**Czech University of Life Sciences Prague**
**Faculty of Economics and Management**
**Department of Economics**


**Bachelor Thesis**

# Analysis of Relationship between Economy of Agrarian Sector and Global Climate Change in a Chosen Region

**Štěpán Bednář**

# CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Department of Economics

Faculty of Economics and Management

# BACHELOR THESIS ASSIGNMENT

Bednář Štěpán

Economics and Management

Thesis title

**Analysis of Relationship between Economy of Agrarian Sector and Global Climate Change in a Chosen Region**

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**Objectives of thesis**

Aim of the thesis is to analyze the relationship between global climate change and economics of agrarian sector. Describe the main view on the global climate change with different approaches to this worldwide issue. Also, how climate change affects the economics.

**Methodology**

The theoretical part will be done along with the available literature, internet sources, analysis and scientific reports relating to the topic of Climate Change. Very important and valuable resereach will be done according to international organizations (IPCC, NASA, NSIDC, OSN, EPA etc.) which did deep analysis for this topic.

Practical part will be done using economic and statistical tools to confirm or deny the hypothesis related to the aim of the thesis.

**Schedule for processing**

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December 2012 - Analysis

January/ February 2013 - Theoretical part + completing practical part

March 15th, 2013 - Thesis submission

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**The proposed extent of the thesis**

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**Keywords**

global climate change, global warming, greenhouse effect, temperature, affects on economy, public goods, agrarian sector, yield

**Recommended information sources**

IPCC (Intergovernmental Panel On Climate Change), Assessment report, Working Group II: Impacts, Adaptation and Vulnerability, chapter 19 , [online] available at http://www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=663

CLAUSSEN, Eileen; COCHRAN, Vicki Arroyo and DAVIS, Debra P. Climate change: science, strategies,. Boston: Brill, c2001, xiii, 399 p. ISBN 90-04-12024-6.

LEROUX, Marcel. Global warming: myth or reality : the erring ways of climatology. Chichester, U.K.: Published in association with Praxis Publishing, c2005, xxv, 509 p. ISBN 3-540-23909-X.

JÄGER, Jill and FERGUSON, H. L. Climate change: science, impacts and policy : proceedings of the Second World Climate Conference. New York: Cambridge University Press, 1991, xiii, 578 p. ISBN 0-521-42630-8.

**The Bachelor Thesis Supervisor**

Procházka Petr, Ing., MSc, Ph.D.

**Last date for the submission**

March 2013

ČESKÁ ZEMĚDĚLSKÁ UNIVERZITA V PRAZE
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Dean

Prague March 7. 2013

**Declaration**

I hereby declare that I have worked on my diploma thesis titled "Analysis of Relationship between Economy of Agrarian Sector and Global Climate Change in Selected Region" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the bachelor thesis, I declare that the thesis does not break copyrights rules of any third person.

Prague, _____

Štěpán Bednář

**Acknowledgement**

Hereby, I would like to thank my supervisor, Ing. Petr Procházka, MSc, Ph.D., for his patience, valuable comments, advices and support during my work on this thesis.

# ANALYSIS OF RELATIONSHIP BETWEEN ECONOMY OF AGRARIAN SECTOR AND GLOBAL CLIMATE CHANGE IN A CHOSEN REGION

# ANALÝZA VZTAHU MEZI EKONOMIÍ AGRÁRNÍHO SEKTORU A GLOBÁLNÍ ZMĚNOU KLIMATU VE VYBRÁNEM REGIONU

**Summary**

The main subject of the thesis is the analysis of problematics of global climate change and its affect on the agrarian sector of the US economy. This ‘change‘ in various level, is topical for the worldwide market, so it is important to look at these climate events from different angles. Scientific researches confirms that the cause of global climate change is the result of humans comsumption. The way how climate change itself is understood can vary. These differences are described in theoretical part of the thesis, as well as the causes of the climate change. Last but not least, it is important to explain and clarify facts, how climate changes affects state of agrarian sector and its contribution to economy. Description of these facts are listed as own research (practical part) of crops production sensitivity to changing temperature in the regions of USA.

**Key Words**

Global climate change

Global warming

Greenhouse effect

Temperature

Affects on economy

Public goods

Agrarian sector

Yield

**Souhrn**

Tématem této práce je analýza problematiky globální změny klimatu a její vliv na agrární sektor tržní ekonomiky v USA. Tato změna se samozřejmě v různé míře dotýká celosvětového thru, a proto je důležité se na tyto klimatické jevy dívat z různých hledisek. Vědecké výzkumy potvrzují, že změna klimatu je důsledkem spotřebního chování člověka. Způsob, jakým je ale globální změna klimatu chápána jako taková, se může lišit. Tyto rozdíly jsou popsány v teoretické části práce, stejně tak jako co změny klimatu způsobuje a jaké jsou hlavní přičiny. V neposlední řadě, je důležité vysvětlit a objasnit skutečnosti, jak změny klimatu působí na stav agráního sektoru a jeho produkci v eknomice. Tento fakt je popsán jako vlastní výzkum závislosti produkce plodin na měnící se teplotě v uzemních regionech USA.

**Klíčová slova**

Globální změna klimatu

Globální oteplování

Skleníkový efekt

Teplota

Vliv na ekonomiku

Veřejný statek

Agrární sektor

Úroda

## List Of Acronyms

| | |
|---|---|
| C | Private consumption |
| $CH_4$ | Methane |
| CIA | Central Intelligence Agency |
| CIP | International Potato Center |
| $CO_2$ | Carbon dioxide |
| D | Demand |
| DICE | Dynamic Integrated Model of Climate and the Economy |
| E | Equilibrium |
| FUND | Climate Framework for Uncertainty, Negotiation and Distribution |
| G | Government spending (sum) |
| GDP | Gross Domestic Product |
| GHG | Greenhouse Gas |
| GISS | Goddard Institute for Space Studies |
| I | Investments by businesses |
| IA | Integrated Assessment Model |
| III | Insurance Information Institute |
| IPCC | Integrated Panel on Climate Change |
| MERGE | Model for Estimating the Regional and Global Effects of Greenhouse Gas Reductions |
| MC | Marginal costs |
| MSB | Marginal social benefits |
| MSC | Marginal social costs |
| NASA | National Aeronautics and Space Administration |
| NASS | National Agriculture Statistics Service |
| NCDC/ NOAA | National Climatic Data Center/ National Oceanic and Atmospheric Administration |
| NSIDC | National Snow and Ice Data Center |
| NX | Net export (Export - Import) |

| | |
|---|---|
| P | Price |
| PAGE | Policy Analysis of the Greenhouse Effect model |
| Q | Quantity |
| RICE | Regional Integrated Climate and Economy model |
| SRES | Special Report on Emissions Scenarios |
| UNFCCC | United Nations Framework Convention on Climate Change |
| USA | United States of America |
| USD | American dollar |
| USDA | United States Department of Agriculture |

## List of Figures, Tables & Diagrams

## Table of Content

# 1. Introduction

In this thesis this impact of global climate change on US agriculture is analyzed and researched. The global climate change. These words became fairly inflected in past decades as media, scientists, politicians and general public became more aware of them and started realizing that perhaps they are not just words, but facts influencing our behavior, market and economy. At first, people were very skeptic, the consumption-oriented economy was the mainstream for every country, but the scientific proofs are very clear in the opposite way. The IPCC concluded that human activities are substantially increasing the level of greenhouse gases which leads to enhancing the greenhouse effect, as a result of this consumption. United States is the country where all climate zones can be found and even though it is an industrial country, agriculture is very important for their economy.

The growth of agricultural output highly depends on weather and climate in general. Temperature change is the factor which is very significant to agriculture and both of increasing or decreasing value, could have devastating effects on production. The USA's agriculture is oriented on production of grain crops such as corn, wheat and soybeans. In production of corn USA is among the top worldwide producers but especially corn is inclining to temperature change.

## 2. Aims & Methodology

As the title of the thesis says, the main aim is to analyze the relationship between global climate change and agrarian sector of US economy. Main objectives are obvious - to find and confirm, whether the temperature change does influence in any direction the production crop in the selected regions of USA. First, it is important to know, how global climate change appears, what are the causes and the way of how it is being understood. Also, the analysis of selected area is important. Crop selection and the details about production, area harvested, price of the commodity and the average temperature. The thesis is processed with quantitative data analysis, where used calculations determine the yield and revenues. On the other hand, qualitative data analysis is used to create figures. Data for both analysis were taken from available and reliable literature, statistics, scientific studies and web articles.

The research is based on so called *simplificationed assumptions*. These assumptions are implied from different scientific studies relied to the topic eg. Hijmans (2003) or Gibson and Paulsen (1999), who contribute to the temperature change predictions. Data used in the thesis are taken from reliable sources and has been processed according to statistical and mathematical deduction using the spreadsheet editor and formulas. The average temperature is calculated from available temperature data. The most exact value is estimated from three weather stations in every of six states for each region.

Total production, influenced by an increasing temperature is calculated by this formula: *Total Production = Total Yield - ( % Change * Total Yield 2015 ).* For revenues, the formula used equal to *Revenues = Price * Total Yield.*

# 3. Introduction of the Global climate change issue

## 3.1. The Definition

The global climate change has become one of the most discussed topics in past few years. It become recognized as the important problem of the twenty-first century and it is a topic of deep discussions in all areas of science, economy, and among public worldwide. But the climate change has been evident already in the past century and the variety of definitions have appeared. Theories and answers to the questions around the change of climate have been stated according to very accurate - but simple predictions models by a climate scientist Wallace Broecker (1975), who was the first one who used the term "global warming" in the meaning of climate change.[1] In his work , the future changes was modeled in average variables based on the increasing consumption and releasing of higher amount of $CO_2$.

On the scientific level, very simply, global warming refers to "the increase in Earth's average surface temperature due to rising levels of greenhouse gases." [2]
"The climate is changing and will continue to change as a result of increased greenhouse gas concentrations in the atmosphere. Largely as a result of human activities." [3] As a result of these activities, the massive increase of $CO_2$ due to burning fossil fuels (the greenhouse effect) also increased the average temperatures and the sea level has rose.

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[1] BROECKER, W. - *Climatic Change: Are We on the Brink of a Pronounced Global Warming?* Science, vol. 189 (8 August 1975), 460-463. ref. 2013-01-03, [online] available at http://blogs.ei.columbia.edu/files/2009/10/broeckerglobalwarming75.pdf

[2] CONWAY, E., *Whats in the name? Global Warming vs Climate change.* published for NASA on 2008-12-05, ref. 2013-01-03, [online] available at http://www.nasa.gov/topics/earth/features/climate_by_any_other_name.html

[3] CLAUSSEN, E.; COCHRAN, V. A. and DAVIS, D. P. - *Climate change: science, strategies,*. Boston: Brill, c2001, xiii, 399 p. ISBN 90-04-12024-6.

There is a unique mixture of several opinions among population today, as the vast amount of different definitions about what the global climate change exist.
No one is really sure which one is the most truthful and which one which depicts it the best.

According to various researches, we can say this term refers to *"a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). May be caused due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use."* [4] and/ or can be also referred as "any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods".[5]

## 3.2. Main cause of the climate change

Over the past decades, the climate change has been examined, analyzed, understood and explained in several miscellaneous ways. This caused the understanding process to be oriented almost one way forward. To determine the most important cause we have to separate main approaches to this problematics. The society around forced most of our population to believe the served facts from mass medias.

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[4] IPCC (Intergovernmental Panel On Climate Change) 2007, Assessment report, Working Group II: Impacts, Adaptation and Vulnerability, chapter 19, ref. 2013-01-03, [online] available at http://www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=663

[5] IPCC (Intergovernmental Panel On Climate Change) 2007, Assessment report, Synthesis Report 2007, ref. 2013-01-03 [online] available at http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

The causes of the climate change are increasingly well understood. Climatologists have compared climate model simulations with observed climate variations in the past, and evaluated possible natural influences such as solar and volcanic activity. According to IPCC's Assessment Report, the conclusion stated: *"There is new and stronger evidence that most of the warming observed over the last 50 years is likely to be attributable to human activities."* [6]

This human influence include burning of fossil fuels, the combustion of biomass and the production of greenhouse gases and aerosols which have an impact upon radioative forcing.[7]

The worlds climate scientists agree, the main cause of the current climate change (global warming trend) is the rapid expansion of so called **"greenhouse effect"** where certain gases warmup the planet's surface. The very simplified explanation could be as follows. The emissive gases absorb infrared radiation and therefore, these gases trap heat within the surface-troposphere system and re-transmit it. This is defined as natural greenhouse effect.

If the quantity of the heat increases, the temperature will rise, usually due to the human activities. This process is called enhanced greenhouse effect.[8]

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[6] McCARTHY, J.J., CANZIANI, O.F., LEARY, N.A., DOKKEN, D.J. and WHITE, K.S.; IPCC, *2001b: Climate Change 2001: Impacts, Adaptation, and Vulnerability. A Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change* Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, ref. 2013-01-04, [online] available at http://www.grida.no/publications/other/ipcc%5Ftar/?src=/climate/ipcc_tar/wg2/index.htm

[7] LEROUX, M. - *Global warming: myth or reality : the erring ways of climatology.* Chichester, U.K.: Published in association with Praxis Publishing, c2005, xxv, 509 p. ISBN 3-540-23909-X.

[8] Published by NASA, ref. 2013-01-04, [online] available at http://climate.nasa.gov/causes

**Principal gases that contribute to the greenhouse effect:** [9]

a) Water vapor which acts as a response to the climate. It is actually the strongest greenhouse gas.[10]

b) Carbon dioxide ($CO_2$). An important component of the atmosphere, released through natural processes (respiration and volcano eruptions) but also through human activities (such as deforestation, land use changes, and burning fossil fuels).

c) Methane ($CH_4$). Produced both through natural sources and human activities (decomposition of wastes in landfills, agriculture, rice cultivation, and manure management associated with domestic livestock). Methane is a far more active greenhouse gas than carbon dioxide, but also one which is much less abundant in the atmosphere.

d) Nitrous oxide. Produced by soil cultivation practices, especially the use of commercial and organic fertilizers, fossil fuel combustion, nitric acid production, and biomass burning.

If we take a look on numerical data, it is evident that since 2005 the concentration of $CO_2$ and $CH_4$ in our atmosphere has reached high proportion compared to the level reached in natural way over 650,000 years.

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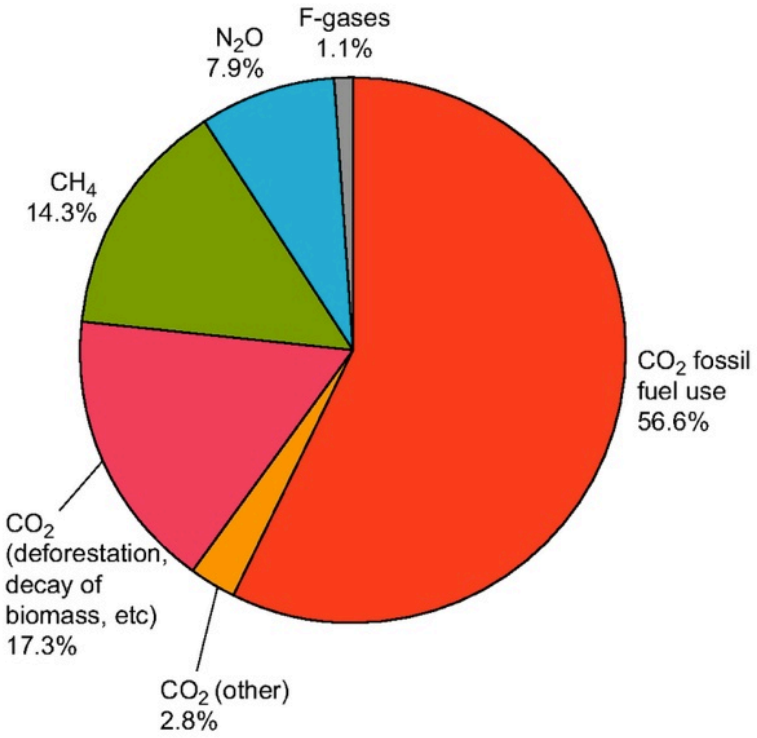
[9] JÄGER, Jill and FERGUSON, H. L. - *Climate change: science, impacts and policy : proceedings of the Second World Climate Conference*. New York: Cambridge University Press, 1991, xiii, 578 p. ISBN 0-521-42630-8.

[10] *Energy Concept Primer,* published by New Mexico Solar Energy Association, ref. 2013-01-04 [online] available at http://www.nmsea.org/Curriculum/Primer/Global_Warming/fossil_fuels_and_global_warming.htm

The emissions on a global basis have grown as a cause of human activities not even in the period of industrial revolution, but also the increase of 70% between 1970 and 2005 is noticeable. Since then, it has increased to 78% (2011) worldwide.[11] See **Figure 1** for more details about GHG emissions.

**Figure 1 - Global Anthropogenic Greenhouse Gases Emissions**




***Source:*** *IPCC Fourth Assessment Report Climate Change 2007: Synthesis Report*

[11] *IPCC Fourth Assessment Report Climate Change 2007: Synthesis Report*, IPCC; ref. 2013-01-04, [online] available at http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

## 3.3. Symptoms & Signs

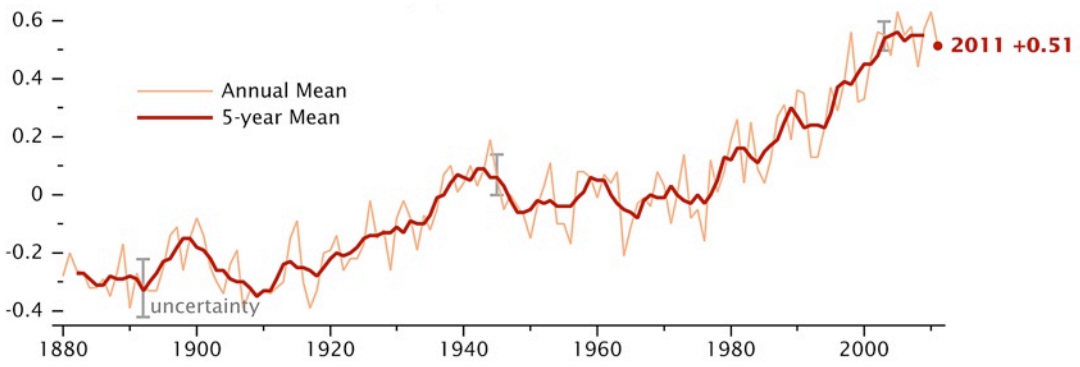
### 3.3.1 The temperature

Climate scientists have identified numerous signs and symptoms of climate change and how it appears and affects the environment. For instance, changing rain and snow patterns, wilder weather, massive droughts, ocean temperature and content of acids, sea level rising, melting glaciers. All of those most visible symptoms have one general cause - the rising level of temperature. We have already observed much higher, warmer weather (temperatures) all around the globe, and both the last IPCC's Report and recent study of NASA is confirming this fact. The global mean temperatures are rising. This average temperature would likely to rise between 1.4 and 5.8 °C in the period from 1990 to 2100 which is very large scale for predictions. On the other hand, according to NASA and GISS, past 10 years have been defined as the warmest decade ever recorded. The mean temperature of globe's surface has changed of +0.51 °C compared to past decade. [12]

In **Figure 2**, it can be seen the complete process of changing global temperature difference until the most recent values. Assuming the pattern of the curve, the average temperature will be still rising.

[12] COLE, S., McCARTHY, L., *NASA Finds 2011 Ninth-Warmest Year on Record,* NASA, published 2012-01-19, ref. 2013-01-04, [online] avalable at http://www.nasa.gov/topics/earth/features/2011-temps.html

**Figure 2 - Global Temperature Change Difference (°C)**




***Source:*** *National Aeronautics and Space Administration (NASA), 2012*

## 3.3.2. Ocean level rising

Other crucial symptom of climate change appearing in our environment include the thawing of Northern permafrost, Arctic sea ice melting and dissolve of glaciers which is leading to stepwise rising of sea level. According to the most recent research by NSIDC from January 2013, an average ice extent in the Arctic was among the lowest data recorded. The linear rate of decline for ice extent was -3.2% per decade, compared to the average from period 1979 to 2000. [13]

Seal level rise is highly devastating symptom for almost 180 coastal and island countries worldwide. According to projections, the scientists from IPCC, expect a rise of global sea level in range of 30 to 110 cm in 200 years period (1990 - 2100), where their best estimate is 66 cm in the year 2100. [14]

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[13] Entry posted by VIZCARRA, N., on Feb 5, 2013, NSIDC (National Snow and Ice Data Center), [online] available at http://nsidc.org/arcticseaicenews/2013/02/a-wintry-mix/

[14] IPCC Fourth Assessment Report Climate Change 2007: Synthesis Report, ref. 2013-01-04, [online] available at http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

## 4. Different Approaches to Climate Change

Global climate change has became a large phenomenon which is being implemented in various definitions depending on certain way of understanding it. One must realize the fact, that global climate change and term "global warming" has not the exactly same meaning by definition. The main approach to climate change can be identified as a collections of scientific facts where climatologists explain its cause based on the knowledge, projections and available evident factors.

There is a question how to accept this issue of climate change whether it is positive or negative. In order of this work and chosen topic, it is at least necessary to accept the climate change as an economic factor and focus on economic aspects of the climate change. The aim of any approach is to reduce or limit the climate change itself. Usually with policies, restrictions issued by government or international organizations created for this particular reason of climate change mitigation.

### 4.1. Science-based

So called **Science-centric approach** refers to an *"approach where only science can provide an objective and sufficient standard of a "safe" or "tolerable" level or rate for climate change, or at least an inflection point beyond which the projected damages of climate change may rise more steeply,"* [15] and only this approach is the essential way how to grasp the climate change issue.

Key and valued indicators are past data of temperature change rates and concentrations of greenhouse gases. This science-based approach runs on the

[15] LEGGET, Jane A. - *Climate Change: Conceptual Approaches and Policy Tools*, Congressional Research Service, published August 29, 2011; ref. 2013-01-04, [online] available at http://www.fas.org/sgp/crs/misc/R41973.pdf

estimations, analysis and projections of relationship between different affects of climate change.

Unfortunately, some misleading tendencies might occur. Although global average temperature is the factor of high importance for climate change; the computed values are based on predictions, assumptions and projected models resulting from the past real world data collections. The nature-results are compared directly with observations.

This simple method is the key for the science but, the awareness or it can be said "belief" or following this scientific method is also essential for an economics. To be a responsible economist, these facts have to be considered in every research.[16]

*"It is important that environmental economics be based on valid science and not conjecture or religious belief if it is to be a reliable guide for policy making."* [16]

## 4.2. Environmental-based

A common way how to understand the climate change is in the was of environmental-based approach where different sciences meet together. It is important to identify this connection in this sub chapter. The "environmental-based approach" includes both "green-concept" and a small proportion of "Environmentalism" where they both seem to have a big participation on the problematics of climate change. However, it does not seem to be correct to follow this approach due to having all these aspects together. The environmental-based approach has "emerged as a key

[16] CARLIN, A. - *A Multidisciplinary, Science-Based Approach to the Economics of Climate Change*; Int. J. Environ. Res. Public Health 2011, International Journal of Environmental Research and Public Health ISSN 1660-4601; Carlin Economics and Science, Fairfax, VA 22031, USA; published 1 April 2011; ref. 2013-01-06, [online] available at http://www.mdpi.com/1660-4601/8/4/985

instrument to confront the concerns across sectors of business and society, offering multiple benefits in a potentially cost-effective manner". [17]

It can also be said, it is a "strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way and which aspires to maintain the natural structure and functioning of ecosystem.

It is addressing the crucial links between climate change, biodiversity and sustainable resource management to provide benefits. Implementing this, the contribution to both the reduction of greenhouse gas emissions and the enhancement of sinks as well as improvement of biodiversity conservation, livelihood opportunities and health and recreational benefits can be achieved." [17]

On the other hand, environmentalism is defined as "an idea that mental a cultural development depends on a human's environment, rather than on their genes," [18] or as "a rational, science-based response to dramatic and deleterious changes to the environment observed in recent decades, where the goal is to identify and document these changes, understand their causes, predict future changes if things continue on the same course, and lessen or avoid future harm through a variety of practical means". [19]

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[17] NAUMANN, S., GERARDO, A., HOLGER, G., FRELIH-LARSEN, A., McKENNA, D., BERRY, P., BURCH, S., SANDERS, M. (ECI) - *Assessment of the potential of ecosystem-based approaches to climate change adaptation and mitigation in Europe, Final Report* (November 2011), [ref. 2013-01-06], [online] available at http://www.ecologic.eu/files/attachments/Projects/2345_eba_ebm_cc_finalreport_23nov2011.pdf

[18] Term *"Environmentalism"*, ref. 2013-01-06, businessdictionary.com, [online] available at http://www.businessdictionary.com/definition/environmentalism.html#ixzz2LSGniKjd

[19] EISENBER, S. - *Is Environmetalism a Religion?*, published February 2011 for NRDC (Natural Resources Defence Council), [ref. 2013-01-06], [online] available at http://www.nrdc.org/thisgreenlife/1102.asp

## 4.3. Economic-based

The fundamental approach for this thesis is of course an economic-based approach. First, it is significant to define climate change as an economic term, and understand is as a factor on the worldwide market. Moreover, it can be referred to "A member of a special kind of economic activity known as global public goods" [20] which can be taken as an separate approach to climate change.

### 4.3.1. Global Public Goods

GDP is understood as any "product that one individual can consume without reducing its availability to another individual and from which no one is excluded." [21]
This special kind of goods has two distinct attributes: non-excludability and non-rivalrous consumption. Term "Non-excludability" describes an impossibility of using and benefiting from such public goods by all customers. In the name of climate change the most suitable instance would be the greenhouse gases emissions produced by each country. As mentioned earlier, GHGs influence the temperature change together. The other feature - "Non-rivalrous consumption" simply defines how "each individual's consumption of such a good leads to no subtraction from any other individual's consumption of the same goods." [22]
Distinctive examples of such global public good could be air, international trade or international environment etc.

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[20] NORDHAUS, W. D. - *Life after Kyoto: Alternative Approaches to Global Warming.*, NBER Working Paper Series, no. 11889, December 2005, ref. 2013-01-07, [online] available at http://www.nber.org/papers/w11889

[21] Term *"Global Public Goods"*; ref. 2013-01-07, [online] available at http://www.investopedia.com/terms/p/public-good.asp#ixzz2KpV4ttjL

[22] SAMUELSON, P. A. - *The Pure Theory of Public Expenditure, Review of Economics and Statistics 36(4):387-389*; published 1954, posted 2007; ref. 2013-01-08, [online] available at http://www.jstor.org/discover/10.2307/1925895?uid=3737856&uid=2&uid=4&sid=21101806794577

“Public goods is generally considered to be a source of market failure. One obvious area of application of the tehory of public goods is to the broad question of the scope of the public sector in the economy and also environmental quality.” [23]

The model of global public goods seems to be growing as a goal needed to be fulfilled. However there are some tasks with no answers. As it is defined as “goods”, there is a question how it supposed to be provided? Who and how this will be financed? This is a complex problem for global private goods because these questions need global answers, decisions and certainly a global coordination.[17]

As an illustration on how public goods stand on market, see **Figure 3**.

A demand curve is defined as a “pseudo-demand curve” because it is based on derivation from an assumption. According to this, it is possible to define the demand itself or to define marginal utility for every consumer for every amount of public goods.

To have a proper market image, it is necessary to have a supply curve. In the case of public goods, supply curve is equal to marginal costs for producing such public goods.[24]

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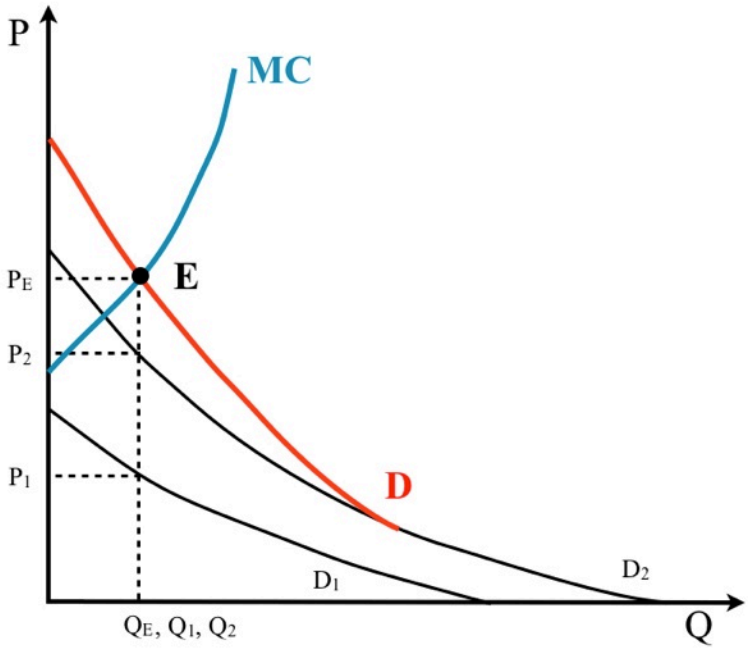
[23] MAGILL, F. N., VARDIABASIS D. and ATKINS, D. - *International encyclopedia of economics. Volume 1*, 1-888, Chicago: Fitzroy Dearborn Publishers, c1997, 2 v. (xxvii, 1735 p.). ISBN 1-884964-826-2.

[24] HOŘEJŠÍ, B., SOUKUPOVÁ J., MACÁKOVÁ L. a SOUKUP J. - *Mikroekonomie*. 4. rozš. vyd. Praha: Management Press, 2006, 573 s. ISBN 80-7261-150-X.

**Figure 3 - Optimum of Public Goods (general image)**




***Source:*** *Figure based upon own knowledge*

## 4.3.2. Integrated Assessment

Another approach or model can be defined broadly as "any model which combines scientific and socio-economic aspects of climate change, primarily for the purpose of assessing policy options for climate change control." [25] Such approach is called Integrated Assessment, also known under acronym IA model.

For integrated assessment this model has been characterized with three main purposes: 1) assess climate change control policies, 2) constructively force multiple dimensions of the climate change problem into the same framework,

[25] KELLY, L.D. and KOLSTAD, D.CH. - Integrated Assessment Model for Climate Change Control., University of California, 1997; ref. 2013-01-12, [online] available at http://www.econ.ucsb.edu/papers/wp31-98.pdf

3) quantify the relative importance of climate change in the context of other environmental and non-environmental problems. [26]

The IA models of climate change focus on advanced scientific and economic aspects, and together, they combine miscellaneous factors affecting and influencing the change of climate. Such socio-economic determinants are emissions, affect on atmosphere, oceans; influence on human activities, represent the method how to assess the policy options for climate change. [22] Following this model, we can find out various guidelines for specific areas which are very important for complexity of economic and climatic sectors as well as for management of uncertainty. IA models also provide some assumptions that appear to be critical and uncertain. These findings demonstrate the results of IA models as the possible final option how to deal with climate change, "although sometimes it is not very clear which assumption drives them." Such result can be "discounting, economic growth, economic response to control policy or long term forecasting." [27]

Other models listed below are more exact form of integrated assessment models, they differ in way how to determine the strategy to the climate change.

### 4.3.3. DICE / RICE Models

First of the more complex integrated assessment models is **Dynamic Integrated Climate and Economy model** - DICE model. This model "attempts to use the tools of modern economics to determine an efficient strategy for coping with the threat of

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[26] Weyant, et. al., *"Integrated Assessment of Climate Change: An Overview and Comparison of Approaches and Results,"* pp. 367-439 in J. P. Bruce, et. al. (eds), Climate Change 1995: Economic and Social Dimensions of Climate Change, Cambridge University Press, Cambridge (1996).

[27] KELLY, L.D. and KOLSTAD, D.CH. - *Integrated Assessment Model for Climate Change Control*., University of California, 1997, ref. 2013-01-12, [online] available at http://www.econ.ucsb.edu/papers/wp31-98.pdf

global climate change." [28] Also, in different meaning, the DICE model is created to "establish the optimum between greenhouse effect and damages on economics". [29]

Methodological and technical assumptions and the results of the Dynamic Integrated model of Climate and the Economy. Fundamentally, the hypothesis behind, is the aim of undertaken environmental policies only if there is some sort of benefit resulting from these actions and only when the results exceed the costs invested to environmental control. General strategy in this approach leads to the dynamic economic optimization, where the key is the construction of strategy which will be efficient. [28]

There exist numerous versions stemmed from DICE model, where the major one is called **RICE (Regional Integrated Climate and Economy model).** It is obvious where is the main difference from the original model - this model is focused on different regions. These eight regions are "assigned to a different climate damage function but based on the same affect categories." [29] Both approaches mentioned here are designed to view climate change in the framework of economic growth theory and include the climate investments in the environment.

"Although the basic structure of the DICE and RICE models has survived in the crucible of scientific criticism, further developments in both economics and the natural science suggest that major revisions of the earlier approaches would be useful. Although no simple solutions have been found, a number of small discoveries and large innovations in the natural and social sciences have come forth." [22]

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[28] NORDHAUS, W. D. - *The 'DICE' Model: Background and Structure of a Dynamic Integrated Climate-Economy Model of the Economics of Global Warming.* paper 1009, February 1992. Cowles Foundation for Research in Economics, Yale University; ref. 2012-01-12, [online] available at http://cowles.econ.yale.edu/P/cd/d10a/d1009.pdf

[29] WARREN, R. - *Spotlighting Impacts Functions in Integrated Assessment*. Norwich: Tyndall Centre for Climate Change Research Working Paper 91, 2006,. [ref. 2009] [online] available at http://www.tyndall.ac.uk/publications/working_papers/twp91.pdf, referred in VODÁK, M. - *Role Ekonomie v Teorii Globálního Oteplování,* Masarykova Univerzita

The major change between RICE and DICE models is the re-specification of the production relations where both models use parameterized relationship between emissions and costs. The RICE model use a three-factor production function in capital, labor and carbon energy. Futhermore, it develops an innovative technique for representing the demand for carbon fuels and uses existing energy-demand studies for calibration. This approach treats the supply of fossil fuels explicitly and uses a market-determined process to drive the depletion of exhaustible carbon fuels. [30]

### 4.3.4. Other Models

There are lots of other models from the complex folder of Integrated Assessment approach. One of them is called **MERGE, Model for Estimating the Regional and Global Effects of Greenhouse Gas Reductions.** Using this model, it is possible to establish an "alternative ways of thinking about climate change.
The model is sufficiently flexible to explore alternative views and determine on a wide range of contentious issues: costs of abatement, damages from climate change, valuation and discounting while using two sets of regionalized damage functions, one for market affects and the other for non-market impacts". [31]

Using various equations to "simulate the effects and outcomes of different policies implemented for mitigation and adaptation to the climate change", we will follow another model, often inflected in the name of climate change, called **PAGE (Policy Analysis of the Greenhouse Effect).** "The main outputs include equity-weighed impacts, calculated as million dollars, that can be consequently divided by regional

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[30] NORDHAUS, W. D. - *The 'DICE' Model: Background and Structure of a Dynamic Integrated Climate-Economy Model of the Economics of Global Warming.* paper 1009, February 1992. Cowles Foundation for Research in Economics, Yale University. [online] available at http://cowles.econ.yale.edu/P/cd/d10a/d1009.pdf

[31] MANNE, A. S. , RICHELS, R.G. - *MERGE: An Integrated Assessment Model for Climate Change,* Stanford University, 2004, ref. 2013-01-13, [online] available at http://www.stanford.edu/group/MERGE/GERAD1.pdf

or global GDP outside the model if desired".= 31 This model also "projects future increases in global mean temperature, the economic costs of damages caused by climate change, the economic costs of mitigation policies and the overall image of adaptation measures (also including costs of adaptation measures, reduction in damages costs from adaptation)." [32]

Last of the models needed to be mentioned, is called **FUND (Climate Framework for Uncertainty, Negotiation and Distribution)**. It is another type of "an integrated assessment model linking projections of populations, economic activity and emissions to simple greenhouse gas cycle, climate and sea-level rise models, and to a model predicting and monetizing welfare impacts." [33] This model was originally set-up to study how capital transfers in climate policy.
But it has developed into a testing model for climate change affects studying. It is a dynamic method often used to express a very important "cost-benefit and cost-effectiveness analyses of greenhouse gas emission reduction policies to study equity of climate change and climate policy." [34]

All the models are using fundamental economic analysis to find out the relationship between climate change and economic costs. Most often used is method called Benefit-Cost analysis which is one of the fundamental economic tools.

**Benefit-Cost Analysis** is a "widely used technique of applied welfare economics, which is focused on the social desirability of undertaking an economic project. A project can be defined as an act of investment, introduction of a new commodity or a

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[32] PAGE model described at Climate CoLab, ref. 2013-01-14, [online] available at http://climatecolab.org/web/guest/resources/-/wiki/Main/PAGE

[33] ANTHOFF, D. - *FUND-Climate Framework for Uncertainty, Negotiation and Distribution*, ref. 2013-02-18, University of California, Berkeley, CA, USA; ref. 2013-01-14 [online] available at http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0564-101.pdf/$file/EE-0564-101.pdf

[34] *FUND Climate Framework for Uncertainty, Negotiation and Distribution,* Hamburg Universität , 2008; ref. 2013-01-14, [online] available at http://www.mi.uni-hamburg.de/FUND.5679.0.html .

change in policy. The leading idea behind is that prevailing market prices involve significant distortions. These prices include the interest rate, the wage rate as well as the rate of foreign exchange. It can arise from market imperfections of one sort or another." [35]

Output resulting from this analysis can be so called **Opportunity cost**, also known as "alternative cost". "It is a decision maker's valuation of the best alternative possible. Nevertheless, under certain circumstances, these costs can be estimated, usually as the value of forgone income. It also expresses the basic relationship between scarcity and choice. If no object or activity that is valued by anyone is scarce, all demands for all persons and in all periods can be satisfied. Also, opportunity cost is the anticipated value of 'that which might be' if choice were made differently." [36] In the context of climate change, we are talking about the investments which have been put in to the process of reducing the climate change and creating policies to do so.

In **Figure 4**, there can be seen a concave curve showing the increasing opportunity cost of investments. To have more investment to climate change policies, government has to give up a certain amount of other investments to do so. Blue arrows depicts the choice between investments (giving up 'other investments' for 'investments to climate change policies'). The opportunity cost of such increasing investments will be higher the more that is being invested.

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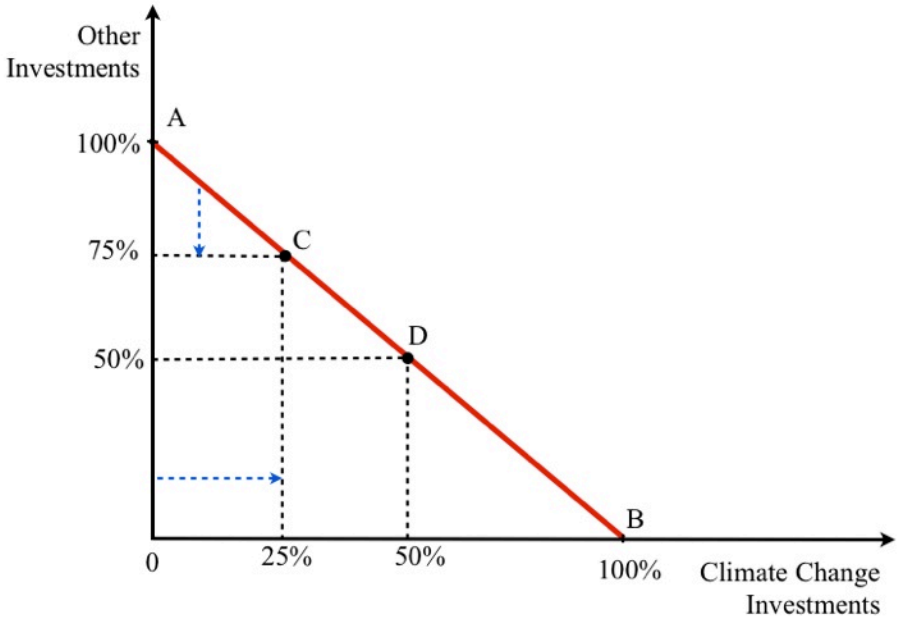
[35] EATWELL, J., MILGATE, M., NEWMAN P. and PALGRAVE, R.H.I. - *The New Palgrave: a dictionary of economics*. Tokyo: Maruzen, 1987, 4 v. ISBN 09-358-5910-1.

[36] MAGILL, F. N., VARDIABASIS D. and ATKINS, D. - *International encyclopedia of economics. Volume 1*, 1-888, Chicago: Fitzroy Dearborn Publishers, c1997, 2 v. (xxvii, 1735 p.). ISBN 1-884964-826-2.

**Figure 4 - Opportunity cost of Investments into Climate change reduction**




***Source:*** *Figure based upon own knowledge*

## 5. Analysis of selected region: USA, country of all climate zones

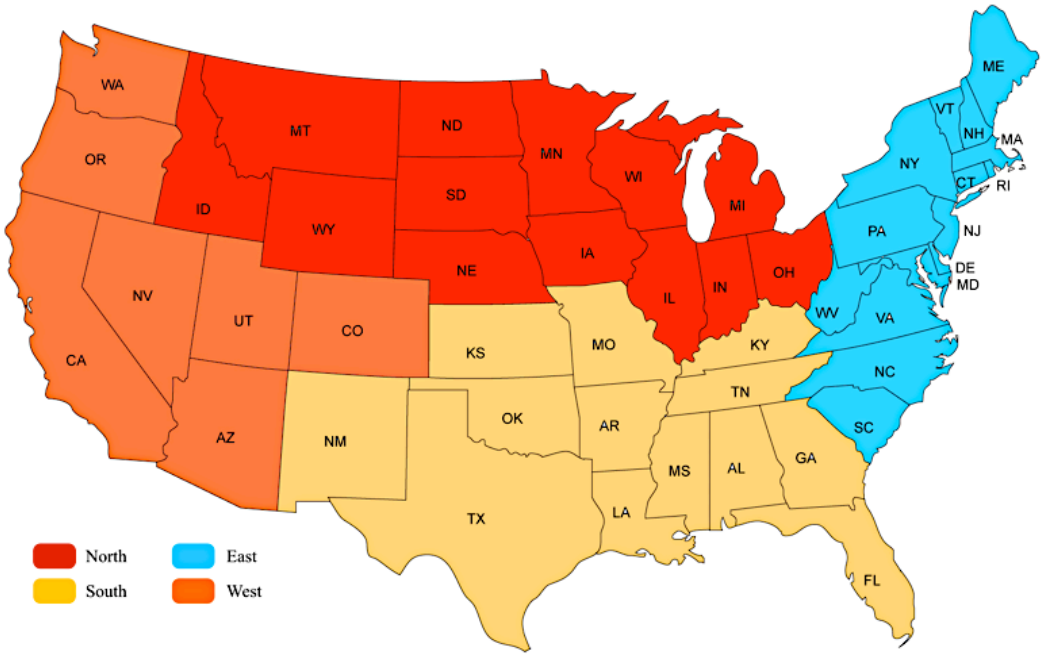
The aim of this chapter is more than obvious - to indtroduce and analyze the country where 'Climate Change' is quite an issue generally. Selection of such area was not easy to decide, as there are countries affected more or countries where this change in climate is more conspicuous and suffering, but for the research it was necessary to select a region where the area is adequate for measuring the differences between various parts of the region itself. The United States has been also selected according to the fact, that it is the country with enormous influence on world's economy as well as it is country being active in the struggle against the global climate change issue. This has became one of the majors in companies' goals.

### 5.1. Area Identification

**The United States of America** is the country situated in more than one climate zones at once and in most cases there are multiple zones within single state. For the main research, it was important to divide the USA region into the parts according to cardinal points. Therefore it can be pointed out that the big influence has the fact that the USA is surrounded by Pacific Ocean from the west, Atlantic Ocean from the east and southeast. The landscape of the country is sundry - coastline plains in the southeast and eastern part, as well as Appallachian Mountains. Around the Great Lakes area, we can find so called central lowlands and in the the centre (from north to south) of the USA, there is an area of great plains and prerriers. In the western part, the terrain is large-scaled. Along the coast, there are valleys and coastline ranges, Sierra Nevada and Cascades right behind, and Rocky Mountains spreading to the North. [37]

[37] Terrain map of USA; ref. 2013-01-17, [online] available at http://www.survivalprimer.com/USARussian_Inv_Map_Huge_FightingZones1.jpg

**Diagram 1 - Geographic Map of USA (cardinal points)**




***Source:*** *Blank template available at freeusandworldmaps.com, modified according to net-gmbh.com*

## 5.1.1. Climatic definition of USA

As mentioned above, the climate of the USA differs according to the area. The most of the area is in temperate climate. "Tropical in Hawaii and Florida and arctic in Alaska. Semiarid climate is characteristic for the great plains west of the Mississippi River, and arid type of climate in the Great Basin of the south-west." [38] As the country of the USA has diverse climate, it is not certain what to consider as straight southern, northern, western or eastern part. Usually, those regions are characterized as a combination but for this research, the best option is to have it divided simply. Furthermore, each part of the USA will be reviewed.

[38] *"The World Factbook - USA",* published at CIA; ref. 2013-02-20, [online] available at https://www.cia.gov/library/publications/the-world-factbook/geos/us.html

**Northern region**

This part of the country experiences cool and wet winters near the coast, is cool and dry inland, and features extreme cold and heavy snows in the mountains. Summer temperatures are cooler and dryer than much of the country. This is because the Pacific Ocean works to cool the air, particularly along the coast. Summer months are by far the sunniest in the Northwest. In the high plains area winters tend to be extremely cold and dry, particularly in the more northern areas of the region. Thunderstorms are very common because of unstable air that is created on hot and humidity. The area around the Great Lakes and so called 'Midwest' is well-known as the "Tornado Alley," and are more prone to tornado activity during the spring months. [39]

**Eastern region**

The climate in this area is very influenced by the Atlantic ocean. Precipitation usually comes in the form of large storm systems that can be even combination of rain, snow and ice together. The combination depends on how the temperature ranges throughout the region. These strong storm systems unique to this climate region, form in the Gulf of Mexico and moves up the East Coast. Hot and humid summers, with the temperatures rising towards the south are evident. [38]

**Southern Region**

Winter months in this region tend to be fairly mild with cool nights, particularly in areas near the Gulf of Mexico. Snowfall occurs the further north in this area (Oklahoma). Louisiana and Mississippi receive the most rain of the region during the winter period. Summers are hot with rain, thunderstorms and heavy rainfall

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[39] FRANCO, V. - *Redional Climates in United States*., Demand Media, ref. 2013-01-18, [online] available athttp://traveltips.usatoday.com/regional-climates-united-states-21675.html

throughout the summer months. Oklahoma and the Texas panhandle are also part of "Tornado Alley," where the occurrence of tornados is more often.[38]

**Western Region**

The western region, characterized with deserts and mountain areas, make it a land of extremes. The desert areas stay warmer year round, while it is much colder in the mountains, and mountain valleys where the altitude is higher, regardless of the season. Summers are hot and dry, with the hottest temperatures heating up the deserts in California and Arizona. Similar to the Northern region, the Pacific Ocean cools the air closer to the coast so summer temperatures remain comfortable. This region gets very little rain in the summer, usually occurring in the mountains during thunderstorms. Spring and fall are relatively mild.[38]

### 5.1.2. Economic definition of USA

The climate change has a massive influence on the function and pulse of economy all around the world. How exactly climate change affects the “market”, will be described in following chapter. It is important in this research to define some basic terms and the key indicator for both climate factor and economic factor before any further analysis. Considering all possibilities, the one which has the highest importance would be GDP.

**Gross Domestic Product (GDP)** is characterized as “the total value of all final goods and services produced in an economy during a given period, usually a year. Including domestically produced final goods and services, capital goods, new construction of structures and changes to inventories.” [40] Also it measures two things

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[40] MANKIW, N. *Principles of economics*. 5th ed. Mason, Ohio: South-Western, c2009, 872 s. International student edition. ISBN 978-0-324-59463-8.

at once - the total income of everyone in the economy and the total expenditure on the economy's output of goods and services, where the rule of 'income must be equal expenditure', is followed. Basically, it is used as "a measure of the size of the economy, providing us a scale against which to measure the economic performance of other years or to compare the economic performance of other countries." [41]

GDP can be easily computed with following formula, assuming all data are available for this action.

**G D P = C + G + I + N X**

"**C**" is equal to all private consumption, or consumer spending, in a nation's economy
"**G**" is the sum of government spending
"**I**" is the sum of all the country's businesses spending on capital
"**NX**" is the nation's total net exports, calculated as total exports minus total imports.[42]

The US' powerful economy with a "per capita GDP of $49,800 is the worlds largest and most technologically advance economy. In this market-oriented economy, private individuals and business firms make most of the decisions, and the federal and state governments buy needed goods and services predominantly in the private marketplace. It is built up mainly just on two sectors: Industrial and Sector of services. The companies in US are at or near the forefront in technological advances, especially in computers and in medical, aerospace, and military equipment." [43] Also, their economy includes following branches of petroleum production, steel, motor vehicles production, food processing, consumer goods and lumber and mining.

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[41] KRUGMAN, P. R. and WELLS, R. - *Economics*. 2nd ed. New York, NY: Worth Publishers, 2009, 1 v. (various pagings). ISBN 0-7167-7158-6.

[42] *"GDP"* definition, Investopedia.com, [ref. 2013-01-20], [online] available at http://www.investopedia.com/terms/g/gdp.asp#ixzz2LeHo6yu2

[43] CIA, *The World Factbook*, Central Intelligence Agency, ref. 2013-01-22, [online] available at https://www.cia.gov/library/publications/the-world-factbook/geos/us.html

Imported oil accounts for nearly 55% of US consumption. In 2012 federal budget deficit reached 7.6% of GDP. Also, through the 2011, the direct costs of the wars totaled nearly $900 billion, according to US government figures. The Agrarian sector has minor participation and includes planting of wheat, corn, other grains, fruits, vegetables, cotton and farming of beef, pork, poultry, production of dairy products, fish and forest products. [44]

## 5.2. Climate change in numbers

"Economic losses from climate-related disasters are already substantial, and they are on the rise. Insured losses alone have jumped from an annual USD 5 billion to 27 billion over the last 40 years. Without further investments in adaptation, climate risks could cost some countries up to 19 percent of annual GDP by 2030 and set back years of development gains. While cost-effective measures could avert a large part of this damage, funds earmarked for adaptation fall far short of what is actually needed globally." [45]

As a matter of fact, weather changes in USA and increased occurrence of natural disasters give us exact record on the amount of damages in the USA. As III (Insurance Information Institute) informed, the overall losses reached over $100 billion in 2012, where losses of agricultural crops were approximately $20 billion overall. [46]

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[44] BRINEY, A., *Geography of the United States of America, Learn All About the United States.*, posted 2010, ref. 2013-01-22, [online] available at http://geography.about.com/od/unitedstatesofamerica/a/unitedstatesgeography.htm

[45] SWISS RE, *Weathering Climate Chnage.,* posted 2010, ref. 2013-01-22, [online] available at http://www.swissre.com/rethinking/climate_and_natural_disaster_risk/Weathering_climate_change.html

[46] Insurence Information Institute., *Natural Disaster Losses - Current Graph*, III 2013, ref. 2013-01-22, [online] available at http://www.iii.org/index.cfm?instanceID=415244

# 6. Sensitivity of crops in US agrarian sector to temperature variability

The main aim of this *assumption-based research* is to find how temperature influence the yield of every crop. This process consists of several steps. After selecting the suitable crop, other important factors, such as average temperature, crop production, price of the crop on the market etc. need to be selected properly.

## 6.1. Processing of data

### 6.1.1. Crop analysis

On selected problematics we can project, whether the climate change has some affect on agrarian sector. If changing in temperature will eventually affects the yield and according to estimates, what would be the difference. For this research it is necessary to choose the most effective and produced crop for each region. This has been decided according to available maps and information from U.S. Department of Agriculture and their agricultural maps. [47]

**Table 1 - Produced crops for US regions [48]**

| **Region** | Northern | Southern | Eastern | Western |
|---|---|---|---|---|
| **Crop** | Corn | Wheat | Soybeans | Potatoes |

***Source:*** *NCDC / NOAA, Temperatures and Precipitations for US agriculture belts*

[47] PEARSON, CH., *Market Clippings: US Crops - Where Are They Grown?*, Alberta.ca, posted 2011, ref. 2013-02-10; [online] available at http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sis5219

[48] Data taken from NOAA, ref. 2013-02-10, [online] available at http://www.ncdc.noaa.gov/temp-and-precip/us-ag-belts.php

According to the crops production summary from USDA it is possible to estimate the yield for each crop according to production and area harvested. To have the best estimate, it is important to take the six states of each region where the crop is produced. The result is yield converted to tons per hectares.

### 6.1.2. Average temperature & price establishing

The factor of average temperature has been calculated from available temperature data. These data are available at Climatezone.com and Weather.com. To have the most exact value, it is necessary to take at least three weather stations in every of six states for each region, the same states as selected in subchapter '6.1. Crop analysis'. For further information see **Appendix 1.** The increase in temperature is established according to the IPCC scenarios SRES. This report shows likely range of temperature increase. For more details about the scenarios see **Appendix 2.**
Based on the likely range the four scenarios has been created with a future temperature change as follows:

Scenario 1 - year 2015 - temperature will not change
Scenario 2 - year 2030 - temperature increase by 1°C
Scenario 3 - year 2050 - temperature increase by 3°C
Scenario 4 - year 2100 - temperature increase by 5°C

**Table 2 - Average Temperature of US Regions (°C)**

| Region | Mean | Median |
|---|---|---|
| West | 13.3 | 11.6 |
| North | 9.5 | 9.8 |
| South | 17.3 | 16.9 |
| East | 13.3 | 12.9 |

***Source:*** *Appendix 1 - Temperatures in Regions of USA (°C)*

The factors of crop production are available online in summary reports, provided by USDA [49]. These reports include information for every American state for each crop mentioned in the thesis as well as, their production, area planted and harvested and information about yield.

Because USA is using imperial unit system, it is necessary to convert some units these units into metric system. Also it is needed to set up adequate ratio for yield. In this case the rate for the relationship between weight and area is set to tons per hectares. This process is done by a few online unit converters such as "convertunits.com" and "onlinecoversion.com".

The factor of price need to be estimated to establish the revenues from the production. The prices are taken from NASS [50] and they need to be converted as well from imperial units to metric units system. The final ratio of the price is US dollars per metric ton.

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[49] *Crop production. United States Department of Agriculture, Statistical Reporting Service, Crop Reporting Board. Summary*., ref. 2013-02-15. ISSN 1057-7823., [online] available at http://usda01.library.cornell.edu/usda/current/CropProdSu/CropProdSu-01-11-2013.pdf

[50] *Agricultural Prices,* NASS, Agricultural Statistics Board, USDA, released 2013; ref. 2013-02-15, ISSN 1937-4216, [online] available at http://usda01.library.cornell.edu/usda/current/AgriPric/AgriPric-02-28-2013.pdf

## 6.2. Estimating the assumptions for yield decrease

The aim of the research is to find how the change in temperature as the result of climate change, influence the production and yield of the crops. To find out the results, they need to be calculated according to the assumed percentage for possible loss by increasing in temperature for each crop. According to Hijmans (2003), in western region for predicted temperature increase of 1°C, the potatoes yield decreases by 3.3%. [51] For wheat the possible yield decrease of 5% for temperature increase of 1°C according to Gibson and Paulsen (1999) from American Society of Agronomy. [52]

The influence of increasing temperature on soybeans and corn is defined by Agronomic Crops Team from Ohio State University. According to their study, the increase in temperature of 29.4 °C leads to the corn yield decrease by 40%. The research requires adequate ratio for the average temperature of 9.5°C of Northern region. This means, the decrease in corn yield would be 13%. Production of soybeans is not so sensitive to the temperature change, so at a possible 10% yield decrease at 29.4°C, the decrease at 13.3°C is 4.5%. [53]

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[51] HIJMANS, R.J., *The Effect of Climate Change on Global Potato Production*, International Potato Center (CIP), 2003; ref. 2013-02-17, [online] available at http://www.saiplatform.org/uploads/Library/Climate_change_potato.pdf

[52] GIBSON, L.R., PAULSEN, G.M., *Yield Components of Wheat Grown under High Temperature Stress during Reproductive Growth*, American Society of Agronomy; published 1999, ref. 2013-02-17, [online] available at https://www.agronomy.org/publications/cs/abstracts/39/6/1841.

[53] *High temperature effects on corn and soybean*; Agronomic Crops Team of Ohio State University Extension, posted 2009, ref. 2013-02-17, [online] available at http://agcrops.osu.edu/drought-resources/high-temperature-effects-on-corn-and-soybean

## 6.3. Results and Findings

According to the assumptions, it is obvious to expect a linear trend in the results. But it is important to realize that it is limited. The actual trend will not be linear because of inherency of other factors of climate change e.g. rainfall, irrigation, soil condition. To calculate the final results, the most important step is to find the right function. As we can see in the content of following tables, they combine all factors which has been explained above - the change in temperature, total production and price. The research is focused on the relationship between the temperature and crop production where all other aspects are ceteris paribus. For the year 2015 we assume, there will be no change in temperature and production will be the same, which is formulated as multiplication of yield and conversion of area harvested.

The increase in temperature of 1°C could be positive for some crops but in the case of crops tested in this research, the yield will be decreasing according to the formula: Total Production = Total Yield - ( % Change * Total Yield 2015 )
Revenues resulting from the fact of decreasing yield are calculated as follows:
Revenues = Price * Total Yield

Both formulas are also used for 3°C and 5°C change for every crop of each region, where the percentage of temperature change differs. For further calculations see **Appendix 3**. Tables listed below, show the amount of decreasing production and revenues for each region.

**Table 3 - Corn Sensitivity to Temperature Change in Northern region**

| Year | Temperature change (°C) | Total Production | Price ($/t) | Revenues ($) | Increased Temp. (°C) |
|---|---|---|---|---|---|
| 2015 | 0 | 1,039,150,063 | 271.25 | 281,864,799,072 | 9.50 |
| 2030 | 1 | 904,060,554 | 271.25 | 245,222,375,193 | 10.50 |
| 2050 | 3 | 633,881,538 | 271.25 | 171,937,527,434 | 12.50 |
| 2100 | 5 | 363,702,522 | 271.25 | 98,652,679,675 | 14.50 |

**Table 4 - Wheat Sensitivity to Temperature Change in Southern region**

| Year | Temperature change (°C) | Total Production | Price ($/t) | Revenues ($) | Increased Temp. (°C) |
|---|---|---|---|---|---|
| 2015 | 0 | 118,666,027 | 284.74 | 33,788,371,199 | 17.30 |
| 2030 | 1 | 112,732,726 | 284.74 | 32,098,952,639 | 18.30 |
| 2050 | 3 | 100,866,123 | 284.74 | 28,720,115,519 | 20.30 |
| 2100 | 5 | 88,999,520 | 284.74 | 25,341,278,399 | 22.30 |

**Table 5 - Soybeans Sensitivity to Temperature Change in Eastern region**

| Year | Temperature change (°C) | Total Production | Price ($/t) | Revenues ($) | Increased Temp. (°C) |
|---|---|---|---|---|---|
| 2015 | 0 | 23,131,042 | 521.76 | 12,068,963,400 | 13.30 |
| 2030 | 1 | 22,090,145 | 521.76 | 11,525,860,047 | 14.30 |
| 2050 | 3 | 20,008,351 | 521.76 | 10,439,653,341 | 16.30 |
| 2100 | 5 | 17,926,557 | 521.76 | 9,353,446,635 | 18.30 |

**Table 6 - Potatoes Sensitivity to Temperature Change in Western region**

| Year | Temperature change (°C) | Total Production | Price ($/t) | Revenues ($) | Increased Temp. (°C) |
|---|---|---|---|---|---|
| 2015 | 0 | 36,626,376 | 0.36 | 13,024,941 | 13.30 |
| 2030 | 1 | 35,417,706 | 0.36 | 12,595,118 | 14.30 |
| 2050 | 3 | 33,000,365 | 0.36 | 11,735,472 | 16.30 |
| 2100 | 5 | 30,583,024 | 0.36 | 10,875,825 | 18.30 |

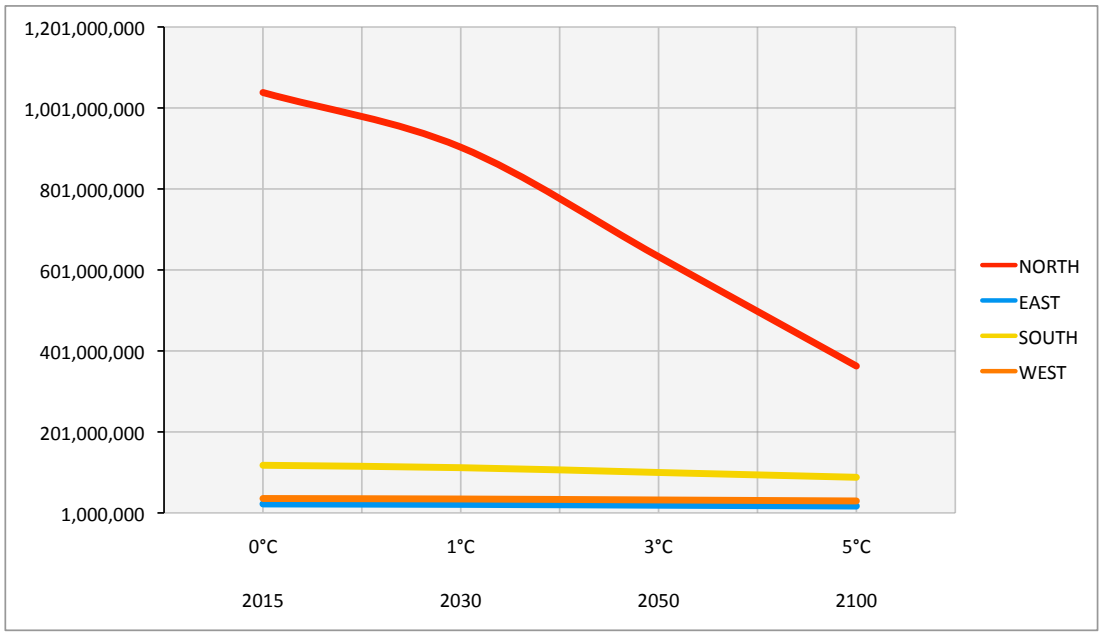
As mentioned in the beginning of the ‘Results’ chapter it is obvious; the more temperature is increasing, the more decrease of production and revenues appear.

According to the calculations, figures listed below clearly show the decreasing production by increasing temperature. The most vulnerable is northern region with

production of corn. This area with biggest production of corn worldwide, also know as "corn belt" [54], tends to have more significant risk of decreasing yield.

On the other hand, regions of South, East and West tend to have yield losses less significant due to the increased temperature.

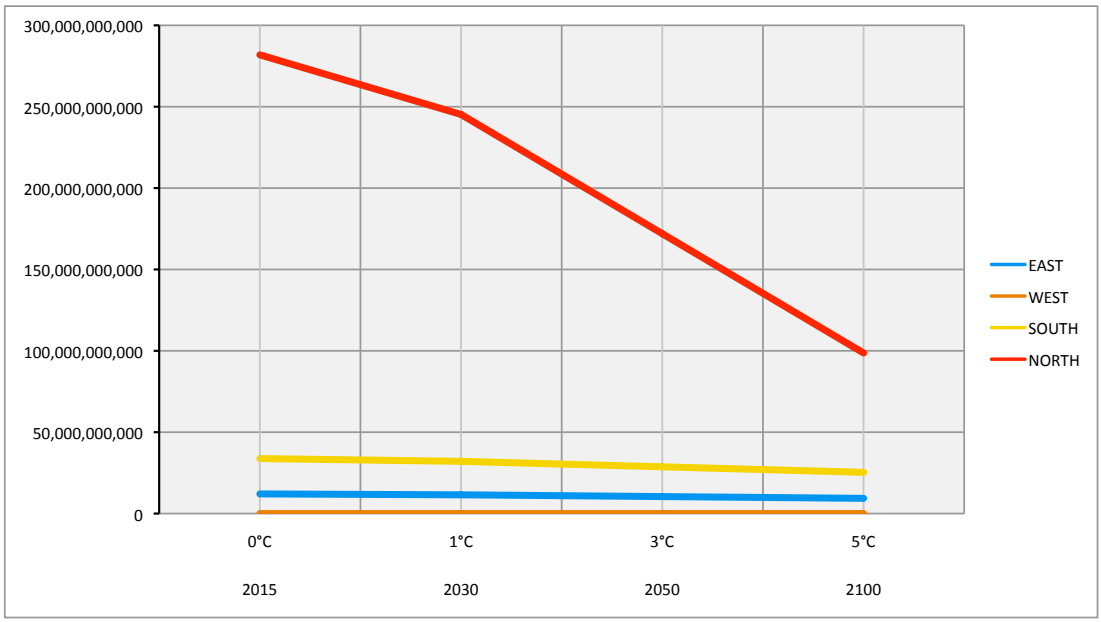
**Figure 5 - Production Change in US Regions Based on Temperature Increase**




In case of revenues, in **Figure 6**, we can observe similar action. Revenues from the production of commodities tends to be lower according to the decreasing production. The most significant decrease of revenues is again in northern region, where is assumed, the revenues will decrease almost twice.

[54] Definiton of *'Corn Belt'*; Britannica.com, ref. 2013-03-03, [online] available at http://www.britannica.com/EBchecked/topic/137792/Corn-Belt

**Figure 6 - Revenues Change in US Regions based on Temperature Change**



## 7. Conclusion

The objective of this thesis was to analyze the relationship between global climate change and economy of agrarian sector in USA. This analysis required a deep research for both meaning of global climate change and the impact on agrarian economy.

The appearance of climate change is more than evident. Especially in the way it occurs - as a massive change in weather condition, melting glaciers and ice packs; is caused by human activities which leads to increasing the level of greenhouse gases due to burning fossil fuels. The increasing temperature seems to be the very significant and can start a variety of other symptoms. How climate change is related to economy is projected in several economic models and it tends to present climate change as a ‘goods’ or ‘commodity’ on the global market.

The happening change of climate is more or less significant for all four regions tested. This fact is clear from decreasing production and from decreasing revenues. As the results presents, area with the most radical decrease in production is Northern region where production will decrease almost twice by increasing in temperature level, as it is the region considered as the area with the biggest production of corn.
The production in other regions tends to decrease significantly less, because the characteristic of each crop differs in sensitivity on temperature. On the long-term perspective, the production tends to decrease by 32% which means the total loss could reach $190 billions by year 2100.

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# 9. Appendices

## Appendix 1 - Temperatures in regions of USA (°C)

### Table 1 - Temperature in Northern region (°C)

| STATE | | Month | | | | | | | | | | | | Annual mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | |
| Illinois | Chicago | 6.1 | -3.7 | 2.9 | 9.2 | 14.9 | 20.3 | 22.9 | 22.1 | 18.0 | 11.6 | 4.4 | -3.0 | **9.4** |
| | Springfield | -0.5 | 2.1 | 7.8 | 13.3 | 18.1 | 22.9 | 25.6 | 24.9 | 20.6 | 14.3 | 7.8 | 1.8 | **13.2** |
| | Peoria | -5.8 | -3.2 | 3.9 | 10.8 | 16.6 | 21.9 | 24.2 | 22.8 | 18.9 | 12.2 | 5.1 | -2.8 | **10.4** |
| Indiana | Fort Wayne | -5.1 | -3.4 | 3.1 | 9.6 | 15.7 | 21.2 | 23.3 | 22.0 | 18.3 | 11.6 | 5.2 | -1.9 | **9.9** |
| | Indianapolis | -3.6 | -1.3 | 5.2 | 11.3 | 17.1 | 22.2 | 24.1 | 22.9 | 19.2 | 12.6 | 6.1 | -0.6 | **11.3** |
| | South Bend | -4.8 | -3.1 | 3.0 | 9.3 | 15.2 | 20.6 | 22.7 | 21.6 | 17.7 | 11.4 | 4.9 | -1.7 | **9.7** |
| Iowa | Des Moines | -7.0 | -4.1 | 2.9 | 10.5 | 16.8 | 22.1 | 24.8 | 23.3 | 18.4 | 11.9 | 3.9 | -4.2 | **9.9** |
| | Sioux City | -7.9 | -4.7 | 2.1 | 10.1 | 16.4 | 21.6 | 24.3 | 22.7 | 17.4 | 11.0 | 2.4 | -5.7 | **9.2** |
| | Waterloo | -9.7 | -6.6 | 1.2 | 9.1 | 15.7 | 20.6 | 22.8 | 21.3 | 16.6 | 10.1 | 2.1 | -6.5 | **8.1** |
| Minnesota | Duluth | -13.9 | -10.9 | -4.2 | 3.7 | 10.4 | 15.4 | 18.9 | 17.6 | 12.3 | 6.5 | -2.0 | -10.7 | **3.6** |
| | Minneapolis | -11.2 | -7.8 | -0.6 | 8.0 | 14.7 | 20.1 | 23.1 | 21.4 | 15.8 | 9.3 | 0.7 | -7.8 | **7.2** |
| | Saint Cloud | -13.3 | -9.8 | -2.4 | 6.4 | 13.3 | 18.2 | 21.2 | 19.5 | 14.1 | 7.7 | -1.3 | -9.9 | **5.3** |
| Nebraska | North Platte | -5.8 | -2.4 | 2.5 | 9.0 | 14.6 | 19.9 | 23.3 | 22.1 | 16.3 | 9.8 | 1.9 | -4.3 | **8.9** |
| | Norfolk | 3.9 | 5.0 | 9.2 | 13.9 | 18.9 | 23.4 | 25.7 | 25.1 | 22.2 | 16.2 | 11.4 | 6.6 | **15.1** |
| | Lincoln | -5.9 | -3.0 | 3.7 | 10.9 | 16.7 | 22.5 | 25.7 | 23.9 | 18.5 | 12.0 | 3.8 | -3.6 | **10.4** |
| Ohio | Cleveland | -4.0 | -2.7 | 2.9 | 8.7 | 14.4 | 19.8 | 22.2 | 21.3 | 17.7 | 11.6 | 5.9 | -0.6 | **9.8** |
| | Dayton | -3.3 | -1.4 | 4.7 | 10.7 | 16.5 | 21.3 | 23.4 | 22.3 | 18.8 | 12.3 | 6.1 | -0.2 | **10.9** |
| | Toledo | -5.3 | -3.8 | 2.3 | 8.7 | 14.8 | 19.9 | 22.3 | 21.1 | 17.2 | 10.7 | 4.4 | -2.3 | **9.2** |
| **AVERAGE (MEAN)** | | -5.1 | -3.3 | 2.8 | 9.3 | 15.0 | 20.0 | 22.5 | 21.4 | 17.2 | 11.2 | 4.4 | -2.4 | **9.5** |
| **MEDIAN** | | -5.3 | -3.2 | 2.9 | 9.3 | 15.7 | 20.6 | 23.3 | 22.1 | 17.7 | 11.6 | 4.4 | -2.8 | **9.8** |

### Table 2 - Temperature in Southern region (°C)

| STATE | | Month | | | | | | | | | | | | Annual mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | |
| Alabama | Huntsville | 3.8 | 6.2 | 11.1 | 16.0 | 20.2 | 24.3 | 26.1 | 25.7 | 22.3 | 16.2 | 10.8 | 6.1 | **15.7** |
| | Mobile | 9.9 | 11.8 | 15.8 | 19.9 | 23.6 | 26.9 | 27.9 | 27.7 | 25.5 | 20.2 | 15.4 | 11.7 | **19.7** |
| | Montgomery | 7.8 | 9.9 | 14.0 | 18.2 | 22.2 | 25.9 | 27.4 | 27.0 | 24.7 | 18.8 | 13.7 | 9.7 | **18.3** |
| Florida | Jacksonville | 11.3 | 12.9 | 16.2 | 19.4 | 23.0 | 26.2 | 27.6 | 27.3 | 25.6 | 21.0 | 16.6 | 12.8 | **20.0** |
| | Miami | 19.6 | 20.3 | 22.1 | 24.0 | 25.9 | 27.4 | 28.1 | 28.2 | 27.7 | 25.7 | 23.1 | 20.6 | **24.4** |
| | Tampa | 15.5 | 16.4 | 19.2 | 21.8 | 25.2 | 27.4 | 28.0 | 28.0 | 27.2 | 23.8 | 19.7 | 16.8 | **22.4** |
| Georgia | Athens | 5.4 | 7.5 | 12.0 | 16.4 | 20.7 | 24.7 | 26.4 | 25.8 | 22.7 | 16.8 | 11.9 | 7.3 | **16.5** |
| | Macon | 7.4 | 9.3 | 13.8 | 17.9 | 22.2 | 25.8 | 27.3 | 26.9 | 24.1 | 18.2 | 13.3 | 9.3 | **18.0** |
| | Savannah | 9.4 | 11.0 | 15.1 | 18.9 | 23.1 | 26.2 | 27.7 | 27.2 | 24.8 | 19.6 | 15.1 | 10.9 | **19.1** |
| Kansas | Concordia | -3.4 | -0.6 | 5.2 | 11.6 | 17.1 | 23.1 | 26.4 | 25.0 | 19.7 | 13.4 | 5.3 | -1.3 | **11.8** |
| | Dodge City | -1.2 | 1.7 | 6.4 | 12.6 | 17.9 | 23.6 | 26.8 | 25.7 | 20.6 | 14.2 | 6.2 | 0.3 | **12.9** |
| | Topeka | -2.9 | 0.1 | 6.4 | 12.7 | 18.1 | 23.1 | 25.8 | 24.6 | 19.9 | 13.5 | 6.1 | -0.7 | **12.2** |
| Oklahoma | Oklahoma City | 2.2 | 4.9 | 10.2 | 15.8 | 20.2 | 24.8 | 27.8 | 27.3 | 22.8 | 16.7 | 9.8 | 4.1 | **15.6** |
| | Tulsa | 1.8 | 4.6 | 10.3 | 16.4 | 20.7 | 25.4 | 28.5 | 27.5 | 22.9 | 16.8 | 9.9 | 3.8 | **15.7** |
| | Norman | 3.0 | 6.0 | 11.0 | 16.0 | 21.0 | 25.0 | 28.0 | 27.0 | 23.0 | 16.0 | 10.0 | 4.0 | **15.8** |
| Texas | Austin | 9.3 | 11.6 | 16.4 | 20.9 | 24.2 | 27.4 | 29.2 | 29.3 | 26.8 | 21.7 | 16.1 | 10.9 | **20.3** |
| | Lubbock | 3.8 | 6.2 | 10.7 | 16.2 | 20.8 | 25.1 | 26.7 | 25.5 | 21.7 | 16.3 | 9.9 | 4.8 | **15.6** |
| | Wichita Falls | 4.3 | 7.1 | 11.9 | 17.3 | 21.8 | 26.6 | 29.4 | 28.7 | 24.1 | 18.1 | 11.3 | 6.0 | **17.2** |
| **AVERAGE (MEAN)** | | 5.7 | 7.8 | 12.1 | 16.6 | 20.7 | 24.5 | 26.4 | 25.9 | 22.9 | 17.7 | 12.4 | 7.8 | **17.3** |
| **MEDIAN** | | 4.3 | 7.1 | 11.9 | 16.4 | 21.0 | 25.4 | 27.6 | 27.0 | 23.0 | 16.8 | 11.3 | 7.3 | **16.9** |

## Table 3 - Temperature in Eastern region (°C)

| STATE | | Month | | | | | | | | | | | | Annual mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | |
| Maryland | Baltimore | -0.1 | 1.6 | 6.7 | 11.9 | 17.4 | 22.5 | 25.0 | 24.2 | 20.3 | 13.7 | 8.2 | 2.6 | **12.8** |
| | Columbia | 1.0 | 3.0 | 7.0 | 13.0 | 18.0 | 23.0 | 26.0 | 26.0 | 21.0 | 14.0 | 9.0 | 3.0 | **13.7** |
| | Hagerstown | -1.0 | 1.0 | 5.0 | 11.0 | 17.0 | 22.0 | 24.0 | 23.0 | 18.0 | 12.0 | 7.0 | 1.0 | **11.7** |
| New Jersey | Atlantic City C.O. | 0.6 | 1.8 | 5.8 | 10.4 | 15.4 | 20.2 | 23.4 | 23.3 | 19.9 | 14.2 | 9.0 | 3.9 | **12.3** |
| | Edison | -1.0 | 1.0 | 5.0 | 11.0 | 16.0 | 22.0 | 24.0 | 23.0 | 19.0 | 13.0 | 8.0 | 2.0 | **11.9** |
| | Newark | -0.8 | 0.6 | 5.6 | 11.3 | 17.1 | 22.6 | 25.4 | 24.7 | 20.4 | 14.2 | 8.5 | 2.2 | **12.7** |
| New York | Albany | -6.3 | -4.7 | 1.3 | 8.0 | 14.2 | 19.4 | 22.1 | 20.9 | 16.3 | 10.1 | 4.3 | -3.1 | **8.6** |
| | Buffalo | -4.7 | -4.2 | 1.0 | 7.3 | 13.7 | 18.8 | 21.7 | 20.6 | 16.6 | 10.6 | 4.7 | -1.6 | **8.7** |
| | Syracuse | -5.3 | -4.4 | 1.1 | 7.6 | 13.9 | 18.5 | 21.3 | 20.2 | 16.4 | 10.4 | 4.7 | -2.1 | **8.6** |
| North Carolina | Asheville | 2.1 | 3.7 | 8.6 | 12.9 | 17.2 | 20.8 | 22.7 | 22.2 | 19.0 | 13.3 | 8.6 | 4.2 | **12.9** |
| | Greensboro | 2.6 | 4.4 | 9.3 | 14.2 | 18.8 | 22.8 | 24.9 | 24.3 | 20.9 | 14.8 | 9.7 | 4.7 | **14.3** |
| | Raleigh | 3.8 | 5.6 | 10.2 | 15.0 | 19.4 | 23.5 | 25.6 | 25.1 | 21.7 | 15.6 | 10.7 | 5.9 | **15.2** |
| South Carolina | Charleston C.O. | 9.1 | 10.6 | 14.4 | 18.6 | 22.7 | 26.0 | 27.7 | 27.2 | 24.9 | 19.9 | 15.4 | 11.2 | **18.9** |
| | Greenville | 4.5 | 6.3 | 10.9 | 15.4 | 19.9 | 23.9 | 25.7 | 25.1 | 21.8 | 15.8 | 10.9 | 6.3 | **15.6** |
| | Columbia | 9.0 | 11.0 | 15.0 | 19.0 | 24.0 | 27.0 | 29.0 | 28.0 | 26.0 | 19.0 | 14.0 | 10.0 | **19.3** |
| Virginia | Charlottesville | 1.0 | 3.0 | 7.0 | 12.0 | 17.0 | 22.0 | 24.0 | 23.0 | 19.0 | 13.0 | 8.0 | 3.0 | **12.7** |
| | Norfolk | 5.0 | 6.0 | 10.0 | 15.0 | 19.0 | 24.0 | 27.0 | 26.0 | 22.0 | 17.0 | 12.0 | 7.0 | **15.8** |
| | Roanoke | 1.4 | 2.9 | 8.2 | 13.1 | 17.8 | 21.9 | 24.2 | 23.7 | 19.8 | 13.6 | 8.6 | 3.5 | **13.2** |
| **AVERAGE (MEAN)** | | 1.2 | 2.7 | 7.1 | 12.1 | 17.0 | 21.4 | 23.7 | 23.1 | 19.6 | 13.9 | 9.1 | 4.0 | **13.3** |
| **MEDIAN** | | 1.0 | 2.9 | 7.0 | 12.0 | 17.2 | 22.0 | 24.2 | 23.7 | 19.9 | 13.7 | 8.6 | 3.5 | **12.9** |

## Table 4 - Temperature in Western region (°C)

| STATE | | Month | | | | | | | | | | | | Annual mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | |
| California | Bakersfield | 8.8 | 11.8 | 14.1 | 17.2 | 21.7 | 25.7 | 28.9 | 28.1 | 24.9 | 19.9 | 13.2 | 8.6 | **18.6** |
| | San Diego | 14.1 | 14.8 | 15.3 | 16.7 | 17.8 | 19.3 | 21.7 | 22.6 | 21.9 | 19.8 | 16.7 | 14.1 | **17.9** |
| | Redding | 7.5 | 10.4 | 11.2 | 14.4 | 19.1 | 24.5 | 27.5 | 26.4 | 23.4 | 17.5 | 11.0 | 7.2 | **16.7** |
| Arizona | Flagstaff | -1.8 | -0.3 | 1.8 | 5.7 | 10.2 | 15.4 | 19.1 | 17.8 | 14.1 | 8.4 | 2.7 | -1.3 | **7.7** |
| | Phoenix | 12.0 | 14.3 | 16.8 | 21.1 | 26.0 | 31.2 | 34.2 | 33.1 | 29.8 | 23.6 | 16.6 | 12.3 | **22.6** |
| | Tucson | 10.7 | 12.4 | 14.8 | 18.8 | 23.3 | 28.8 | 30.3 | 29.2 | 26.9 | 21.3 | 15.1 | 11.1 | **20.2** |
| Nevada | Elko | -3.8 | -0.3 | 3.1 | 6.8 | 11.7 | 16.9 | 21.5 | 20.4 | 14.8 | 8.7 | 2.1 | -3.5 | **8.2** |
| | Las Vegas | 7.5 | 10.6 | 13.5 | 17.8 | 23.3 | 29.4 | 32.8 | 31.5 | 26.9 | 20.2 | 12.8 | 7.6 | **19.5** |
| | Reno | 0.5 | 3.3 | 6.0 | 9.2 | 13.6 | 18.4 | 22.0 | 20.9 | 15.8 | 10.4 | 4.6 | 0.4 | **10.4** |
| Washington | Seattle C.O. | 5.2 | 6.8 | 8.1 | 10.2 | 13.4 | 16.3 | 18.5 | 18.7 | 16.0 | 11.9 | 7.9 | 5.3 | **11.6** |
| | Spokane | -2.7 | 0.7 | 3.7 | 7.7 | 12.2 | 16.7 | 20.4 | 20.2 | 14.9 | 8.5 | 1.7 | -2.3 | **8.5** |
| | Olympia | 3.3 | 5.1 | 6.6 | 8.6 | 11.8 | 14.8 | 17.2 | 17.4 | 14.4 | 9.8 | 5.8 | 3.4 | **9.8** |
| Colorado | Denver | -1.3 | 0.8 | 3.9 | 9.0 | 14.0 | 19.4 | 23.1 | 21.9 | 16.8 | 10.8 | 3.9 | -0.6 | **10.2** |
| | Grand Junction | -3.9 | 1.4 | 6.3 | 11.2 | 16.7 | 22.4 | 26.0 | 24.7 | 19.4 | 12.6 | 4.7 | -1.8 | **11.7** |
| | Pueblo | -1.2 | 1.7 | 5.4 | 11.0 | 16.2 | 21.7 | 25.1 | 23.5 | 18.8 | 12.0 | 4.7 | -0.5 | **11.5** |
| Oregon | Astoria | 5.5 | 6.8 | 7.6 | 9.0 | 11.4 | 13.8 | 15.6 | 15.9 | 14.7 | 11.4 | 8.3 | 5.8 | **10.5** |
| | Medford | 3.4 | 6.0 | 8.3 | 10.7 | 14.6 | 19.2 | 22.7 | 22.5 | 18.6 | 12.7 | 6.7 | 3.2 | **12.4** |
| | Pendleton | 0.8 | 4.0 | 7.1 | 10.2 | 14.4 | 19.0 | 22.7 | 22.2 | 17.3 | 11.3 | 5.3 | 1.3 | **11.3** |
| **AVERAGE (MEAN)** | | 3.5 | 5.9 | 8.2 | 11.5 | 15.6 | 19.9 | 23.0 | 22.4 | 18.9 | 13.7 | 8.1 | 4.3 | **13.3** |
| **MEDIAN** | | 3.3 | 5.1 | 7.1 | 10.2 | 14.4 | 19.2 | 22.7 | 22.2 | 17.3 | 11.9 | 6.7 | 3.4 | **11.6** |

## Appendix 2 - The Emissions Scenarios of the Special Report on Emissions 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 thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural 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 increasing population. Economic development is primarily regionally oriented and per capita 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 information 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, intermediate levels of economic development, and less rapid and more diverse technological change than in the A1 and B1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

**Table 5 - Temperature change scenarios by IPCC**

| Case | Temperature change (°C at 2090-2099 relative to 1980-1999) [a, d] | |
|---|---|---|
| | Best estimate | *Likely* range |
| Constant year 2000 concentrations[b] | 0.6 | 0.3 – 0.9 |
| B1 scenario | 1.8 | 1.1 – 2.9 |
| A1T scenario | 2.4 | 1.4 – 3.8 |
| B2 scenario | 2.4 | 1.4 – 3.8 |
| A1B scenario | 2.8 | 1.7 – 4.4 |
| A2 scenario | 3.4 | 2.0 – 5.4 |
| A1FI scenario | 4.0 | 2.4 – 6.4 |

***Source**: Integrated Panel on Climate Change Report, 2007*

## Appendix 3 - Production and yield of crops in US regions - Calculations

### Table 6 - Corn production in Northern region

| STATE | Area (ha) | Yield (t/ha) | Production (t) |
|---|---|---|---|
| Illinois | 4,957,399 | 6.59 | 32,672,475 |
| Indiana | 2,440,254 | 6.21 | 15,163,839 |
| Iowa | 5,544,193 | 8.60 | 47,675,777 |
| Minnesota | 3,371,031 | 10.36 | 34,912,873 |
| Nebraska | 3,682,639 | 8.91 | 32,823,613 |
| Ohio | 1,477,103 | 7.72 | 11,403,932 |
| **TOTAL** | **21,472,620** | **48.39** | |
| **PRODUCTION** | | | **1,039,150,063** |

### Table 7 - Wheat production in Southern region

| STATE | Area (ha) | Yield (t/ha) | Production (t) |
|---|---|---|---|
| Alabama | 76,890 | 3.97 | 305,084 |
| Florida | 6,070 | 2.76 | 16,737 |
| Georgia | 93,078 | 3.30 | 306,717 |
| Kansas | 3,682,639 | 2.82 | 10,401,698 |
| Oklahoma | 1,740,148 | 2.42 | 4,212,933 |
| Texas | 1,214,057 | 2.15 | 2,612,671 |
| **TOTAL** | **6,812,882** | **17.42** | |
| **PRODUCTION** | | | **118,666,027** |

### Table 8 - Soybeans production in Eastern region

| STATE | Area (ha) | Yield (t/ha) | Production (t) |
|---|---|---|---|
| Maryland | 194,249 | 3.16 | 613,978 |
| New Jersey | 38,850 | 2.62 | 101,894 |
| New York | 127,476 | 3.09 | 394,350 |
| North Carolina | 643,450 | 2.62 | 1,687,622 |
| South Carolina | 153,781 | 2.29 | 351,622 |
| Virginia | 234,718 | 2.82 | 662,965 |
| **TOTAL** | **1,392,523** | **16.61** | |
| **PRODUCTION** | | | **23,131,042** |

### Table 9 - Potatoes production in Western region

| STATE | Area (ha) | Yield (t/ha) | Production (t) |
|---|---|---|---|
| Arizona | 1,497 | 25.2 | 37,784 |
| California | 15,297 | 47.2 | 721,756 |
| Colorado | 24,241 | 43.4 | 1,052,062 |
| Nevada | 2,873 | 43.7 | 125,600 |
| Oregon | 16,956 | 61.6 | 1,045,304 |
| Washington | 66,368 | 66.7 | 4,426,154 |
| **TOTAL** | **127,233** | **287.87** | |
| **PRODUCTION** | | | **36,626,376** |