon dioxide emission will double within 40 years; its amount will be close to 42 billion tons. China's share will be 13 billion tons from this, because its carbon dioxide emission will quintuplicate in comparison to 1900, as expected. After the prediction of IEA, it means that more than 30% of the world's entire carbon dioxide emission will originate from China in 2030. However, other countries also play a role in the increase of the consolidated world data. China's responsibility is illustrated very well by the fact that it causes 48.3% of the global growth. Consequently, China has to take a significant role in stopping the global climate change because, in the lack of their assistance, the adverse processes cannot be stopped (Oberheitmann – Sternfeld, 2009).

Table 2 Consumption of primary energy in China and the world as a whole

Reference scenario				
	Consumption of energy (million TCE)			
	1990	2005	2015	2030
Coal	763	1,563	2,670	3,427
Oil	166	467	776	1,154
Gas	19	60	156	284
Nuclear power	0	20	46	96
Hydroelectric power	16	49	89	123
Biomass and refase	286	324	321	324
Other renewable sources of energy	0	4	17	47
Sum total for China	1,249	2,489	4,073	5,456
Sum total for the world	12,507	16,327	20,516	25,316
China's world share (%)	10.0	15.2	19.9	21.6
	CO2 emissions (million tonnes)			
Coal	2,201	4,509	7,703	9,888
Oil	356	1,004	1,667	2,481
Gas	31	99	256	467
Sum total for China	2,588	5,612	9,627	12,836
Sum total for the world	20,688	26,620	34,071	41,905
China's world share (%)	12.5	21.1	28.3	30.6

Source: Oberheitmann, A. – Sternfeld, E. (2009) Climate Change in China – The Development of China's Climate Policy and Its Integration into a New International Post-Kyoto Climate Regime, *Journal of Current Chinese Affairs*, 3/2009, pp150.

However, many are sceptical about China's climate policy. Pan (2011) thinks that one has to admit that the country has taken essential steps in the past years to handle the problem. Of course, it is also true that the work has to be carried on: progressive, coordinated measures are needed in the future too. In addition, one cannot disregard the fact either that the emerging country is facing a special dilemma situation. As a developing country, it has to fulfil the transformations, so that its development does not become endangered. It is clear that it cannot be successful alone; international support and within this, technological cooperation, is essential to the change. As some developed countries showed that the growth of a country and the population's standard of living can be maintained at low carbon dioxide emission too, China cannot use it as an excuse that as a latecomer it has to follow the same way to rise. The fact that the developed countries argue with this can be partly accepted, which should really encourage China to follow their steps. However, the reasoning is incomplete, because China is still on the lower level of its development and the funds it would spend on the transformation would hinder back its growth for a while anyway. To put it another way, the amount of the capital available determines China's possibilities. If the developed countries are willing to help China with technology transfer and other cooperation, it is also expected to make sacrifices. If China accepts these conditions, it can also reasonably expect other big polluters to change their habits too. In the judgement of the problem, it is very important to consider the question from China's viewpoint as well. Although the country's relevant duties are very difficult and its position differs from that of the developed countries in many respects, it sets very ambitious targets for itself, which, if it can really achieve, can set a precedent.

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13. The effects of climate change on (the European) agriculture

13.1 Introduction[72]

The history of agriculture has clearly shown a significant ability to adapt to changing conditions coming from different sources. Most of them occurred autonomously and there were no need for conscious response by farmers and agricultural planners (Brooks et al., 2005). Although one should notice that the current changes (global warming, variable weather, natural disasters, etc.) are far beyond the natural adaptation abilities of agriculture. Not only farmers, but also policy makers have to do their best to maintain the quantity and quality of agricultural production. Of course, the extent of these problems differs from country to country. While most of the developing countries are facing with both of them, developed countries were able to get rid of the problem of insufficient production and in some cases they suffer from overproduction, especially the European Union.

Agriculture plays a special role in climate change since, on the one hand, it causes it in many ways, but on the other hand suffers from it. Agricultural production requires various inputs including significant amount of water, pesticides, fertilizers, fodder, etc. Industrial agriculture uses more chemicals and pollutes air and soil, contributes to erosion, salinization, loss of forests and biodiversity, etc. However, plants are able to absorb CO_2 and different ingredients from the soil and create food, feed or biofuels. But the latter topic is controversial itself. It is not clear, namely, what costs and benefits come from producing of biofuels and the energy balance of the total process is very doubtful.[73] In addition to these, agriculture may contribute to the conservation of the water base.

[72] The authors were supported by TAMOP-4.2.1.B-09/1/KMR-2010-0005 project in the research for this paper.

[73] According to some studies (lead mainly by University of California, Berkeley) this picture is rather negative, for example in case of ethanol production using corn grain required 29% more fossil energy than the ethanol fuel produced (Pimentel-Patzek, 2005). Biofuel production has an influence on food production as well. The increasing demand for both food and biofuels might result in shortages on both fields (Pimentel et. al., 2009).

The general symptoms of climate change are more or less the same in every continent. Climatic zones are moving, weather is becoming warmer with huge anomalies in precipitation, which may induce water shortages. Climate change will have many impacts on agriculture and this will lead to many risks and opportunities. To minimize the negative impacts of climate change on European agriculture, and to take advantage of the potential benefits, adaptation efforts will need to be introduced at all levels and may need to be coordinated across the EU. Changes at the level of an individual farmer, relating to tillage practice, cultivar variety, planting date can also contribute to the efficient adaptation to climate impacts. However, farm businesses are unlikely to be able to adapt to the extent, speed and severity of impacts of changing climatic patterns and extreme events, leaving European agriculture increasingly unstable and vulnerable. Owing to this overall rules for farm support, Rural Development policy and crisis management will play important roles in the future CAP.

Nevertheless, European agriculture is going to face serious challenges in the coming decades. These are the loss of comparative advantage in relation to international growers, competition for international markets, declining rural populations, land deterioration, competition for water resources, rising costs due to environmental protection policies, but the most threatening one is undoubtedly the climate change. Demographic changes are causing water shortages and agricultural production fall short in many areas, involving serious consequences at local and regional levels. Population and land-use dynamics, and the overall policies for environmental protection, agriculture, and water resource management, are the key drivers for possible adaptation options to climate change.

Despite climate change is always made appear as having negative consequences, it is important to know that opportunities for farmers may also arise as a consequence of climate change. There may be regions where the higher average temperature will result in increased yield of current crops, or might allow the cultivation of new ones. These favorable changes of conditions could increase farm incomes. In some parts of the EU, farmers may benefit if they have access to capital or knowledge that will enable them to adapt their farming practices to take advantages of these potential opportunities. The most important role of the various measures of the future CAP should be to support these actions in order to translate the opportunities into benefits, just as to mitigate the potential effects of the expected risks. For the most vulnerable farming communities in Europe, the realization of any opportunity that might arise could have critical importance to their economic survival (European Commission (2009b)).

13.2 Agro-climatic zones in Europe

Of course, not all effects will come up equally in all regions of Europe. Since the states have various climate and so agricultural profiles, they will face the consequences of climate change also in different form and on a different scale. To demonstrate these different effects, zones with similar climatic attributes are needed to be set up.

In several studies, so-called "agro-climatic" zones of the EU have been used to differentiate estimated climate change impacts. For the analysis in the study Adaptation to Climate Change in the Agricultural Sector (Iglesias et al. (2007)) nine agro-climatic zones were determined, which were modified by applying climate change scenarios, so the future changes caused by climate change have been taken into account. The nine agro-climatic zones and the incorporated states are as below (Table 1).

Table 1 Agro-climatic zones in Europe

Agro-climatic zone	Countries or areas of countries within the region
Boreal	Norway, Northern Sweden, Finland, Latvia, Estonia
Atlantic North	Scotland and Ireland
Atlantic Central	England and Wales, The Netherlands, Belgium, Luxemburg, Northern France, Western Germany, Denmark and Southern Sweden
Atlantic South	Portugal, North-West Spain, Western France
Continental North	Eastern Germany, Poland, Lithuania, Belarus, Czech Republic, Slovakia, Northern Ukraine and Eastern Austria
Continental South	Hungary, Serbia, Romania, Moldova, FYROM, Southern Ukraine and North-Eastern Turkey
Alpine	Switzerland, Western Austria, Slovenia
Mediterranean North	Northern Spain, Southern France, Corsica, Northern Italy, Croatia, Bulgaria, the Macedonian region of Greece, North-Western Turkey
Mediterranean South	Southern Spain, Sardinia, Southern Italy, Albania, Greece (except Macedonia), South-Western Turkey

Source: Iglesias et al. (2007), p. 28.

Going down in table 1, the anticipated effects of climate change will become worse. The next table gives on overview of the risks and opportunities on the level of agro-climatic zones (Table 2).

Table 2 Risks and opportunities by agro-climatic zones

Description	Bor	Atl N	Atl C	Atl S	Cnt N	Cnt S	Alp	Md N	Md S
Risks									
Crop area change due to decrease in optimal farming conditions		M	M	M	M	M	M	M	H
Crop productivity decrease		M	M	M	M	M	M	M	M
Increased risk of agricultural pests, diseases, weeds	H	M	H	H	H	H	M	H	H
Crop quality decrease			M	M	M	M		M	H
Increased risk of floods	H		H		H		H		
Increased risk of drought and water scarcity		H	H	H	H	H	H	H	H
Increased irrigation requirements				M		H		H	H
Water quality deterioration	H	H	H		H		H		
Soil erosion, salinization, desertification	H			M		H	H	H	H
Loss of glaziers and alteration of permafrost	M						H		
Deterioration of conditions for livestock	H	H	H	L	H	L	H	L	M
Sea level rise	H	H	H	H	H			H	H
Opportunities									
Crop distribution changes leading to increase in optimal farming conditions	H	H	H	M	H	H	H	M	
Crop productivity increase	M	H	M	M	M		H		
Water availability	H	M	H	H	H		M		
Lower energy costs for glasshouses	M			M	M	M		M	
Improvement in livestock productivity	H	H	H		H		H		

H=High M=Medium L=Low

Source: Iglesias et al. (2007), p. v. As the table above shows, risks relate mainly to potential changes in precipitation patterns in the Alpine, Boreal, Atlantic North and Atlantic Central and Continental North zones with projected increases in winter rainfall and decreases in water availability in summer. Therefore strategies are needed to reduce the effects of winter flooding, water logging and reduced water quality, while implementing measures for capturing and storing water to ensure adequate supply during the summer (European Commission (2009a)).

In the Continental North areas total annual rainfall is expected to increase, with precipitation increases in the winter while reduction in summer could occur in several areas. The increased rainfall is predicted to lead to a greater number of intense rainfall events and to increase the risk of flooding, which may be particularly severe as this area has large areas of low-lying land vulnerable to flooding from rivers. A warmer climate may lead to an increase in the northern range over which crops such as soya, sunflowers may be grown and potential increases in yield from the longer growing season (Iglesias et al. (2007)).

In the Boreal, there will be potential for cultivating new areas and crops due to much longer growing seasons. Yields could increase under limited warming, but agriculture could suffer from new pests and diseases. The warmer climate could aggravate the problems of water quality in the Baltic Sea.

The increasingly extreme weather events will affect vulnerable mountain areas. Mountain Alpine regions are particularly vulnerable as temperature increases are expected to be above average and other climate change impacts, such as decreased snow cover may have further impacts on hydrological cycles and reduce biodiversity in many river basins (European Commission (2009a)). In the Alpine, Boreal, Atlantic, and Continental North agro-climatic zones, a lengthened growing season and an extension of the frost-free period may increase the productivity of some crops and enhance the suitability of these zones for the growth of other crops (Iglesias et al. (2007)). However, these changes will only be possible if there is sufficient water available.

Rising sea levels are a particular risk in the Atlantic central zone, requiring either improved defenses or the abandonment of land. Hard defenses are extremely expensive and not cost-effective. The greater intensity of winter precipitation and warmer temperatures in this area are expected to increase the frequency of storms and flooding, especially because there are several large rivers in this zone. Summers are predicted to become dryer and hotter. The longer growing season is forecasted to increase yields of wheat. There is also likely to be an increase in the northern range, where crops such as soya and sunflowers may be grown (Iglesias et al. (2007)). The greatest problem to be faced by agriculture in this zone may be rising sea level, which may affect low-lying land in Eastern England and the North Sea coasts of Belgium, the Netherlands and Germany, some of the most productive agricultural areas in those countries. Reduced water resources during summer may lead to conflicting demands between agriculture and other users.

Although new pests and diseases present a high risk in the Boreal, Atlantic Central, and Continental North zones, there is likely to be considerable opportunity in these zones for increased agricultural production. The yields of current crops are set to increase, together with the area of potentially productive land. There are also opportunities for the introduction of new crop types, and may be potential for increased livestock production in some zones. However, there is also a possibility that optimal growing conditions may shift from areas that have a large proportion of fertile soils towards those where soils are less fertile and, therefore, less able to produce higher yields.

In the Atlantic South, Continental South and Mediterranean zones, the greatest risks could arise from reduced crop yields and conflicts over reduced water supply. Strategies need to be developed to adopt cultivars or crops better suited to water and heat stress (Kurukulasuriya - Rosenthal (2003)). Also, a greater risk of forest fires has been identified in this area. Problems from new pests and diseases are also considered a high risk in these zones. These changes are expected to reduce the diversity of Mediterranean species. There are few opportunities, although in parts of the Continental South zone, there may be some scope for the introduction of new crops.

The delineation of agro-climatic zones in Europe is demonstrated below (Table 3). The shift of these zones may lead to loss of some indigenous crop varieties, regional shifts in farming practices and to shifts in optimal conditions for pest species and disease types.

Table 3 The delineation of agro-climatic zones in Europe

Agro-climatic area	2006	2080
Boreal	Sweden, Finland, Latvia, Estonia, Norway	EU: Sweden, Finland, Norway
Atlantic north	Ireland, Scotland	Ireland, Scotland
Atlantic central	England & Wales, Benelux, Central and Northern France, Western Germany, Denmark, Southern Sweden	England & Wales, Benelux, Central and Northern France, Western Germany, Denmark, Southern Sweden, Southern Norway, Southern Finland
Atlantic south	Northern Portugal, Galicia, Western France	Northern Portugal, Galicia, Western France
Continental north	Eastern Germany, Poland, Lithuania, Northern Ukraine, Czech Republic, Slovakia, Eastern Austria, Belarus	Eastern Germany, Poland, Lithuania, Latvia, Estonia, Northern Ukraine, Czech Republic, Slovakia, Belarus
Continental south	Hungary, Romania, Serbia, Moldova, FYROM, Southern Ukraine, North-Eastern Turkey	Hungary, Romania, Eastern Austria, Serbia, Moldova, FYROM, Southern Ukraine, North-Eastern Turkey
Mediterranean north	Northern Spain, Southern France, Corsica, Northern Italy, Bulgaria, the Macedonian region of Greece, North-Western Turkey, Croatia	North-Western Spain, Southern France, Corsica, Northern Italy, Bulgaria
Mediterranean south	Southern Spain, Southern Italy, Greece, Southern Turkey	Central Spain, Southern France
Alpine	Western Austria, Slovenia, Switzerland	Western Austria, Slovenia, Switzerland

Source: Iglesias et al. (2007), p. 12-13.

Climatic changes, in general, are likely to shift the zones of optimal production areas for specific crops in the EU. Temperature increases tend to speed the maturation of annual crops, therefore reducing their total yield potential. When the optimum temperature is exceeded, plant growth tends to be reduced. The optimum temperature varies between species, but most of the crops are sensitive to high temperature. Crop yield and quality may decrease, causing loss of rural income due to the problems of pests and diseases as well. The mitigation of these problems may lead to a decrease in water quality from the increased use of pesticides.

In turn, such changes in productivity may affect the total agricultural output of the EU and its share of international commodity trading. Varying seasonality and inter-annual variability will affect crop cycles and farm management, affecting yields and rural economies. Temperatures are expected to rise beyond the optimum growing conditions for many common crop species, and also increased concentrations of tropospheric ozone are expected to reduce crop yields.

In some regions a positive relationship between temperature and crop yield is forecasted, with higher temperature and increased CO_2 concentration producing more yields. However, an insufficient supply of water or nutrients, coupled with increased weed competition is expected to frequently negate the fertilizing impact of higher CO_2 levels (Iglesias et al. (2007)).

New crops such as soya could be grown in future conditions to produce livestock feed. Warmer and drier climatic conditions may also reduce forage production leading to changes in optimal farming systems and a loss of income in areas dependent on grazing agriculture (DG AGRI (2008a)). Decreased availability of water may lead to insufficient water being available for irrigation resulting in crops suffering moisture stress. For crop production, a change in the seasonality of precipitation may be even more important than a change in the annual total. Inter-annual variability of precipitation is a major cause of variation in crop yields and yield quality. Crop yields are most likely to suffer if dry periods occur during critical developmental stages. In case of most grain crops flowering is especially sensitive to water stress. Increasing demand for water is likely to lead to increased groundwater abstraction and thus depletion of those resources. Excessively wet years may also cause yield declines due to waterlogging and increased pest infestations (DG AGRI (2008a)). Heavy rainfall may damage younger plants.

Lower levels of winter rainfall will lead to decreased water quality. Other changes in crop growth, such as reduced yields and in consequence of this use of extra fertilizer and manure, will extend the problem of water quality. Increased salinity, as a result of drought or sea level rise, may lead to land becoming unsuitable for cropping and being abandoned (EEA (2008b)). In extreme cases this may lead to desertification. Increased intensity of precipitation is likely to cause erosion and increase the occurrence of storm flooding and storm damage and lead to greater incidences of waterlogging.

A warmer and drier climate may reduce forage production leading to changes in optimal farming systems and a loss of income in grazing agriculture. In some northern areas, a warmer climate and therefore an extended growing season has the potential to increase forage production. A shift in the location of optimal conditions for specific crop or livestock production systems may lead to loss of rural income and soil deterioration in the areas where those modes of production can no longer be maintained. Such losses of farming practices may lead to loss of cultural heritage, land abandonment and increased risk of desertification (European Commission (2009a)). Rising sea levels may also lead to land use changes and land abandonment.

The need for increased spending as a result of damage caused by extreme weather events will lead to a loss of rural income and economic imbalances between the more and less prosperous parts of Europe.

13.3 Impacts of climate change

The four most influential factors of climate change on agro-ecosystems are CO_2, temperature, rain and wind. They have different and sometimes controversial effects on the ecosystem. As it was mentioned above, higher CO_2 content may increase yields, though weeds can grow faster too. It is more or less the same with temperature: it will have good effects on crops in the colder parts of the continents (e.g. Northern America, Northern Europe, etc.), but negative effects on the originally warmer parts of the continents (Southern Europe[74], Africa, etc.). Increased precipitation may occur in some areas, while other areas will face with much less rain, but water quality and quantity problems (early spring runoff peaks vs. higher winter flows) can be expected everywhere (Falloon – Betts (2010)). The table below shows the most probable influence of these factors on the agro-ecosystem (Table 4).

[74] It is to be mentioned that climate change will cause enormous changes in energy demand as the projected temperature increases will result higher need for cooling (EEA (2008a)). The opposite can be predicted for Northern Europe, where heating demand will be lower.

Table 4 Influence of CO_2, temperature, rainfall and wind on various components of the agro-ecosystem

Component	Influence of factor		
	CO_2	Temperature	Rain/wind
Plants	Dry matter growth Water use	Growth duration	Dry matter growth
Animals	Fodder yield	Growth and reproduction	Health
Water	Soil moisture	Irrigation demand Salinization	Groundwater
Soil	SOM turnover*	SOM turnover Nutrient supply	Erosion by wind and water
Pests/diseases	Quality of host biomass	Generation time Earliness of attack	Transmission of diseases
Weeds	Competition	Herbicide efficacy	–

* Soil Organic Matter concentration
Source: Olesen – Bindi (2004), p. 40.

Climate change will manifest itself in various forms. One of the most important consequences are that temperatures will rise all over Europe, especially during winter. According to the IPCC, global warming will cause a temperature increase of 1.8şC to 4şC over the next century compared to 1990 levels (IPCC (2007)). Besides annual total precipitation may increase, but so may inter-season variability as well, while summer rainfall is likely to be lower throughout Europe, with periods of intense rainfall becoming more common and less winter precipitation falling as snow. Although difficult to forecast, the incidences of extreme weather events is likely to rise in a warmer climate. This will mean more flooding, higher winds, destructive precipitation events and longer periods of drought. Sea level is predicted to rise by as much as 5 meters (EEA (2008b)). One of the effects of this is likely to be the salinization of water resources in coastal areas. And in addition, we must not forget that the atmospheric levels of CO_2 and ozone will rise.

The combination of long-term changes and the greater frequency of extreme weather events are likely to have adverse impacts on the agricultural sector. It will directly impact agricultural production and production methods. Reductions in crop yield (or increased yield variabilities) and quality as the result of reduced water availability and precipitation variability could result in loss of rural income. This loss of income will be further worsened by the need for increased spending as a result of damage caused by extreme weather events.

On the one hand, heavier winter rain and the decreased proportion of winter precipitation falling and being stored as snow will increase the occurrence of floods, damaging crops at vulnerable stages of development and disrupting farm activity. Excessively wet years may cause declining yields as a result of waterlogging and increased pest and disease problems (DG AGRI (2008b)). Intense rain and hailstorms can affect the yield and quality of vulnerable crops, such as soft fruits. Sea level rise will directly impact some agricultural land, contribute to greater pressures via changes in land use around urban areas and increase the salinity of some of the water resources. Increased salinity may result in land abandonment as it becomes unsuitable for cropping.

On the other hand, reduced water availability caused by drought may lead to insufficient water available for irrigation, crops suffering from heat and drought stress, and increased competition for water resources may result in higher prices and regulatory pressure (DG AGRI (2008a)). As a consequence of drought, the quality of land resources will be worsened by soil degradation, which will lead to a decrease in yields and subsequently weak food security.

As a response to reduced nutrient uptake, increased manure and fertilizer may be applied. This may lead to a reduction in water quality as nutrients will not be sufficiently diluted by rainfall. The table below summarizes climate and related physical factors relevant to agricultural production (Table 5).

As it can be seen from the table above, the possible effects of these various factors can be very different, but most of them will increase yield variability and require instant actions. The only factor with mostly positive influence on production is the rising atmospheric CO_2 via increasing photosynthesis. Although Grace et al. (2002) argued that temperature has much more (negative) effects by limiting photosynthesis over a certain temperature range than CO_2 has. Investing in more resistant crops is important, but it can not answer all the challenging physical factors. Regional differences have to be kept in mind. The northern and the southern parts of the Earth will benefit from higher precipitation and warmer weather, while the central (especially tropical and sub-tropical) areas will suffer from them. It will affect the productivity of both crop and livestock sectors, which is even more of a vital problem for African (non-oil exporting) countries, where agriculture is undoubtedly the most important sector measured either by its contribution to the national GDP or to export revenues.

Table 5 Climate change and related factors relevant to agricultural production at a global scale

Climate and related physical factors	Expected direction of change	Potential impacts on agricultural production	Confidence level of the potential impact
Atmospheric CO_2	Increase	Increased biomass production and increased potential efficiency of physiological water use in crops and weeds. Modified hydrologic balance of soils due to C/N ratio modification. Changed weed ecology with potential for increased weed competition with crops	Medium
		Agro-ecosystems modification	High
		N cycle modification	High
		Lower yield increase than expected	Low
Atmospheric O_3	Increase	Crop yield decrease	Low
Sea level	Increase	Sea level intrusion in coastal agricultural areas and salinization of water supplies	High
Extreme events	Poorly known, but significant increased temporal and spatial variability expected. Increased frequency of floods and droughts	Crop failure. Yield decrease. Competition for water	High
Precipitation intensity	Intensified hydrological cycle, but with regional variations	Changed patterns of erosion and accretion. Changed storm impacts. Changed occurrence of storm flooding and storm damage. Increased water logging. Increased pest damage	High
Temperature	Increase	Modifications in crop suitability and productivity. Changes in weeds, crop pests and diseases. Changes in water requirements. Changes in crop quality	High
	Differences in day/night temperature	Modifications in crop productivity and quality	Medium
Heat stress	Increases in heat waves	Damage to grain formation, increase in some pests	High

Source: Iglesias et al. (2009b), p. 10.

According to the Global Environmental Outlook of the United Nations Environment Programme[75], different continents will face with different problems:

- Africa has the worst perspectives as the main problems are lower yields and desertification . It will lead to food insecurity, as well as increased malnutrition and hunger. Especially lake fish production will decrease due to rising water temperature (UNEP (2007)). Increased water stress can cause additional problems. The problems of the key sector in the majority of the countries will have serious financial consequences in terms of lower export incomes.
- Asia will also have to face adverse effects. Higher yields and more utilized agricultural areas available are expected in the Northern part, while the Southern part will have lower yields and less agricultural area available. In addition to these, higher sea level (especially in the mega-delta regions) and more extreme weather events will cause further problems.
- Australia will experience overall balanced impacts. However, the loss of biodiversity seems to be unavoidable.
- Europe will have more or less the same prospects as Asia: better opportunities on the Northern part and worse situation on the Southern part.
- North America's perspectives are similar to Asia's and Europe's. The winner is expected to be Canada on this continent.
- South America has to be prepared for worse agricultural conditions caused by the climate change. Although the yield decrease may be in a reasonable range and can be compensated by plant breeding and technological interventions in the intervening period (Jones – Thorton (2003)).

13.4 Modelling the impacts of climate change on agriculture

Forecasting the possible effect of climate change on agriculture is a very topical issue. Modelling is very important as it can help identify the key problems and proper adaptation measures and give answers to several questions by pointing out the direction and magnitude of changes.[76] They can be divided into two parts: global and regional climate models (GCMs and RCMs). It is to be mentioned that these models are very sensitive to the initial data, especially to variation in temperature and rainfall, and GCMs often require detailed regional spatial analyses (Olesen et al. (2007)).

[75] More details at http://www.unep.org

[76] From this aspect, the results of IMPACCT (Integrated Management oPtions for Agricultural Climate Change miTigation), a project organized by the University of Hertfordshire, are interesting: a working greenhouse gas (GHG) emission counter. It may be used on national, regional or farm level in order to identify GHG reducing actions. More details at http://sitem.herts.ac.uk/aeru/impacct

There are at least three model families in use: process-based crop models, empirical statistical models and production functions. Naturally, all of them have strengths and weaknesses. Table 6 shows the main characteristics of the most commonly used models.

Table 6 Summary of the characteristics of process-based crop models, empirical models and crop production functions

Type of methodological approach	**Description and use**	**Strengths**	**Weaknesses**
Process-based crop models	Calculate crop responses to factors that affect growth and yield (i.e., climate, soils, and management). Used by many agricultural scientists for research and development.	Process based, widely calibrated, and validated. Useful for testing a broad range of adaptations. Test mitigation and adaptation strategies simultaneously. Available for most major crops.	Require detailed weather and management data for best results.
Empirical statistical models	Based on the empirical relationship between observed climate and crop responses. Used in yield prediction for famine early warning and commodity markets.	Present day crop and climatic variations are well described.	Do not explain causal mechanisms. May not capture future climate crop relationships or CO_2 fertilization.
Production functions derived from crop models and validated with empirical data	Based on the statistical relationship between simulated crop responses to a range of climate and management options. Used in climate change impact analysis.	Allow to expand the results over large areas. Include conditions that are without the range of historical observations. Allow to simulate optimal management and therefore estimate possible adaptation.	Causal mechanisms are only partially explained. Spatial validation is limited due to limitations in the database.

Iglesias et al. (2009b), p. 17.

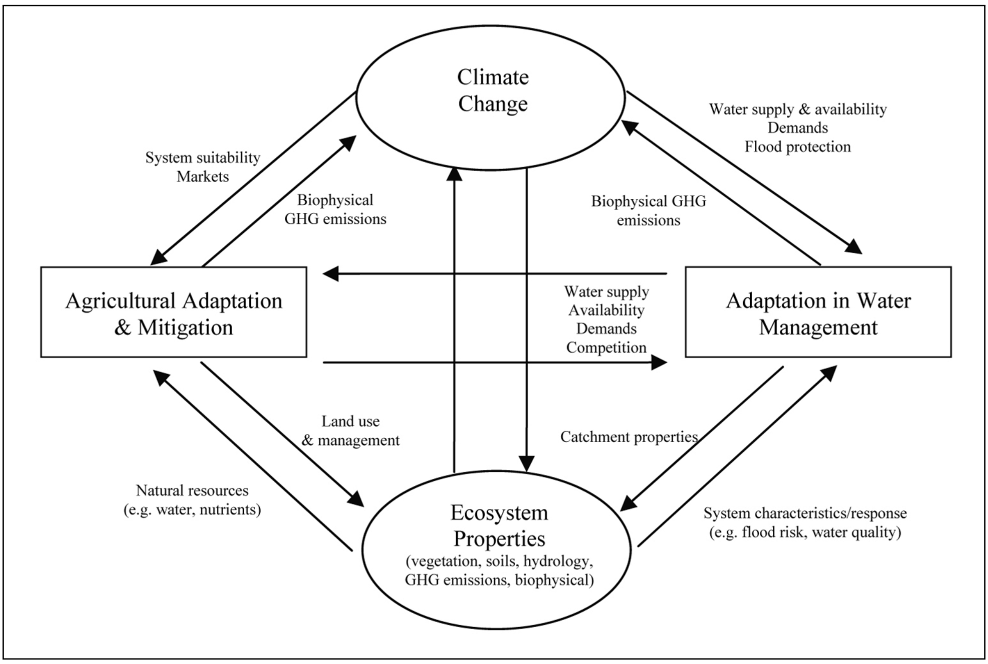
The model suitable for analyzing the given problem always depends on the situation at hand and on the aims of the modeller.

13.5 Adaptation measures

In agreement with many authors (e.g. Olesen – Bindi (2004)), adaptation means long term issues, because in the short run we may speak only about adjustments. Some elements of production may be changed easily and immediately (e.g. optimized production, timing, fertilizer use, change in varieties, water conserving practices), but the introduction of irrigation or structural changes (e.g. land use patterns) take time. Sustainability should also be highlighted as an important element of adaptation measures. It is not only in line with long term objectives, but also helps reduce the vulnerability to climate change by enhancing adaptive capacity and increasing resilience (UNEP (2007)).

It must be stressed that adaptation and mitigation require integrated approach as none of the important elements can be handled separately. Interactions between climate change, adaptation and ecosystem properties are extremely important. Each element of this system has effect on all the others and vice versa (Figure 1).

Figure 1 Interactions between climate change, adaptation/mitigation in agriculture, adaptation in water management and ecosystem



Source: Falloon – Betts (2010), p. 5668.

It also should be kept in mind that the likelihood of various impacts are different. In addition, the expected negative effects are often accompanied by further negative impacts (e.g. in case of lack of irrigation, less precipitation causes lower yields). Obviously, the adaptive capacity of agriculture depends on the nature and magnitude of changes. Table 7 shows the most relevant impacts on the agro-ecosystem, their uncertainty levels, impacts and adaptive capacity.

As it can be seen from the table above, some of the problems are expected to be occurred in special areas, regions or countries. For the most part, developing countries are in danger (e.g. water availability, soil fertility and erosion, etc.). Some of the changes have serious impacts on rural environment, rural life (loss of rural income, outmigration, loss of cultural heritage, etc.) as additional effects. Although one might notice that the adaptive capacity is mostly on moderate/high level.

The different agro-climatic zones will not only face different impacts, risks and opportunities, but will also have different adaptation options for the same risks because of different adaptive capacities. Southern regions should increase the capture and storage of water to ensure adequate supplies. Water storage capacity need to be increased to capture a greater proportion of winter rainfall. As an opposite, Northern states are receiving a large proportion of their annual precipitation in summer. Differences can be seen at farm level too. Intensive farming systems, which are very common in Western Europe, are less sensitive to climate change because the impact on their production is lower, while low input farming systems are in danger (Chloupek et al. (2004)). Another aspect of production is specialization. Climate change has higher effects on specialized farms than on mixed farms (Olesen – Bindi (2002)). In case of livestock sector, methane emission can cause problems by contributing to greenhouse effects. The suitable solution is already in use, but biogas production can not be an issue in case of low scale farming (e.g. small farms with a few cows).[77]

There is a higher need for irrigation due to the drought in the Southern M-editerranean zone than in the North. Therefore extensification of production would be advisable in the Southern part of Europe, while the Northern part will be more suitable for intensive production (Olesen – Bindi (2004)). As a consequence of this, there is a higher awareness of climate change impacts and a higher willingness to take adaptive measures and to seek alternative modes of production in the Southern agro-climatic zones than in the Northern ones (European Commission (2009a)).

[77] In the case of biogas production, the proper use of gas is also an important issue. Local use is essential as biogas cleaning is very costly and therefore it makes almost no sense to do it in order to pump the biogas into the gas supply system.

Table 7 Characterization of agronomic and farming sector impacts, adaptive capacity, and sector outcomes

Impact	Uncertainty level	Expected intensity of negative effects	Socioeconomic and other secondary impacts	Adaptive capacity
5Changes in crop growth conditions	Medium	High for some crops and regions	Changes in optimal farming systems; Relocation of farm processing industry; Increased economic risk; Loss of rural income; Pollution by nutrient leaching; Biodiversity.	Moderate to high
Changes in optimal conditions for livestock	High	Medium	Changes in optimal farming systems; Loss of rural income.	High for intensive production systems
Changes in precipitation and availability of water	Medium to low	High for developing countries	Increased demand for irrigation; Decreased yield of crops; Increased risk of soil salinization; Increased water shortage; Loss of rural income.	Moderate
Changes in agricultural pests	High to very high	Medium	Pollution by increased use of pesticides; Decreased yield and quality of crops; Increased economic risk; Loss of rural income.	Moderate to high
Changes in soil fertility and erosion	Medium	High for developing countries	Pollution by nutrient leaching; Biodiversity; Decreased yield of crops; Land abandonment; Increased risk of desertification; Loss of rural income.	Moderate
Changes in optimal farming systems	High	High for areas where current optimal farming systems are extensive	Changes in crop and livestock production activities; Relocation of farm processing industry; Loss of rural income; Pollution by nutrient leaching; Biodiversity.	Moderate
Relocation of farm processing industry	High	High for some food industries requiring large infrastructure or local labor	Loss of rural income; Loss of cultural heritage.	Moderate
Increased (economic) risk	Medium	High for crops cultivated near their climatic limits	Loss of rural income.	Low
Loss of rural income and cultural heritage	High	Not characterized	Land abandonment; Increased risk of desertification; Welfare decrease in rural societies; Migration to urban areas; Biodiversity.	Moderate

Iglesias et al. (2009b), p. 35

Farmers have always adapted to changes in climate. The challenge now is to adapt within very short periods of time to potentially extreme impacts, and new risks and opportunities. This will be achieved through a combination of managerial, infrastructural and technical measures (European Commission (2009b)). Diversification is also an important tool in farmers' hand, especially from financial point of view. Many of the possible adaptation measures to address the risks and opportunities identified in the nine agro-climatic zones can be applied at farm level, with correct management. But there is a need for EU measures as well to help farmers cope with the forecasted loss of agricultural production. While in a global economy it might be argued that the market should be left to resolve such issues, it must also be remembered that social and environmental issues are closely affected by this one, which may fail without any support. Insurance needs to be considered to allow farmers to increase their adaptation to climate change.

The current CAP measures are only partly adequate to adapt the new conditions. Several changes need to be done in the future CAP in order to make the instruments appropriate and flexible enough to ease the Europe-wide different adaptation. Short-term measures involving policy development and knowledge transfer must be put first in place. Existing CAP mechanisms can be used to stimulate and facilitate adaptation and other mechanisms must also be used, such as insurance and partnerships (European Commission (2009a)).

The Good Agricultural and Environmental Condition (GAEC) standards provide the Member States with the required flexibility to use locally appropriate management practices. However the instrument could be improved by indentifying each Member State's major environmental threats, which should be focused on.

Member States should be required to make farmers aware of climate change issues, particularly for new entrants such as young farmers. Developing the role and scope of the Farm Advisory System (FAS) would be a feasible option for effective knowledge transfer. For the best result, the use of FAS should even be obligatory for farmers.

The Rural Development Programs have the potential to support the adaptation by obligating Member States to consider the impacts of future climate change across all axes. The aim of the mitigation of climate change would be achieved better by linking funding to cross-compliance (Iglesias et al. (2007)). Adjusting the criteria for those eligible for rural development support for areas with high vulnerability to climate change may be an option to facilitate their adaptation. But it should mentioned that the European Union has already recognized the importance of proactive actions and funded numerous projects related to climate change adaption (e.g. see Policy Research Corporation (2009), Annex III.).

The actual state of adaptation differs from country to country. More developed and/or affected countries are playing a leading role in the process. The following table gives an overview of the actual state of adaptation strategies in Europe (Table 8).

Table 8 Summary of national adaptation strategies in the EU-27 and other European countries

Status of the national adaptation strategies	**Countries**
Developed	Finland, Spain, France, Sweden
Under preparation, to be published in the near future (EU-27)	The Netherlands, UK
Under preparation, to be published in the near future (other European countries)	Norway
First steps	Rest of the countries

Source: Iglesias (2009), p. 159

As a key area of addressing climate change, adaptation researches has quite an old history. Most of the possible answers are well known, but only some of them are widely used. Introducing them requires not only time and money, but also changes in people's attitude towards public goods, (positive) externalities, education and in some cases strong political will. The following table contains suggested policies to support adaptation of European countries (Table 9).

Table 9 Suggested resource based policies to support adaptation of European agriculture to climate change

Resource	Policy
Land	Reforming agricultural policy to encourage flexible land use. The great extent of Europe cropland across diverse climates will provide diversity for adaptation
Water	Reforming water markets and raising the value of crop per volume of water used to encourage more prudent use of water. Water management, that already limits agriculture in some regions, is crucial for adapting to drier climate
Nutrients	Improving nutrient use efficiencies through changes in cropping systems and development and adoption of new nutrient management technologies. Nutrient management needs to be tailored to the changes in crop production as affected by climate change, and utilisation efficiencies must be increased, especially for nitrogen, in order to reduce nitrous oxide emissions
Agrochemicals	Support for integrated pest management systems (IPMS) should be increased through a combination of education, regulation and taxation. There will be a need to adapt existing IPMS's to the changing climatic regimes
Energy	Improving the efficiency in food production and exploring new biological fuels and ways to store more carbon in trees and soils. Reliable and sustainable energy supply is essential for many adaptations to new climate and for mitigation policies. There are also a number of options to reduce energy use in agriculture
Genetic diversity	Assembling, preserving and characterising plant and animal genes and conducting research on alternative crops and animals. Genetic diversity and new genetic material will provide important basic material for adapting crops species to changing climatic conditions
Research capacity	Encouraging research on adaptation, developing new farming systems and developing alternative foods. Increased investments in agricultural research may provide new sources of knowledge and technology for adaptation to climate change
Information	Enhancing national systems that disseminate information on agricultural research and technology, and systems encourages information exchange among farmers. Fast and efficient information dissemination and exchange to and between farmers using the new technologies (e.g. internet) will speed up the rate of adaptation to climatic and market changes
Culture	Integrating environmental, agricultural and cultural policies to preserve the heritage of rural environments. Integration of policies will be required to maintain and preserve the heritage of rural environments which are dominated by agricultural practices influenced by climate

Source: Easterling (1996) modified by Olesen – Bindi (2002), p. 255.

13.6. CAP beyond 2013 and the adaptation

The 2003 CAP reforms were a first step towards a framework for the sustainable development of EU agriculture. The central objective of the reforms was to promote a competitive and market-responsive agricultural sector. High standards for the environment, the public, animal and plant health, and animal welfare were key issues during the reform. Decoupling helped reach greater market responsiveness, while higher standards were achieved through cross-compliance. When improving the CAP measures, the focus should be on the aim to be better suited to climate change adaptation. Fortunately, the challenges represented by the climate change are widely known among the developers of the future CAP. The direction of the CAP beyond 2013 is going to be built on the 2003 reforms, with a continued shift from market intervention and further decoupling. In order to create well targeted measures it is also necessary to elaborate the good allocation of resources. For this reason, the current reform of the CAP must be accompanied in time by the creation of the new Multiannual Financial Framework (MFF).

The CAP 2020 Presidency Conclusions (Council of the European Union (2011)) clearly establish that "the CAP already includes significant green elements". While cross-compliance with GAEC standards promotes the reduction and control of undesirable impacts of agriculture on the natural environment, the so-called agro-environmental schemes under the second pillar benefit conservation and landscape management efforts.

As put forward in the CAP 2020 Presidency Conclusions, further greening "must be based upon the experience of the CAP's current green policy measures". The bipolar structure, i.e. cross compliance and the second pillar's agro-environmental payments, has proven its worth Europe-wide. However, additional values and a certain extent of fine-tuning are welcome.

At the discussion of the Commissions proposal on the CAP beyond 2013 there were two approaches in the further greening of the CAP. Some MSs proposed a cross-compliance-focused solution, i.e. to refine the GAEC standards to meet additional or higher environmental values. On the other hand, there were hints that the Commission is devoted to give greening a "targeted" priority and couple green payments with certain environmental performance. According to the Commission's proposal on the Multiannual Financial Framework 2014-2020 (European Commission (2011)) the Commission intends to couple 30% of the direct payments to green measures. This approach, in spite of the good intention, carries the possibility of complication (instead of simplification) and an interference with pillar two agro-environmental measures.

This sort of greening measures have different impacts on holdings that are located in designated areas (e.g. Natura 2000) and also on those that are not. Evidently, such location implies natural and administrative burdens on the economical efficiency of production. Carrying out environmental efforts is, in some cases, perfectly proportional with size in terms of variable costs or opportunity costs. However, certain limitations of the farming activity (e.g. altered grazing or mowing periods) come across as quality losses which may have a more severe impact on small-scale farms. Not only the different size of holdings, but also the diverse conditions in MSs have different consequences in terms of economic performance of apparently similar holdings. For this reason the flexibility provided for the MSs is crucial. As for the proportionality with efforts to achieve CAP objectives, the objectives must be translated into proper measures and programs, and then no doubt the farmers participating in the different measures will get only the amount of support they deserve for their activity and ambitions. This would lead to the efficient and well targeted allocation of the reduced resources which were indicated by the new MFF.

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United Nations: http://www.unep.org/ (Global Environmental Outlook of the United Nations Environment Programme)

Csaba Horváth

14. Resource shock cycles - A historical view on climate change challenges on global society

14.1 Introduction[78]

Ever since the work „The Limits to Growth" by Donella Meadows, it has been an important question whether one day the present patterns of economic expansion will overrun the capacity of natural resources. The question however regarding what will be the first symptoms of such a crisis if it does happen one day is rarely asked. What kind of symptomes will show us that such a crisis is on its way? If we can't answer that question, then how can we be sure that it is not already going on right now? This chapter aimes to focuse on these questions.

We can not see the future, so predictions os such specific issues can be seen as highly speculative. One thing that we can do however is to get an overview on events that have occured before among similar circumstances in history, and try to get a conclusion on present trends using the experience of the past. We use this method to get closer to the answer for the question described above.

We take two historical examples of a socio-economic system overrunning it's rescources: One of those are the demographic cycles of medieval Europe, and the other one is the „high level equilibrium trap" of early modern China, described by Mark Elvin. We decided to chose these two cases due to the fact that one of the two, medieval Europe shows a previous experience of our own western civilization running over its rescources, while the other one, the case of early modern China represents the most highly developed and industrialized premodern socio-economic system that is known to have faced such a challenge.

We examine that out of the symptomes that we can see in these two cases, which symptomes could be relevant and have the possibility to appear in our present global socio-economic system, as well as the effects that they could have on it.

For resource crises probably one of the best concepts to understand them is the concept of demographic cycles. This concept is interesting because it gives an

[78] This study was supported by TÁMOP-4.2.1/B-09/01KMR-2010-0005

overview how the population, the natural resources, and technology to exploit these resources, have interacted for centuries or millenea. The concept of demographic cycles has shown that the history of mankind is not linear, but cyclic even in this aspect, and even in the long run. Usually, one such cycle is opened by a wave of innovation, that enables the economi eighther to use new resources, and/or to exploit old resources with a higher efficiency. Looking back for centuries, such waves of innovation were new methods in agriculture, while int he last 300 years, such a waves were the industrial revolutions. Such an innovative wave was always followed by a period of economic prosperity. In this period, the new technologies have provided such an abundance of resources, that exeeds the needs of the economy for a while. The period of prosperity is ended by the period of crisis. This means resource shortages, shortages of food, industrial raw materials, and energy. In traditional societies these crises are usually accompanied by symptoms that are traditionally known in our western civilization as the four horsemen of the apocalypse: war, famine, epidemics, and death. Food shortages caused famine, famine caused epidemics, and economic turmoil caused social and political turmoil. In case of a favourable scenario, such crises were usually ended by a new wave of innovation, opening a new cycle.[79]

Looking back at history, we can take two such cycles as most significant historical precedents: One of them is the case of medieval Europe from the turn of the first milleneum till the middle of the 15th century. The other is the case of early modern China from the mid 17th century until the early 20th century. From these two, one of them, medieval Europe is interesting for us because it's the most significant western example, while the other, the case of early modern China is interesting, because as a more highly developed economy, it shows symptoms that are closer to problems of present day world economy.

Among the present circumstances, the possible effects of climate change are also not negligable, since they can siginificantly contribute to the affects of a resource crisis. In this respect this chapter also takes an overview on two past cases. One of them is the so called Little Ice Age of 14th-19th century Europe, while the other is the beginning of the Holocene climate 11 600 years ago. Regarding these two examples of climate change, on one hand, the Little Ice Age is closer to us in time. It occurred in historical times, it affected an agricultural civilization. On the other hand, the scale of climate change predicted by the IPCC until 2100, is in much larger in magnitude than the Little ice age, and can only be measured to prehistoric cilmate fluctuations that occurred 11 600 years ago and before. Thanks to advanced methods such as ice core analysis, by now much information is available regarding the character, the magnitude and the time scale of those

[79] Cameron

prehistoric climate fluctuations, as well as regarding their impact on contemporary prehistoric human societies and cultures.

The methodology of this chapter is to

- Get an overview of
  - Reasons of past resource crises and character of past climate changes
  - Social and economic syptoms, events and consequences of past resources crises, social and economic impact of past climate changes
- Check similarities and differences between these events and present conditions, signs of which symptomes of past crises can we detect today,
- Try to figure out what social and economic impact could these symptomes have in our present global socio-economic structure on the long run.

14.2 Historical precedent #1: Medieval Europe

During the last two hundred years the middle ages had often been labeled as generally backward. In reality however, it has been an extremely diverse historical period regarding social and economic development. After the fall of the Roman Empire, Europe was not able to recover for centuries. From 406 AD, when the invadors broke through the Limes, until the turn of the first milleneum, lasted the dark ages, six centuries haunted by the four horsemen of apocalypse.

The changes at the turn of the first milleneum however, meant a new wave of innovation, and start of three centuries of prosperity. More advanced agricultural technologies have spread, that, together with the stabilization of European monarchies, and new intellectual as well as material goods introduced by returning crudaders from the Middle East, as well as reform sin the Catholic Church as opened a three hundred years long golden age of medieval Europe. Populatin and economy was almost constantly growing for three centuries. Economic prosperity was accompanied by cultural prosperity: knightly culture, gothic art, scholasticism, etc. By the mid 14th century however, population growth has reached the maximum that could be supported by the current level of technology and agriculture. As a consequence, for the next one hundred years, from about 1350 till about 1450, the four horsemen of apocalypse appeared again. Besides famines, it is enough to think about the Hundred Years War between England and France, and peasant rebellions such as the Jacquerie and Wat Tyler, and the bubonic plague.[80]

[80] Cameron

The 300-400 years before the malthusian crisis of the 14th century were a period of unique economic as well as demographic boom. At the beginning of the 9th century, the population of Europe was about 45 millon. By the year 1000, it has reached 52 million, by 1200 about 61 million, and at the early 14th century, when the economy of Europe has reached the maximum level that contemporary resources and technology could support, it peaked at 86 million. As the capacity of agriculture could not support the population growth any longer, the first dramatic symptom of overpopulation was a famine of a continental scale, not seen for many years before. It occurred in 1315-1317, and it affected most of Western and Central Europe.[81] As usual, chronic food shortages weakened the immune system of people, and as a consequence, increased the risk of epidemics. Therefore, it may not be a mere coincidence, that the most severe pandemic in Europe in 800 years, the Balck Death has appeared during this Malthusian crisis. The pandemic swept across Europe between 1347 and 1351, killing millions of people. Although it is more difficult to find a direct link between economic and political turmoil, it is interesting to notice that the 100 Years War, a war unusually devastating even in medieval Europe, and affecting France, the most populous European country of those times, has also taken place during this resource crisis. This war was accompanied by a major peasant revolt in France as well, the Jacquerie, also of a scale not seen for many centuries before. As a result of all these factors, the population of Europe has declined from 86 million in the early 14th century to only about 60 million around 1425.[82]

The decline was visible int he intellectual life as well: A sharp intelectual and moral decline of the Catholic church, that has soon triggered the protestant reformtion as an answer. This crisis was ended by the age of exploration and European colonisation.[83]

14.3 Historical precedent #2: 19th century China and the high level equilibrium trap

In the case of imperial China, the 100-150 years from the mid 17th till the late 18th century was the last premodern period of prosperity. The final crisis closing this cycle, has been described by Mark Elvin in his book „The Pattern of the Chinese Past". This crisis can be interesting to us, because it shows the collapse of an economy that was relatively well developed, and well industrialized in premodern circumstances, and a collapse that had its primary cause int he lack of resources. Early

[81] Pounds; 9th-14th centuries
[82] Pounds, The late medieval
[83] Cameron

modern China had some features, that made her more similar to present day world economy in many aspects, than contemporary western economies. While colonizing european powers of that time were enabled to consume the natural resources of sparsely populated colonized regions due to its isolationist policies, China could rely mostly only on itsown internal resources. Due to its high degree of development, these factors did at first not cause food shortages, but shortages in industrial raw materials and energy.

According to the „high equillibrium trap" concept of Mark Elvin, such circumstances put pressure ont he industrial sector at first. When spending their income, people put their basic biological needs (such as food) as their top priority, followed by basic household needs (such as household energy consumption, or things like firewood as its premodern equivalent), and only the rest of their income goes for other goods. This remaining part of household income provides demand for all other economic sectors of industry, services, etc. In the case of a resource crisis however, food prices and energy prices soar. This means a decline of exactly that remaining part of household income, that provides demand for all sectors of economy, other than food and household energy. This means shrinking demand, that even by itself puts a growing pressure on the industrial (and service) sectors of the economy. To make things worse, rising prices of energy and industrial raw materials cause higher production and transportation costs. So, as for the industrial sector, we can see a double pressure on it. Shrinking demand on one side, as well as rising production and transportation costs on the other side. Rising transportation and production costs can be compensated by rising the prices of produced goods, but that will decrease demand for those goods, and if demand itself is already shrinking due to rising food and household energy prices, it makes that way impossible to follow.

According to this concept, the first phase is the rise of transportation and production costs due to rising prices of energy and raw materials, and the second phase is the decrease of demand due to rising prices of food and household energy. As the example of medieval europe showes, usually a wave of innovation can provide a way out of such a crisis. According to the concept, of the „high level equilibrium trap", in the case of 19th century China, the nature of the crisis made such a wave of innovation extremely difficult, if not impossible to happen. This was the consequence of several causes:

- The difficulties in the industrial sector described above, combined with high food prices, and high raw material prices caused a flow of capital out from the industrial sector into agriculture and mining.
- Soaring prices of energy and industrial raw materials caused the relative price of human labour to decrease compared to the price of mechanized labour. This encouraged the use of human labour force instead of further mechanization.

These circumstances alltogether caused a dead end for the industrial sector of 19th century China.[84]

The devastating afects of increasingly chronic resource shortage on the industrial sector and on the ability for innovation were visible in everyday life. The slow, gradual decline had it's nadir in the late 19th century, but it's first symptoms have already appeared a century before, and kept deteriorating from decade to decade. As food supply struggled to follow the growth of demand, not only food prices have increased, but also the remaining portion of income that people could spent on other goods, has declined. Food prices upwards, and at the same time demand for other goods down, it became more and more profitable for farmers to grow rice, wheat, and millet on their fields, instead of such things as breeding draught animals, growing fodder, foresting for lumber, etc. This caused shorteges in all these goods. Shortage of draught animals and fodder caused travelling by carriages or on horse to become unaffordable for most Chinese. Reports from early modern China are depicting the paradox that while Chinese roads were among the best built and most convenient in the world, most people using these roads were travelling on foot. Shortage of lumber made it more and more expensive to built houses, ships, as well as premodern industrial machinery. Here we can see how food shortages indirectly caused the decline of premodern Chinese industry, not only by shrinking the demand for its goods, but also by making its machinery more and more expensive as a consequence of lumber shortage. Premodern industrial machinery became less and less profitable due not only the high price of lumber, but due to shortages of metallic ores as well. China saw an increasing shortage of copper and iron ores, causeing the price of these metals to rise as well. Although the economy of early modern China, with its premodern industry was not as energy dependent as our present world economy, to some extent, the resource crisis also caused energy shortages as well. As farmers cleared forests, at first firewood became too expensive, and later, as farmers turned marshlands into rice fields, the reed used instead of firewood became expensive as well. It is obvious, how these factors have caused a decline in the ability for industrial innovation. This setback in industry had direct backlash in the agriculture as well. Piston pump, a premodern machinery well known in China, would have been vital for irrigation in the Chinese agriculture. Contemporary piston pumps however, were made of copper, and due to copper ore shortages this made them so expensive, that Chinese farmers could not afford them. Without piston pupmps, irrigation was not as effective as it could have been. This factor contributed to rising food prices, and there we can see how this the vicious circle goes around.[85]

[84] Elvin
[85] Elvin – The High Level Equilibrium Trap

As in the case of 14th century Europe, the resource crisis of 19th century China has also caused a decline in population before growth started again. During the relatively prosperous 18th century, the population of China has almost tripled, from around 150 million to around 400 million. As the resource crisis worsened, the population of China was stagnating throughout the 19th century, and it returned to considerable population growth in fact only after the middle of the 20th century.[86]

An interesting fact about the decline of 19th century China, that as in the case of 14th century Europe, the resource crisis was accompanied by a pandemic in this case as well. Although not at the scale of the Balck Death a pandemic of bubonic plague known as “The Third Pandemic”, swept across China, and spread into neighbouring parts of Asia during the late 19th century. In China and India it has killed 12 million people.[87] It is interesting to notice, that resource crises, if accompanied by food shortages were followed by pandemics in the cases of both 14th century Europe, and 19th century China.

14.4 The symptoms

After getting an overview of historical examples, we can summerize the symptomes: Soaring consumption causes high prices of energy, industrial raw materials and food. As high energy prices cause transportation costs to rise, this gives an extra rise to food and industrial raw material prices. These factors alltogether cause a significant shuft in the structure of household consumption. Part of household income that is spent on basic food and household energy, rises. As a consequence, the remaining part of household income, providing demand for all other goods, shrinks. At the same time, high energy and industrial raw material prices makes the production of industrial goods more expensive, while energy prices make their transport more expensive. Shrinking demand on one hand, and rising production and transport costs ont he other hand put a double pressure on the industrial sector. This is worsened by a negative loop, as difficulties in the industrial sector accompanied by high natural resource prices encourage a capital flow out from the industrial sector into mining and agriculture. This crisis of the industrial sector causes an increase in unemployment as well. By discouraging innovation, these factors makes the negative loop even worse. Capital flow out from the industrial sector already makes circumstances unsuitable for innovation, and to makes things worse, hig unemployment accompanied by high energy prices makes human labour relatively cheap compared to mechanization.

[86] Comparing Population Growth: China, India, Africa, Latin America, Western Europe, United States — Visualizing Economics

[87] http://history.cultural-china.com/en/34History6529.html

This is the point where the chrisis reached in 19th century China, but did not evolve further. Now we can take a look, how would it look like, if the negative loops of such a crisis evolve further: The factors described above may cause several unemployment and food shortages in urban centers. Rising uneployment is already part of the crsis described above. If the urban industrial and service sectors can not produce a profit enough to miport an adequate food (and energy) supply in the towns, then it can cause a shortage of these esources in urban centers. As a consequence, the flow of people can follow the flow of capital: Out from urban, industrial centers into agricultural rural areas and mining areas. To protect their wealth from newcomers from the towns among circumstances determined by food shortages, agricultural enterprises can soon turn into armed, self-supporting agricultural estates. A combination of economically and demographically collapsing urban centers, self-supporting armed agricultural estates with a capacity to feed only a limited number of people, and food shortages may cause a decline of population in general.

14.5 A possible third historical precedent: The fall of the Roman Empire

As taking a look over these symptoms, we can notice something very interesting. The economic and demographic nature of the fall of the Roman Empire is still subject to dispute among historitians. If we take a look at the collapse of the Roman Empire, we can identify most of the symptomes identified above: Collapse of the industrial secotr, urban centers, that have lost their economic viability, lacking sufficient industry to feed their people. Flow of people from urban centers tor ural areas. For a few centuries, the Roman Empire has artificially kept these urban centers alive by the taxation of the rural areas, but after the collapse, they has to face depopulation at last. People have migrated into the rural areas, where self-supporting agricultural estates were born. A combination of economically and demographically collapsing urban centers, and self-supporting armed agricultural estates caused a decline of population in general.[88] It is striking to see that these are exactly the symptoms that we have analysed above. A further deterioration of symptomes that have appeared in China as part of the „high level equilibrium trap". Further deterioration of the high level equilibrium trap, China would certainly have to face the same symptoms, and such a crisis would certainly evolve into such consequences in any economy. Were the causes the same? Did the economy of the Roman Empire have to face a resource crisis? We don't know, but the symptomes are definetly the same. We have a good reason to believe, that if the symptoms are the

[88] Pounds / From the second to the ninth century

same, the causes may be the same as well. Would the sophisticated industrial sector of Antiquity collapse if it had an adequate demand for its goods? Would urban centers of the Roman Empire become economically passive without a cause? Rationally thinking, we have a strong reason to assume economic causes behind these phenomenon, and since smptomes are exactly the same, these economic causes are likely to be a resource crisis. We can not prove it, but the collapse of the Roman Empire is likely to be a third –and in its magnitude the most significtant- historical example of a resource crisis.

14.6 Climate change- A factor with the risk of further deteriorating impact

At the present World, one more factor that can have an intensifying contribution to a rescource crisis, is the phenomenon of climte change. To examine the risk posed by climate change, again we can take a short overview of historical precedents regarding the economic and social impact of past climatic anomalies.

We can sort these precedents into two chategories, preihistoric and historic climate changes. Since the beginning of the existence of anatomically modern human, our planet has witnessed several major climate changes. Out of these, however, in respect of their numbers only a fragment of these, and in recpect of their magnitude only some of the most modest took place in historical times.

According to the Fourth Assesment Report of the IPCC, global average surface temperature rise between 1990 and 2100 can be expected to be between 1.1 C and 6.4 C.[89] If we compare this range of possible futre climate change, to past climate changes, a 1.1 C scenario is close to the modest magnitude of the recent Little Ice Age, that occured in historical times between 1300 and 1850, and caused only relatively minor agricultural disorders, while a 6.4 C scenario would mean a magnitude of those apocalyptic prehistoric anomalies that characterized the climate of our planet before the start of the Holocene 11 600 years ago.

[89] IPCC Fourth Assesment Report

14.7 Prehistoric climate changes

Data available about the „Ice Age”, known as the „Würm Glacial” in geology, of between 70 000 and 11 600 years ago, can bring us to sinister conclusion. The case of the Ice age is especially interesting regarding the bare existence of agricultural civilization.

According to the most recent scientific datam anatomically modern humans exist since 195 000 years ago. The phrase „anatomically modern human” means the present state of human evolution, humans anatomically identical with the present human population of Earth, including a brain capacity that is identical with what we have now. Modern Humans spread from Africa to Eurasia about 70 000 years ago. On the other hand, agricultural civilization has started only about 10 000 years ago, while the first great civilizations such as Egypt, Mesopothamia, and the Indus Valley civilization appear only about 5000 years ago. Seeing these numbers, a simple question araises. If anatomically modern humans with their physical appearance as well as their brain capacity identical to ours have inhabited Africa and Eurasia for the last 70 000 years, then why did agriculture appear only 10 000 years ago?

A slow exponential cultural evolution where such a long time is needed to reach social and demographic conditions would seem a tempting explanation, but recent research on prehistoric climate and the origins of agriculture gives us a more complex explanation.

It seems, that the Würm Ice Age, from 70 000 to 11 600 years ago, had a global climate, that was not only colder in average compared to the present, but also much more extreme and variable, with so frequent and large scale climatic anomalies, that made agriculture simply impossible on the long run. The dawn of agriculture around roughly10 000 years ago strikingly coincides with the start of the present stable climatic period 11 600 years ago.

Regarding this issue, interesting conclusions are drawn in the paper „The Origins of Agriculture as a Natural Experiment in Cultural Evolution” by Peter J. Richerson, Robert Boyd, and Robert L. Bettinger.

In their paper, Richerson, Boyd and Bettinger base their conclusions about Ice Age climate on ice core anaylsis. Ice core analysis is perhaps the most effective way to follow prehistoric climate trends. The method consists of drilling through the ice caps of the Antarctic and Greenland, removing an ice core where layers of the ice cap can be analysed. Ice caps of the Antarctic and Greenland originates of layers of compressed snow, that has been thickening by layers of new snow from year to fear for hundreds of thousands years. Consequently the layers of ice resemble the growth rings of a tree, where each layer of ice contains information about athmospheric conditions of the year when it was formed as a layer of fresh snow.

By this method, the climatic history of the last 80 000 years can be followed by a resolution of little more than a decade, while for the last 3000 years, monthly resolution is possible.

According to these analyses, global climate during the Würm Ice Age (70 000 – 11 600 bp) was not only cold, but also extremely arid, as well as characterized by extreme fluctuations and anomalies on the frequency of a few decades. In a global climate already cold and arid, our ancestors had to live among circumstances where climatic anomalies of a catastrophic scale, such as extreme droughts, floods, storms, unusually hot or unusually cold years, etc. of a magnitude that occures once a century since 11 600 years ago, occured once a decade. Also climate belts kept moving back and forth between different geographic altitudes so frequently, what means that in the viewpoint of humans, climate was changing again and again in every few decades. Pollen analyses shows, that even the natural flora was unable to change itself with the frequency of climate belt shifts, and therefore was int he state of constant chaotic reorganization for thousands and thousands of years.[90]

Since the end of the Ice Age 11 600 years ago, the cilmate of our planet has been stable, with only rare and modest anomalies, easily predictable seasons, geographically stable belts of different climates, therefore suitable for agriculture. If the climate of a certain geographical area remains relatively the same for a series of human lifetimes, it gives a possibility to select and specialize those species of plants that are suitable for that climate. Predictable system of seasons (dry and rainy, winter and summer, etc.) enables humans to develop a schedule for agriclutural activities, when to plant and when to harvest etc., a schedule that can be used for generations. If the occurance of climatic anomalies such as extreme droughts, extreme floods, storms, etc. is rare, this enables humans to base themselves on agricultural sources of food on the long term, with minimal risk.

The climate of the Holocene, the present geological period does have a climate with such advatages. The Würm Ice Age however, did not have.

The hypothesis of Richerson, Boyd and Bettinger is also supported by the fact, that while we have no knowledge of any established agricultural civilization from the cilmatically variable Würm period, (70 000 – 11 600 bp) it is a sharp contrast, that during the climatically stable Holocene (from 11 600 bp till the present) agriculture was introduced independently about ten times in ten different parts of the world. (For example, in ancient South America it was invented completely inde-

[90] Richerson, Boyd and Bettinger – Was agriculture impossible in the Pleistocene?

pendently from Eurasia, in South China it was invented independently from the ancient Near East.) While during the Ice Age, no agricultural civilization managed to develop, as soon as the stable climate of the Holocene has started, agricultural civilizations started to appear at several different parts of the Earth, independently from each other.[91]

A very interesting tace of how climate and the introduction of agriculture has affected eachother, is the case of the Natufian culture. This culture has covered the area of present day Syria, Israel, Lebanon and Jordan at the end of the Würm Ice age, and at the beginning of the Holocene. Before its last severe period, the Würm Ice Age has experienced a brief milder period 14 500 – 12 900 bp, called the Alleröd-Bölling period. Archeological records show that in this period, the population of the Natufian culture has increasingly turned to the direction of a semi-agricultural lifestyle, and wilde cereals formed an increasing part of their diet. Tis brief mild period has ended however around 12 900 years ago, before they could have managed to start an established agricultural economy. The last severe period of the Würm Ice age, the so called Younger Dryas lasted from 12 900 years ago till the end of the Ice age in 11 600 years ago. According to archeological records, the population of the Natufian culture has returned to hunting-gathering lifestyle, and abandoned experimenting with wild cereals. Then the Ice Age ended, and the stable and mild Holocene climate has started after 11 600 years ago, and soon the Natufian culture has shifted to agriculture, becoming the core of the spread of agriculture, the Neolothic Revolution in Western Asia and Europe.[92]

If the hypothesis of Richerson, Boyd and Bettinger is correct, it means two important things.

- The reason why agriculture was introduced only about 10 000, and not 20 000 or 30 000 years ago, is not that humans of the Ice Age would have been less intelligent than us but that global climate simply made it impossible for them to develop and maintain agricultural civilizations. This also means that even if humans have the mental and physical capacity for an agricultural civilization, such an economic structure can only be maintained among favourable global climatic conditions. Regarding this issue, something what may give us a sinister perspective is that during the last 70 000 years, since mankind has spread from Africa throughout Eurasia, only the most recent 10 000 years had a global climate suitable for agriculture. This means that on the (very) long run, having a global climate suitable for agriculture seems to be more an exception than a rule.

[91] Richerson, Boyd and Bettinger – Variation among different centers of domestication
[92] Richerson, Boyd and Bettinger – Was agriculture impossible in the Pleistocene?

- Regarding climate, what matters is not the average temperature, but the stability of climate. Agriculture is possible in a wide range of different climates, if these climates are stable. Of course, with different intensity and different planted crops, but agriculture is well functioning in several different climatic areas from Denmark to the highlands of New Guinea, from West Africa to North China. It seems that the main condition for agriculture is that whatever climate a geographic area may have, it must be stable, with an easily predictable, transparent system of seasons, and only seldom and modest climatic anomalies. This means that neighther a global warming, nor a global cooling would pose a serious threat on the agricultural basis of our postindustrial civilization, unless the new warmer or cooler climate remains as stable as the Holocene climate has been during the last 11 600 years. The danger is not warming or cooling, but global climate losing the stability of the last 11 600 years, and the return of the chaotic, instable variable character of the previous 60 000 years. Of course, the greater is the change in global climate, the greater is the danger of its system to destabilize.

14.8 Climate change in historical times: The Little Ice Age, 1300-1850

Among climate changes in historical times, the most well known and often discussed is the so called „Little Ice Age". It had the most significant affects in Europe, and it's most severe part happened during the 16th-18th centuries. It was modest compared to the fluctuations of the Ice Age. While global average temperature rise at the end of the Younger Dryas was about 10C at the beginning of the Holocene, temperature drop in Europe during the Little Ice age was less than one celsius. It also caused an increased variability of climate, but of course, again very modest compared to those of prehistoric times. Still, it did have an economic impact. The beginning of the little Ice Age int he 14th century coincides with the overpupulation triggered resource crisis of medieval Europe. This can be interesting for us, because in this case a resource crisis coincided with a climate change, a coincidence that has a chance to happen in our case as well. Regarding the symptomes, for the agriculture of already overpopulated Europe, the beginning of the Little Ice age was the „last drop in the cup", and contributed to trigger the continental wide famine of 1315-1317. The climate change of the Little Ice Age had a significant economic affect, when the economy of medieval Europe was already in a resource crisis.[93] After the European economy has succesfully managed to reach a new level of innovation, and start a new demographic cycle in the 15th century, this healthy European economy

[93] Chavas and Bromley

proved to be strong enough to cope with the challange posed by the Little Ice age. It did cause difficulties, but these difficulties turned out to be not very serious, except for some extreme cases, such as sea ice preventing fishing during some winters around Iceland.[94] It seems that while a climate change of the magnitude of the Little Ice Age of 1300-1850 can have serious worsen an already occuring economic crisis as it has happend in 1315-1317, but an otherwise healthy economic system can succesfully deal with it without serious trouble as it happened in 16th-18th century Europe.

14.9 Time scale and magnitude of climate changes

If we are trying to draw conclusions for the potential economic and social impact of present climate change, we have to compare it with the past climate changes described above. If the present climate change will be as limited as the Little Ice Age of 1300-1850 was, it means that by damaging the agriculture, it can further deteriorate an already occuring resource crisis, but basically is a challange that can be suffesfully dealt with. If however it causes climate fluctuations and destabilisation of a scale of the prehistoric times before 11 600 years ago, the situation would show a much more gloomy picture. If the hypothesis of Richerson, Boyd and Bettinger is right, the return of a prehistoric degree of instability and variability in the global climate could without exaggeration literally wipe the present complex civilization off the Earth. If agriculture becomes unsustainable, and the agricultural bases of the present world economy cease to exist, the complex postindustrial structure built on these bases would simply collapse.

In this respect, regarding past climate changes described above, two factors are important: The magnitude and the time scale of these changes, compared to predictions of the IPCC for the present climate change. The Little Ice Age 1300-1850 caused an average annual temperature change less than 1C. The end of the Younger Dryas and the beginning of the Holocene 11 600 years ago caused a 10 C change. The Fourth Assesment Report of the IPCC predicts a change between 1.1 and 6.4 C for the period 1990-2100. The report also predicts an increased variability in climate, what – as we could see – is the most dangerous possible affect.[95] This means that the present climate change can result in an inpact almost anywhere between the modest historical, and the extreme prehistoric magnitudes. If we calculate with the median of the two extremes given by the IPCC, the impact of the present climate

[94] Mann
[95] Fourth Assesment Report of the IPCC

change is likely to be close to the magnitude of extreme prehistoric changes, therefore posing a serious challenge for global agriculture.

The time scale of changes is also a significant factor. In their paper ont he time scale of climate changes, Jonathan Adams et al. drowes the conclusion that climate changes beyond a certain scale have an affect of extremely fast occurence, and that the present global climate change has the risk of reaching that magnitude. Ice core samples show that at the end of the Younger Dryas and the start of the Holocene 11 600 years ago, the warming has occured not gradually, but in a series of rapid steps of less than 5 years each, with long calm perids between them. Half of the total warming of 10 C occured within a period of just 15 years.[96] Such an extremely rapid climate change today would certainly have devastating impact on global agriculture.

14.10 What symptoms can we see in our days?

Now we can take a look if we can we actually see any of these smyptomes right now, and if yes, which ones of them? What we can certainly see now, is that following a one year recovery after the monetary crisis of 2007-2008, energy, food, and industrial raw material prices were again at a record high.[97] What we have to find out if this rise of prices is just a seasonal anomaly, or if it shows long term trends?

Commodity prices can temporarly be influenced by political events. How can one tell the difference between seasonal price fluctuations and long term trends? Why do such trends appeare now, and not before? Previous, temporary rises of energy prices, such as the 1973, and the 1979-1980 oil shocks were usually caused by politically motivated cuts in crude oil production. Such an event in our days was the North African turmoil in 2011. High energy prices of our days however, are accompanied by record high consumption and record high production. Global energy consumption has reached a record high by the end of the year 2010. Global crude oil production has also reached a record high in 2010, but it still was not enough to keep energy prices down. Therefore, while the shocks of 1973 and 1979-1980 were the consequences of not economic, but political causes, present day soar of energy prices has real economic causes. Crude oil prices have already reached 95 USD per barrel by December 2010, before the start of the North African revolutions.

[96] Adams et al.- Sudden transitions after 115 000 years ago
[97] Commodity Prices - Price Charts, Data, and News - IndexMundi

The question is further complicated by the virtual character of present day world economy. The 2007-2008 monetary crisis, as well as earlier crises, did not directly originate in the real economy. Such crises of the virtual economy can be misleading, and can hide long term tendecies of the real economy. Some monetary crises are caused by trends in real economy, while some are not, and this can be hardly judged by us, outsiders. Booms and busts in the economy can hide long term trends in the case of natural resources. While a boom can cause a temporary irrealistic rise, a bust can cause a temporary irrealistic decline in the prices of natural resources. So booms can cause a false illusion that we are running out of natural resources while we are not, and bust can cause a false illusion of having an abundance of those, when it is not true. Then after such temporary anomalies, long term trends become dominant again.

From this aspect, the present situation gives a gloomy perspective. By early 2011, we were right after an extremely severe monetary crisis, that has occured in 2007-2008. Such crises cause a temporary fall in commodity prices, hiding problems for a while that way. Global crude oil consumption has however reached a record high by the end of 2010[98], just one year after the end of the crisis. The case is similar regarding commodity prices. They have reached pre-crisis levels as soon as early 2011. The monetary crisis should have provided a temporary ease of the pressure caused by high commodity prices. It did, but only for one year. The recovery of commodity prices after the crisis was extremely quick. Commodity prices have recovered top re-crisis levels before world economy could have reached the high growth rates of the early 2000s. As of August 2011, it seems that we are entering a financial crisis again, and only this factor has made energy prices to decline from their high level in late 2010 and early 2011.

14.11 Why do we have to face these symptoms now and not earlier?

The next question: Why does such a crisis appear right now? The last two decades have been marked by the emergence of economies with high population, but with poor natural resources. While the superowers of the cold war, the USA and the USSR were both rich in natural resources, emerging economies today, such as China and India are extremely poor in those. While proved crude oil reserves per capita are more than 613 barrels in the EAEC block (Russia, Belarus, Kazakhstan, Kyrgyzstan, Tajikistan) and 452 barrels in the NAFTA block (Canada + Mexico + USA) they are just 24 barrels int he EEA (EU+EFTA), less than 16 barrels in the ASEAN+3 block

[98] Reuters: World oil demand to hit record high this year: IEA

(China, Japan, SOuth Korea and the ASEAN countries) and as few as less than 5 barrels in India. While Until China and India did not play a major role in World Economy, they did not appear as a significant demand at the global market of natural resources.[99] Due to their industrialization however, they are increasingly playing a role of demand on the global market of energy, food, and industrial raw materials, pushing prices higher and higher. According to predictions, while the energy consumption of the OECD countries alltogether will grow only by 14% from 2007 to 2035, energy consumption of non-OECD Asian countries (excluding the Middle East and the former USSR) will grow by more than 78%. As a consequence, while int he year 2007, energy consumption of the OECD countries alltogether was almost double of energy consumption of non-OECD Asian countries (excluding the Middle East and the former USSR) by 2035 the ratio will change to about 1:1. This relatively resource-poor region is predicted to give almost half of the growth of energy consumption between 2007 and 2035.[100] The emergence of resource-poor Asian economies also transform world economy into the direction of the high level equilibrium trap in an other aspect. In a way their growth turns the core-periphery world economic system upside down.

The point of the core-periphery structure is that the engine of world economy is the interaction between a core, smaller in population and resources, and a periphery, larger in population and resources. The core produces highly sophisticated industrial goods, and exports them to the periphery. In exchange it imports natural resources (agricultural products, industrial raw materials, and energy) from the periphery. Due to the smaller size of the core, and larger size of the periphery, global market of industrial products is characterized by a relatively high demand and low supply, leading to high prices, while global market of natural resources is characterized by an abundance of these resources, causing low prices. This causes an unequal trade between the core and the periphery, where the core gets the gain. In such a system, the core reaches its prosperity by using the natural resources of the periphery.[101]

We can ask the question, however, what if the relative demographic sizes of the core and the periphery shifts? The larger the core grows, and the smaller the periphery shrinks, the harder competition for natural resources of the periphery becomes. This leads to rising prices of those natural resources of the periphery. At the same time, a larger core means the production of more industrial goods, therefore a fall of the prices of those. This turns the system a bit less profitable for the core, and a bit more profitable for the periphery.

[99] CIA World Factbook
[100] EIA - 2010 International Energy Outlook - World Energy Demand and Economic Outlook
[101] Wallerstein, pp. 23-41

That is exactly where present day world economy seems heading to. While in 2005, Western Europe gave only 6.14% of global population, and North America gave 5.1%, East and Southeast Asia gave 31.95%, and South Asia an other 23.3%.[102] These figures means that if the role of Asia (or East and Southeast Asia alone) switches to a core role instead of a periphery role, this will significantly change the relative demographic sizes of the global core and global periphery. If this causes a more severe competition for natural resources, and a more severe competition for the markets of industrial products, it gives a key contribution to a high level equilibrium trap.

14.12 Conclusion

In the chapter above, we tried to identify the usual symptoms and pattern of aresource crises, and tried to find out whethere if we can face any of those symptoms now. We can certainly see phenomena that look like early symptoms of a resource crisis. After one year of recovery, food and energy prices have already reached precrisis levels, and global energy consumption has peaked at a record high. It is a question, that with high food, energy, and industrial row material prices, whether if world economy can keep such a high growth rate, that it showed in the previous decades with low resource prices. And if high prices are part of a long term trend, what perspective of growth does it show for the next 10-20 years? After a certain point, soaring energy, food, and raw material prices cause an economic slowdown, and if they rise even further, this can cause a general crisis of the industrial and service sectors. We have certainly not reached these levels yet, but predictions show a likely possibility for it. An other question is that what comes next? Usually a new wave of innovation gives a way out of the crisis, and opens a new cycle.

In the agricultural economy of medieval Europe even the introduction of a new type of plow could have such a significance. In our postindustrial global economy, however, an adequate wave of innovation can only come from such a highly sophisticated level of science and technology, that needs a complex industrial background to provide suitable facilities for research. A new type of plow could have been developed and tested in the backyard of a village smith, but a functional fusion reactor obviously can not. Regarding this matter, a major danger for our future is the phenomenon that we have seen in the case of 18th-19th century China. In highly developed economies, where an industrial background is needed for innovation, if resource shortages cause a decline in the industrial sector, beyond a certain point of

[102] World Resources Institute – Earth Trends

decline the industrial sector can lose the capacity to support further innovation. This can cause a vicious cycle, where the innovation needed to break out from the resource crisis can not develop due to the decline of the industrial sector, caused by the very same resource crisis.

Where climate change can contribute a resource crisis is agriculture. Climate change can cause a major setback in global agriculture, what would cause a serious increase in food prices, and as we have seen in the case of 19th century China, chronically high food prices can indirectly undermine the industrial and service sectors. A climate change can have such affects alone, even if the economy is otherwise healthy. If there is already a resource crisis, in that case climate change can further deteriorate it by boosting the already existing agricultural causes of the crisis. As according to the forecast of the IPCC, temperature rise can be anywhere between 1.1 C and 6.4 C, what means that its impact can be anywhere between modest historical and extreme prehistoric levels. If we calculate with a median of the possible range predicted by the IPCC, that would mean an impact more severe than we have ever seen during historical times. That assumes serious damage in global agriculture. Of course, the present high-tech agriculture (equipped with sophisticated types of irrigation systems, greenhouses, etc., not to mention the GMO) may have better chances to deal with the challenges of a climate change, than premodern agriculture had, but still, climatic anomalies not seen for thousands of years would cause a serious challenge anyway.

One more factor that we have seen in the case of previous resource crises is the occurrence of a pandemic. The Black Death during the crisis of 14th century Europe, the Third Pandemic during the crisis of 19th century China, and if we look at the suspected but not proved case of the collapse of the Roman Empire, the Iustinian Plague in the 6th century. Worsening living condicions and chronic food shortages seem to increase the risk of pandemics. Of course, regarding our highly sophisticated medical science and global medical structure, such a pandemic seems unimaginable today.

To summarize: What also makes our perspective gloomy, is the fact that it is not a rule for a needed wave of innovation to come shortly after the crisis has started. For medieval Europe, it took a century to recover from the crisis. Int he case of early modern China, the high level equlibrium trap caused such a negative loop, that the crisis has in fact lased well into the 20th century, and China has managed to recover only by integrating into the world economy during the last 30 years. If the collapse of the Roman Empire was an example for a resource crisis, (what we can not prove, but it certainly shows familiar symptomes) that means that the crisis has lasted for more then five hundred years before medieval Europe has started to prosper at the turn of the first milleneum. So, a new wave of innovation is by no means sure. If it does happen, it certainly opens a new age of prosperity, but we can not be sure if it happens at all. In our case, the question is that can we have a hope for a new wave of innovation that restructures global economy in a favourable way, and if yes, then what kind of wave of innovation can we expect? It seems that the key in our resource crisis is energy. So that kind of innovation that may enable us to start a new cycle could be a new source of energy. Among such potential new sources, perhaps fusion energy seems to be the most promising. It needs deuterium as fuel, that can be extracted from water, so our planet has more fuel for that kind of energy than for most forms of energy that we use now. Its efficiency is far beyond the efficiency of most sources of energy that we use now. It produces Helium, that is a neutral, eco-friendly gas. So in many aspects, fusion energy seems to be a promising potential for innovation. This, however could be the subject of an other paper. The next decades, however, will certainly show us if we find the suitable innovation or not.

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