The fight against climate change and the aviation industry. A cross-disciplinary approach for effective economic policies.

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Abstract

Climate change is one of the gravest "diseases" of the modern era. Anhropogenic contribution with the tremendous expansion in industrialization needs to be kept controlled to fight for a livable future. Aviation industry, an important economic actor is also a contributor to global warming. The thesis introduces the phenomenon of climate change, showing the role of aviation in it. It reveals why it would be important for economic policy to address the problem and what approach should it follow to implement effective goal-orientated sectorial solutions that promote sustainable economic growth.

keywords*: aviation, aircraft, climate-change, emission, greenhouse gas, global warming, policy*

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- ACI: Airports Council International
- AFTK/AFTM: Available Freight Tonne Kilometers/Mile
- ASK/ASM: Available Seat Kilometers/Mile
- ASK: Emission/Available Seat-Kilometer
- ATAG: Air Transport Action Group
- ATC: Air Traffic Control
- ATK: Emission/Available Tonne-Kilometer
- BDL: Bundesverband der Deutschen Luftverkehrswirtschaft
- CH_4: Methane
- CO_2: Carbon dioxide
- EEA: European Economic Area
- EEA: European Environment Agency
- ETS: European Trading System
- FLF: Freight Load Factor
- FSC: Full-Service Carrier
- FTK/CGK: Freight/Cargo Tonne Kilometres
- GDP: Gross Domestic Product
- GHG: Greenhouse Gas
- IATA: International Air Transport Association
- ICAO: International Civil Aviation Organization
- IDD: International Disaster Database
- IEA: International Energy Agency

- INGO: International Non-Governmental Organizations
- IPCC: Intrergovernmental Panel on Climate Change
- JMA: Japan Meteorological Agency
- LCC: Low Cost Carreer (eg. Ryanair, Jeststar, AirAsia)
- LECZ: Low Elevation Coastal Zone
- MBM: Market-Based Measure
- NASA GISS: Goddard Institute for Space Studies
- NASA: National Aeronautics and Space Administration
- NGO: Non-Governmental Organization
- NOAA NCDC: National Climatic Data Center
- NOAA: National Oceanic and Atmospheric Administration
- NRC: Norwegian Refugee Council
- NSIDC: National Snow and Ice Data Center
- $O_{3:}$ Ozone
- PIT: Personal Income Tax
- PLF: Passenger Load Factor
- RPMs/RPKs: Revenue Passenger Kilometres/Miles
- UK Met Office: United Kingdom Meteorological Office
- UNFCCC: United Nations Framework Convention on Climate Change
- USSR: Union of Soviet Socialist Republics
- VAT: Value Added Tax
- WATS: World Air Transport Statistics
- WMO: World Meteorological Organization
- WWI: World War I.

(Photo: Lufthansa)

"Anyone who believes exponential growth can go on forever in a finite world is either a madman or an economist."

/ Kenneth Boulding/

Introductory thoughts

The actuality of thesis topic choice

From day to day more and more horrific pictures and data are revealed in connection with climate change and environmental deterioration, highlighting the human role in it. It is one of the most urging and significant issues of our present but with enormous effects on the future.

Looking up the different statistical data about air quality and the carbon-dioxide emission level of our developed world is quite disappointing. The decrease in flora, such as woods and rainforests that could absorb the gases and turn them into oxygen[1] with the help of sunlight, further enhances the power of greenhouse effect. About the latter, it is widely known that it triggers climate change which can result in tragic consequences. Often we hear about the submerging islands, the acidifying seas and the desertification and intensification of storms and floods that are attributed to this phenomenon.

[1] According to the general carbon-dioxide cycle, with the help of sunlight during the day. See eg..: NASA Earth Obseratory. The fast carbon cycle. (available at: http://earthobservatory.nasa.gov/Features/CarbonCycle/page3.php, visited: 2015. 05.01.)

Although commitments are made to decrease emission and to tackle climate change, some industries where emission is a huge level continue to elevate. *Stern*, in his analysis named transport and electricity among the fastest developing main hasteners of greenhouse effect.[2]

Within transport, aviation, including its civil and cargo branch is one of the most booming sectors with increasing importance. Some innovation has already been implemented to support the fight against climate change in air transportation, and to curb the level of emissions, but some standards still need to be improved to be successful even with an expanding industry.

A common economic policy to reach the above goals could be extremely important in order to reach rapid solutions that are needed.

Purpose of the thesis

The general purpose of the thesis is that among many others, it calls the attention of people, including policy makers to the real dangers climate change can have on humanity. On the other hand it tries to make a connection between various different disciplines with economics.

The purpose of the paper in the narrow extent is to show the relationship between one particular segment of the economy/industry, aviation, and its role in mitigating climate change, if there is any. The paper would like to prove that both climate change and aviation play a crucial role in everyday life and in global economy and that the two are interrelated at a certain extent, which is significant in policy consideration. I would like to reveal, why the two

[2] Stern, N. What is the Economics of Climate Change? World Economics. Vol 7. No 2. April-June 2006 (available at: https://www.humphreyfellowship.org/system/files/stern_summary___what_is_the_economics_of_climate_change.pdf, visited: 2015.03.28.)

should be handled parallel to each other in order to promote sustainable growth and economic profitability of air transportation.

With the paper I also would like to show, that regarding policy making and academic research, in order to address the problem of global warming and policy making, it is useful to take a slightly comprehensive approach, while when trying to find a solution it is better to choose a particular field that can enhance policy making more directly.

Although several papers are based on the different topics covered by the thesis, there is a relative lack of research based on the method this paper will cover and by targeting (within general economic policy) economic policy of aviation in light of climate change. I personally hope this thesis will induce further research in the area or could serve as an idea for policy making.

From the perspective of the writer, the purpose is to contribute to my future academic and professional career, where I plan to continue my research I have begun 3 years ago on different aspects of climate change, including legal, political and economic, all from an international point of view.

The thesis would like answer the following questions in order to serve its purpose:

- What is climate change? Does it really exist?
- How climate change effects our environment?
- What is the role of aviation in current economy?
- Is there any relation between aviation and climate change?
- What is the role of economic policy in addressing "climate-friendly aviation"?
- Why is it economically reasonable to encompass climate change and aviation in policies?

Delimitation of the content

As the thesis aims to focus on policy, it does not tend to rely in details on existing academic literature, nor on methods for measurement, but rather on facts revealed by them, and especially by respected organizations engaged in the topic of climate change and/or aviation.

As the economics of climate change is quite a broad topic to cover, I found it a better option to limit it to concentrate rather on a more narrow policy segment, to be able to provide more effective policy options. Due to the scope of the thesis, the economic relevance of climate change in light of aviation policies, the paper does not intend to focus merely on economic aspects, although they are being mentioned at the extent they might be relevant for justification.

Since the thesis gathers evidence from different fields of science, a broad analysis in each of areas covered is not feasible. Only factual information relevant for the research will be introduced at the extent which is coherent with the context and makes understanding easier.

Following the latter logic of the paper, as climate change is a complex area with serious modeling and quantitative work behind it, introducing the whole concept with describing existing methods would be impossible and inconsistent with the paper's main focus. Hence, the thesis is limited to only mentioning some of the methods of how to get scientific evidence on climate change, but would rather stick to the main results of such research instead of detailing processes to measure the effects of climate change. Within aviation, the paper focuses on analysis on its civil branch, while it does not focus on military aviation, being a specific "industry".

Methodology and literature

As previously mentioned, the current paper is policy focused. Hence, it tries to avoid to be built up on deep numerical and economic background analysis. Instead, it tries to reveal the relationship among the different facts examined and put them in policy context in a practical way to be more straightforward and awareness-raising and more adaptable for policy-making. For this, I found the best method to be as an interdisciplinary, facts-based, comparative analysis, with own conclusions and policy implications gained from the evaluation of the works of recognized scholars and of the interconnection observed from the different researched areas.

The interrelation between climate change and economics has been researched and appeared in economic literature at a large extent, even by recognized and eminent economists and academics such as *Nordhaus*, *Stern* and *Acemoglu*. *Nordhaus*, in one of his related works, for instance, examined the effects of hurricanes on the economy and argued that climate change does effect to occurrence of such events. He used the following interdisciplinary (economics, geophysics and geography) formula to determine the actual outcomes, taking into consideration the damage, capital features (eg. vulnerability) and storm characteristics:[3]

$$V_{it} = f\{Q_t, KQ_t, Kdens_{it}, Kvul_{it}, storm[STT_t(T_t)]\}$$

1. figure: The relationship between hurricane damages and global warming. Nordhaus p. 11.

Though, this is not the sole quantitative approach set to quantify real effects. On the other hand, as we will notice later, determining the broad effects of climate change, cannot be simplified as much. Albeit *Gramelsberger* and *Feichter* advocate for a model-based,

[3] Nordhaus, W. D., 2010: The economics of hurricanes and implications of global warming. Climate Change Economics, 1(1), 1-20, DOI: 10.1142/S2010007810000054. p. 11

numerical approach to address the issue, they argue that instead of simple predictions, clear data is needed with clearly set policy targets instead of long-lasting and costly cost-benefits analysis in order to reach policy results. From a practical consideration it could be helpful to eliminate the continuous pros and cons and the fight between economics and climate change, since the current situation does require fast and effective steps to take.[4]

Although, contrary to previous authors, the well-know Stern Review is rather a cost-benefit based work. It contains different estimates for damages by climate change. On the other hand, it offers a broad scale of economic policy options for the mitigation of the effects. It could be considered as one of the core papers for the broad topic of climate change economics. Despite the fact that in some aspects it is less practical and focuses more on the balance between economics and climate change, its collected findings are useful for introducing the issue and for launching long term debates.

IPCC report, as another important source for research is based on multidisciplinary findings encompassing a wide range of areas affiliated with climate change, therefore it is essential to check for all dealing with global warming from all fields of science. Despite the robust data and the large number papers available on the topic, the understanding of climate change is still ongoing, and needed several years to be even accepted as a valid theory. Since a vast number of resources are available in the broader topic, I decided to rely on the most relevant and most recognized works as main sources for my thesis, especially, the latter two for climate change.

Regarding aviation, almost all major organizations and airlines published their strategies on "green aviation" and climate change. From these, I consider as primary the publications by ICAO and IATA. Their wide access to direct statistical data and their professionalism in aviation enables the outreach to valuable and reliable research materials.

[4] Gramelsberger, Gabriele; Feichter, Johann. Climate Change and Policy. The Calculability of Climate Change and the Challenge of Uncertainty. 2011. Springer

As the paper is based on a different way to approach aviation and climate change and has a different approach– it does not tend to rely in details on previous academic research within the broad area of climate economics, neither solely about aviation climate policy, but rather on institutional and scientific experiments and analyses that can lead to the main idea of the thesis. Although the previous two areas have a developed literature, the exact research of aviation related economic policy in regards with climate change mitigation has not been elaborated at a significant extent and still needs consideration due to the emerging importance of air traffic.

Structure of the paper

In the first two chapters I introduce the phenomenon of climate change from different aspects to reveal its importance for policy and for better understanding.

In the third chapter, I analyze aviation industry, sketching up its structure and its role in climate change. This chapter tends to highlight the significance of aviation from one part, from the other hand its connections with climate change. It also serves to reveal the main characteristics to be able to give a proper policy response.

The fourth chapter will observe the possible solutions to cope with climate change in light of aviation. Or, what could be an answer to mitigate emissions and climate footprints of aviation.

The conclusions section sums up all the major findings of each chapter.

Chapter 1: About climate change in a nutshell[5]

The following two chapters serve to justify the actuality of the topic of climate change in our days, relying on scientific evidence and introducing basic information about the definitions, characteristics and dangers of it. On the other hand, it focuses on providing a clearer understanding of the process of climate change, which is often disregarded by analysis. Therefore, still nowadays, although people from different social layers know about the expressions related to climate change, sometimes it is hard to understand their actual meaning.

1.1 Defining climate change and discovering its primary causes and effects

First of all, to understand the phenomenon of climate change, it is extremely important to first define it. Although several definitions do exist in literature, I would pick two of them, which I find relevant for the current paper and for academic purposes generally. The *Intergovernmental Panel on Climate Change (IPCC)* in its 2007 Synthesis report determines it as

[5] Relying on the former research conducted by the author of the thesis. Koska, Ramona; A nemzetközi jog új kihívásai: Az éghajlatváltozás és az "Atlantisz-Szindróma". Hontalanok és "klímamenekültek" a süllyedő szigetállamokból az államiság kérdésének viszonylatából. Thesis, Eötvös Loránd University, 2013. and Koska, Ramóna; Az éghajlatváltozás és a klímamenekültek koncepciója : „Elcsépelt kísérlet vagy érdemben megrágott kutyacsont?". Thesis, Corvinus University of Budapest, 2013.

"....a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties and that persists to an extended period, typically decades or longer."[6]

According to the 1992 *United Nations Framework Convention on Climate Change (UNFCCC),* climate change

"...means a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods."[7]

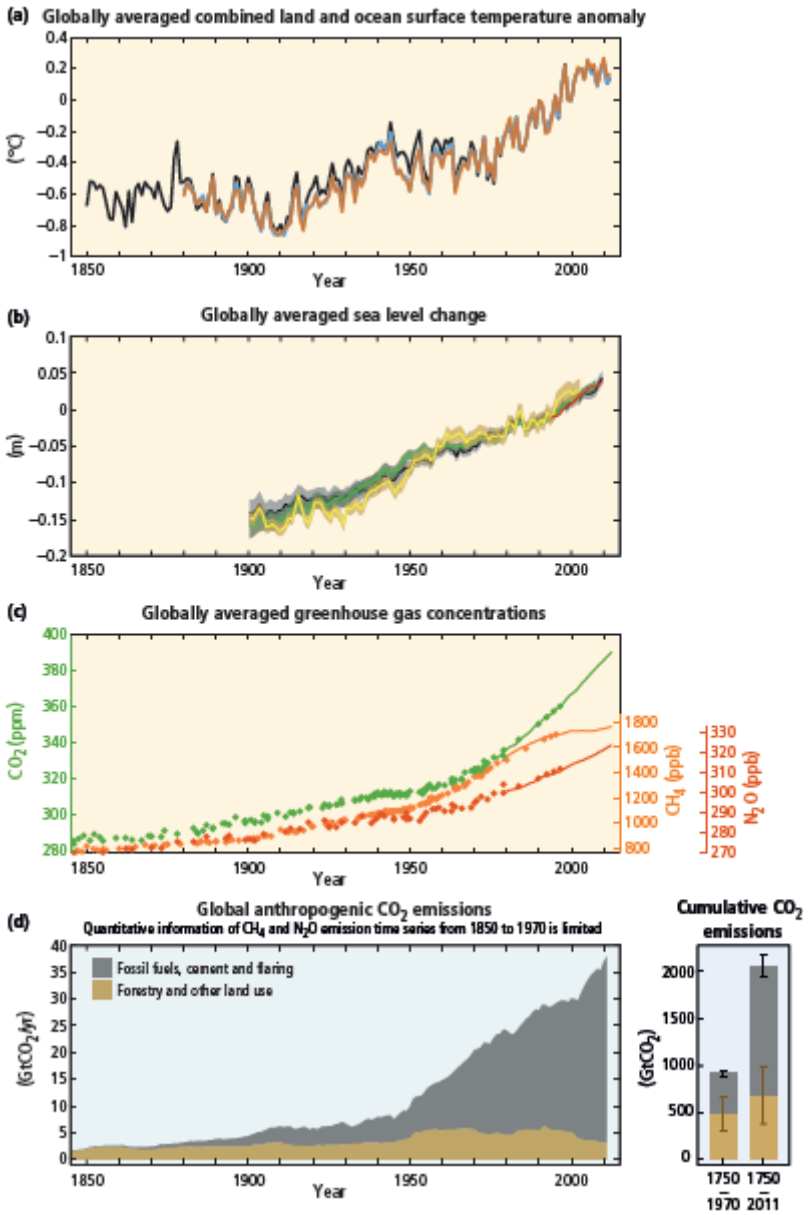
While the first definition rather focuses on the measurability and leaves a broader interpretation for the causes, the second one specifies human activity as its reason without determining the concept of change. This thesis uses as its basis the mixture of the two, changes being attributable to human activities with a measurable change in the properties.

According to the IPCC, global climate warming is an unquestionable phenomenon that is well proved by evidences based on observation. Data supporting it could be for instance the escalation in the mean temperature of air and oceans, in the volume of melting ice and snow and the global average increase in the sea level. Apart from the natural changes in climate,

[6] IPCC, 2007: Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, p. 30.

[7] United Nations Framework Convention on Climate Change, May 9, 1992, S. Treaty Doc No. 102-38, 1771 U.N.T.S. 107., Article 1. point 2. (available also at: https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf)

human activities, such as the increase in CO_2 and GHG emissions contribute to the accelerated process largely[8]



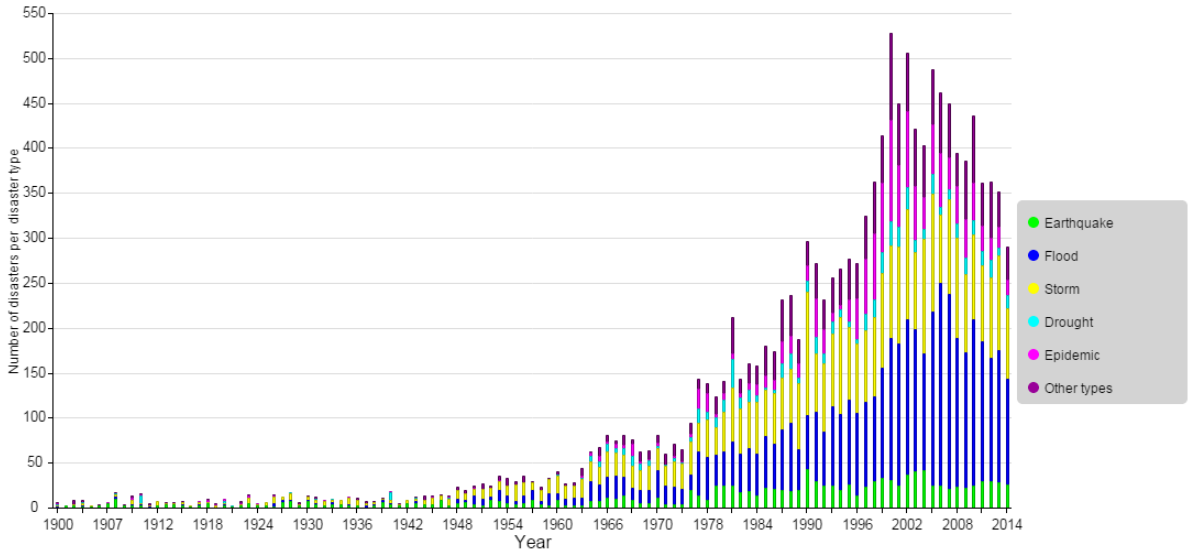
2. **Figure: Relationship between climate change factors. (Source: IPCC Synthesis Report p. 3.)**

[8] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, pp. 2-4. (available at: http://www.ipcc.ch/report/ar5/syr/, visited: 2015. 04.20.)

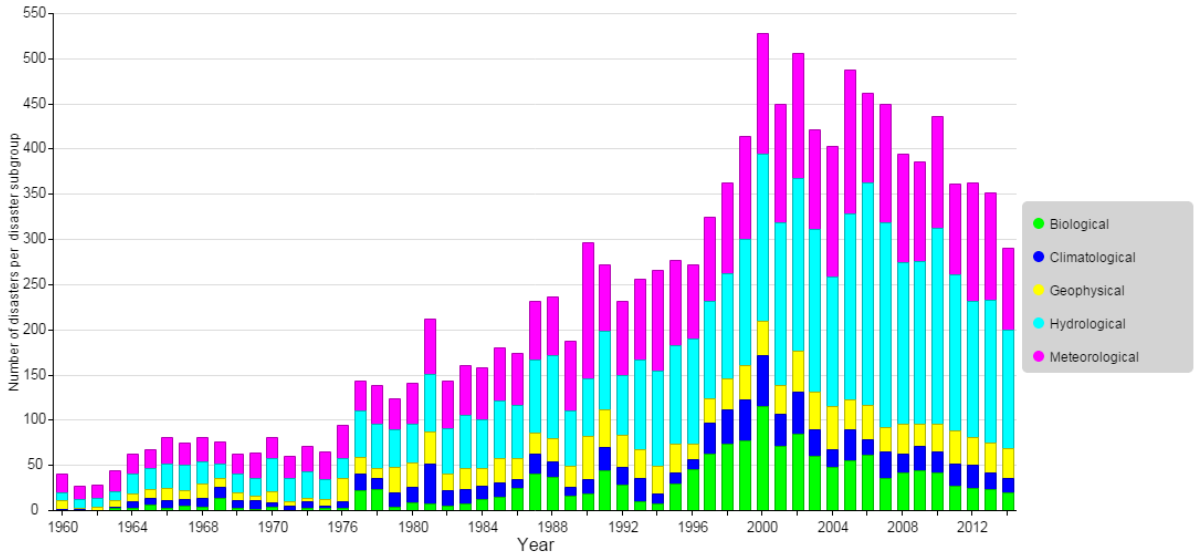
The figure shows that within the last 50 years, temperature and sea level have risen significantly, while greenhouse concentration and anthropogenic carbon-dioxide emissions show the same pattern. Due to the warmed temperature, snow-cover on the Northern Hemisphere has decreased, which resulted in further sea-level rise. It is a generally approved evidence among scientists (such as the above IPCC report), who find clear correlation among these changes and the emissions.

Research conducted by EM-DAT The International Disaster Database (IDD), on the other hand, shows that from the second half of the 20th century - when the rate of technological development have begun to accelerate exponentially in parallel with the rate of emissions - reveal that the number of natural disasters have also incremented within the same timeframe.

Albeit the compelling switches observable in the graphs might partially be attributable to the lack of widespread information due to the less advanced technical circumstances in preceding eras, it is not satisfactory to disproof the trends and that there might be also some relationship between the frequency of certain natural catastrophes (for instance inundations) and human-influenced climate change.



3. Figure: Total number of reported natural disasters by type of the disaster from 1900-2014. (Source: EM-DAT disaster database disaster trends.)



4. Figure: Number of natural disasters from 1960 – 2014 by category of disaster. (Based on: EM-DAT disaster database)

As the graphs show, although lately there was a little decline in the occurrences of natural disasters, comparing to the previous decades it still has changed sharply. According to the statistical data, the most causes of all natural disasters were floods and storms (nowadays more often feared to happen as byproducts of environmental change), while other factors such

as earthquakes played a smaller role. Regarding the nature of catastrophes, if we add up those that could be related to a changing climate (climatological, hydrological and meteorological disasters), they make up the largest part of all the registered events.

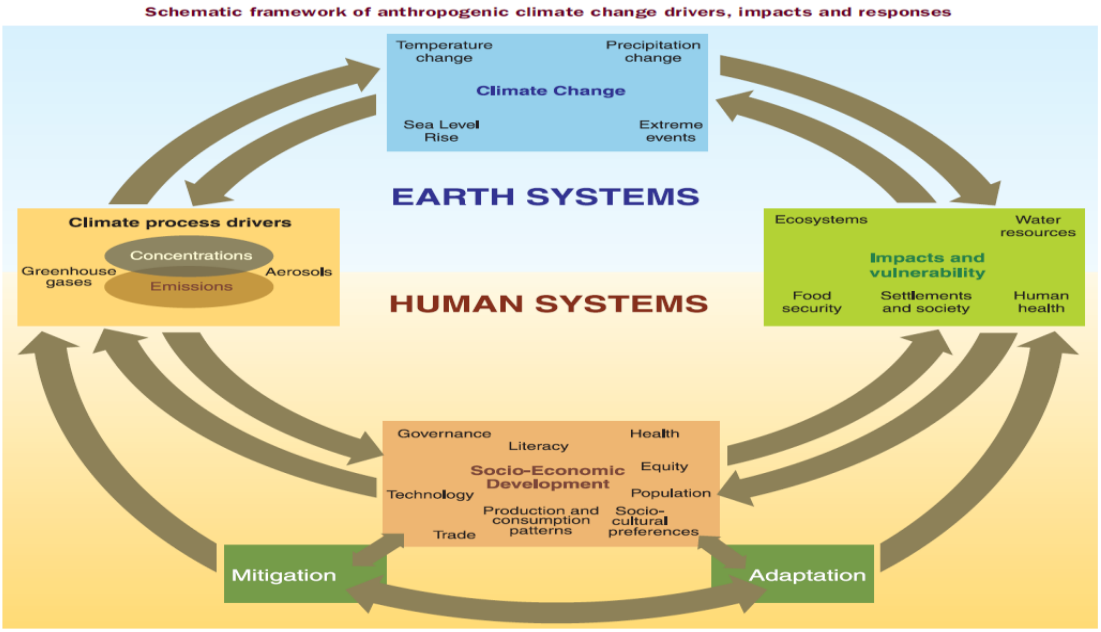
This all further raises suspects about a trend that goes to the sinister direction and which should be reversed and tackled at least in the scale we, the human race are responsible for it with our contaminating activity. If we cannot find solutions, the future is not quite promising to our living conditions.

Despite the already existing evidence, a smaller number of skeptics still deny the existence, the harmful effects and causes of climate change and human contribution to it, and some finds a conspiracy theory behind the phenomenon.[9]

1.2 Mapping the human-relevant features of climate change

Climate change can affect our lives various ways, and it would be nearly impossible to list them all. These effects are frequently strongly intertwined, the one generating the other, the other reflecting the one, while generating another effect and so on, as seen in the figure. To facilitate the transparency of the complex structure of outcomes, here, I present a classification or categorization of climate-change effects and different possible influenced areas (with only taxative listing, though), of which some I am going to analyze more in details in the next chapter.

[9] See eg.: Nongovernmental International Panel on Climate Change (Heartland Institute) website at: http://climatechangereconsidered.org/



5. Figure: Climate change drivers and the cycle of interconnection. Source: IPCC (2007) Synth. Rep. p. 26.

The effects of climate change can by their nature be:

- economic
- health-related
- environmental
- food and drinking water related
- industrial
- agricultural
- political
- social
- migratory
- security

By their proximity:

- direct
- indirect

By their endurance:

- enduring events
- onefold events

By their gravity:

- serious
- perceivable
- light

By the territory affected:

- global
- continental
- regional
- national
- local
-

According to the categorization the *Norwegian Refugee Council (NRC)* made, the **development phase** of harmful effects could be a matter of distinction.[10]

- sudden onset of events (eg: storms, hurricanes, floods)
- slowly developing effects (eg. desertification, sea-level rise)

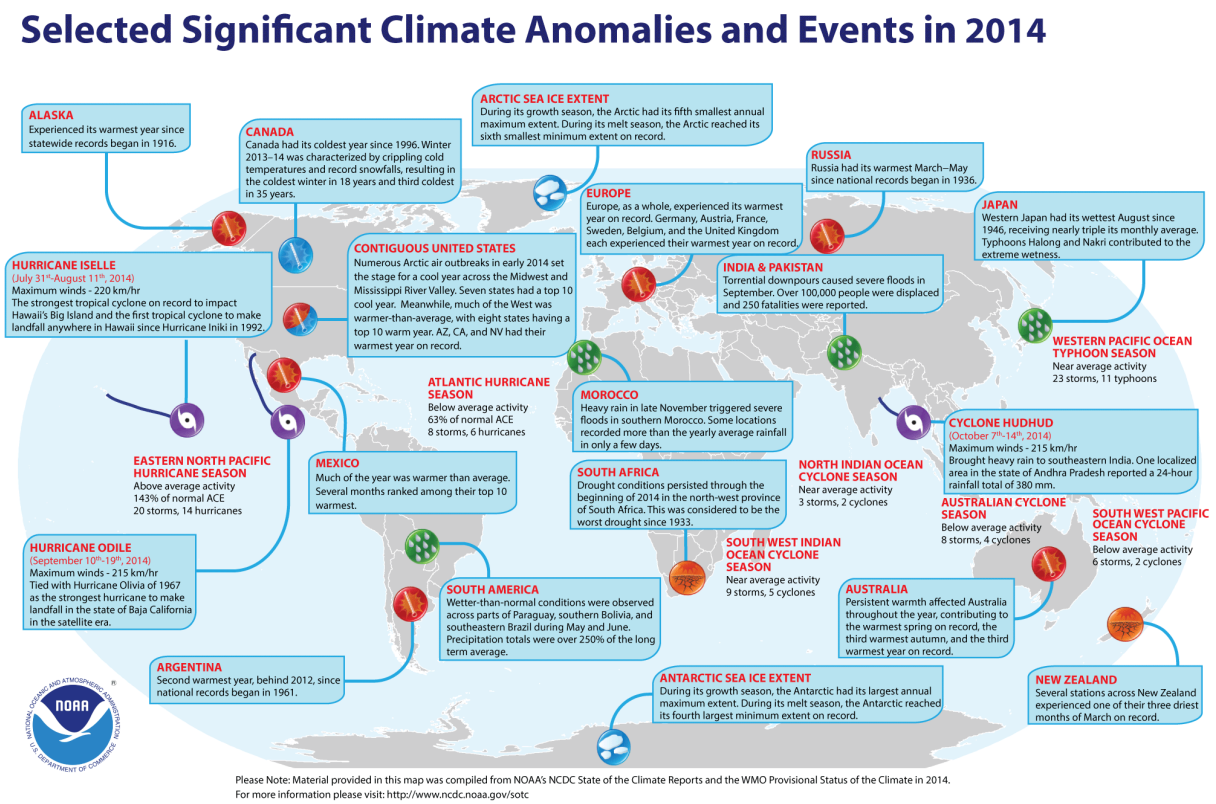
The major possible effects on humanity are as follows:

- spread of diseases

[10], visited: 2015.03.29.)

- exhaustion of some natural resources
- habitat decay and making areas uninhabitable
- erosion of continental areas
- industrial and agricultural decline
- mass migration
- scarcity of food and water (famine and thirst)
- extinction of species, problems with biodiversity and spread of pests
- security issues (revolts, armed conflicts for the possession of scarce resources)

For the year, 2014, the *US National Climatic Data Center (NCDC) of National Oceanic and Atmospheric Administration (NOAA)* made a collection of severe events happening in 2014 around the globe. The figure shows decrease in arctic ice, typhoons and storms and floods among others.



6. Figure: Climate Anomalies and Events in 2014. (Source: NOAA)

Although, there is major consensus on the primary effects of climate change, the system if much more complex than we could imagine. The research to characterize possible threats and to provide measurements for it does not only require scientific knowledge from various subjects (physics, biology, mathematics etc.), but great quantitative analysis and serious modeling. On the other hand, this modeling cannot be justified with a single model or formula gained from a certain discipline, albeit, some could be more helpful than others. *Gramelsberger* and *Feichter* emphasize the importance of meteorology, especially computational meteorology. They, at the same time, warn about uncertainties and myths surrounding the area, and the difficulties in establishing an overall scenario for the science of climate change. On the other hand, every region is about to face its own consequences of human ignorance within the past according to their own natural facilities and the nature of problems occurring can be the opposite of one another. Some regions might benefit, while others can suffer badly. Local measurements and the observation of derivations therefore are also essential. The results in the differences of opinions people have about it. Which, at the end, end in cumbersome negotiations and policy targets. This is why quantitative proof, at the largest possible extent, supports the claims. Probably, for today, the most tangible results are obtained from measuring the accumulation of CO_2 and by setting up targets.[11]

The current thesis, therefore, does not presume or state that it covers the full complexity of climate change. It just, provides a relatively short and more or less synthetic overview of the most important phenomena related to climate change. Those, that should be taken into consideration when creating a policy response. The next chapter is going to analyze some of these elements more in details.

[11] Gramelsberger, G. ; Feichter, J. Climate Change and Policy.

2. How climate change affects human living space and why is it relevant for economic policy? – a scientific overview

The origin of the science of climate change is rooted back to the 19th century with the work of *Tyndall, Arrhenius and Fourier,* but it has developed a lot during the 20th century, especially through the activities of IPCC.[12] Climate change enhanced by human-influence (or anthropogenic climate-change) is extremely important and cannot be disregarded. Its malicious and degrading effects do not only endanger, but in some parts of our planet, they make living impossible. Although the phenomenon itself is still surrounded by uncertainties, there is strong agreement among scholars and scientists on various aspects of it, including its potential perilous outcomes.

Most often heard fears are the melting of polar ice and the upscaling in average temperature. Nonetheless, still only a few people approach this problem thoroughly, taking into account how manifold it is.

For a policy approach, hence, a basic explanation is inevitable to be able to develop a proper policy response, and to see how the issue is policy-relevant due to its weight. First, the paper describes the major effects in an interdisciplinary-scientific way for broader understanding. After introducing the above ideas, it turns to explain the economic effects, relating them to the previous findings of the research carried out for the thesis. Then, I am going to point out, why the topic is of climate change is practically essential for economic policy, and why it requires fast and prescient response.

[12] Stern. What is the Economics of Climate Change p. 2.

Since the change in the levels of oceans and the rise in temperature are amongst the most noticeable and imminent byproducts that could directly and indirectly affect millions of lives, the paper puts a larger emphasis on analyzing them as main coefficients for the research topic.

2.1 Sea-level rise and the melting cryosphere

The level of sea is constantly on an increase, which could be attributed to various variants. Amongst its most important factors, the melting of glaciers and ice sheets can be mentioned. As a result of the natural climate cycle, average temperature has risen, which highly influenced the diminishment of ice layers. Further developing the process, it eventuates in the elevated oceanic water supply and a higher sea level.

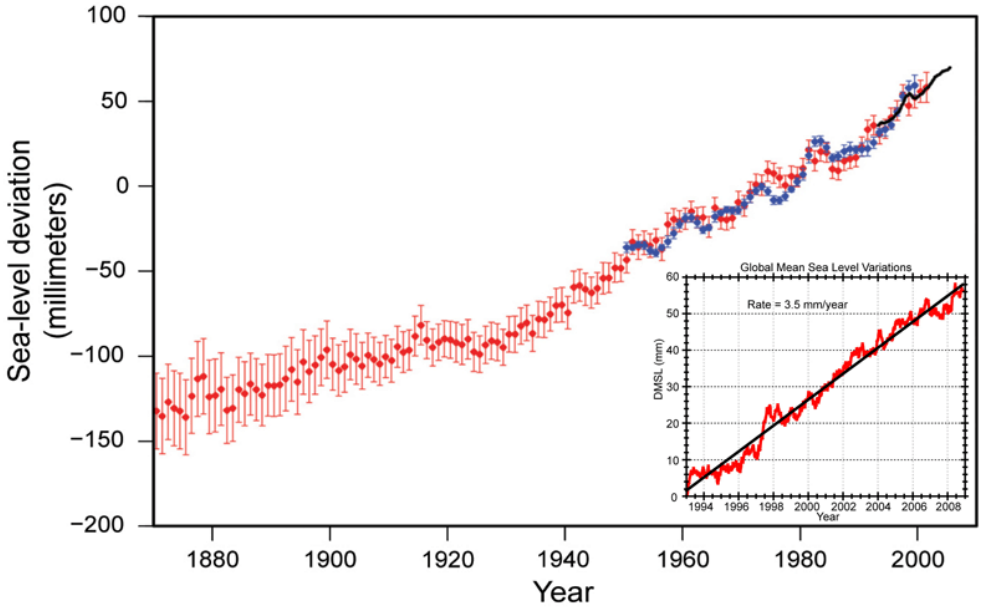
The drastic rise within the last few decades is an alarming sign, which is a hardly debatable consequence of rapid climate change induced by anthropogenic influence that has been covered by both academic and public literature.[13]

Expressing it through numbers, based on the findings of the US *NCDC – NOAA* it means a yearly 1.7 mm average increase projected to the past 100 years. Since 1993, a sharper shift can be observed, which means approximately 3.5 mm per year.[14] From the postindustrial era, water level has emerged by circa 20 cm.[15]

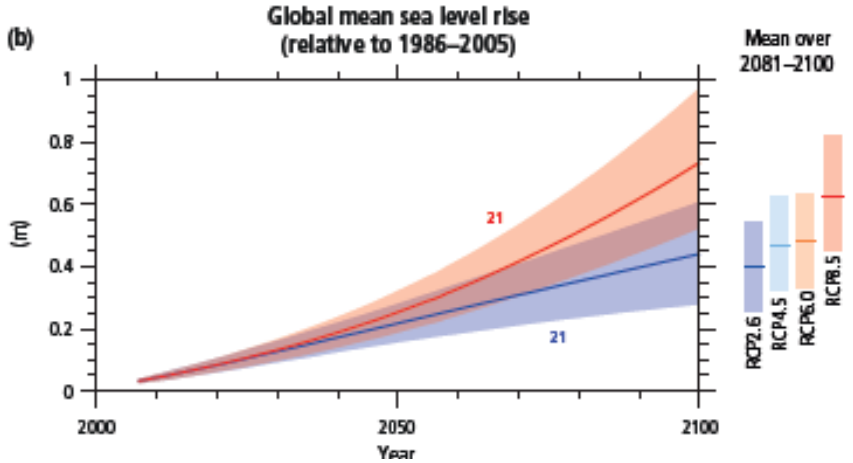
[13] See eg.: H Goelzer, P Huybrechts, S C B Raper, M-F Loutre, H Goosse, T Fichefet. Millennial total sea-level commitments projected with the Earth system model of intermediate complexity LOVECLIM. Environmental Research Letters, 2012; 7 (4): 045401 DOI: 10.1088/1748-9326/7/4/045401

[14] National Oceanic and Atmospheric Administration – NOAA, Natoinal Climatic Data Center /USA, Department of Commerce/, Global climate change indicators. (available at: https://www.ncdc.noaa.gov/indicators/, visited: 2015.03.25.)

[15] World Bank. 2012. Turn Down the Heat: Why a 4°C Warmer World Must Be Avoided. Washington, DC. © World Bank. p. ix. (available at: https://openknowledge.worldbank.org/handle/10986/11860, visited: 2015. 03.20.)



7. Figure: Sea-level deviation. (Source: NCDC Global Climate Change Indicators.)



8. Figure: Global mean sea level rise and projections until 2100. (Source: IPCC 2014 Synth. Rep. p. 11.)

IPCC expects a larger scale rise in during the 21st century with a warming ocean temperature especially around the subtropical regions and the Northern Hemisphere.[16] It is not a promising projection, regarding the fact that one of the main accelerators of sea-level rise is the rise in average ocean temperature compared to previous centuries, which speeds up the

[16] IPCC 2014. Synth Rep. p. 11.

melting process of the cryosphere. From the beginning of the 1950's, water temperature have raised by 0.9 C º.[17]

First, based on elementary physics, if the ocean temperature grows, the water becomes subject of thermal expansion, which means in a simplified way that seas in the world would need more space (or their volume would expand) responding the heat. [18] Taking into consideration the fact that the global sea volume is around 1.33 billion km^3 according to NOAA[19], even a minor change in temperature can produce perceivable results, especially in the case of low-lying areas.

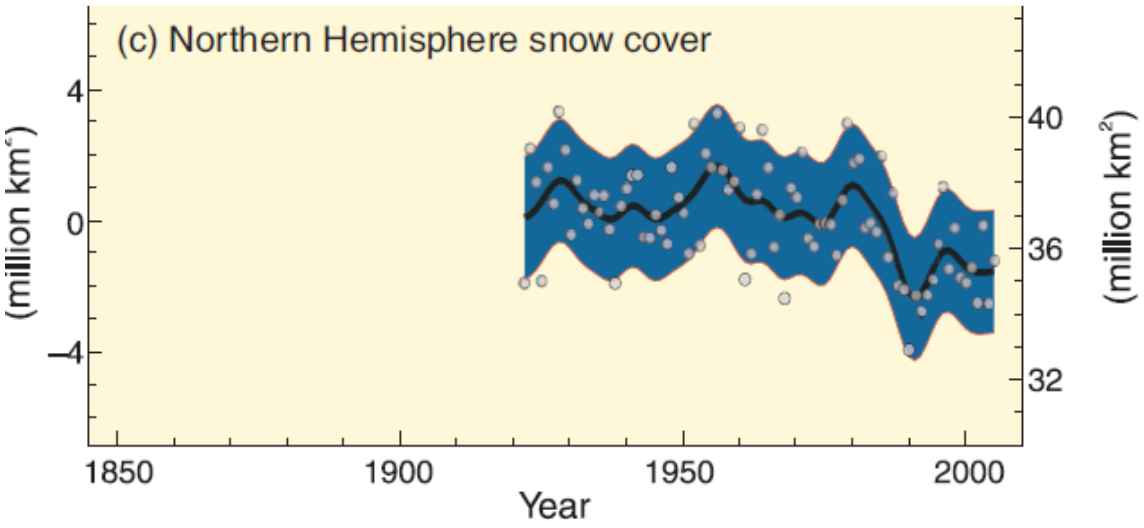
Nevertheless, thermal expansion is just one little coefficient of the increasing level, which is less significant, that something else, we more often hear about. As aforementioned, the temperature increase also relates to the melting ice of polar and other, terrestrial areas (eg. Greenland) and that of glaciers.

This type of change is often mentioned as the so-called "glacial eustasy" or "glacioeustasy", which refers to the case when increase or decrease in the sea-level is induced by the alteration of terrestrial ice surfaces. Or in other words, it means that ocean-volume is changed by the factor, whether the water supply is stored in ice form or in "oceanic", liquid water substance. The expansion of the water-level due to the shrinking cryosphere hence is called eustatic change.[20]

Based on the calculations of *National Snow and Ice Data Center (NSIDC)*, if the whole ice surface on Earth melted, nearly 70 m increased could be observed in ocean-levels.

[17] World Bank 2012. Turn Down the Heat, p. ix.
[18] For exact calculations see eg.: McDougall, T.J., R. Feistel, F. J. Millero, D. R. Jackett, D. G. Wright, B. A. King, G. M. Marion, C.-T. A. Chen and P. Spitzer, 2009: Calculation of the Thermophysical Properties of Seawater, Global Ship-based Repeat Hydrography Manual, IOCCP Report No. 14, ICPO Publication Series no. 134., p. 20.
[19] NOAA National Centers for Environmental Information, Volumes of the World's Oceans from ETOPO1. (available at: http://ngdc.noaa.gov/mgg/global/etopo1_ocean_volumes.html, visited: 2015. 03.24.)
[20] Dr. Völgyesi Lajos: A geoid időbeli változása a tengerszint-változások alapján,. 1996, Geodézia és Kartográfia, Vol. 48, Nr. 6, pp. 26-33. p.4.

At the same time, NSIDC concluded that permafrost on the North Pole have already been reduced by about 80%.[21] On 25th February, 2015, the polar ice cap has peaked to its highest extent during the year, which resulted to be the record lowest comparing to previous observations.[22] Data collected by NCDC and *World Meteorological Organization (WMO)* show that the recent scale of yearly summer ice loss accounts to more than 60. 000km^2. That is about the two thirds of the size of Hungary, and around one fifth of Germany's. Research predicts that by 2050 there will not remain hardly any ocean ice.[23]



9. Figure: Decrease in the snow cover of the Northern Hemisphere. (Source: IPCC Synthesis Report, 2007, p.37.)

However, melting layers of ice do not solely affect sea-levels. There is a correlation between the amount of ice and snow and the average temperature, called as "albedo-effect". It means that from one part the increase in temperature results in a decrease of snow cap, but the diminishing effect reversely further elevates the average temperature. Since, comparing to the

[21] National Snow and Ice Data Center, The Contribution of the Cryosphere to Changes in Sea Level. (available: http://nsidc.org/cryosphere/sotc/sea_level.html, visited: 2015.03.20.)
[22] The National Snow and Ice Data Center (NSIDC) media publication. Arctic sea ice maximum reaches lowest extent on record. 19 March 2015. (available at: http://nsidc.org/news/newsroom/arctic-sea-ice-maximum-reaches-lowest-extent-record, visited: 2015.04.13.)
[23] Pearson, Pam; Bodin, Svante; Nordberg, Lars; Pettus, Ashley. 2013. Main report. Washington DC; World Bank. (available at: http://documents.worldbank.org/curated/en/2013/10/18496924/thin-ice-cutting-pollution-can-slow-warming-save-lives-vol-1-2-main-report, visited: 2015.04.23.) See also the statistics of NCDC. (available at: National Climatic Data Center (available at: http://www.ncdc.noaa.gov)

higher absorption of sunbeam of plain surfaces without snow, ice surfaces are capable of reflecting about 80-90% of solar radiation back. The fall in the reflected energy as a result of shrinking snowy surfaces leads to a higher absorption of light energy, therefore transferring more heat to the environment that again leads to the increment in the temperature.[24]

Borrowing the term from economic glossary, I would denote it as the ***"albedo-multiplier of climate change"***. This phenomenon could also be associated with the sea-level rise, and it is strongly correlated to other coefficients of global warming as well.

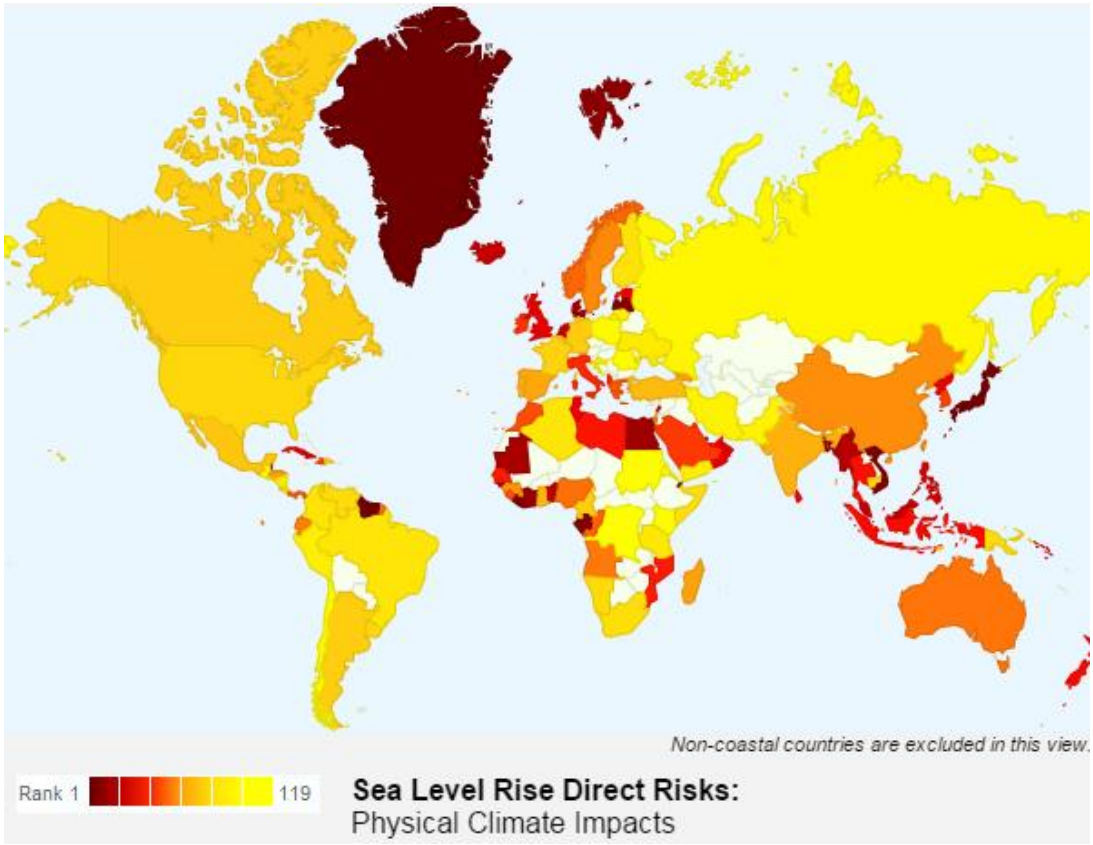
According to the IPCC forecast, with the current level of GHG emission, by the end of the 21st century a sea-level rise of 0.2-0.5m on a yearly average seem to be a predicted scenario (varying from different areas, with the possibility of 0.8 m rise in certain territories).[25]

This, regarding human circumstances could have devastating effects. As a consequence of the higher volume of oceans several coastal areas would be posed to the danger of erosion and submersion. On one hand, it would deteriorate production possibilities, while, on the other hand it would destroy a substantial land area capable for human life. Likewise, increased precipitation, which more frequently happens nowadays, together with this rise would trigger floods. The highly endangered territories would mostly be the low-lying lands in Asia and Africa, those that are many times the most populated and impoverished regions. Threatening the habitats of millions of people would be a great human catastrophe.[26]

The submersion of land could also affect developed countries, such as the Netherlands. The existence of some island nations built on atolls (mainly in the Pacific) like Kiribati, Tuvalu, Marshall Islands and even the world-famous desired tourist dream

[24] NSIDC. Albedo. (elérhető: http://nsidc.org/cryosphere/seaice/processes/albedo.html, visited: 2015.04.27.)
[25] IPCC 2014 Synth. Rep. p. 13.
[26] IPCC 2007 Synthesis Report. p. 48.

destination, the Maldives in the Indian Ocean is in imminent danger based on the frightful reports and researches. Millions of people would become subject to leave their homes because of their perishing homelands.



10. Figure: Direct effects of sea-level rise predicted by the end of the 21st century. (Small island nations due to their size are not included in the map, although they are amongst the most affected.) (Source: Center For Global Development (CGD))

According to estimations made by *Small*, about the 23% of the whole world population, calculating only with the current, but continuously growing number of people it means 1.66 billion humans live within 100km distance from the coastal zone in places situated less then 100m above current sea-level. In these regions population density is about third times larger than that of the inland areas.[27] The number of people living in the Low Elevation Coastal Zone (LECZ) is around 10%. It means, they live in places lower than 10 m

[27] Small, Christopher and Nicholls, Robert J. (2003) A global analysis of human settlement in coastal zones. *Journal of Coastal Research*, 19, (3), 584-599., p. 584

above the ocean level.[28] From this data it seems obvious that that habitat of millions is in real danger in the not so long run.

2.2 The rise in average temperature and the ecosystem

In the previous subchapter, the interaction between the sea-level and temperature rise has already been revealed. On the other hand, approaching the topic of temperature change from the aspect of ecosystem is worth to elaborate.

From the beginning of the technical boom, temperature statistics show an increasing trend. WMO conclusions, based on the analysis of the most prominent climate science institutes (the NOAA, *Japan Meteorological Agency*, *NASA Goddard Institute*, *UK Met Office Hadley Centre)* show, that the year 2014 was the record warmest regarding land and ocean temperatures from the 1880's (the date from when data is available) and warns about the trend.[29]

It is the 38th year in a row now, when mean temperatures reach a level above average. The fact that nine out of ten record-level temperature measures has occurred during the 21st century, is extremely alerting. Only the year 1998 was the "outlier" from the previous era with its high values in the comparison.[30] Within the past decade, global average temperature change has grown to 0.16 – 0.20 ºC comparing to the 0.06 ºC increase measured during the 20th century.

On the following page the table shows the most outstanding anomalies. For the creation of the table I mainly relied on the datasets of the previously mentioned organizations that also contributed to the WMO opinion on 2014's record.

[28] McGranahan, G., Balk, D. and Anderson, B. (2007) The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. Environment and Urbanization, 19(1): 17-37. (available at: http://dx.doi.org/10.1177/0956247807076960, visited: 2015.04.23.) p. 17

[29]World Meteorological Organization. Media Centre. Press release No1. Warming Trend Continues in 2014. (available at: https://www.wmo.int/media/?q=content/warming-trend-continues-2014, visited: 2015.04.28.)

[30]National Climatic Data Center. Global Analysis – Annual 2014. (available at: http://www.ncdc.noaa.gov/sotc/global/2014/13, visited: 2015.03.29.)

Temperature anomalies records								
	NOAA NCDC		Japanese Meteorological Agency		Hadley Center UK Met Office		NASA GISS	
Rank	Year	Anomaly s	Year	Anomaly	Year	Anomaly	Year	Anomaly
1	2014	0.69	2014	0.63	2014	0.68	2014	0.71
2	2010	0.65	1998	0.58	2010	0.68	2010	0.70
3	2005	0.65	2013	0.56	2005	0.66	2005	0.69
4	1998	0.63	2010	0.56	1998	0.66	2007	0.67
5	2013	0.62	2005	0.53	2003	0.63	2002	0.65
6	2003	0.62	2009	0.52	2009	0.62	2003	0.64
7	2002	0.61	2006	0.52	2006	0.62	1998	0.64
8	2006	0.60	2003	0.52	2002	0.62	2013	0.63
9	2009	0.59	2002	0.52	2013	0.61	2009	0.63
10	2007	0.59	2007	0.49	2007	0.61	2006	0.63

Data obtained from the following datasets:

NOAA: https://www.ncdc.noaa.gov/sotc/global/2014/13

JMA: http://ds.data.jma.go.jp/tcc/tcc/products/gwp/temp/ann_wld.html

NASA: http://data.giss.nasa.gov/gistemp/tabledata_v3/GLB.Ts+dSST.txt

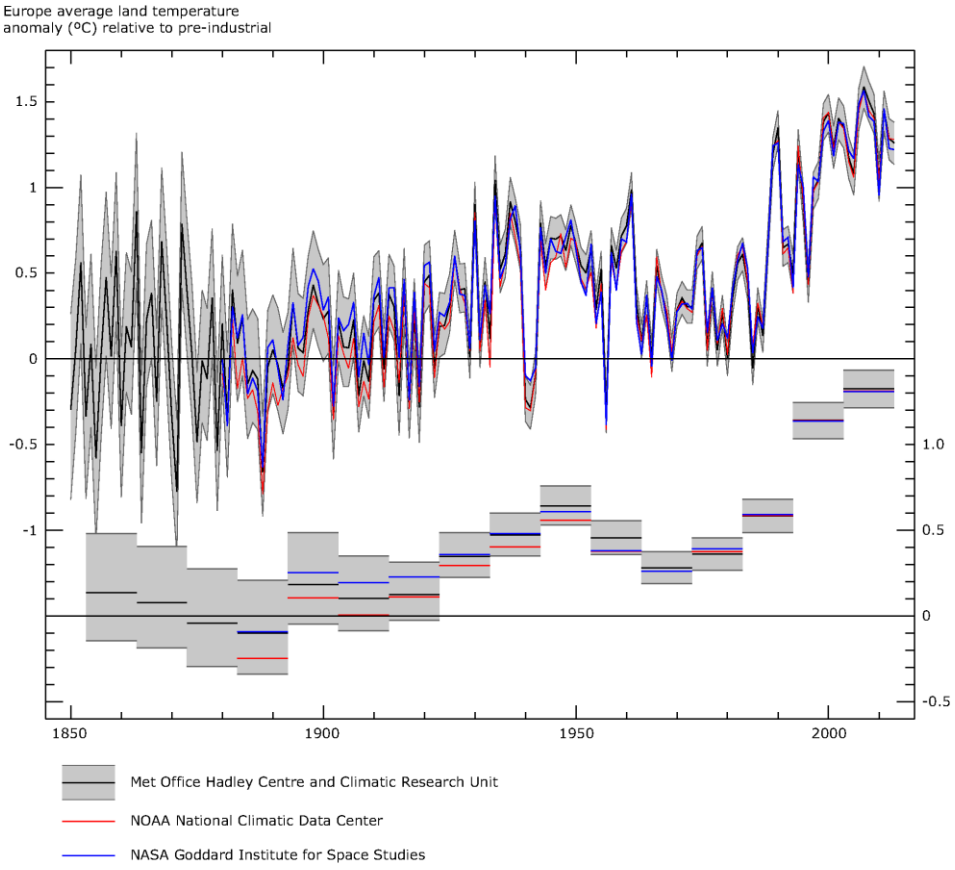
Met: http://www.metoffice.gov.uk/hadobs/hadcrut4/data/current/time_series/HadCRUT.4.3.0.0.annual_ns_avg.txt

1. Table: Temperature anomalies records. The table shows the anomalies, expressed in Celsius grades measured in the deviation from to the 20th century average temperature as a base period. Since almost all the different organizations relied on different base periods for their time series, an adjustment was needed to obtain the anomalies in relation to the 20th century average in order to provide a unified picture of the measures taken by the above bodies.

Although the results obtained from the various time series slightly differ in their order and in values, 2014 shows to be the top value for all the examined datasets. We can also observe that the top 10 listed years are merely the same, but occasionally they take a different order within different columns.

Despite the minor discrepancies, the trend of increasing temperature and positive deviation from the previous century can clearly be shown from the table, which is justified by the very similar numerical results from the scientifically most recognized climatic data adaptors.

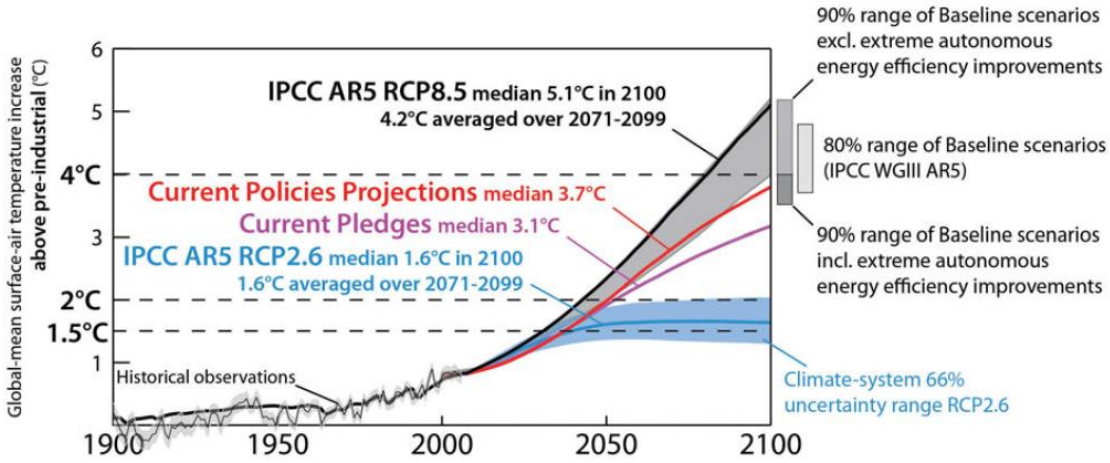
In Europe, as revealed by the *European Environment Agency (EEA)* it even surpassed the global mean value. The average temperature for the previous decade is 1.3 ºC higher than it was in the pre-industrial era. Forecasts expect a rise between 1.8 - 4 ºC. Extreme heat events have become more frequent, with a nearly tripled amount of heat waves, while cold-related extremities seem to decrease sharply. Europe is projected to continue its above-average temperature rise in the century.[31]



11. Figure: European average air temperature anomalies (1850 to 2013) in °C over land areas only. (Source: EEA. Available: http://www.eea.europa.eu/data-and-maps/figures/european-annual-average-temperature-deviations-1850-2008-relative-to-the-1850-1899-average-in-oc-the-lines-refer-to-10-year-moving-average-the-bars-to-the-annual-land-only-european-average-5)

[31] European Environment Agency (EEA). Global and European temperature (CSI 012/CLIM 001) - Assessment published Aug 2014. (available at: http://www.eea.europa.eu/data-and-maps/indicators/global-and-european-temperature/global-and-european-temperature-assessment-8, visited: 2015.04.28.)

The World Bank highlights in its report, that the global community has committed itself to the responsibility to curb temperature rise down below 2 ºC, the value before the beginning of the industrial era, serving as the base period. They also expect that with the circa 1.5 ºC warming, by 2100, global sea-level would rise by more than 30 cm, with the appearance of severe droughts in some regions and the possible extinction of all coral reefs devastatingly infecting marine biodiversity. At the same time, there are fears that the current commitments made within the UNFCCC can lead to an even worse scenario, an increase of 3.8 – 4 ºC by the end of the century.[32]



12. Figure: Projections on temperature rise within the 21st century, taking into consideration international pledges and policies. (Source: World Bank Report, p. 6.)

Global warming causes several effects for both humanity, both wildlife. An average 2-3 ºC increase in the temperature can lead to the extinction of some species and burgeon of pests. Elevated sea water temperature results in acidification and the disappearing of coral

[32] See: World Bank Group. 2014. Turn Down the Heat : Confronting the New Climate Normal. Washington, DC: World Bank. © World Bank. (available at https://openknowledge.worldbank.org/handle/10986/20595, visited: 2015.04.23.) License: CC BY 3.0 IGO, p. 4.5.; and The World Bank News. World Is Locked into About 1.5°C Warming & Risks Are Rising, New Climate Report Finds. November 23, 2014. (available at: http://www.worldbank.org/en/news/feature/2014/11/23/climate-report-finds-temperature-rise-locked-in-risks-rising, visited: 2015.04.23.)

reefs and different specimen. It results in a large abashment in biodiversity. It effectuates tragic environmental consequences and the suffering of a large percentage of wildlife. On the other hand, the food supply of groups of people depending on fishing and hunting the "wild resources" for self-sustainment, is also endangered (for example people who are living in island regions, feeding on marine supplies). Coral reefs, in addition, apart from being rich in different forms of life, can serve as a protection for coastal lands. Hence, with their evanescence, some lands would be more exposed to environmental impact, such as the people living in those areas.[33]

As a consequence of climate change, extreme floods cause severe problems in some areas, while others are subject to droughts and desertification, generating poor living conditions. Both phenomena contribute to the fall in agricultural production, threatening and degrading food security, in some territories, at a serious level, like in some countries in Africa, where food supply sometimes is really small even among "general" circumstances.

For instance, in 2012, in the USA droughts affected nearly the 80% of agricultural areas, which was the most serious such event from the 1950's.[34] Large acres of land got demolished, which makes the devastating effects of climate change more apparent and visible in the first world as well. By the end of the century we can expect a growth in occurrences of drought. It also helps for pollutants to settle, further generating other problems.[35]

The IPCC concluded that in the event of the increase in average temperatures by about 1-3 ºC, highlands and upper-lying areas could benefit from growing agricultural production, while low-lying and dry lands would suffer from remarkable loss, although it still would be able to result in a positive average growth of production. At the same time, a rise by more

[33] The World Bank: Climate Change Report Warns of Dramatically Warmer World This Century (available at: http://climatechange.worldbank.org/content/climate-change-report-warns-dramatically-warmer-world-century, visited: 2015.03.24.)
[34] A Report for the World Bank (2012). p.xiv.
[35] IPCC (2014) Synth. Rep. p. 68.

than the above measure would result in negative growth.[36] Not only the production and access to food would be endangered, but other economic problems are likely to occur as well, related to price stability and supply-demand relationship. The increased food demand by the booming population with the projected loss in yield can jeopardize global economy, causing crises.[37]

Besides food, water security is another important issue related to global warming. Because of droughts, freshwater sources might run dry that would increase insecurity and scarcity. It would risk the life of people living in those areas and could make raising animals and yielding crops close to impossible there.

Floods have become more frequent lately as a factor of human-triggered climate change. It can pose danger on lives, health and on the supply of potable water as well. During inundations, there is real peril that sewage and other contaminating and contagious substances would flush together with drinking water, making it undrinkable and propelling health risks for consumption and everyday use. On the other hand, the location of water resources constantly shifts due to climatic transformation.[38]In the 21st century, the number of people facing water scarcity will further increase, while renewable sources of water will decrease or disappear in some regions.[39]

The vicissitudes in weather incorporate more and more frequently in cyclones, hurricanes, tornados and impetuous storms even in areas, where they were not typical formerly. Poland is a good example for that, which was hit by heavy hurricanes, lately by "Xavier", in 2013.[40]

[36] IPCC (2007). Synth. Rep., p. 48.
[37] see IPCC (2014) Synth Rep. p. 69.
[38] ibid. p. 49.
[39] IPCC (2014) Synth. Rep. pp. 67-68.
[40] See eg.: National Poland Express (NPE). Hurricane 'Xavier' hits Poland. 6th December 2013. (available at: http://www.newpolandexpress.pl/polish_news_story-6117-hurricane_xavier_hits_poland.php, visited: 2015. 03.24.)

Regarding health risks, temperature-rise and heat-waves effectuate serious harmful medical outcome. Extreme weather favors the spread of infectious, bacterial and viral diseases that could easily turn into epidemics. It also raises chances for other illnesses, such as diarrheal and other gastrointestinal, respiratory, cardiovascular and other types of health problems. For the same instance, fatality rate among such conditions would likely to upsurge. Albeit, in some parts of the world, warming could cause some beneficial results, these are far more negligible than the harm it is capable of inflicting.[41]

The 2010 heat-wave in Russia caused the deaths of about 55.000 people, and decreased crop production by circa 25%. One billion hectares of agricultural land burnt down and generated around 15 billion dollar economic damage.[42]

Melting cryosphere would not solely affect sea-level. Underneath the ice-cover, for instance in Siberia enormous gas reserves, such as methane, are sealed up. With the disappearance of "topcoats", these would be released into the atmosphere. On one hand, they would further increase the accumulation of greenhouse gases in the environment, while on the other hand some of them would be in itself harmful for health and biodiversity. Nonetheless, even with the pretermission of this dreadful scenario, the environment's CO_2 absorption capacity is being more and more reduced, when emissions continue to grow. Predictions fear that the earth soon might deplete its maximum absorption capacities that would farther intensify the "negative dividends" of climate change on the ecosystem and humanity, spiraling the process at a higher rate.[43]

In addition to all the above, the increase in temperature could encumber economic growth, with special regard to developing countries. It could endanger political, agricultural

[41] IPCC (2007) Synth. Rep.. p.48.
[42] A Report for the World Bank, (2012). p. xiv
[43] See eg. IPCC (2007) Synth. Rep. p .48.

and peace stability, indirectly effecting turmoil in areas of serious degradation as a grievous response to helplessness. Climate mass migration is another feature of warming, which has already begun.[44]

2.3 Potential effects on economy

In the previous parts, the thesis already shed light on some economic-related affects of climate change. This whole section is dedicated to reveal the nexus between climate change and economics. Nonetheless, it is almost impossible to create a comprehensive summary of all the changes in economic variables and fields global warming is capable of inducing.

First, as (global) economy is the area, which is primarily indirectly affected by climate change and indirect effects are harder to predict or to measure their scale in relation to the core problem. That is why sometimes it makes it harder to convince policy makers about the connection between the two, making it more difficult to trigger a proper policy response and to promulgate the economic weight towards a greater audience (although, nowadays this pattern seems to shift to a positive direction). At the same time, there are plenty of economic/econometric resources available for the estimation of probable effects that could be useful in predicting them and helpful for policy making.

Second, as we have seen from former parts of the paper, elements of climate change are sometimes strongly entangled and are in various ways interconnected (for instance, weather might influence crop production in different ways while also having affect on people's lives, which can affect prices, demand, supply, production and other economic factors as well), therefore it is unlikely that one can make an overall analysis comprising of all possible approaches and areas connected.

[44] A Report for the World Bank (2012). p. xiv.

Third, there are structural and environmental differences among the countries of the world, therefore it causes difficulties to sketch the possible "global" economic effects caused by climate change.

Fourth, in other cases, there is a lack of satisfactory resources on the particular issues. This gap is appearing especially as a result of the underrepresentation of case studies on developing countries that frequently are most affected regions.

.Paradoxically, although there is a gap in some areas of economics of climate change, still several researches embrace the topic and it is so broad that quite a few books could be written on it, the current thesis will only highlight some of the effects, to emphasize the importance of climate change and that it does not only affects the society, but the economy as well. For economic policy it is important to convince policy makers that they need to coordinate their decisions in order to prevent climate change to cause grave economic problems. At the same time, for it to happen, policies to reduce and tackle climate change should be introduced.

For the purpose of the current thesis, though, it is reasonable to emphasize and collect the most important and widely mentioned facts for a basic overview of the economic importance.

The IPCC report groups the effects on the economy according to the industry affected, based mainly on supply and demand:[45]

- tourism
- heating/cooling (energy consumption)
- health services

[45] IPCC Report (2014). Chapter 10.

- transportation
- insurance
- water infrastructure

Its findings reveal both the negative and positive outcomes and show whether signs are positive or negative and the extent these sectors are sensitive to climate change. Overall, the majority of papers argue that economic disadvantages out of climate change highly overrun possible benefits.

2.3.1 Summarizing the general findings regarding socio-economic effects[46]

The following conclusions are the ones that could be understood as some of the effects on the global economy. Nevertheless, they must be interpreted carefully, first because of the reasons listed above, and as sometimes the available literature does not provide clear and consistent results

Energy demand is likely to rise in the future (eg. because of the increased demand for cooling and the decreased efficiency of different type of energy resources) with short term price rise due to extreme conditions and an approximate -3 – 1.2% change in the GDP, where developed countries could benefit more and warmer areas would be affected ate a higher level.

Changes in water supply can have significant effects on the economy from various aspects. Flooding and droughts are likely to destroy high values of capital and land. It could

[46] Based on the IPCC (2014). Chapter 10, complemented with findings generally appearing in relevant documents, and with conclusions of the writer, following the logical order of IPCC (2014).

also raise costs for public health (for instance due to the contamination of potable water) and government and private spending on damage control.

Prices of water are likely to rise in areas of scarcity that is enhanced by the fact of decreasing freshwater supply and increasing population

.

Although the literature on the effects on transportation is limited, some logical conclusions can be drawn. On one hand, the growing rate of transport greatly contributes to the level of GHG emission thus hastening global warming. On the other hand, climate change also has negative effects on transportation in return.

Road and railroad qualities, for instance, might worsen due to extreme weather conditions and are exposed to damage that also raise maintenance and security costs and their allocation that partially will probably levied on 'consumers of the roads', influencing thus various sectors of the economy, including households, production, trade, etc.

Water transport could also be vulnerable to weather conditions – like floods, storms that could prevent ship transportation. Ports are possible subjects to damage like railways and roads. At the same time, in colder regions, due to the loss of ice, longer shipping periods are possible with the likeliness of lower costs.

Air traffic, similarly to other segments of transport could be influenced in various ways. First, the maintenance of airports and runways is likely to become more costly and complicated, with security problems with precipitation and adaptation to it. Storms, with increased turbulence, apart from causing disturbances in air traffic raise safety issues. Technical concerns might occur as well, as with growing temperature the density of air decreases, causing probable delays and again, security threats in landing and taking off.

Tourism industry might suffer from the deterioration of nature and popular tourist tropical beach destinations, such as the Maldives, from the submersion of land.

Financial instruments and insurances will change due to the increased hazardous risk regarding health and unpredictable environmental events that will alter the system of premiums and raise costs.

Deteriorating health conditions due to health problems caused by extreme weather and the spread of diseases facilitated by the side-effects of global warming will likely to raise costs and expenditure on healthcare both for the public both for the private segments.

Another serious issue often disregarded is climate change migration or the issue of climate refugees. When places become uninhabitable and even before it happens, people would escape from places where their living conditions are worsened. Again, the most affected regions would be those, where population density is the highest and where the largest numbers of people live. They are mainly the developing countries and a vast number of people are living in coastal areas. The fleeing from these places has already begun and more and more researchers care about the phenomenon both from legal and from economic aspects. The position of such people is yet officially undefined and sometimes it is hard to differentiate them from economic migrants. The issue is serious and estimations project millions of people to leave their homes. It causes severe socio-economic effects and both target both origin countries need to act to find solutions. For instance, Australia, being one of the targets have already begun to introduce specific schemes for those arriving from sinking island regions, although, yet, rather on economic principles. This mass migration can at the same time rise

costs of social protection system and healthcare, highly alter labor market and productivity in affected regions, mainly causing difficulties in efficiency and sustainability.

Security threats as byproducts of climate change would likely to emerge when life circumstances and the outreach to basic products would be endangered by climate change. As a result of dissatisfaction in some regions turmoil and uprising can be expected. First, it would raise expenditure on public security, second, these clashes might endanger economic activities and production in regions of conflict.

Agricultural benefit might occur in some colder places due to warming (eg. Canada, Sweden), while others, again, especially those underdeveloped would suffer from the lack of productivity and from severe natural events, the loss of arable land the increase of pests have negative effects.

On the other hand, from the loss of habitat and changes in the ecosystem, some species would go extinct. For instance, the acidification of oceans lead to the death of coral reefs and different fishes, whereas organisms that are not useful for fishing would outnumber the previous group. Of course, this phenomenon is also related to overfishing, but climate change further deteriorates the situation.

As previously mentioned, from several aspects, climate change will have more negative effects on the poor people and underdeveloped regions that will harm their competitiveness and their catch-up with developed nations. On a global level it does not have positive outcome on the performance of global market.

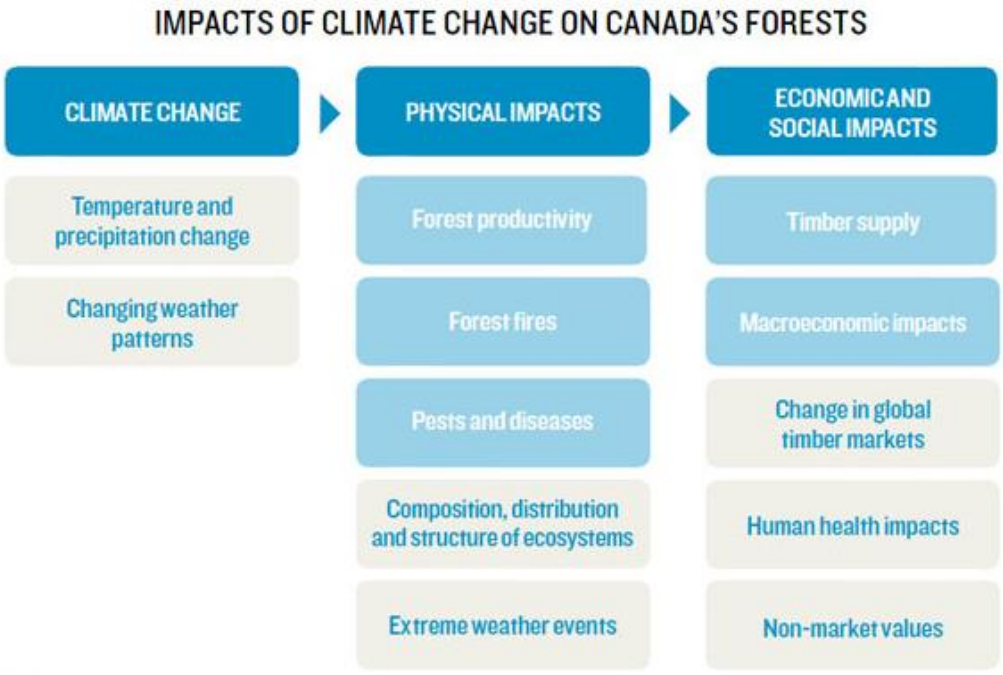
Overall, although some regions would benefit from the growth of productivity, the volume of loss in primary products – mainly food – including crop yields and fruits, is likely to highly overrun that of the benefits.

Different markets will be affected at a global level by climate change. For example, the loss of productivity in agricultural sector would increase the prices of some goods and people will likely to change their consumer habits as a result of it, although it is just one minor segment. Housing and insurance market, due to extreme events will be posed to change as well, to mention another example.

Labor market, due to health risks and decreased mental and physical capacities among extreme circumstances can lower productivity largely. In some countries where for example heat would rise to an unbearable level, it can be extremely costly or even impossible to create safe and manageable working conditions and to keep productivity at the same level.

Some industries in hazardous areas are subject to destruction and would need to move to other places where they could continue their activities, while those without necessary financial resources to do so would probably perish. Other industries, relying on resources being destroyed or becoming more costly can face enormous costs and damages.

To see the complexity of the issue and how many areas of the economy can be adversely impacted, the following figure about Canadian timber production, which is only a minor component of the whole economy, is a good example. Using the logics of *"a minore ad maius"*, if even in a tiny selected bit of a whole economy climate change can cause such an economic chain reaction, what could be the situation considering the whole world and the whole sectors.

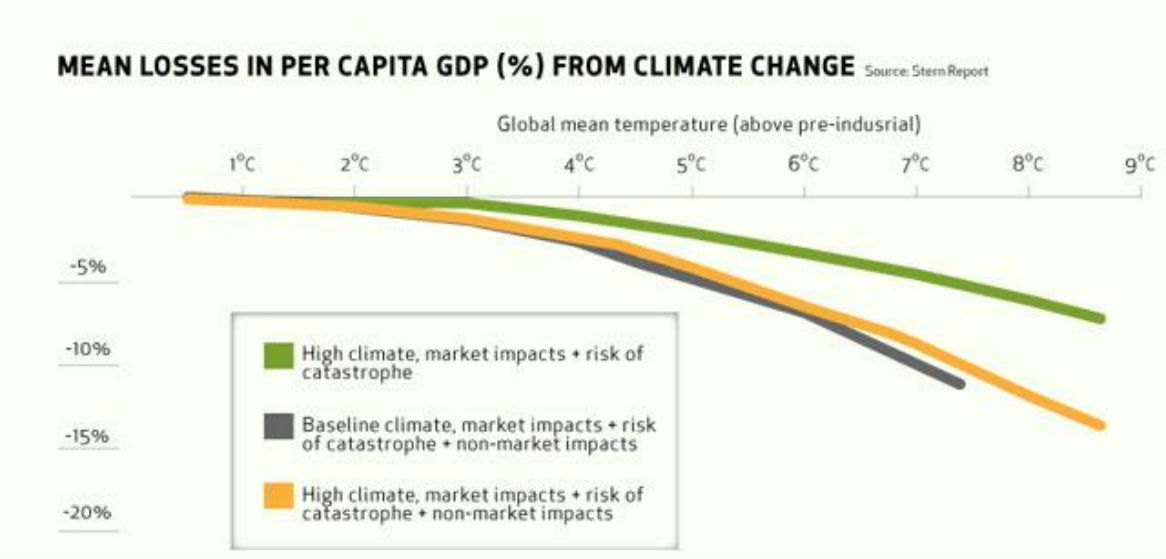


13. Figure: Climate change effects on Canada's forests. (Source: National Roundtable on the Environment and Economy –Canada)

As we can see from the picture, climate change can cause a variety of physical impacts (that vary according to the inflicted areas, industries and segments), which result in economic and social impacts. Regarding forest industry it can change due to temperature and precipitation change with changes in weather that leads to diseases, ecosystem changes, forest fires and the loss of productivity. In economic terms it has impacts on the supply of timber that further affects the macroeconomic indicators, global market and health. We can imagine it as a cycle of mutual impacts and we can use the analogy for other sectors as well (substituting with sectorial specificities).

As *Stern* also mentions, growth will be influenced by the circumstances climate change creates and the interconnections between events and economic trends. As previously mentioned we cannot create an exhaustive list, on the other hand, it might vary from regions to regions. On global average, though the economic costs of climate change are way higher

than the income gained from benefits. All in all, as a result of the combined impacts on the economy, GDP will undergo a fall and we can expect negative macroeconomic turns.



14. Figure: Estimated GDP loss according to the Stern Report.

We can see, on the other hand that some effects are not easy to measure and sometimes we underestimate the loss if we cannot think outside the box. Let us take the example of sea-level rise and coastal destruction. By sinking lands we do not only lose property and the value associated to it, or the land as "term of production" or revenue fall from tourism in the affected areas but something more. The cultural value and the immeasurable value people attribute to it, so the "public value", which has a huge cost.[47]

Overall welfare is about to decrease, the economy will suffer, on the other hand it still would need to keep in pace with development at a sustainable level. Though, it will be complicated with approaching the nature's limits of sustainability. With the decrease in natural capacities (land loss, wildlife loss, agricultural loss etc.) and the increase in emissions due to economic growth, economic capacities will also shrink.

[47] Stern, Nicolas. What is the Economics of Climate Change? 2006. World Economics. Vol 7. No. 2

For policymakers, especially at the global level, it is hard to reach an agreement, especially if it involves a sensitive issue that would at a certain extent put more control on economic activities. Common aims should be defined that are acceptable for decision makers and for industries.[48] In the case of climate change moral argumentations would count a lot, but they should be backed with scientific data that shows the complexities of climate change and how it interacts with everyday life and proves that altogether it is their economic and personal interest to take effective steps against it.

First and foremost, it is important that they get familiar with the phenomenon of climate change. To further develop direct policies that can be effective, apart from a global target, direct and industrial based sub-policies would be necessary to implement, which require specific considerations and knowledge.

To illustrate the statement and to deal with one of the most important related areas, I chose aviation, being an element of energy-use, which is responsible for about the 2/3 of current emission levels.[49] In the following chapter, to follow the logics of the paper, therefore, the industrial structure and its economic performance will be introduced hand with its climate impact.

[48] ibid.
[49] ibid.

3. Aviation industry and climate change

Aviation is one of the fastest expanding and most significant industries in transportation, despite the fact that it only has a short history, beginning in the 20th century. It is one of the main catalysts of globalization and economy. Its importance can be well expressed by statistical data.

When we use the term "aviation" it comprises civil aviation (commercial aviation including passenger and cargo flights and private service or non-commercial services) and military aviation. In this thesis, the connotation refers to its civilian branch as the focus of policy research.

The current chapter focuses on the trends in civil aviation industry to highlight its importance in global economy. At the same time, it examines the footprints it has on the environment and especially on its role in climate change.

3.2 The structure and the economic performance of aviation – some highlighted statistical data

In order to have a better outlook on aviation, and to be able to connect it properly to the policy sector, it is important to see, who are the main actors of aviation. Revealing what does its structure look like, to be able to give proper policy response on climate change prevention adaptations, taking into consideration the specificities of the industry.

Following the fast development, one of the greatest of the century, by now aviation plays an outstanding role not only in everyday life, but also it highly affects different sectors

of the economy. It enhances trade and investment, creates employments for thousands of people (including ground services worldwide), helps businesses and economy to develop and triggers tourism in certain regions. Aircraft production, on the other hand, highly enhances technological development.

3.2.1. Structure of the industry

Civil and commercial aviation consist of several actors, as the sector itself is extremely diverse and has many branches. First of all, there are those segments responsible for air services, while others do ground services still related to aviation. Not only those form part of the industry, who are actually responsible for transportation and related office work, but also those serving the services are (eg. onboard meal producers, manufacturers).

The major "actors" of the industry are the following:

- airlines (eg. cargo, passenger, low cost carriers, full service carriers)
- airline alliances
- producers of aircraft appliances/equipments (eg. engine manufacturers)
- airports
- aircraft manufacturers

Apart from the above listed actors, governments, international organizations (such as ICAO), transportation agencies (eg. IATA) and other industrial alliances also play a crucial role in the industry, determining the rules, providing guidelines and frames for the industry. In the next part the paper introduces some of the structural specificities with a few details about leading parties.

Airlines

In the world there are about 1400 commercial airlines[50] including cargo and passenger flights and the number is growing. Passenger airlines can be further divided into two main segments: Full Service Carriers (FSC) or Low Cost Carriers (LCC). Of the overall market, average the share among FSCs and LLCs was the following respectively: 78%, 22%.[51] The latter, although tends to be more and more responsible for the huge expansion aviation experiences in our days and slowly seems to overtake more shares.

Other distribution in the market is highly influenced by the existence of airline alliances, Star Alliance (eg. Lufthansa, TAP, Turkish Airlines), SkyTeam (eg. KLM, Delta, Air France) and Oneworld (eg. British Airways, Qantas, American Airlines), to which the majority of well-known airlines are members and thus form different cooperative groups with other airlines. .

Creating a ranking amongst airlines can be challenging as there are several criteria along which it can be carried out. Here, the paper introduces some of these to give a ground for comparison.

IATA creates different rankings every year on airlines in it publication, the *World Air Transport Statistics (WATS).* In its statistics, in terms of number of scheduled passengers taken at international transport, the top 3 airlines are *Ryanair*, *easyJet* and *Lufthansa* respectively. It shows that the major number of passengers on global flights is carried by

[50] ATAG. Aviation benefits. p. 6.
[51] Israel, Marc: Low Cost Airlines Market Research (2014.). AirlineProfiler. (available at: http://www.airlineprofiler.eu/2014/07/international-low-cost-airline-market-research/, visited: 2015. 04.30.)

European airlines (having 7 out of the top 10), where the greatest volume is achieved by two LLC's from the continent.[52]

Rank	Airline	Thousands
1	Ryanair	81,395
2	easyJet	52,787
3	Lufthansa	50,739
4	Emirates	43,335
5	British Airways	33,803
6	Air France	33,118
7	Turkish Airlines	27,407
8	KLM	26,581
9	United Airlines	25,002
10	Delta Air Lines	23,086

2. Table: Scheduled Passengers Carried (International). (Source: IATA)

In domestic transport *Southwest Airlines*, *Delta* and *China Southern* were the leaders and no European airliner landed in the top 10. In total comparison (domestic and international) Delta, Southwest and China Southern were the top 3 and there were only three European airlines in the list, the ones also leading the international ranking.

It reveals that in Europe domestic aviations is less significant in Europe, while in other continents it is so dominant that they highly overrun international traffic, with for instance Southwest Airlines having over 115.000 passengers on domestic flights.

Rank	Airline	Thousands
1	Delta Air Lines	120,636
2	Southwest Airlines	115,323
3	China Southern Airlines	91,504
4	United Airlines	90,161
5	American Airlines	86,823
6	Ryanair	81,395
7	Lufthansa	63,273
8	China Eastern Airlines	62,653
9	easyJet	58,410

[52] IATA WATS Publication. (2014) Scheduled Passengers Carried. (available at: https://www.iata.org/publications/pages/wats-passenger-carried.aspx, visited: 2015.05.10.)

10	US Airways	56,708

3. Table. Total passengers carried. (Source: IATA)

In terms of passenger kilometers flown, European carriers have again greater ranking in international comparison with Lufthansa being the third and 5 of the top 10 are Europeans airlines. Overall, United Airlines, Delta and *Emirates* top the ranking.[53] The statistics measure the number of kilometers flown for each passenger travelling by the airline.

Total (International + Domestic)

Rank	Airline	Millions
1	United Airlines	286,802
2	Delta Air Lines	277,560
3	Emirates	209,377
4	American Airlines	206,551
5	China Southern Airlines	147,841
6	Southwest Airlines	145,124
7	Lufthansa	144,236
8	Air France	136,405
9	British Airways	130,129
10	Qantas Airways	110,203

4. Table. Scheduled Passenger Kilometres Flown.

On the basis of Scheduled Freight Tonne/Km, the international top 1 place of for Emirates. From European airliners only Lufthansa and Cargolux made in the top 10, just as in total comparison, where the American FedEx has become the greatest cargo transporter.[54]

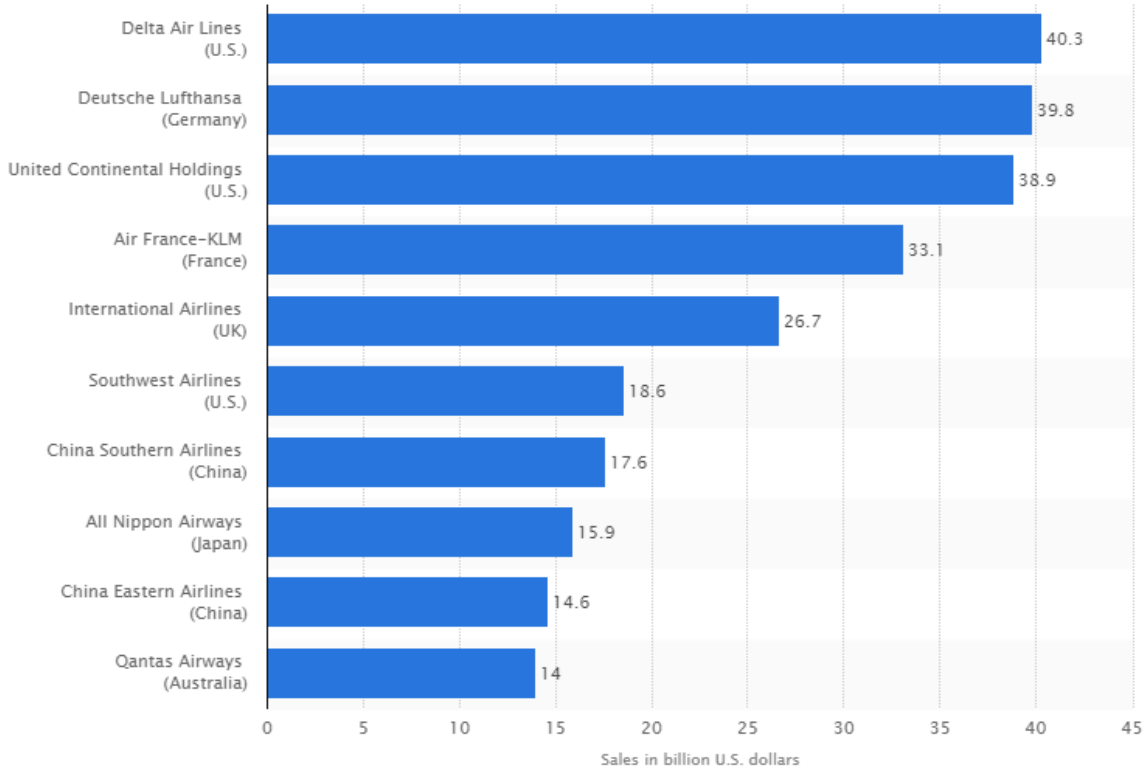
Rank	Airline	Millions
1	FedEx	16,127
2	UPS Airlines	10,584
3	Emirates	10,459

[53] IATA WATS 58th Edition. Scheduled Passenger – Kilometres Flown. (available at: https://www.iata.org/publications/pages/wats-passenger-km.aspx, visited: 2015.05.09.)
[54] IATA WATS 58th Edition. Scheduled Freight Tonne – Kilometres (available at: http://www.iata.org/publications/Pages/wats-freight-km.aspx, visited: 2015.04.29.)

4	Cathay Pacific Airways	8,241
5	Korean Air Lines	7,666
6	Lufthansa	7,218
7	Singapore Airlines	6,240
8	Cargolux	5,225
9	Qatar Airways	4,972
10	China Airlines	4,813

5. Table: Leading airlines in cargo flight tone/km (Source: IATA)

Regarding the revenues made by airlines, for the year 2014, leading airlines were Delta (over 40 bn revenue generated), Lufthansa and United Continental Holdings.



15. Figure: World Airline ranking by passenger revenues in 2014. (Source: Statista)

Adding that all, we can conclude that among the most significant airlines (including cargo and passenger) we can find: Delta, Lufthansa, United, Emirates, China Southern and FedEx. According to *Statista*, for the year 2013, Lufthansa was the first airline in sale and

Delta made the highest net profit (2.7 bn USD). In terms of brand value, in 2014, Emirates topped the list with around 5.5 billion USD.[55]

For Middle East companies like Qatar Airways, Emirates and Etihad Airways, (and also for airports) the current market changes towards Asia and other developing regions are highly favorable. The location of their fleet base places them in a central location, from where almost all important destinations can be reached within less than 10 hours.

Hence, they are gaining more and more shares in international transportation and can improve their fleets at a high rate as a result of increased demand for their services. They are slowly taking the place of legacy airlines on routes from Asia to Europe and in some main routes to Africa.[56] On the other hand, the rise of LLCs seems inevitable as their offer in prices seldom lower than that of legacy airlines, which, for mainly economy passengers can be a good reason to choose their services. Their business models are becoming popular in many countries, and their ancillary revenues overrun that of FSCs as a result of additional fees for extra services. Apart from these factors, their emergence is supported with automated systems and the liberalization and deregulation of air transportation. The leading of such airlines are Ryanair (being "ultra-low market") and Southwest.[57] In Europe other important companies are WizzAir and easyJet, while in the Asia-Pacific region, AirAsia holds a huge market share.

I found it important to reveal, as especially the companies with leading role can have important effects on others by implementing policies on climate change.

Airports

[55] Statista. Statistics and facts about passenger airlines. (Available at: http://www.statista.com/topics/1151/passenger-airlines/, visited: 2015.04.28.)
[56] Clayton, Edward. PWC
[57] Statista. Revenue of commercial airlines worldwide from 2004 to 2015 (in billion USD). (available at: http://www.statista.com/statistics/278372/revenue-of-commercial-airlines-worldwide/

Airports are responsible for a huge amount of economic effects aviation produces. On the other hand, their climate footprint is also relevant taking into consideration the huge traffic they handle. The number of airports with scheduled commercial flights in the world is now over 3800[58], which is expected to increase in the future with the expansion of aviation industry.

Statistical data shows that Hartsfield-Jackson Atlanta International Airport (over 9 million passengers) is the busiest airport of the world in yearly passenger volume, while Hong Kong International Airport is the most significant in terms of cargo trans cportation, where about 4 million t cargo load is handled annually. Hong Kong did not solely win the overall comparison, but it has the largest international cargo traffic as well.[59]

Airports Council International (ACI) published ranking of airports in different aspects. They show a positive growth for nearly all of the leading airports for the year 2014. They also reveal that the largest hub airport and the busiest airport in terms of international passenger traffic in the world is Dubai, thanks to its great geographical location. Istanbul, on the other hand is the fastest growing airport, with a growth rate of 10.7% in passenger volumes.[60]

[58] ATAG. Aviation benefits. p. 6.
[59] ibid
[60] Airports Council International. ACI Media Releases. March 26, 2015. (available at: http://www.aci.aero/News/Releases/Most-Recent/2015/03/26/ACI--World-releases-preliminary-world-airport-traffic-and-rankings-for-2014--DXB-becomes-busiest-airport-for-international-passenger-traffic-, visited: 2015. 04.29.)

World's busiest airports – Preliminary ranking
Table 1 – Total passenger traffic 2014

RANK 2014	RANK 2013	AIRPORT CITY / COUNTRY / CODE	PASSENGERS (Enplaning and deplaning)	PASSENGERS Percent change
1	1	ATLANTA GA, US (ATL)	96 178 899	1.9
2	2	BEIJING, CN (PEK)	86 128 270	2.9
3	3	LONDON, GB (LHR)	73 408 489	1.4
4	4	TOKYO, JP (HND)	72 826 565	5.7
5	6	LOS ANGELES CA, US (LAX)	70 663 265	6.0
6	7	DUBAI, AE (DXB)	70 475 636	6.1
7	5	CHICAGO IL, US (ORD)	69 999 010	4.6
8	8	PARIS, FR (CDG)	63 813 756	2.8
9	9	DALLAS/FORT WORTH TX, US (DFW)	63 554 402	5.1
10	10	HONG KONG, HK (HKG)	63 121 786	5.9
11	12	FRANKFURT, DE (FRA)	59 566 132	2.6
12	11	JAKARTA, ID (CGK)	57 221 169	-3.6
13	18	ISTANBUL, TR (IST)	56 767 108	10.7
14	14	AMSTERDAM, NL (AMS)	54 978 023	4.6
15	16	GUANGZHOU, CN (CAN)	54 780 346	4.4
16	13	SINGAPORE, SG (SIN)	54 093 000	0.7
17	15	DENVER CO, US (DEN)	53 472 514	1.7
18	19	NEW YORK NY, US (JFK)	53 254 533	5.6
19	21	SHANGHAI, CN (PVG)	51 687 894	9.5
20	20	KUALA LUMPUR, MY (KUL)	48 930 409	3.0

16. Figure: World's busiest passenger airports. (Source: ACI)

World's busiest airports – Preliminary ranking
Table 3 – Total air cargo traffic 2014

RANK 2014	RANK 2013	AIRPORT CITY / COUNTRY / CODE	CARGO (Metric tonnes) Loaded and unloaded	CARGO (Metric tonnes) Percent change
1	1	HONG KONG, HK (HKG)	4 415 983	6.0
2	2	MEMPHIS TN, US (MEM)	4 258 531	2.9
3	3	SHANGHAI, CN (PVG)	3 181 654	8.6
4	4	INCHEON, KR (ICN)	2 557 681	3.8
5	6	ANCHORAGE AK, US (ANC)*	2 492 754	3.0
6	5	DUBAI, AE (DXB)	2 367 574	-3.1
7	7	LOUISVILLE KY, US (SDF)	2 293 231	3.5
8	10	TOKYO, JP (NRT)	2 133 542	5.6
9	8	FRANKFURT, DE (FRA)	2 131 976	1.8
10	11	TAIPEI, TW (TPE)	2 088 727	6.2
11	9	PARIS, FR (CDG)	2 086 487	0.8
12	12	MIAMI FL, US (MIA)	1 998 779	2.8
13	13	SINGAPORE, SG (SIN)	1 880 100	0.4
14	14	BEIJING, CN (PEK)	1 848 251	0.3
15	15	LOS ANGELES CA, US (LAX)	1 816 269	3.7
16	16	AMSTERDAM, NL (AMS)	1 670 676	6.7
17	17	LONDON, GB (LHR)	1 588 655	4.9
18	18	GUANGZHOU, CN (CAN)	1 454 044	11.0
19	21	CHICAGO IL, US (ORD)	1 377 664	12.1
20	19	NEW YORK NY, US (JFK)	1 303 889	0.6

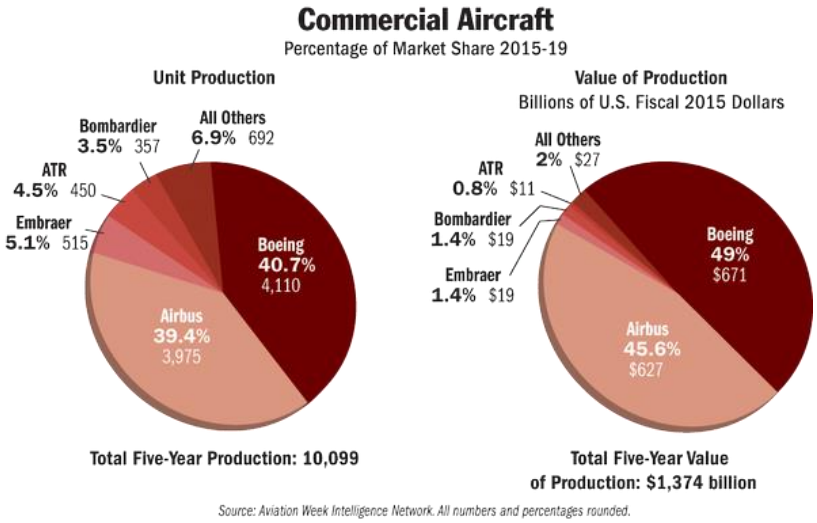
*includes transit freight

17. Figure: World's busiest airports – air cargo traffic 2014. (Source: ACI)

Aircraft and engine manufacturers

Undoubtedly, the world's largest commercial aircraft manufacturers are *Airbus* and *Boeing* (while *Bombardier* and *Cessna* are leading in business jets), having altogether a market share of around 90%, and it will unlikely to change at a large extent within the next few years.

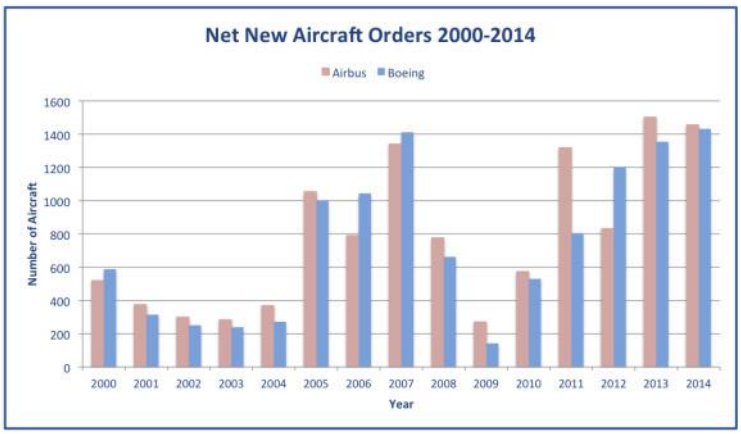
In 2008 a new ambitious company entered into the market, namely, the Chinese Comac. With their presence, Asian commercial aircraft production appeared on the stage. It is possible that they will continue to grow within the next few years, but it is rather unlikely that they will shortly become fierce competitors to Boeing or Airbus. Especially that other companies like Bombardier also take their part from commercial aviation, but with minor role.



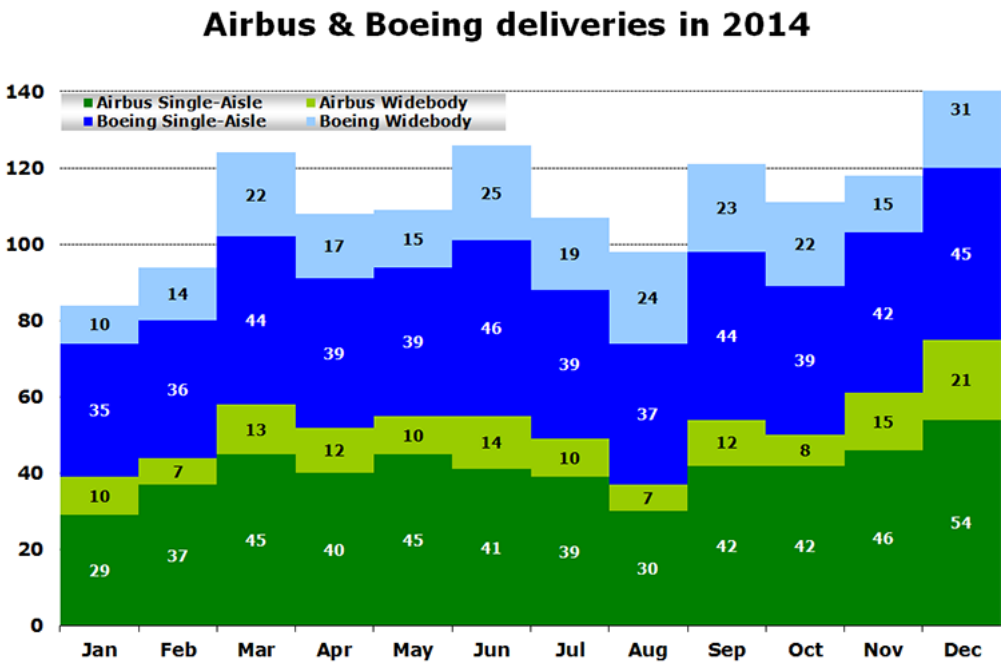
18. Figure: Market share of commercial airliners – prediction for 2015-2019. Source: Aviation Week Intelligence Network.

The companies are competing head to head in both wide-body (eg. B747, A380), both single-aisle aircraft (eg. B737, A320) production. In the year 2014, they delivered over 1300

frames to their costumer airlines. The deliveries have grown by 6% comparing to the previous year.[61] Though the number of deliveries and market share has been slightly higher for Boeing for the past decade and last year, Boeing could deliver more aircrafts, while Airbus had more orders in total. The graphs below well represent the close race between the companies.



19. Figure. Aircraft Orders 2000-2014. Source: CAPA.

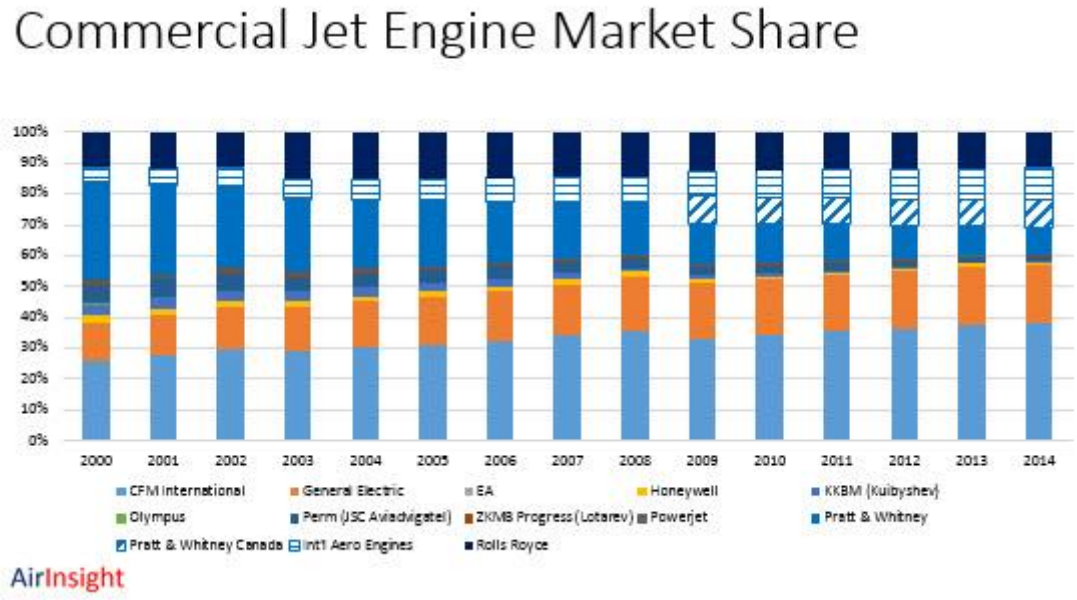


20. Figure. Deliveries of Airbus and Boeing for the year 2014. Source: anna aero (airline network news and analysis)

[61] anna aero: Airbus-Boeing 2014 deliveries up 6%; Seattle wins as Airbus hands over #1 A350-900 to Qatar Airways. 16 Jan 2015. Market Trends. (available at: http://www.anna.aero/2015/01/16/record-year-for-airbus-boeing-seattle-wins-delivery-race/, visited: 2015. 04.30.)

Due to the expanding aviation sector and to the need to change aircrafts, the demand for their products will probably increase further. In order to shorten the waiting list for their products, Boeing, for instance already had to fasten its production rate.[62]

Regarding jet engine producers, the market is more diverse with more leading companies apparent. At the moment CFM, being the provider for the most popular single-aisle aircrafts (737s and A320s) could develop a leading role. In regards with wide-body planes, on the other hand, GE (with being the manufacturer for B777 engines) and Rolls Roys (with market share of 10-15%, exclusive producer for the new A350s and A330 and orders in A380) have secured their positions.[63]



21. Figure: Commercial Jet Engine Market. (Source: AirInsight).

[62] Trepis Team. Boeing Leads Airbus In The Race For New Commercial Airplane Orders In 2014. 08/18/2014. Forbes (available at: http://www.forbes.com/sites/greatspeculations/2014/08/18/boeing-leads-airbus-in-the-race-for-new-commercial-airplane-orders-in-2014/, visited: 2015.04.29.)

[63] Schonland, Addison. The Engine Game. 2015. AirInsight. A Commercial Aviation Consultancy. Available at: http://airinsight.com/2015/05/06/the-engine-game/#.VWGeUNLtmkp, visited: 2015.04.29.)

Although, as previously mentioned, aviation still goes under a more or less steady-growth at an overall level, the companies listed in this subchapter are currently the most important in the industry and probably will be in the near future.

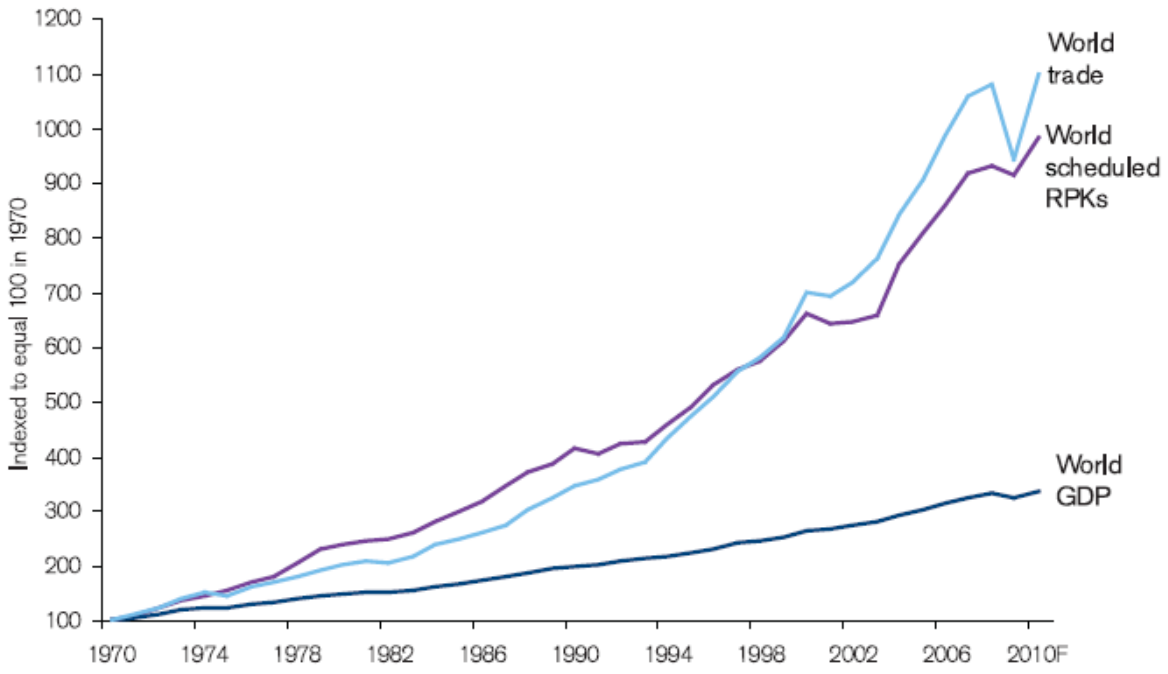
Therefore, for policy implications it is important to calculate with them, and to observe their specificities mainly as they determine the whole sector and are responsible for the controlling measures introduced in emissions.

After we have gained a basic view of the structure of aviation, in the next subchapter I show how the whole air transportation industry contributes to the economy, which is one of the important points to take into consideration when we decide to develop policies on climate change reduction.

3.2.2. Economic performance

International Air Transport Association (IATA) in its 2007 report shows that aviation is one of the most important stimuli for world economy. Within the last four decades it managed to reach a ten times growth, which is 3 times larger than that of the world economy.[64]

[64] Porter, Michael E. International Air Transport Association Vision 2050. 2011, IATA Report. p. 4.



22. Figure: Air Travel Expansion from the 1970's (Source: IATA)

It highly facilitates the reach to markets and maintaining connection between them and helps countries to be integrated into world economy. It boosts productivity and growth in the long term taking into consideration the factors of production (eg. labor and capital). In addition, enables facilitated reach to resources and improves the competitiveness of countries through connectivity and the additional GDP generated. IATA encourages further investment in aviation as the average rate of return from the industry continues to be large.

Beyond the above, it finds that capital investment has a significant effect of productivity of labor. With a +1% change in investment, productivity grows by about 0.37%. At the same time, focusing on R&D in aviation could further increase productivity. They led to the conclusion that on a long run, investment affects more developing countries'

productivity due to their present smaller connectivity that can be improved through developments in aviation industry.[65]

	Kenya	Cambodia	Jordan	El Salvador	Jamaica
Investment (US$ million)	351	538	360	488	168
Increase in national connectivity / GDP	59%	46%	55%	35%	28%
Impact on GDP (%)	0.42%	0.32%	0.39%	0.25%	0.20%
Impact on GDP (US$ million)	209	100	100	85	26
Annual Economic Rate of Return (%)	59%	19%	28%	16%	16%

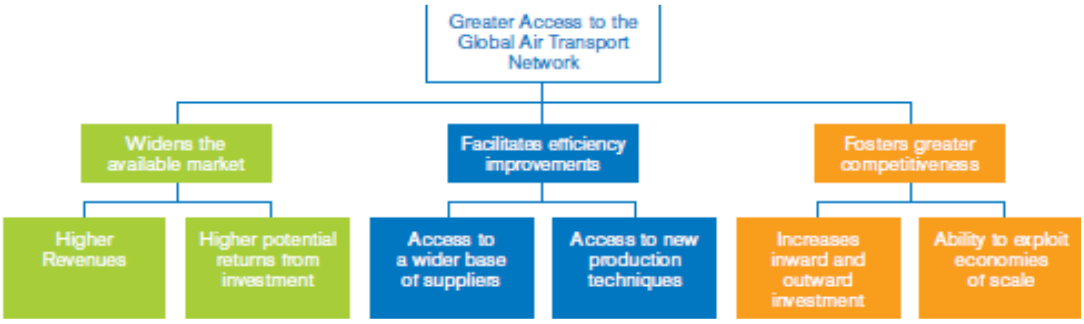
23. Figure: Aviation Investment and Economic Rate of Return (source: IATA)

One of the most direct effects aviation can have on the economy realizes through connectivity. Among other benefits, it enables even remote and secluded parts of the world to reach out to global markets and economy and also to facilitate their accessibility.

Other elements related to connectivity can be measured by the increased local competitiveness and efficiency development as a result of more apparent foreign presence. On the other hand, it stimulates companies, with now broader access to different markets to spend more on R&D if they aim to expand and grow their businesses. With gates opened up by aviation it becomes much easier for them. Supply structure can be made more flexible by the variety of possible products appearing and the decreased need for long run storage capacities.

IATA argues that a +10% change in connectivity might induce long term productivity and GDP increase of around 0.07% a year.[66]

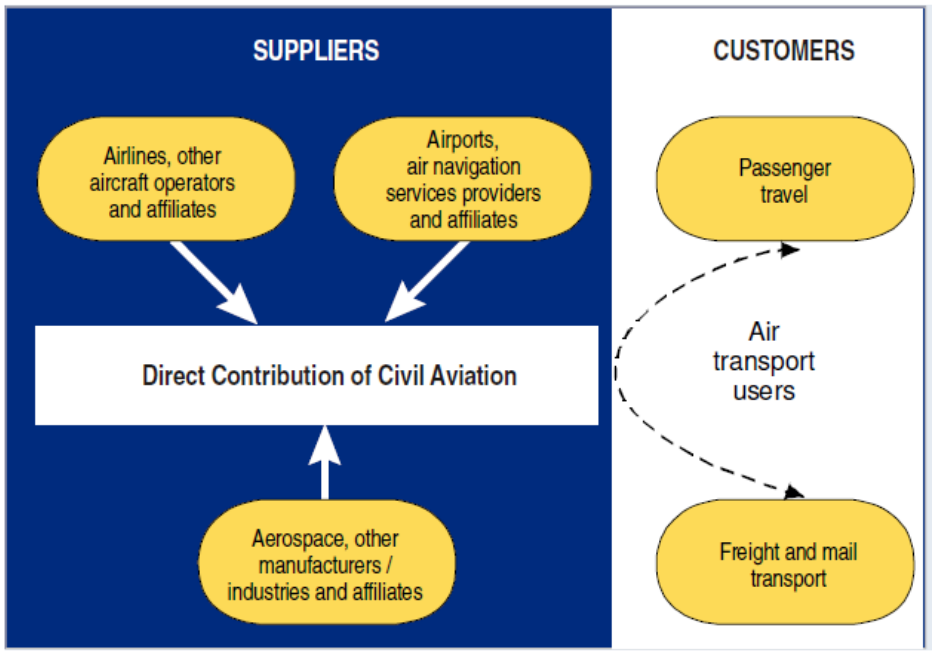
[65] Smyth, Mark; Pearce, Brian. Aviation Economic Benefits. IATA Economics Briefing Nº 8. (2007), pp.38. Chapter 1. IATA. (available at: http://www.iata.org/whatwedo/Documents/economics/aviation_economic_benefits.pdf, visited: 2015.05.02.)
[66] IATA. Aviation Economic Benefits. (2007) Chapter 05



24. Figure: Effects of connectivity on the economy. (Source: IATA)

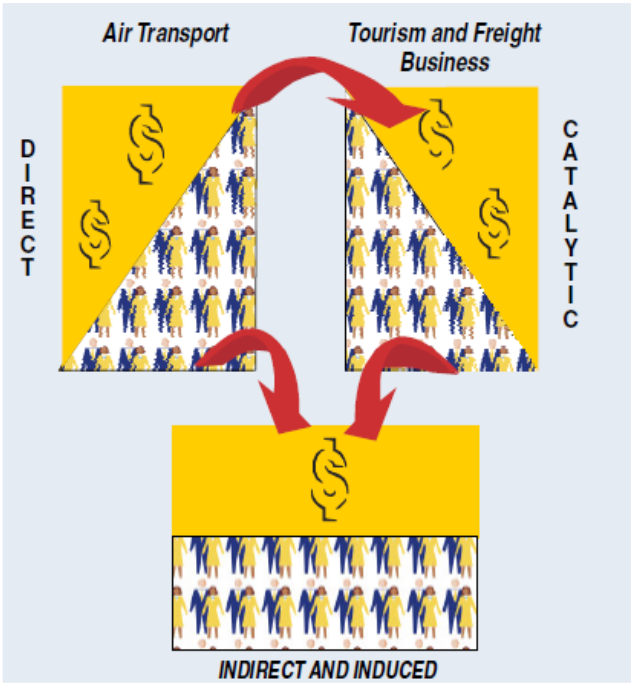
ICAO also observed the economic contribution of aviation, also focusing on the economic effects of different huge airports (eg. the Los Angeles Airport). It confirms the generally accepted view that the space of growth in the industry is greater than in most other sectors of the economy, with air transport being its major component. They consider the industry important in world economy. In 2001, for instance, when the organization made a research, it was responsible for about the 40% of the value of global manufacturer export and nearly half of the 700 million tourists used flights to reach their destinations.

ICAO differentiates between "direct" and "multiplier effects". The first one refers to the "final product" the industry offers, or in other terms, the direct services airlines provide (eg. cargo, travel) and to the sectors of the economy used by aviation (eg. labor force employed by aviation services).



25. Figure. Direct Contribution of Civil Aviation. Source: ICAO

The latter contribution, on the other hand, includes indirect labor and output created and other factors, defined by them as "catalytic" (travel, tourism, eg. hotels, excursions) and "induced demand effects" (consumer and public expenditures and income/revenues gained - both direct and indirect - eg. taxation, costs of air travel).



26. Figure: Indirect and induced contribution of civil aviation. (Source: ICAO).

They estimate that by a 100 unit increase in jobs and 100 USD output produced by aviation, a circa 325 USD and 610 employments are supported in other sectors and that over 4.5% of the total global output is a side-product of air transport regarding GDP.[67]

The benefits of aviation are more apparent for developing countries. Tendencies show that the "center of gravity" in aviation seems to move towards those regions[68] that can further enhance their development and investment opportunities.

Similarly, *Air Transport Action Group (ATAG),* in collaboration with *Oxford Economics*, created a report on the weight and benefits of air transportation. They estimate that aviation has about 2.4 billion USD impact on the economy.

Moreover, according to them, more than 58 million workplaces are created by the industry worldwide, comprising of aviation itself (employing around 8.7 million people directly) and generated tourism activities, making it one of the greatest employers. To global economy, this employment rate adds 3.5 times more, than by jobs in any other industry.

The nature of employments aviation provides is extremely diverse, but it is a sector, which employs and requires an exceptional number of high-skilled labor-force, including engineers, analyst, technicians and lawyers that need specific and sophisticated training. Hence, it also promotes capital investment in education and increases productivity through the highly-skilled and experienced workforce. To be able to employ people for its needs, different sectors of aviation offer good opportunities for training and specific education.

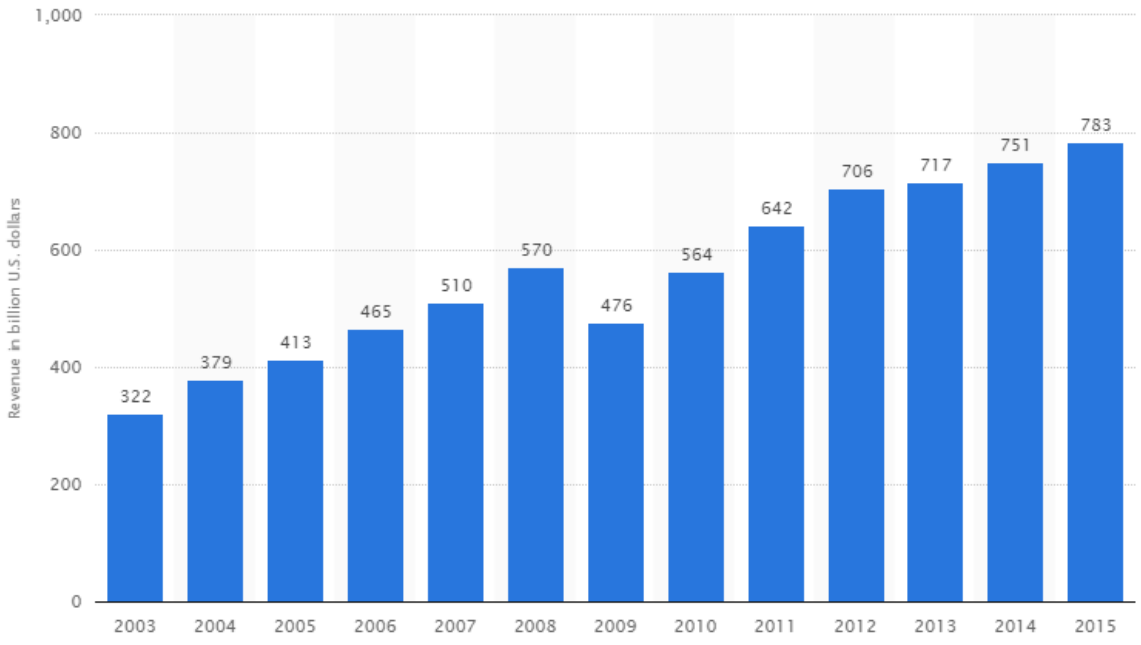
The industry produces more than 600 billion USD of GDP per annum, and on the predictions of IATA, from the 2004 level of 369 bn USD, by 2014, this amount approximately doubled to about 740 bn USD. If we substituted this amount as that of a

[67] ICAO: Economic Contribution of Civil Aviation. Circular 292-AT/124 (2005). pp.
[68] Clayton, Edward. 2015 Aviation Trends. Industry Perspectives. PWC. (2015) (available at: http://www.strategyand.pwc.com/perspectives/2015-aviation-trends, visited: 2015.05.03.)

country, it would globally rank around the 21st place, overtaking some of the G20 countries even.[69]

It stimulates investments, spending and government revenues. The industry, taking into consideration its volume, is one of the greatest tax payers worldwide, responsible for contributing to the state budget for various bases directly and indirectly (corporate taxes, PIT, taxes on transportation, export and import, etc.).

According to Statista, the 2014 revenues rose to 783 bn USD, which counts for a 7.4% compound growth per annum. They denoted the year 2009 as the beginning of "golden age" in aviation, as a result of it. The EU, Brazil, the US and China are now amongst the most significant markets.[70]



27. Figure: Airline revenues created annually in bn. USD (source: Statista)

[69] ibid.

[70] Statista. Revenue of commercial airlines worldwide from 2004 to 2015 (in billion USD). (available at: http://www.statista.com/statistics/278372/revenue-of-commercial-airlines-worldwide/, visited: 2015.05.10.)

Other projections by ATAG show that by 2026 its support to world GDP will reach around 1 000 billion to the world GDP. Altogether, it contributes to about the 3.4% of global GDP.

However, in trade, air transportation only carries around half percent of all shipments, in money terms it makes a significant amount of around 35%, of world trade as commodities transported through the air usually hold greater value. In 2012, over 6 trillion USD value goods were carried via air.

With the fast development of Asian countries, world trade expands rapidly, which is relying more on more on aviation therefore, being a fast and reliable method for the transportation of goods, including products that cannot survive for a long period of time, such as some food products, vegetables and fruits. Their exporters are highly dependent on air transportation to be able to export their products. ATAG states, that around 1.6 million "livelihoods" are involved (directly or indirectly) in the transportation goods to only the UK market, which is only a small percentage of any such activities.[71]

With regards to traffic, more than 3 billion passengers have been travelling by airlines globally within 2013. The sector has 80% greater occupancy than any other means of transportation. The majority of passengers were domestic passengers and the busiest pathway was the Asia-Pacific route.[72]

Tourism is one of the greatest accelerators of economic growth, creating several jobs and inducing spending. More than half of international tourists now travel by air transportation. Thus, countries secluded can be reached more easily, promoting tourism and development in those areas previously not reachable. Thanks to aviation, the costs and speed of travelling it offers, a greater number of travelers decide to discover far-lying regions or island nations which would be hard and lengthy to reach by any other means of transportation.

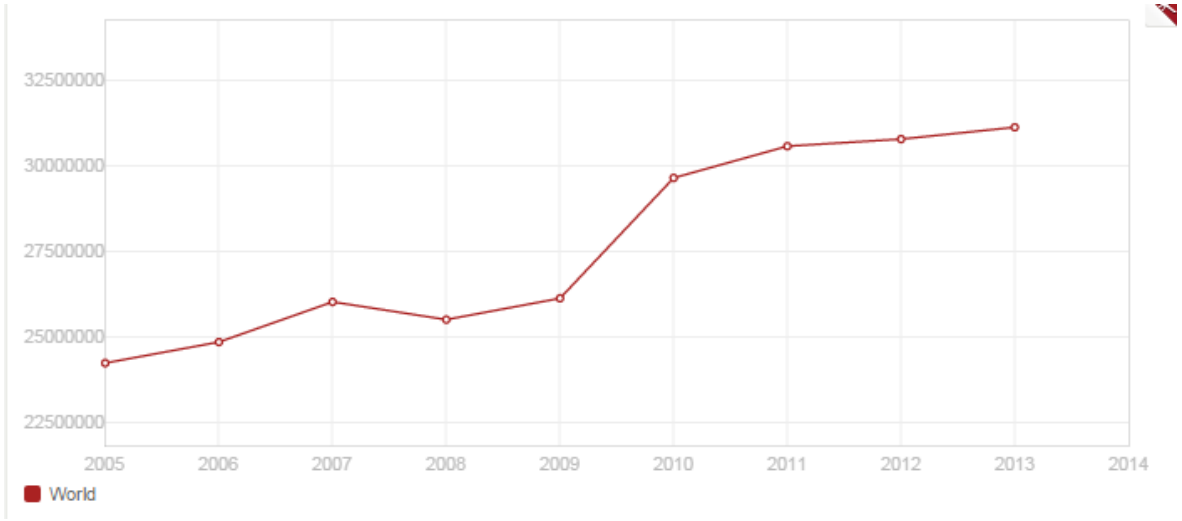
[71] Air Transport Action Group (ATAG). Aviation: Benefits Beyond Borders. (2014) ATAG: Geneva, Switzerland. pp. 68., p. 13.
[72] ATAG. Aviation benefits. Executive summary.

These regions include underdeveloped parts of the world like African and Asian countries. ATAG estimates that about 2.5 million African jobs are supported by visitors carried by airlines.[73] The income generated by tourism in the destination country can serve as a fund for development and a natural stimulator to improve living conditions and the catch up with developed countries without any artificial and sometimes questionable economic intervention, such as direct fund aids.

Apart from transportation, world trade and services and tourism, high-tech industry and innovation is strongly supported by aviation. In order to be able to constantly serve the demand at the most cost efficient and in the safest way, and to enhance competitive position, aviation industry constantly requires technical advancement. One of the regions harvesting from it was the emerging Asia-Pacific market, where often cheap and advanced technological producing capacities and rapid development is observable. It well attracted investment from aviation industry (with special regards to Boeing) in countries such as Japan and China, Malysia and Signapore which catalyzed the development. [74]

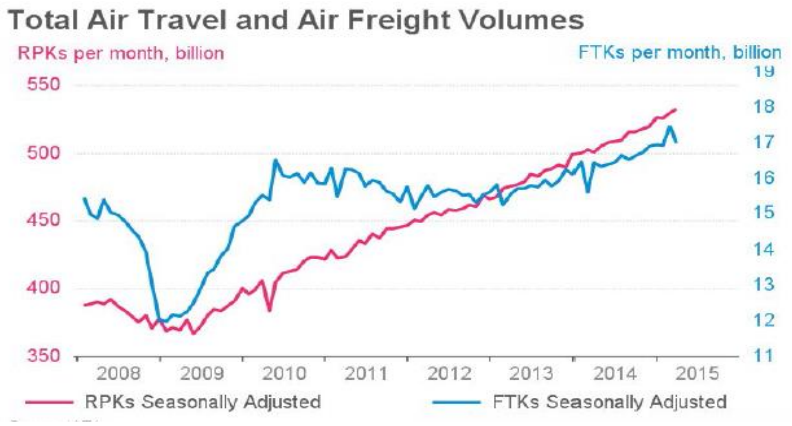
Based on the World Bank database, the number of take-offs by registered carriers has significantly reached within the last decade, reaching over 31 million departures in the year 2013.[75]

[73] Ibid.
[74] ATAG. Aviation benefits. p. 11.
[75] The World Bank. Data. Air transport, registered carrier departures worldwide. (available at: http://data.worldbank.org/indicator/IS.AIR.DPRT/countries?display=graph, visited: 2015. 04.29.)



28. Figure: Number of departures by commercial airliners. Source: World Bank.

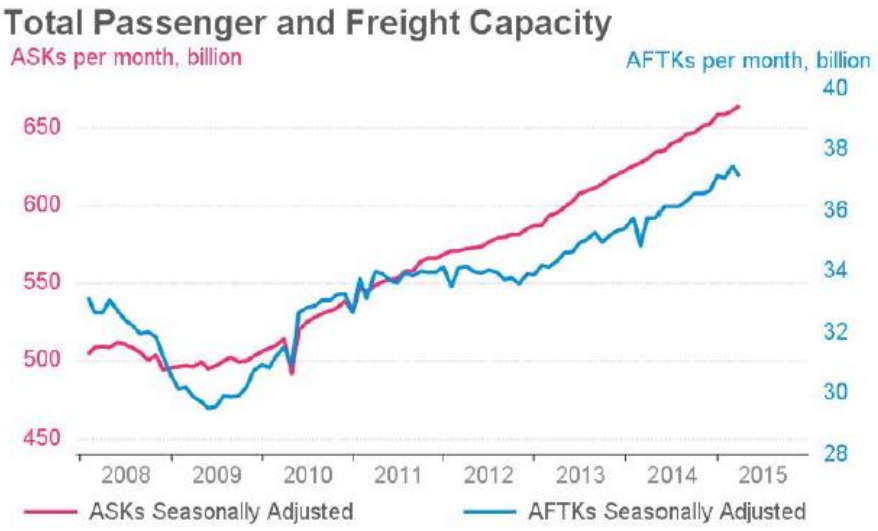
IATA economics forecasts a further increasing demand for passenger aviation for 2015 and it sees an expansion in it rate of growth. The decrease in fuel prices also can trigger demand.[76] Although, during the economic crisis in 2008 aviation also faced a huge shock with a severe decline, but after the year it again began to regenerate. From the graph below, the volume of air transportation is constantly growing from then on, and based on the majority of forecasts, it will expand more in the future.



29. Figure: Air Travel and Air Freight Volumes in Revenue Passenger Kilometers (RPK) and Freight Tonne per Kilometers (FTK). (Source: IATA)

[76] IATA Economics, Airlines Financial Monitor. March-April 2015 (available at: http://www.iata.org/whatwedo/Documents/economics/Airlines-Financial-Monitor-Apr-15.pdf, visited: 2015.05.10.)

A similar positive re-growth is shown in the industry's capacity. One of the explanations for it is that the industry has to respond to the growth in demand to provide it with the necessary amount of supply.



30. Figure: Total Passenger Fright Capacity from 2008 measured in Available Seat Kilometers (ASK) and Available Freight Tonne Kilometers (AFTK) (Source: IATA)

Load factors for both passenger, both cargo is on an increasing level as well, which well indicates that the demand contributes to better occupancy and load during flights. According to IATA, the sharper growth in passenger load can be attributed to the increasing demand (despite the expansion in seat capacity). The increase is more perceivable on domestic passenger flights. Regarding cargo, the higher expansion in Air Freight Capacity, the increasing demand kept the load factor at its previous level, due to the simultaneous expansion in capacity at a larger space.[77]

[77] ibid.

31. **Figure: Load factors and Passenger and Freight Markets in Passenger Load Factors (PLF) and Freight Load Factors (FLF)**

Surprisingly, despite the fact that airline industry continues to expand quickly with increasing demand and the huge amount of GDP it generates, its profit margin remains very low, about 3% altogether. It is especially the case of passenger airlines that often struggle for survival and for positive outcome.[78]

Industrial forecasts

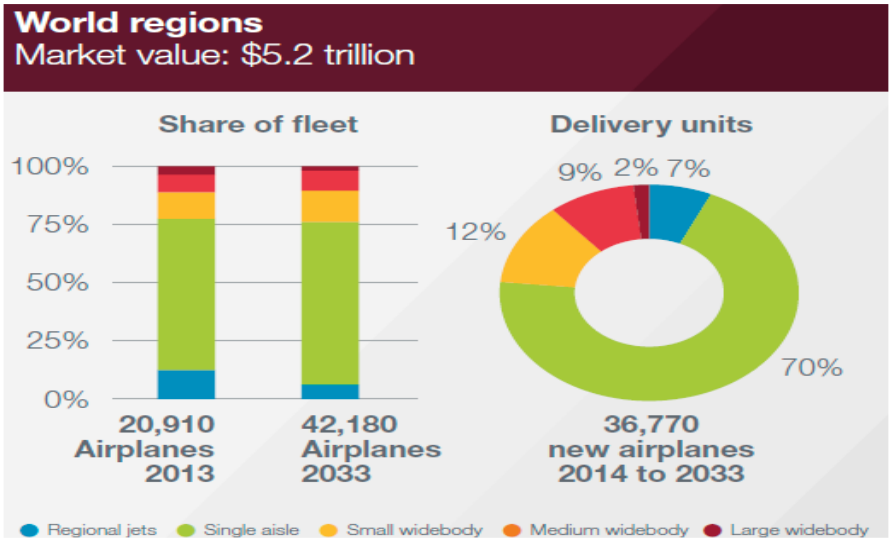
As aforementioned, the majority of predictions show a continuous growth in aviation, gaining more weight in world economy over the century. The growth can be indicated with the expected number of jobs, GDP generated, air cargo volume, production of aircrafts and equipments, expansion of tourism, outreach to isolated regions, acceleration of world trade, passenger volume, R&D activities related and other relevant indicators. Though, some of

[78] Clayton, Edward. PWC.

them are extremely difficult to measure punctually directly in line with aviation, its role is obvious.

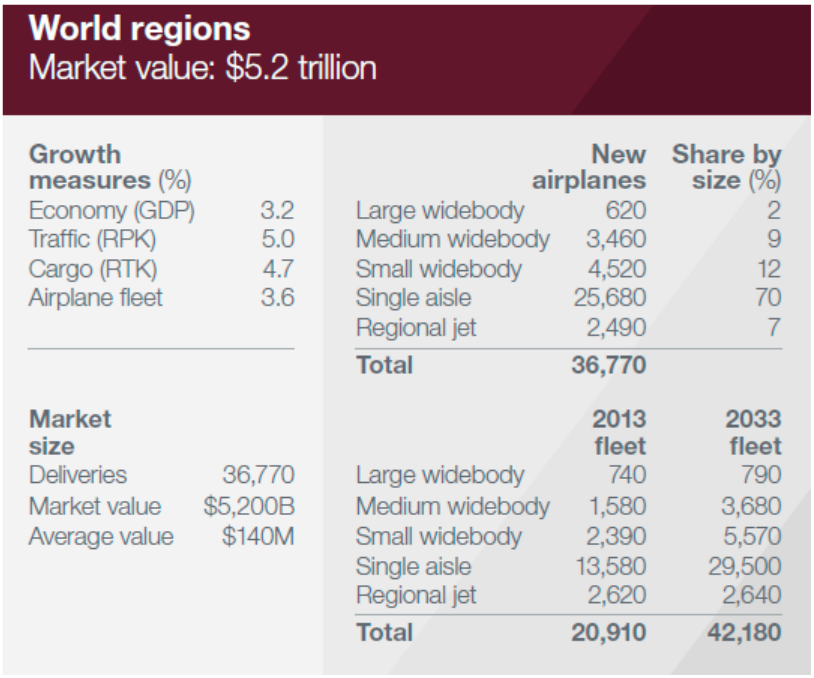
In their vision, the IATA, by 2050 forecasts to carry a yearly 16 bn passengers and over 400 million t of freight. Once, because of the increase in population, second, because they project an expansion two times bigger than that of the GDP. On the other hand, they expect great technological advances that are more sustainable, which enables a greater expansion at the market.[79]

Boeing calculates a growth in demand for aircrafts, reaching altogether over 36 thousand new planes, worth about 5.2 trillion USD, with a 3.6% increase in air traffic. About half of them will serve to substitute elder planes in service, the majority of which will be written out. Single-aisle planes will continue to be the primary targets of market demand (but in wide-body aircraft growth is expectable as well). The large increase, from one hand, can be attributed to emerging markets, where the rate of expansion will be greater than in developed regions. In terms of GDP, a 3.2% rise is projected with revenues from cargo and passenger traffic simultaneously increasing on a global average.



32. Figure. Aircraft demand growth by 2033 (Source: Boeing)

[79] IATA Vision 20150. p. 61.



World regions
Market value: $5.2 trillion

Growth measures (%)	
Economy (GDP)	3.2
Traffic (RPK)	5.0
Cargo (RTK)	4.7
Airplane fleet	3.6

Market size	
Deliveries	36,770
Market value	$5,200B
Average value	$140M

	New airplanes	Share by size (%)
Large widebody	620	2
Medium widebody	3,460	9
Small widebody	4,520	12
Single aisle	25,680	70
Regional jet	2,490	7
Total	**36,770**	

	2013 fleet	2033 fleet
Large widebody	740	790
Medium widebody	1,580	3,680
Small widebody	2,390	5,570
Single aisle	13,580	29,500
Regional jet	2,620	2,640
Total	**20,910**	**42,180**

33. Figure. Air transportation growth by 2033. (Sorce: Boeing)

As demand grows and the industry expands, within 20 years they believe that over half million new pilots and technicians will be required by the industry. Training on advanced technology will be a priority.[80]

At the same time, the industry has to keep in mind other factors in their growth like fuel efficiency – especially as oil resources are limited and the emissions. It must be able to provide an eco-friendly, sustainable growth, which will be more accentual in the future.

3.3 Aviation and climate change

A number of people are afraid of contrails on the skies now, claiming that they are products of chemical weapons of mass destruction, naming these stripes as “chemtrails”. According to them, aviation is a tool to poison the people and the environment. These

[80] Boeing Current Market Outlook 2014-2033. 2015. Boeing Market Analysis..

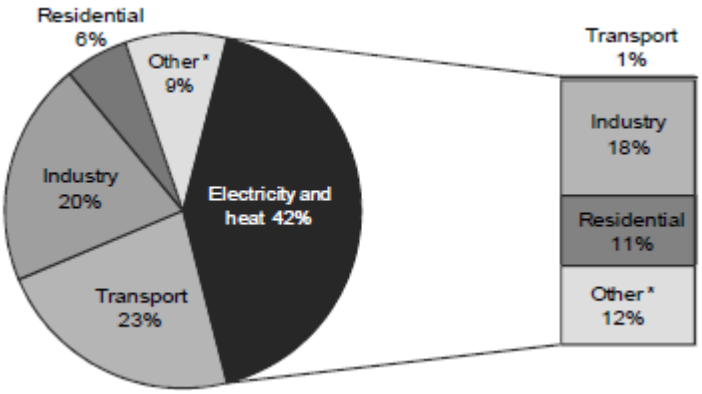
conspiracy theory statements about the harmful nature of aviation, though, completely lack scientific knowledge and validity.

At the same time, leaving behind the world of conspiracy theory and urban legends believers, we might say that aviation can have negative contribution to the environment, thus, to human well-being and health, but rather from other perspective, from its addition to climate change. Even condensation trails can have environmental effects, but not in a way conteo followers suppose. The next part of the thesis is dedicated to introduce such effects. But, how significant are they? The current subchapter tries to clear misperceptions about the greenhouse impact of aviation.

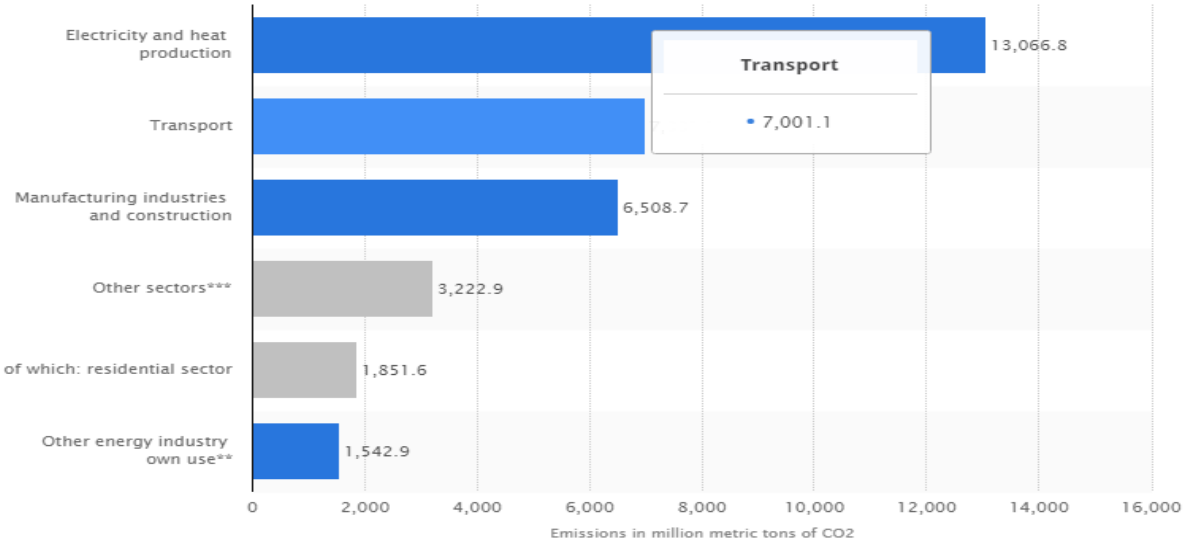
3.3.1. Measuring impacts - emissions and other factors

As referred previously, energy use accounts for about the 2/3 of all emissions that include fuel usage. The leading consumers of energy are the industrial and transportation sectors. Over 90% of fuels used in transportation are petroleum products[81], one source that are responsible for CO_2 emissions into the atmosphere, the gas, which plays the major role in GHG emissions. For instance, in 2011, about 33 bn metric tons of carbon-dioxide had been released into the air by human activities. Over 7 bn metric tons of emissions are arising from transportation itself. It is about the 21% of the total emissions. Results gained from other sources are similar. The International Energy Agency (IEA) estimations show that in 2012, transportation was responsible for about the 23% of total emissions. As we can see, transportation counts for more than 1/5 of emissions.

[81] see eg.: eia. U.S. Energy Informatioan Administration. Energy Perspectives: Industrial and transportation sectors lead energy use by sector. (available at: http://www.eia.gov/todayinenergy/detail.cfm?id=9250, visited: 2015.03.30.)



34. Figure. Figure. Emissions of CO_2, by sector – 2012. (Source: IEA)



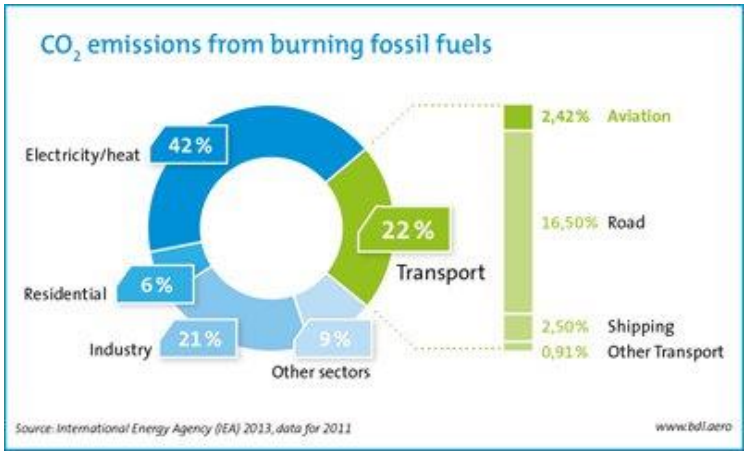
35. Figure: 2011 CO_2 emissions by sector in bn metric tons. (Source: Statista)

ATAG reveals that over the year 2013, of the total amount of more than 36 billion tons of carbon-dioxide, aviation made a contribution of 705 million tons. In global comparison, in average, it makes about the 2% of human emissions. At the same time, comparing to the 58% rise in the heat and electricity sector between 2000 and 2011, aviation emissions rose by 13% only, partially due to more advanced technologies.[82]

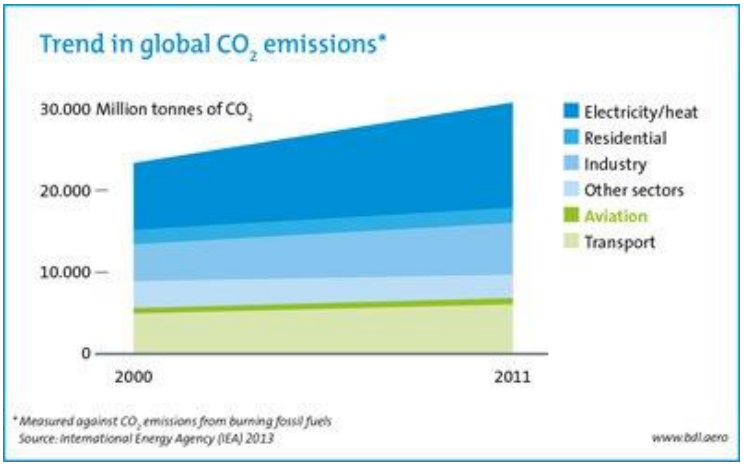
Within transportation it stands for about 12% that is highly lower than that of road transportation. Around the 80% of the whole emission is a product of journeys over 1 500 km.

[82] BDL. Energy Efficiency Report 2014. (available at: http://www.bdl.aero/en/bdl-reports-en/energy-efficiency-report-2014/, visited: 2015. 05.12.)

On these routes, generally there is no proper alternative mean of transportation to switch to. In use of jet fuel it meant a circa 273 bn liters, worth about 210 bn USD.[83]



36. Figure. CO_2 emissions from fuel. (Source: BDL)



37. Figure. Global emissions, all industries. (Source: BDL)

When we talk about aviation, we should not stick with CO_2 measures. Assessing the elements related to climate change. There is much more than that. The IPCC created a special report on aviation in 1999, where they listed in details the contribution of aviation to climate change. Later, in their 2007 and 2014 report they adjusted their findings.

Apart from CO_2, via aviation, other substances also get into the stratosphere, the troposphere and finally the atmosphere, modifying greenhouse volume that need to be taken

[83] ATAG report

into account when addressing climate change. Other major components of aviation emissions are H_2O (water vapor), soot, SO_x (sulfur oxides), NO_2, and NO (NO_x together). Their combined radiative forcing will probably be 2-4 times than the forcing power from aviation CO_2 emission solely. In addition to that, IPCC projects a growth in emissions, with the CO_2 estimating around 2% growth. Its estimates show an approximate that aviation is responsible for 3% of human radiating force contribution, which might increase to 5% (0.19 Wm^{-2}) by 2050.[84]

The IPCC report reveals the following findings on the emissions:[85]

- *Ozone (O_3) production* (which is a GHG that also protects the surface from malicious UV rays in upper stratosphere) increases in lower altitudes where subsonic planes fly (9000 – 13000m or 27 000 – 42 000 feet), as NO_x catalyzes its production at these heights. Approximately 6% increase is produced by air transportation, which is projected to grow about 12% within the half of the 21st century. This increase will likely to enhance greenhouse effect and climate change, though its extent is unclear. However, in the upper stratosphere and with supersonic planes that fly at higher altitudes, where NO_x have a different effect and water vapor and sulfur thins ozone layer partially. At the same time, NO_x emission curbs CH_4 concentration indirectly, that has minor cooling effect.

  The thicker the ozone layer, the less GHG is able to escape to the space, thus fuelling warming. (Whereas, too thin ozone layer has adverse effect, by letting harmful UV rays into the surface).

[84] IPCC Special Report. Aviation and the Global Atmosphere. (1999) edited by: Penner, Joyce E.; Lister, David H. Summary for Policymakers. Cambridge University Press. (available at: http://www.ipcc.ch/ipccreports/sres/aviation/, visited: 2015.05.05.) p. 6.
[85] IPCC Special Report. Summary for Policymakers. IPCC Report 2007, IPCC Mitigation of Climate Change 2014. Chapter 8.

- *Condensation trails and cirrus clouds*: Condensation trails (formulated by water vapor also being GHG) cover about the 0.1% of the skies and it projected to increase to 0.5%. They, similarly to thin clouds in the air, contribute to the warming as they actually act as them. Although clouds also reflect sunlight back into space, their component is water vapor that retains heat and contributes to warming. Their exact radiating force, though, is unclear. In addition, they induce the creation of cirrus clouds (about 0.4%) that cover about the 30% of the sky. The problem with them is that they tend to magnify global warming. From the incoming sunlight they let about the 9/10 to reach the surface, while reflects only a minor, about 1/10 back with the albedo effect. Nonetheless, about the 50% of the infrared light from surface is reflected back by the cirrus clouds. The increased thermal radiation in the atmosphere accelerates warming.

- Other substances such as water vapor in lower altitudes and soot also add to the radiating effect for a similar raison.

As it reveals from the report Albeit, lately, emissions from newer aircrafts decreased, without more stringent measures, due to the industrial expansion, they would probably grow over the period of time.

The following table shows some patterns of approximate emissions from different aircraft. durint landing and take-off phase. (LTO).

Aircraft type	CO	CO2	HC	NOx	Fuel
Airbus A319	0,73	2310	0,59	8,73	730
Airbus A320	0,77	2440	0,57	9,01	770
Airbus A321	0,96	3020	1,42	16,72	960
Airbus A330-200/300	2,23	7050	1,28	35,57	2230
Airbus A340-200	1,86	5890	4,2	28,31	1860
Airbus A340-300	2,02	6380	3,9	34,81	2020
Airbus A340-500/600	3,37	10660	0,14	64,45	3370
Airbus A380	2,44	7378,6	0,81	58,08	2342
Boeing 737-300/400/500	13,03	2480	0,84	7,19	780
Boeing 737-600	8,65	2280	1,01	7,66	720
Boeing 737-700	8	2460	0,86	9,12	780
Boeing 737-800/900	7,07	2780	0,72	12,3	880
Boeing 747-200	79,78	11370	18,24	49,52	3600
Boeing 747-400	26,72	10240	2,25	42,88	3240
Boeing 777-200/300	12,76	8100	0,66	52,81	2560
MD-11	20,59	7290	2,37	35,65	2310

6. Table. Emissions by different types of aircrafts in kg/LTO. (Data source: ICAO)

From the table we can see that newer aircraft has better performance regarding emissions. For instance, the biggest aircraft, A380 produces less emission, than the smaller A340 (also a four-engine wide-body plane). We can even more perceive the difference in generation when we look at the emission of "jumbo jet", B 747, that the emission for the earlier aircraft (200 series) is way higher than that of the newer. Although the table does not contain the new 747-800 it has even better performance, being a good match for A380.

Just as in other fields of climate change, there are uncertainties in the exact impact of aviation. One of them is that, although by now there exist some more or less reliable measures to estimates emissions, but it depends on various factors. Hence, claiming that the climate footprint for a particular aircraft type is *x* tons needs careful consideration. Some of the

components that must be weighed when calculating consumption and emission are the following: aircraft type (weight, equipments, design, performance), engine type and performance, external and internal characteristics of the flight (eg. altitude, flight phase, speed, load), fuel composition among others.[86]

With their help we could give the fuel combustion for a particular flight complementing it with the kilometers traveled. This, in order to receive the total number should be calculated taking into consideration the number of flights during a certain period of time. Usually, when giving such results, the emission per available seat kilometers (ASK) or that of tonne-kilometers (ATK) are used as units of measurement.

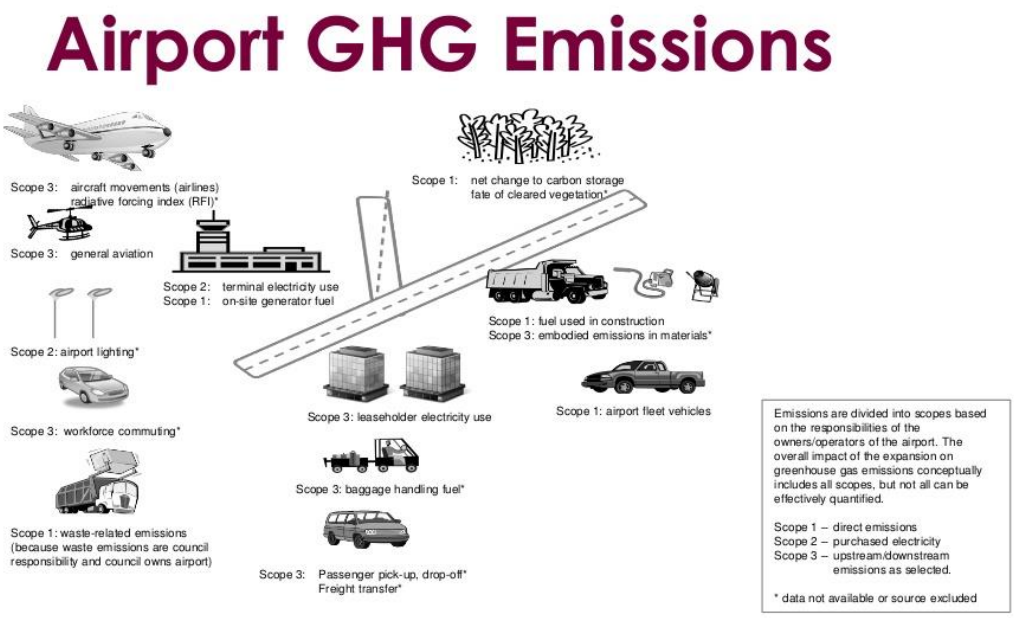
Other uncertainty is arising from the hard estimation of exact effects aviation emissions other than CO_2, especially at higher altitudes, although scientific experiments have helped to provide some measures. While some particular aircraft types are well-predictable due to the knowledge about them, some are less.

Probably, the 2% of total climate change effects arising from aviation, for the first instance does not seem a tremendous amount and even on the above graph comparing to all emission arising from different resources it seems only a tiny bit, we shall not forget that if we compare it to the number of industries existing in the world it makes another sense. At the same time, everything is a matter of perspective. If we measure the personal footprint for each method of transportation, we might end in air transport being the highest emitter of all, having the largest footprint per passenger kilometer. At least, some claim so. For the year 2013, BDL revealed an average fuel consumption of only 3.68 liters/100km/passenger.[87] If we consider the average consumption for example of a car is about 7 liter/100 km (but could be

[86] Bernardo, Jose; Boling, Brian. CO_2 Emission Metrics for Commercial Aircraft Certification: A National Airspace System Perspective. (2012) Partnership for AiR Transportation Noise and Emissions Reduction, Massachusets Institute of Technology (available at: http://web.mit.edu/aeroastro/partner/reports/proj30/proj30ato.pdf, visited: 2015.05.05.)
[87] BDL. Energy Efficiency Report 2014.

significantly higher or lower depending on several factors). If only one person is travelling in a car, personal footprint is higher than in case of aviation. We shall not forget that aviation is to be the mean of transportation with highest occupancy rate, so we can approach the issue from several sides.

This, on the other hand only embodies air transportation sector, which is a segment of the whole aviation industry. The related segments, like airports, infrastructure, manufacturing and services with their energy use contribute to emissions as well. The exact extent of how much, though, would be hard to measure. The following image sheds lights on how it could happen for instance in case of airports. It can occur from the general operation of airports (electricity use, baggage handling and other airport vehicles, airport lightning, aircraft movement radiation) and joint activities (eg. through pick-up of passengers, consumption during construction).



7. Table. Greenhouse Emissions of Airports. (Source: CASANZ – Lisa Smith)

Nonetheless, we have seen from previous parts that aviation embraces various areas that are on a path of growth. Hence, for policy considerations, one should not forget about considering these factors apart from air traffic.

3.3.2. Mitigating impacts – the "historic" commitment

The IPCC in its 1999 report estimated that emission arising from air transportation will increase within the next 50 years, with the possibility to raise its contribution to 15%. Airlines, manufacturers and organizations realize more and more that they need to take steps against climate change. First as pressure and expectations are growing and second as they realized that for improving their performance they should reduce fuel costs which makes a large portion of the whole operation.

In 2008, aviation industry agreed on the reduction of emissions that has become the strategy for ATAG and for its members, signed by the majority of large actors in aviation industry, including aircraft and engine manufacturers.

In 2012 at the Doha UNFCCC round, they presented their commitments. At the same time, they put a pressure on ICAO to adopt common regulations and to coordinate the realization of the straty, and on the international community to introduce a global climate agreement.

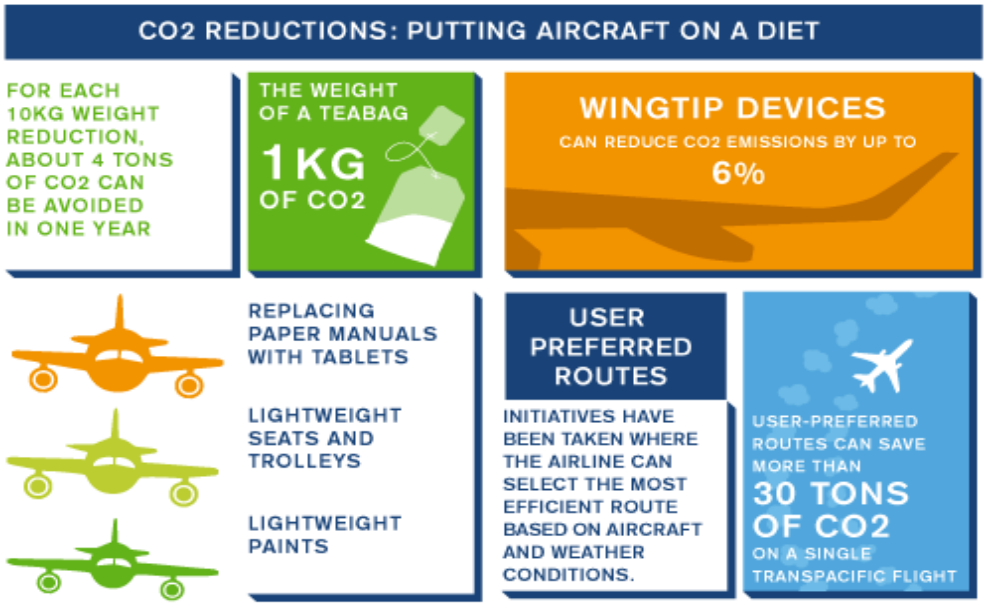
In 2013, at its 69th Annual General Meeting in Cape town, IATA embodied the strategies into a resolution. They later named it as a "historic agreement".

The strategy[88] consists of three main time-frames that are different phases of their carbon-neutral growth target. They apply a 4-pillar fuel efficacy method in order to mitigate emissions.

1. ***Technological development***: It builds on the incentive to replace the old fleet to newer models by investing around 1.3 trillion USD. A new generation of aircraft is about 1/5 more fuel efficient comparing to its predecessor thanks to the new technologies that are introduced at a rapid rate. One direction to move towards in the future will be the shift in fuel use to alternate fuels such as biofuels derived from algae and other renewable and eco-friendly resources that could curb emissions by about eighty percent.
2. ***Improving infrastructure:*** A decrease in flight time by 1 min can cut emissions by 100 kg/flight. It could be reached through an enhanced, unified management system, like "open sky" programs, where ATC is working in a common operation. Flying user preferred routes with choosing the most efficient aircraft and weather conditions can reduce emissions by 30 tons a year.
3. ***Performance and operational advancement:*** New methods and equipments are being used to decrease emissions. For instance, equipping aircrafts with wingtips, such as winglets and sharklets that are more and more widely used on aircrafts can cut emissions by 6%. Continuous descent landing might spare up to 150 kg of carbon-dioxide emission for each flight. Decreasing weight of aircrafts can cut emissions at a huge extent. This could be reached via various ways eg by installing

[88] see: A Sustainable Flightpath Towards Reducing Emissions. A Position Paper Presented by the Global Aviation Industry. (2012) UNFCCC Climate Talks, Doha. (available at: http://www.atag.org/component/downloads/downloads/203.html, visited: 2015. 05.16.) and IATA. Resolution on the Imlementation of the Aviation "CNG2020" Strategy". IATA 69th Annual General Meeting. (2013) (available at: http://www.iata.org/pressroom/pr/Documents/agm69-resolution-cng2020.pdf, visited: 2015.05.13.)

light weight seats, replacing paper materials and using lightweight paints. By 10kg decrease in weight, an additional 4 tons of CO_2 could be withheld.



38. **Figure.** **CO_2** Reductions through actions. (Source:: IATA)

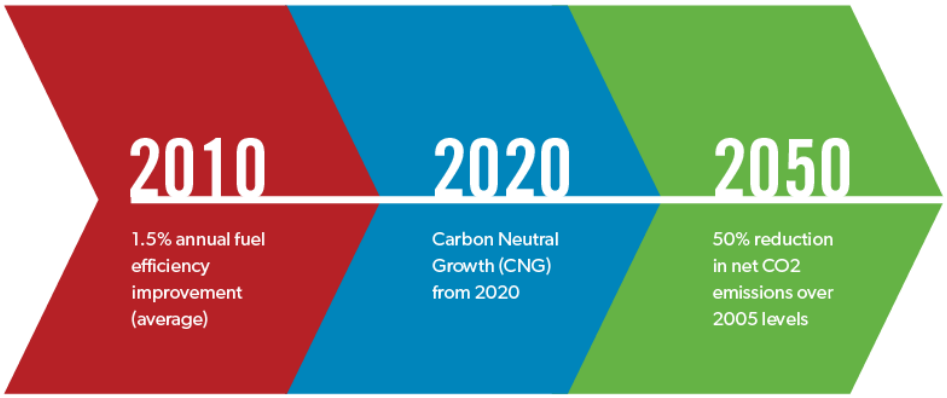
4. ***Cost-effective economic planning:*** In order to realize goals to maintain a carbon-neutral growth, careful and practical economic policies are needed. Market based strategies need to be elaborated at a global level in collaboration with governments. This fourth pillar was the core element of the strategy, placing a huge emphasis on the introduction of market-based measures (MBMs)

   They should provide the growth of aviation keeping in mind climate targets and economic rationale. They should avoid duplication and double taxation with the potential exclusion of market distortive measures and barriers in relation to aviation, while they incite additional investment into R&D to reduce harmful emissions.

   The sector considers levied taxes as “environmentally inefficient” and obstructive in light of climate aspirations and call for reductions. They advocate for the reinvestment of revenues gained out of the mitigation activity of the industry and

open outreach to carbon market. For smooth communication and ensuring global standards they would like to urge the establishment of common administrative bodies and the promotion of catch up and assistance for developing countries.

39. **Figure: CO_2** Reductions through actions. (Source:: IATA)



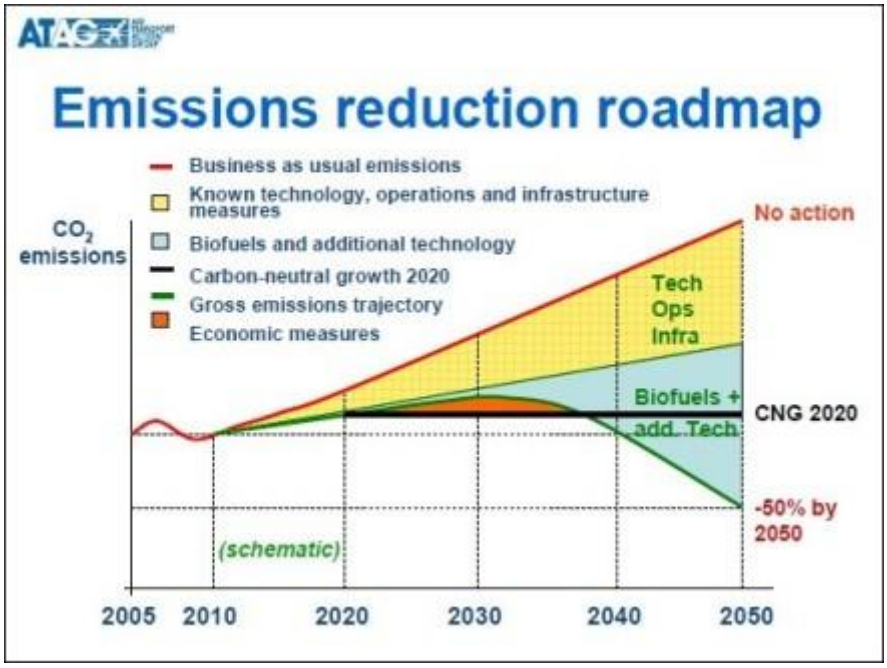
40. Figure. Aviation action plan for carbon-neutral growth. (Source: Airlines for America)

I. **phase: 2009 – 2020:** For the first period the industry targets to improve efficiency by 1.5% yearly. It would require the acquisition of over 10 thousand new aircraft, at a value of about 1.3 trillion USD by 2020. In the first phase of the strategy there is great incentive for the introduction of new measures and the replacement in the fleet, that can lead to a 17% curtailment of emissions by the end of the phase.

II. **phase: 2020 – 2050:** The period of carbon-neutral growth. It means that emissions that overrun the limit of carbon-neutrality despite the use of new

methods and technologies should be compensated or offset by proper market measures and capping.

III. **2050:** After reaching carbon-neutral growth and applying new techniques to decrease emissions, by 2050, air transportation does not only want to reach neutrality, but would like to cut its emissions to 50% of the 2005 level, regardless of the volume of growth. .



41. **Figure: Emissions reduction roadmap. (Source: IATA)**

In 2012, June, ICAO with ATAG launched a program called a "Flightpath to a Sustainable Future". It was a biofuel initiative for the Rio+20 to represent the goals in aviation to turn to alternate energies. Through this initiative, as a symbolic move, ICAO Secretary General, Raymond Benjamin was supposed to the conference with connecting flights through four legs using alternate energy such as camelina, cooking oil, jatropha, and corn oil. Companies as Boeing, Bombardier, Airbus, AeroMexico, GOL and others partnered to successfully carry out the operation.

The initiative was a tool to deliver messages that aviation actors are committed to green energy and they invited policy makers to elaborate sustainable solutions, finding a fine line between environmental, economic and social considerations, and developing a stable policy framework with concentrating on alternate energy and new technologies. [89]

In September, 2013, at the 38th ICAO Assembly, the 191 IATA member states agreed that by 2016, for the next Assembly they will elaborate MBMs for aviation.

The European Union, though, was the first to act. As a result of dissatisfaction with the ICAO's inaction, the European Union unilaterally incorporated air traffic into its European Trading System (ETS) with the adoption of their legislative framework as early as 2008. It meant that all international flights with origin or destination to the EU must cover their emissions by carbon fees levied by the EU.

Asia and the US and affiliated airlines opposed the idea of such "penalties". In 2012, ICAO called the EU to suspend its practice. To the pressure, and in order to leave time to negotiate the international agreement, Member States withdrew the involvement of aviation in its carbon scheme for a year where flights from non-European countries were exempt from regulations. Nonetheless, the EU stated that they find a global regulatory framework desirable.

In 2013 the law has been amended to include flights from the EEA, where those who perform minimal emissions can be exempt from the rule. As part of MBM, EU involved aviation in the ETS the way that airlines are recipients of "tradable allowances" of emissions.

[89] ICAO News Release. Flightpath to a Sustainable Future the ICAO RIO+20 Initiative. (2012). (available at: http://www.icao.int/Newsroom/News%20Doc%202012/COM.11.12.EN.pdf, visited: 2015.05.13.) and ICAO. FlightPath to a Sustainable Future. The RIO+20 Global Biofuels Initiative. Review (2012) (available at: http://www.icao.int/environmental-protection/documents/icao_env_rio+20_report_2012-08-10_web.pdf, visited: 2015.05.13.)

The EU concluded that this is the MBMs are the most cost-efficient solution, providing environmental benefits for a lower price.[90]

Besides increasing international aspirations to reduce emissions, individual commitments of companies such as manufacturers and airlines are also being made.

ICAO measures for 2016 would be essential to lay down a global framework created with the collaboration of policy makers and actors of the industry to fulfill targets laid down in 2008. Apart from a framework, clear economic policies has to be made in order to address the issue in terms of economic factors and growth, taken into consideration the economic weight of both aviation industry, both climate change. The next chapter is going to introduce some of the areas that need to be approached when creating a climate-friendly economic policy on aviation.

[90] See: European Commission. Climate Actoin. Reducing emissions from aviation. Policy. (available at: http://ec.europa.eu/clima/policies/transport/aviation/index_en.htm, visited: 2015.05.20.) and DIRECTIVE 2008/101/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 November 2008 amending Directive 2003/87/EC so as to include aviation activities in the scheme for greenhouse gas emission allowance trading within the Community. (2009) Official Journal of the European Union.

4. Policy implications

The paper showed that climate change is a real threat to both the environment and the economy and it requires instantaneous actions and mitigation to ensure a sustainable future. Besides climate change policy, economic policy should also individually (although in harmony with climate policy) address it as it has a lot of interconnections with the global economy.

Aviation is an industry that plays a role in anthropogenic GHG emissions, thus contributes to climate change. Being one of the fastest growing sectors, estimations show that its "participation rate among climate change generators" will continue to rise.

On the other hand, the industry has imminent influence on global economy and has great potential to support economic growth, international market integration, technological development and other socio-economic benefits. Economic policy, therefore should create strategies that enable a sustainable growth for this industry, generating economic yield.

With the commitments members of the aviation industry made and the ICAO promise to elaborate MBMs for the implementation of the carbon reduction strategy, an important step will be made towards emission reductions, but economic policies at different levels should be created in the future to successfully adapt to the climate change.

Besides, a common (albeit adaptable) framework is needed that would lay down the principles for economic-policy making on climate change that could serve as a universal basic guidance about the specificities that should be taken into consideration.

In this chapter, I will mention some elements that should be considered when creating such specific economic policies. Some of them could be generally applied to other industries as well, while some of them are directly addressing the sustainability of aviation policy.

4.1 Factors to consider when creating climate-specific economic policy

The major issues needed to be focused on in order to establish economic policies addressing climate change are the following:

- The levels of policy making
- Methodology to develop an economic policy
- Priorities

The levels of policy making

In order to successfully and utterly address the problem of climate change within the aviation industry, a cross-sectorial, broad approach is necessary. It means that both the civil and public sphere at different levels must be involved in policy-making and policy implementation, as the issue in itself is extremely urgent.

Within the same common frame and guidelines (central or global policies), the policy should be adapted to the needs of the certain "sub-areas", such as countries and local communities.

Both the aviation industry both global warming might be accompanied with dynamic shifts. As it has been revealed, on the other hand, the predictions on climate change's possible effects might not prepare policy makers for everything, and sometimes they might be

inaccurate. Some of them can be related to aviation (like the air density and economic effects) that can alter aviation as well. Moreover, due to for instance unexpected technological development or changes, shocks in the economy, air transportation can be seriously affected, that could incite systematic transformation even within a short run.

Therefore, policies should be formed in a more flexible way (with keeping the targets) to enable them to instantaneously react and adapt to deviations and needs productively at the different levels. In other words, instead of a solely top-to-bottom decision-making and execution, a mixed approach with bottom-up initiatives should be applied.

What are the levels of policy-making that should be taken into consideration for an overall approach?

By geographic/administrative factors:

- international level
- continental level/union level
- country/domestic level
- regional level
- local level

By actors (with actors from different geographic/hierarchic level getting involved in the policy of the relevant level)

- International/transnational organizations (including INGOs) and international political forums dealing with climate change and/or aviation eg.: IATA, ATAG, United Nations and ICAO, EU bodies

- Domestic, regional (in countries where applicable) and local organizations (including NGOs) and political/governing bodies eg.: governments, related ministries and administrative bodies, parliaments at national, (regional) and local levels, relevant organizations.
- Experts: Experts from the above mentioned institutions, individuals affiliated with the policy issue from different backgrounds (economics, environmental sciences, aviation, lawyers etc.), universities, where relevant research is conducted.
- Corporate level: businesses involved in the policy issue inter/trans/multinational and/or national, local, regional (eg. airlines, aircraft manufacturers, trade and workers unions).

Methodology

First of all, mere economic estimations and economic data is not satisfactory to create really efficient economic policies focusing on climate change mitigation. Climate change is a complex issue in itself, and in addition we would like to incorporate a particular industry in climate orientated economic policy making, it will get even more complicated. At the same time for the best solutions it should be the right way to measure. A cross-sectorial approach, based on data gained from other disciplines is inevitable to measure the capacities and possibilities within the limits of a particular industry so that it will be beneficial both for the industry, both for the economy in general and for climate change. The setting up of working group consisting of different experts, alongside economists, on the actual field can help in the proposal of an economic policy that takes all the above aspects into consideration.

The second issue, which is correlated to the previous, is that policies often build solely up on the economic modeling and the economic methods of analyzing, which are primarily

the cost-benefit, the cost-effective and the distributional analysis.[91] Although they are essential to carry out in most cases, sometimes they lack consideration of existing data from other disciplines and simply develop policies on the basis of the highest economic benefit, which might be problematic in a case of a sensitive area like climate change. Therefore, together with/or instead of such analysis, clear and scientifically reasonable targets must be set up for policies with the help of well-quantified and pre-measured data.

Clear policies like that would also ease compliance with the measures.

Priorities

Sole economic purposes shall not prevail over climate change reduction. They are not necessarily 'opposite poles' in policy making, but could be understood simultaneously in relation to one another. As we have seen, climate change is intertwined with economics from various perspectives, and with careful economic planning, taken into consideration the impacts climate change might have on the economy, considerate measures could and should be developed that are beneficial for both the climate (and in return to the economy indirectly) and for the global economy directly.

4.2 Creating a climate-considerate sectorial policy on aviation

When it comes to sector specific "climate-economic" policy and aviation, several aspects can be taken into consideration to improve emissions without endangering the economic performance of aviation industry, and indeed, further ameliorating it. First and

[91] Mahashabde, Anuja. Assessing environmental benefits and economic costs of aviation environmental policy measures. (2009) MIT PhD thesis. (available at: http://lae.mit.edu/uploads/LAE_report_series/2009/LAE-2009-003-T.pdf, visited: 2015. 05.21.) p. 33.

foremost, what is important is that policy-makers and members of the industry have to maintain incessant transparent communication to be able to harmonize their interests and share reliable data and plans with each other (without endangering competition and market-sensitive information). Up to recently (with the first most relevant step by EU), it was a problem that policies, even market-measure based climate policies did not encompass aviation emissions directly into their frame, and otherwise it is still relatively underregulated. This, on the other hand, needs to be changed as soon as possible (within the above double-efficiency scope – essential for the industry and the economy, and for the climate).

On the other hand, due to its economic weight and growth potential, the operation of aviation industry should be facilitated, but with stringent, necessary and proportionate measures and limitations on emissions.

The curtailment and control should not exclusively target carbon-dioxide measures, but other GHGs as well.

The thesis considers the following elements to be essential for consideration when trying to create a sustainable aviation, without damaging its potential.

- Structural relation
- The reliance on alternative segments of transportation
- Market possibilities

Structural elements

It denotes intra industrial facilities that can be targeted for the purpose of growth with climate mitigation. The paper will introduce some of them, mainly those also entailed in the current commitments, as they are the most significant factors. On the other hand, at the first instance, economic policy should first weigh voluntary commitments and strategies for climate change mitigation and create apt policy response to them.

Fuel

As the major cost component for airlines is fuel (around 50%), it is worth to consider more and more options to increase the cut in consumption, to turn to more fuel efficient solutions and/or to find alternative fuelling, which is more environmental friendly.

The problem is, that in order to implement more fuel-efficient solutions, airlines usually have to modify also the available equipments and technology, which, can be very costly. Therefore, it is reasonable to measure to efficiency of such measures in the long run. The fact that many airlines have a narrow profit rate even makes such decisions harder. For airlines with more financial resources, it is far easier to adapt such measures. Luckily, though, generally these are the leading airlines with the largest fleet and operations.

On the other hand, apart from the need to operate more efficiently, actors in the aviation industry have to take other factors into consideration. The fact that oil resources are finite and that they are in danger of depletion should urge actions on developing alternate solutions, such as alternative fuel and more fuel efficient equipment. Although in the oil industry experiments are ongoing to find the best ways for crude oil extraction and to encounter new oil fields, even if they make progress, one can expect a rise in oil prices as

supply will shrink. On the other hand, the future requires more cost-efficient and sustainable solutions. Not only for the sake of economics, but for the sake of human health and life.

The already existing aspirations to turn to renewable and eco-friendly alternate fuels should be supported by economic policy, and not restrictively for aviation but for other industrial areas as well.

At the moment, several types of alternate fuels are being researched, many of them are the so called "biofuels", made out of natural, sustainable elements. They could be made of for example.

- oil gained from crops and plants that are less polluting to the atmosphere
- algae powered "propulsion" which is an effective and sustainable method, and even helps to absorb some malicious substances
- waste "recycling" (eg. cooking oil, urban waste and fat gained out of animal carcass)
- the use of renewable energy (solar power, for instance is an extremely promising and attractive area to be adapted to aviation)

Corporations, like Boeing, invest enormous amounts in developing new fuel compositions. The above company, for instance, set the goal to reach the 1% global jet demand, or 600 million gallons (over 2.2 million liters) for biofuels by 2016. For the current target, they are working on such substances that can substitute traditional, kerosene based jet fuel, without the need for important structural changes (eg. the replacement of jet engines). They name it the "drop-in" fuel that can be injected into and directly blended with jet fuel.[92]

We must keep in mind, though, that there are some challenges in applying alternate fuels. It has to be sustainable, which also means that it must not jeopardize human food

[92] Boeing. 2014 Environment Report. (available at: http://www.boeing.com/aboutus/environment/environment_report_14/4.2_engaging_the_industry.html, visited: 2015.05.24.)

supplies, nor the biodiversity. Another ponderosity occurring in relation to aviation is that it needs fuel that can provide extremely powerful performance to "mobilize" airplanes and to withstand and adapt to various circumstances, including atmospheric and ground impacts, weather vicissitude, and heat discrepancies, while at least maintaining the same level of safety (but preferably better) and without raising any safety concerns.

Many alternative fuel sources are still in experimental phase and they need some more time to be usable without concerns. On the other hand, yet, without sufficient supply and a relatively narrow market and the humongous amounts spent on research, they might be quite costly at the moment. This factor, though would be overcome soon after the technology becomes widespread and available. And finally, for more sophisticated and effective solutions, most likely important structural changes need to undergo, consuming high investment values.

Design, fleet and operations: With different modifications of aircraft design, making it more convenient to aerodynamics and environmental circumstances, large sums of emissions could be spared. Replacing elder fleet and or engines to new more economical aircraft, albeit expensive, is inevitable., With introducing more effective operational methods, the situation is the same. The climate (through "greener" operation and the economy (through investments and better use of resources) can get great benefits out of it.

Research and development: Undoubtedly one of the most important area that can be related to almost any element of aviation. Developing new methods, new technologies, fuels, mechanisms can result in huge benefits not only for aviation, but for the climate, global economy and humanity. Therefore, this area should be supported within sustainability limits and climate considerations, naturally. With new products of research extreme portion of

emissions can be mitigated. At the same time, it is usually an expensive activity, which meas that it requires great investment.

Climate-friendly operations of joint segments: The use of alternate, renewable energies and power saving and reliance on new, more eco-friendly technologies is essential in segments of aviation other than carriers as well (eg. airports, manufacturing, services, ATC). Thus, emissions could be cut back.

Alternative means of transportation

In this part I would like to point out why is it almost impossible to rely on alternative means of transportation in various cases, and when it would be even more harmful in terms of climate change mitigation and policy aims.

Many cases, the answer is simple: because there is no practical and more efficient solution. It can occur for different various reasons.

- Distance and time: For specific routes, especially long-haul ones, the travel time would be multiplied by using other means of transportation, which is in many cases would result in a huge disadvantage of consumers.
- Geographic features: Sometimes, simply due to natural facts, it is impossible to change from aviation to another mean of transportation. For instance, in an area surrounded by high mountains, the building and maintenance of tunnels and other roads (if possible) could highly increase cost and efficiency. If we consider the

approaching of remote islands in the ocean, on the other hand, it is almost (if not) impossible to build roads/railways there.

***Road transportation**:* The sector is greater than aviation in both size, both emissions, as the largest contributor to transportation's GHG emitters. Although easy to reach and better, more climate friendly technologies are becoming available, practically it hardly can substitute aviation given its limits of speed, occupancy factors and carriage capacities. It rather serves a market that aviation does not (short distance, often inter-country), although international transportation is also significant, but not necessarily any better than aviation. Since road transportation is a more problematic area within climate change and it is even harder to find a consequent economic policy on it, even if circumstances are given it will unlikely take the place of aviation, especially until there is no existent solutions for the internal problems of the segment.

Railway transportation: On shorter, rather intercontintental/country distances (usually less than 500 miles), fast speed trains could be a solution with reduced energy use. One of the best practices to mention could be observed in Japan, with the *"Shinkansen".* They managed to reach a 40% decrease in energy use by carrying out structural changes. They altered the nose and the length, decreased the weight and used advanced electronics. It is also possible to reach a minimum amount of emissions, likely lower than that of aviation.[93] In the future, on the above mentioned, long-haul routes the new technology of bullet trains might be able to substitute air transportation.

[93] IPCC Report. 2014. p. 614

We shall not forget, though, that operations and building infrastructure also go with emissions and energy use. On the other hand, building up the necessary infrastructure requires great amounts of money, which is probably much higher than expanding an already existing one, while considering the climate, not to mention the fact that building new rail lines can have negative impacts on the environment (the flora and fauna). As mentioned above, on some routes, though it is technically impossible or simply not practical to replace aviation.

Despite all the other, the new and energy-saver railway technology might be a valid competitor for some flights in the future.

Water Transportation: *IMO* advocates that maritime transportation is one of the most fuel efficient solutions, as its contribution made below 3% of all emissions, while it carried over 90% of world trade volume.[94] However, even with the best available technology to decrease emissions arising from water transportation according to today's available knowledge, it could only be a viable alternative for aviation for mass-cargo transportation, where time is not an important factor in shipping and where the nature of the shipment allows so. Even then, we must not forget that we need another elementary factor for shipping, which is: water. Hence, water transportation cannot (efficiently) replace aviation where there are no suitable waterways. Regarding passenger passport, at the same time, it is almost impossible that within the current possibilities water transportation can fill the place of aviation. If we consider the scale of the whole industry (not only transportation) and its growth measure and economic contribution, although the large extent of international trade is carried out via shipping, measuring the total economic contribution of aviation (including employments,

[94] Internatonal Maritime Organization. Further rogress Made by MEPC 61 (September/October 2010) on Technical, Operational and Market-Based Measures. (available at: http://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Further-Progress-Made-by-MEPC-61---September---October-2010---on-Technical,-Operational-and-Market-Based-Measures.aspx, visited: 2015. 04.20.)

GDP generation, growth factor and technological development eg), it is neither the best alternative, even if the infrastructure is more or less given.

On the other hand, the economy should by no means undermine the operations of any of the transportation segments on mere economic basis, nor through oversubsidizing one. Minor exceptions (within limits) could be allowed only and if only, the economic performance and the climate impact altogether (with high weight on the latter) and the effectivity surpass that of another. It cannot be subject of only economic preference making. What is important that these industries if possible should be handled in blocks – measuring the overall climate impact that arises from the whole segment and not only transportation.

Market measures

It encompasses all the activities how economic policy allows aviation to perform at the market, what obligations allowances it receives to operate (if any). For certain, aviation should be supported in order to further provide economic growth and great research results and to satisfy the increasing demand for its services (again, within the context of all the previous arguments). Clear and practical market measures should be elaborated that contribute to the diminishment of GHG emissions and climate change and for it different financial and market tools could be applied. A portion of the amount of money generated by the industry should be expended on the harm it causes. About how, various scenarios exist, The thesis highlights two of them

Trading emissions

By this, aviation emissions would be involved in the global trading scheme of emitted GHG, where the industry would operate within the UNFCCC target scheme, receiving pre-determined allowance. For the short term objectives of fight against climate change it is reasonable, on the other hand it controls airlines climate actions, making them pay for extra usage or letting them to trade with remnant stocks. On the other hand, strict measures should be adopted on their designated consumption, taking into considerations realities and the self-sustainability of the industry.

Application of the "polluter pays" principle

Some claim that in order to create balance between aviation emissions and their effects, the polluter should pay its price. Mainly they name the VAT that airlines often are exempt to pay in schemes to decrease their costs on fuel and aircrafts that also induces investment in aviation and helps to generate more profitability. They claim that aviation has an "unfair advantage" comparing to other sectors in transportation.

One way they would like to gain compensation for the damage is through fuel taxes and emission levies (that the pollutant covers the expenses of emissions) as it would incite the investment for less "harmful" aircrafts, on the other hand it would shrink demand for aviation which would help alternate means of transportation to break through.[95]

The principle that the pollutant has to pay is a reasonable argument, although levying extra taxes and fees might have contraproductive effects not only on development and investments into climate friendly solutions, but in costumer welfare. Therefore, I would prefer the trading schemes more with strict limit and with impetus to invest in sustainable energy.

[95] See eg.: Friends of the Earth. Aviation and global climate change. (available at: http://www.foe.co.uk/sites/default/files/downloads/aviation_climate_change.pdf, visited: 2015.05.10.)

Last, but not least, it would be crucial for policy making to assess aviation industry as a whole, not only air transportation, when addressing its climate operations. The industry as a unit triggers enormous economic benefits and its core elements are operationally interrelated. On the other hand, according to this interconnection, for climate change they are hand in hand responsible (although in different proportion). For the best climate-considerate economic policies, hence, comprehensive approach is needed, incorporating actors such as airports.

Concluding remarks

The first part of the paper dealt with climate impacts on the environment. It showed that the process poses an imminent threat to the environment, biosphere and also to humans and the economy. Often when it comes to policy making, decisions makers find a conflict between economic and environmental perspectives that is a wrong approach. They should not be treated separately but rather conjunctively. The thesis showed that global economy is in various ways affected and can be affected by climate change.

Although, positive outcome is also possible regionally or locally at the global average level we can expect negative turnout. Hence, economic policies should address climate effective solutions for their own good in the long run. Rationally, sometimes it is not as possible. Due to short term policies and changes in governments, several policies are carried out for a short run with aspirations to reach success within this time frame. Moral reasoning and pressure based on scientific evidence could be a tool for influencing such decisions.

When elaborating (climate-effective) economic policies, again, besides mere economic calculations and economic attributes, sector-specific analysis should always accompany such decisions backed with the structural understanding of the targeted sector, including basic information from sciences other than economics (eg. physics). Instead of the cost-benefit analysis, decisions made on targets based on concrete data could be an alternative solution for such issues.

The second part of the thesis dealt with the aviation industry. It showed that it is a huge industry with various branches and does not only consist of the most apparent sector, the airlines and air traffic.

It generates a humongous benefit for the economic, although some actors in the industry (including airlines) work with relatively low revenue margin. It contributes to economic growth and in the future the rate of contribution will further increase, given, that aviation is one of the fastest expanding industries. For the global economy aviation is essential as it helps to connect different countries and facilitates travel and business connections, even to far-away secluded lands. For these remote countries, aviation enables to directly join the global economy. Being a rapidly incrementing area, important R&D activities are financed and supported by aviation that enhances technological development. Based on all the above, aviation is a crucial element of the economy, hence it deserves special regard in policy making.

On the other hand, transportation is one of the major contributors to anthropogenic greenhouse gas emissions, within which, aviation is responsible for about the 3% of the total volume emitted into the atmosphere. As the sector will continue to grow, emissions would also likely to rise if no action is taken, despite the fact that modern technological solutions curtail emissions. For aviation, the environment and even, based on the above logic, the economy would benefit in solutions mitigating aviation's climate impact. Several solutions could be considered when deciding on effective actions (eg. alternate fuels, alternate transportation methods, market tools, etc.).

Lately, commitments have been made from the aviation industry to cut emissions back by 50% of the 2005 level until 2050 in three main phases. The international community, through ICAO decided to elaborate market-based-mechanisms by 2016 in order to facilitate

reaching the targets laid down in the industry's climate strategy. Once carried out, it will be an essential momentum in the fight against climate change.

The issue, without doubts, needs a common framework, and, due to their importance, continuous economic policies dealing with the issue. Apart from global policies, local, regional policies should be implemented. On the other hand, as again, aviation is a core industry for the economy with great potential and which has various benefits over other similar economic segments, policies should aspire to encourage its growth, but strictly in harmony with sustainability and climate-mitigating perspectives for the sake of all.

However, what would be important in policy making, is that it should not only address air transportation in relation with climate change, but also other actors related to it, such as airports. There is a two-way rationale behind it. First, as emissions related to aviation are not only a product of air transportation, but for instance the energy use of joint activities. From the economic perspective, because economic contribution of aviation at a large percent appears as a consequence of peer industries to air transportation.

The method on how to approach climate-relevant sectorial policies is not only valid for aviation, but for all other related sectors. The given area must be understood in its structure and its connection to climate change should be explored. Apart from economics, data gained from other sciences revealing the facts and capacities should be considered instead of/or alongside with policy preparation methods such as cost-benefit analysis. Since urgent action is needed, instead of pure putative modeling methods and perspectives, clear and determined targets should be determined in the long run, derived directly from existing scientific data.

When constructing a policy, besides the latter, the following factors should be taken into consideration conjunctively, and policies, based on them, should be adjusted accordingly:

general economic trends and growth factors, economic trends and considerations in the specific sector, the economic importance/weight of the sector and the climate effects of such actions with special attention to the possible impacts of climate change on global economy.

Policy-makers, world leaders and industries must understand that purely larger economic benefits should not prevail over climate issues, especially that the latter is capable of causing serious economic impacts as well. They have to be balanced as they are intertwined. Climate change is threatening our future and we have already crossed the line to hesitate and make preferences for the disadvantage of climate. Quick, effective, science-backed and sustainable decisions and policies are needed where responsible actors collaborate. Thus, we can have a livable future and a prosperously and sustainably expanding global market.

"That's the thing about Mother Nature, she really doesn't care what economic bracket you're in."

/Whoopi Goldberg/

(Source: Brown Political Review)

Glossary

(Comment: The glossary serves the purpose to familiarize with technical expressions occuring int he thesis. It is created in a simplified language, in order to enhance general understanding. Therefore, determinations are not exact definitions and sometimes avoid reliance on strict *„terminus technicus"*)

- *Albedo effect*: A measure that indicates how much the energy arising from sun is reflected back from the Earth to space. Albedo effect in other words is the Earth's cooling effect from reflecting thermal radiation from the sun.

- *Ancillary revenue*: Revenues generated by airlines from sources other than tickets. These can be for instance: baggage fee, onboard meal and drinks. Generally LCCs

have more revenue arising from such sources, as they usually attach fees for extra services that are part of services offered by FSAs.

- *ASK/ATK*: Units that show the emission produced by an aircraft taking into consideration available seats and freight tonne, calculated in relation with the kilometers traveled by the aircraft.

- *Atmosphere:* Is the gas mass surrounding the Earth's surface Its border with outer space cannot puntually be determined, since it does not have fix ending but it gradually thins. Nevertheless, usually we denote it by the „Kármán line", or the boundary of aeronautics, which is at about 100 km above sea-level.

- *Available Freight Tonne Kilometer/Mile*: Indicates the capacity of air cargo an aircraft carries. Obtained by multiplying the distance traveled to the destionation with the freight tonne.

- *Available Seat Kilometers/Mile*: Shows the passenger carrying capacity of certain aircrafts. The value is calculated given the number of seats, multiplied by kilometers/miles traveled until the destination.

- *Cirrus clouds*: A type of clouds appearing in the sky, now covering about the 30% of the skies. Their characteristic is thin, stripe-like appearance.

- *Civil aviation*: commercial aviation including passenger and cargo flights and private services.

- *Climate change:* For the purposes of the current thesis, by the term, climate change, we denote lasting deviations in the average Earth climate arising from a result of anthropogenic contribution (eg. the emissions of gases) as a consequence of greenhouse accumulation and global warming.

- *Condensation trail*: A byproduct of aviation. Technically, they are artificially generated clouds, primarily made of water vapor, generated by fuel combustion.They are the trails that aircraft engines leave behind when flying.

- *Connectivity*: the accessibility of global air transportation system from contintent's/country's/regional main airports.

- *Cryosphere:* Water surfaces and grounds of the Earth appearing in solid (ice) substance, in a temperature below 0. Eg.: glacier, icebergs, ice sheets. permafrost.

- *Freight Load Factor*: Measures freight capacity efficiency. Calculated as the ratio of the aircrafts total freight capacity and the average freight load.

- *Freight Tonne Kilometres/Miles*: It is a measure expressed in each unit of tons carried for each 1 kilometre/mile.

- *Global warming:* The increase in GHG and the intensifying greenhouse effect leads to the phenomenon called „global warming", which results in the growth of global sea and surface temperature.

- *Greenhouse effect*: The effect in which the accumulation of different gases stuck in the atmosphere prevents the heat from the reflecting sunrays from the Earth surface to escape from Earth, hence keeping the atmosphere warmer.

- *Greenhouse gas*: Substances that by their accumulation in the Earth's atmosphere cause warming of the surface (eg.: ozone, methane, carbon-dioxide) and are able to induce global warming.

- *Passenger Load Factor*: A measure for passenger capacity usage for ailrines per flights. It indicates how efficient is the usage/occupancy on average per flights. It is received by the ratio of available seats and passengers traveling.

- *Permafrost (cryotic soil)*: A soil surface that is frozen (having a temperature below 0) for at least 2 years permanently.

- *Radiative forcing (climate forcing)*: A measure, often used to express climate changing coefficient of a certain activity. It shows the differnce between incoming sunlight absorbed by the surface and reflected. A general unit of measurement for it is Wats/$m^{2.}$A positive change means warming effect, the opposite is cooling.

- *Revenue Passenger Kilometer/Mile*: Number of customers flying on airlines per each unit of travel (km/mile). (Passengers without revenue, like employees are exlcuded).

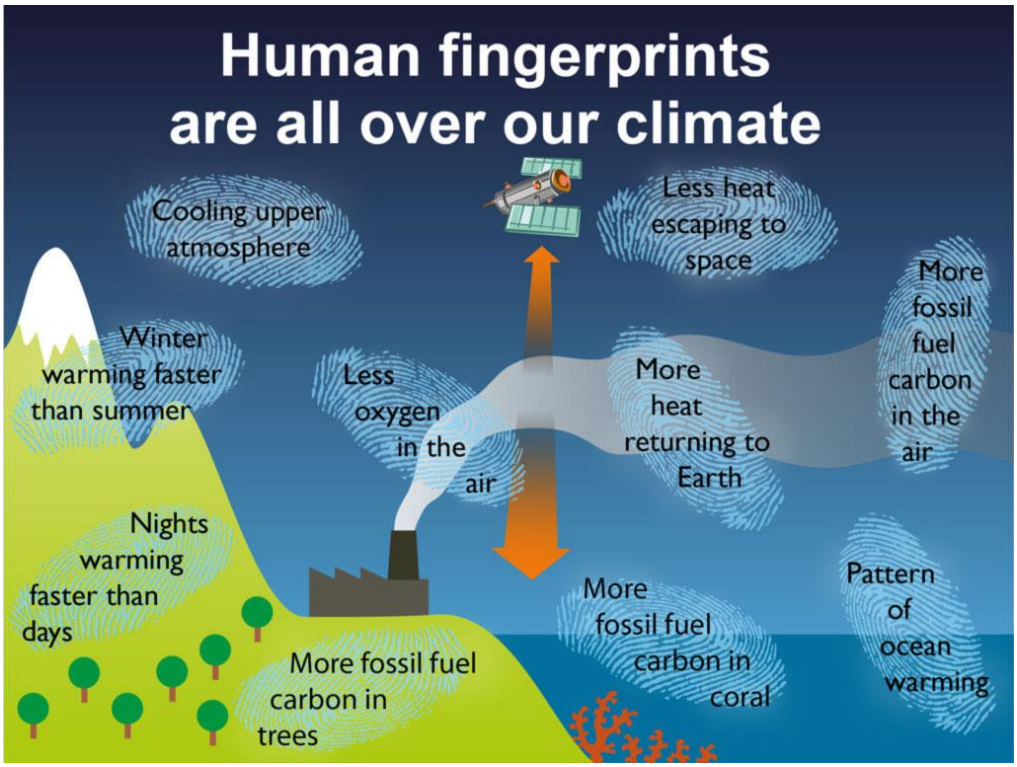
- *Sea level*: The average surface level of ocean(s). Among other roles it has, it is used to be the zero point for measurements of height and elevation on surface (eg. mountains). Usually it is the mid-level of the sea between high and low tide.

- *Stratosphere*: The second layer of the atmosphere, stretching from about 8-15 km to 50-60 km.

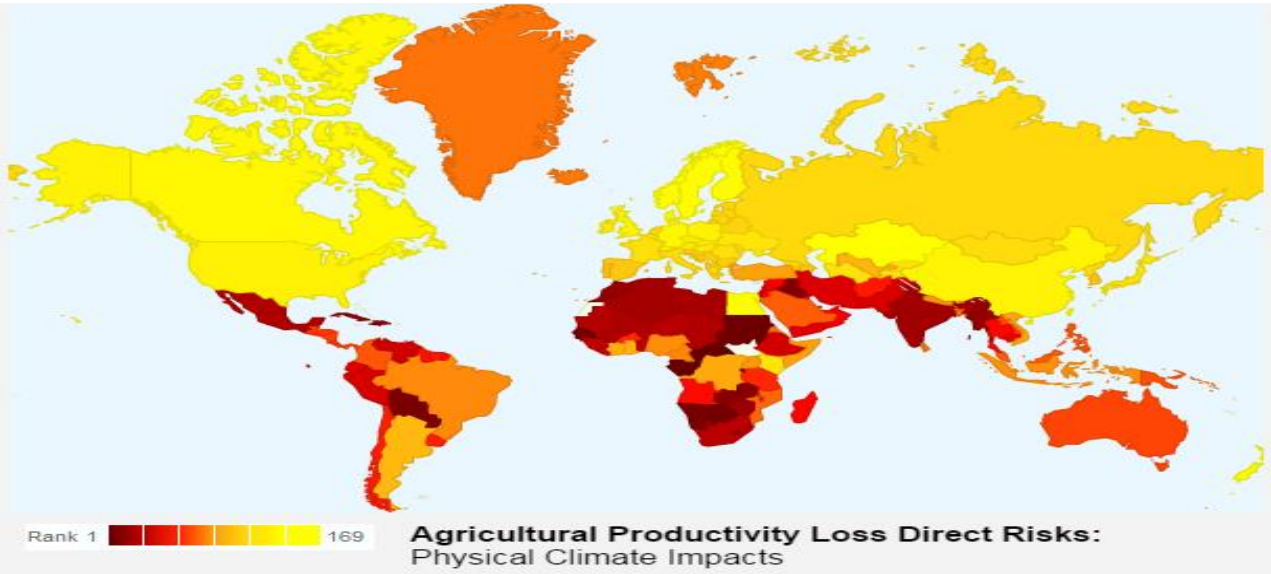
- *Troposphere*: The lowest strata in atmosphere stretching up to 17 km at average (with lowest 7 km, highest 20 km). It contains ¾ of the mass of the atmosphere and almost 100% of aerosols and water vapor. The majority of weather phenomenons are occuring within this layer, such as the greenhouse effect.

Appendix

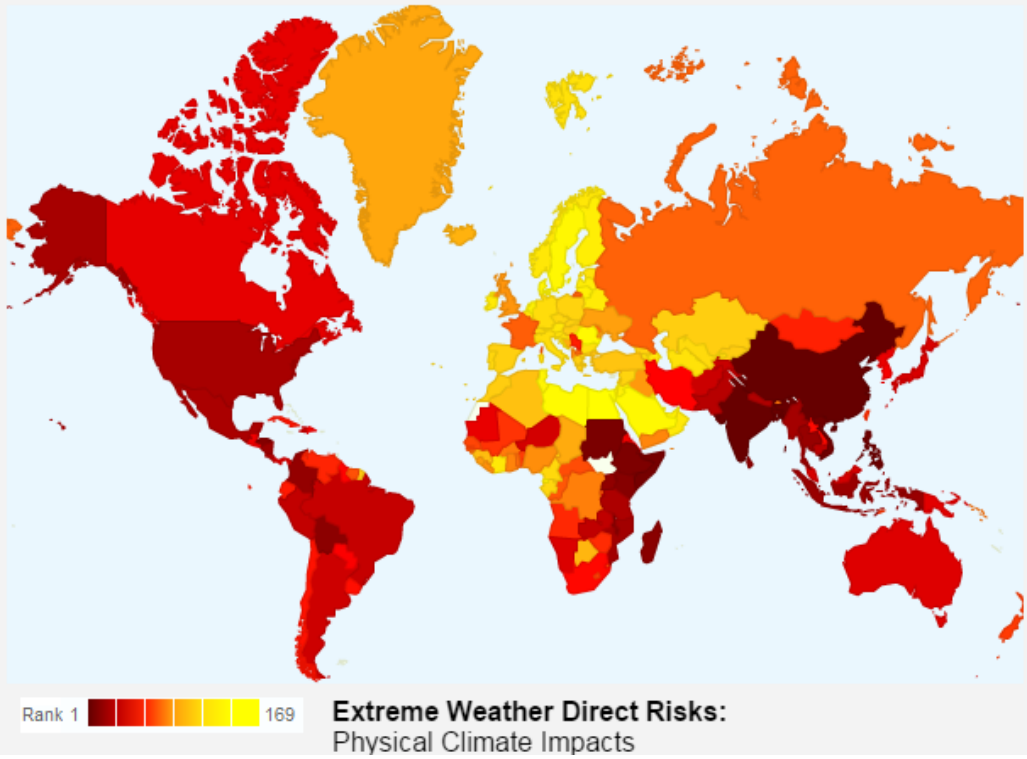
Additional figures on climate change and aviation



Greenhouse effect and climate change (Source: Skeptical Science)



(Source: CGD)



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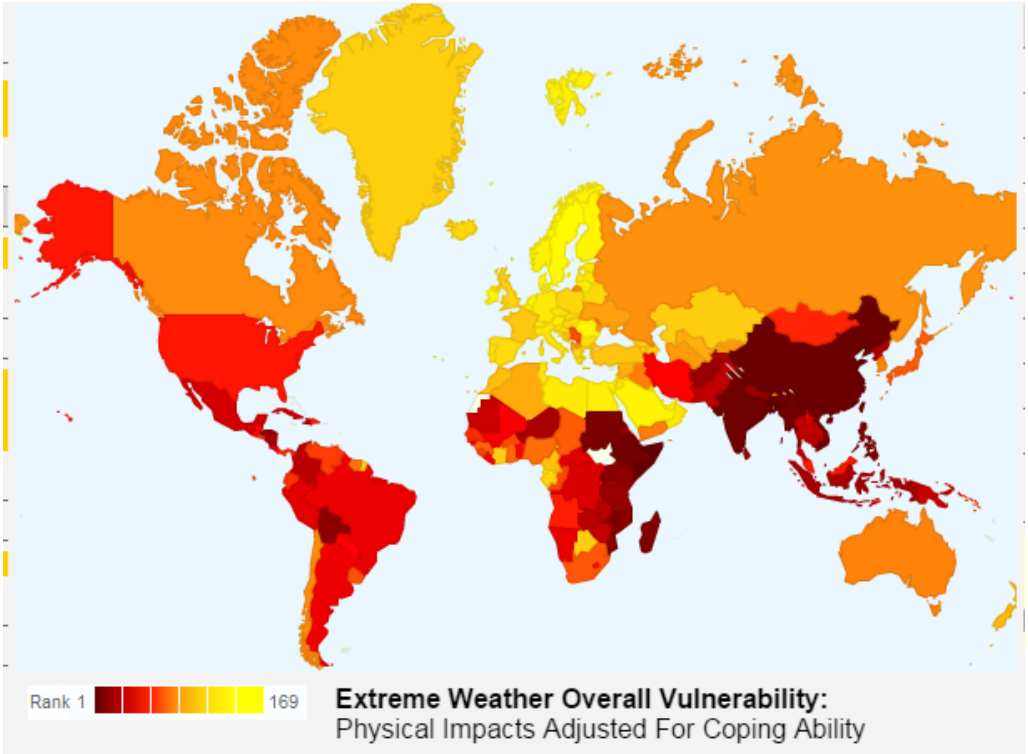
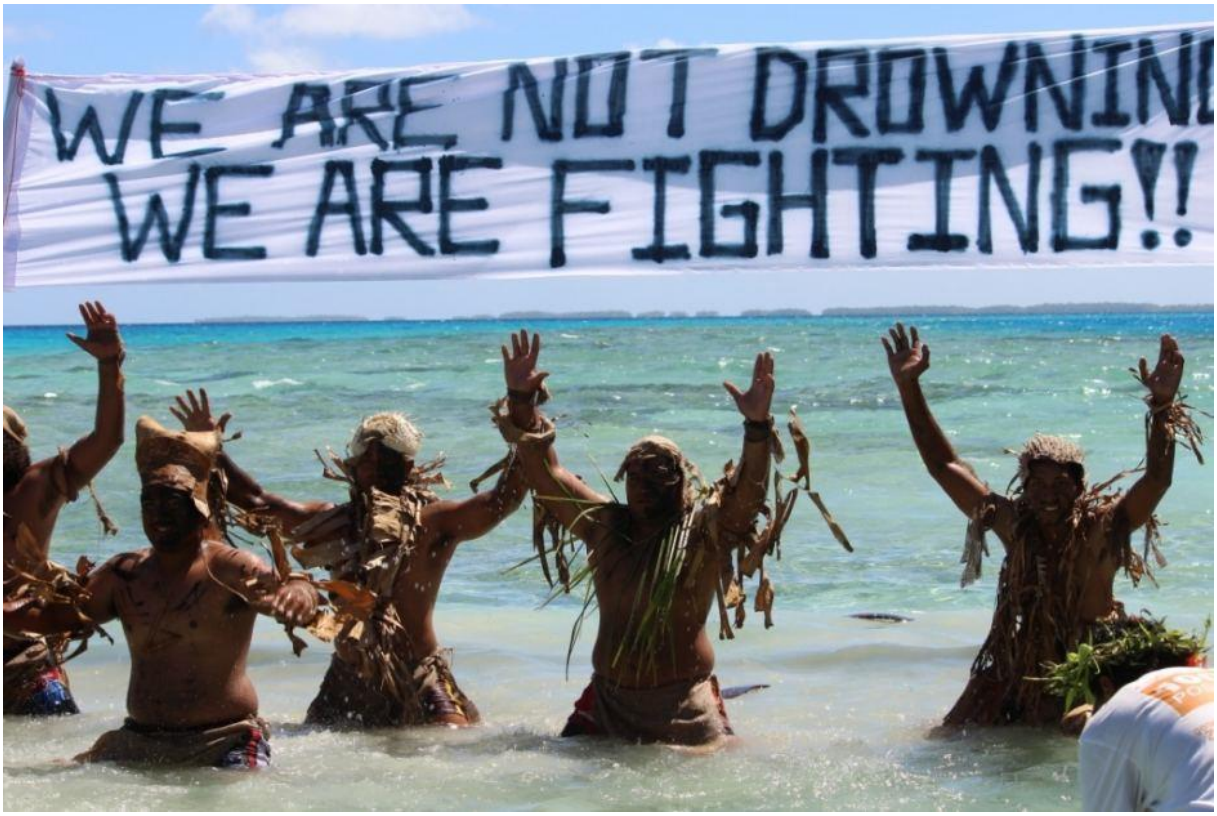


(Source: CGD)

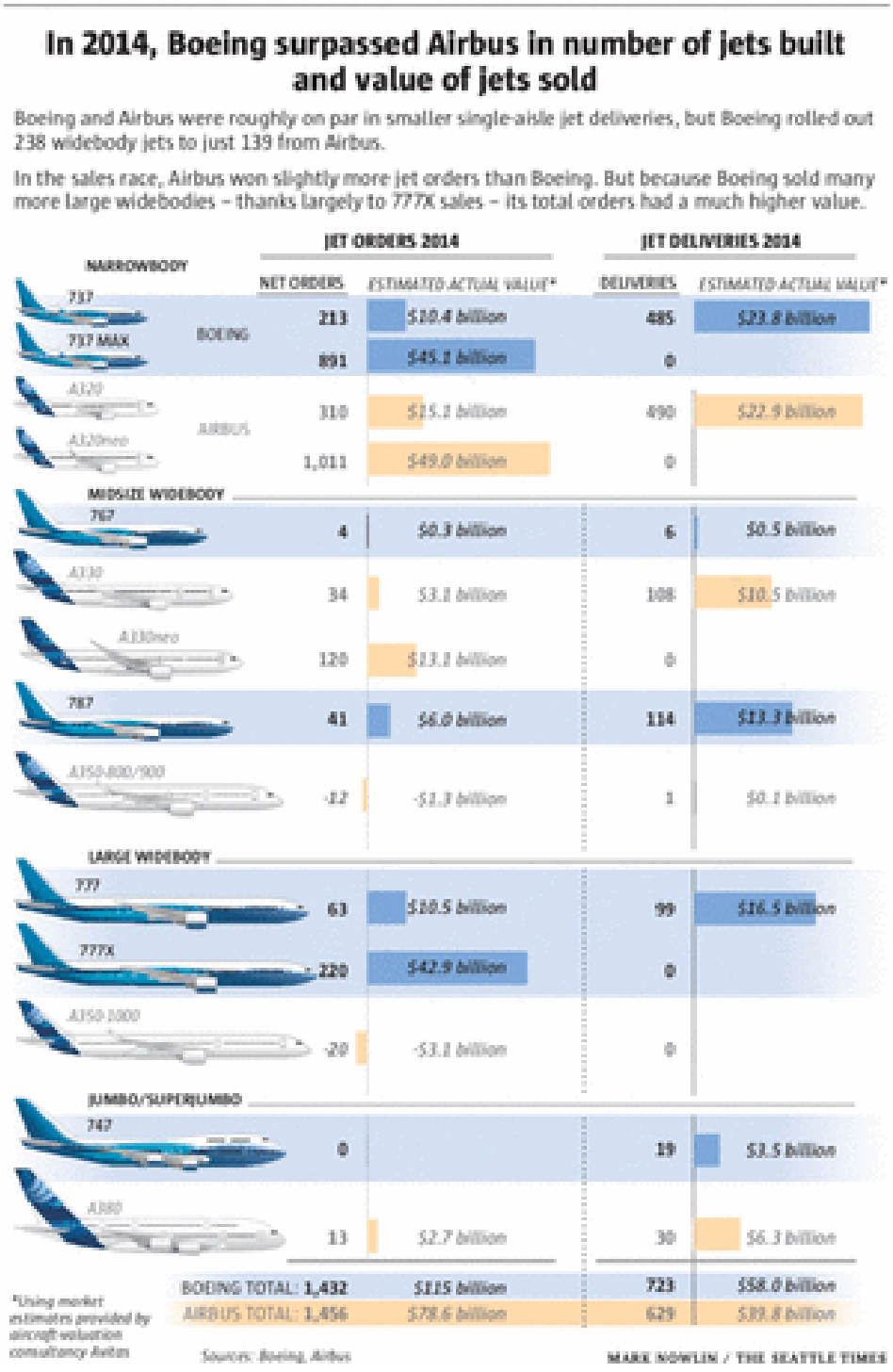
Bangladesh and Global Warming (Photo credits: Gary Brassch)

Polar bear and melting ice cape (Source: Telegraph)

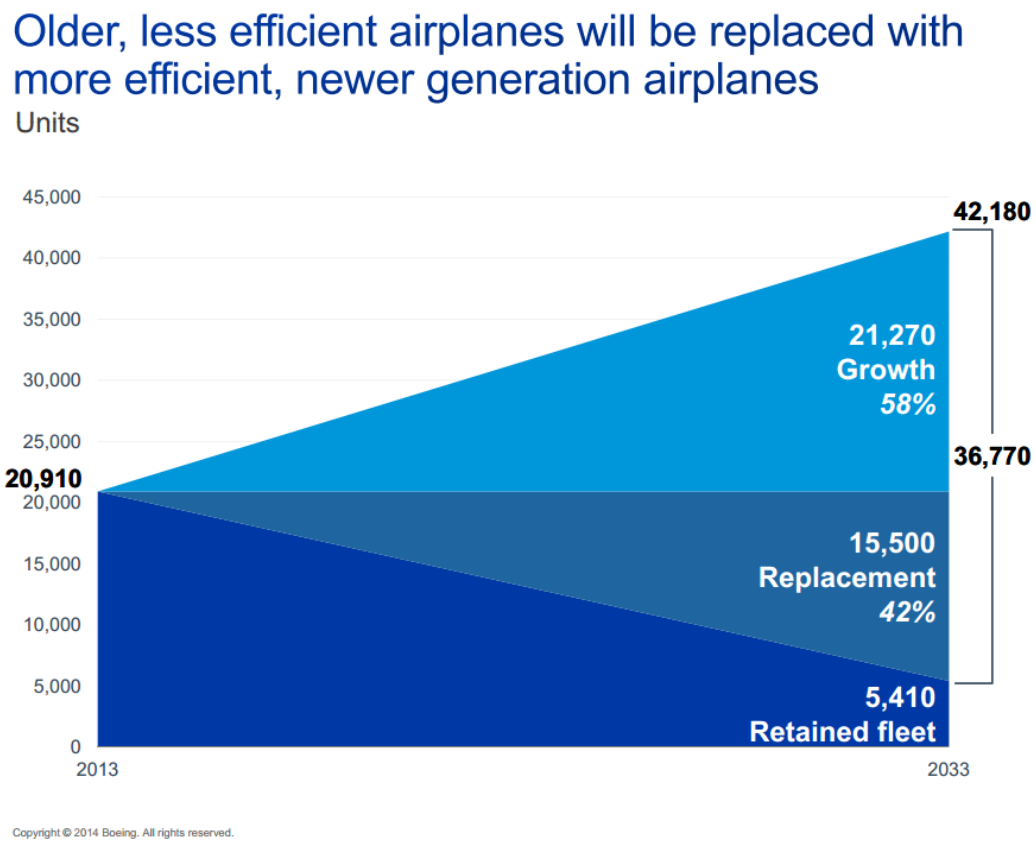


Tokelau people dance against climate change (Source: ABC News)

(Source: WWF)



Boeing and Airbus competition, aircraft alternatives (Source: The Seattle Times)



Aircraft replacement future prediction (Source: Boeing)

Aircraft GHG emissions

Type of operations	CO_2-e (t)			
	2012[1]	2020	2030	2040
Half of Landing Take Off (LTO) emissions[2]				
Commercial	6,190	12,080	24,020	31,390
General aviation	2,030	2,370	2,880	2,880
Helicopter	3,620	4,230	5,130	5,130
Total	11,840	18,680	32,030	39,400
Half of flight emissions				
Commercial	49,670	140,930	342,590	405,410
General aviation	3,820	4,450	5,400	5,400
Helicopter	7,170	8,370	10,150	10,150
Total	60,660	153,750	358,140	420,960
Half of flight emissions with an RFI of 2.7 applied				
Total	150,000	390,000	940,000	1,110,000

[1] Baseline.

[2] 100% of LTO emissions is used for local flights (that originate at and return to the airport).

(Source: Lisa Smith, Casanz)

The beginning of aviation industry – how it emerged

Men always wanted to conquer the skies. Probably everyone heard about the ancient legend of Daedalus and Icaros, which is one of the oldest remaining stories about people's efforts to fly.

The famous artist, mathematician and inventor, the father of Mona Lisa, *Leonardo da Vinci* studied the physics of flying at the end of the 15th century. His drawings and his plans of his machine, the "ornithoper" – which served as a basic idea for the creation of the helicopter made some contributions to future research.[96]

In 1863, the term, aviation (originating from the Latin word: avis, bird) was introduced by the French *La Landelle*.[97]

The first real success story of flying was that of *Otto Lilienthal*, a German engineer who built the fist glider that was able to carry a human and to reach long distances. Finally, after flying over two thousand times, he lost control of his machine, dying in the crash in 1896.[98]

The most memorable moment at the birth of aviation, though, was the development made by the Wright brothers (Orville and Wilbur). They studied how to cope with the problems their predecessor, like Lilienthal faced. Namely, how to make the glider stable in air, and how to control it during flight. For their research they built a wind tunnel to be able to anticipate possible effects of currents and air movements in mid-air. After years of working on it and building several models, in 1903 they equipped it with a motor, gasoline engine.

[96] NASA webpage. History of Flight. Available at: https://www.grc.nasa.gov/www/k-12/UEET/StudentSite/historyofflight.html, visited: 2015. 04.23.)

[97] see eg.: Bretagne aviation. Gabriel de la Landelle - inventeur du mot "aviation" en 1863. (available at: http://www.bretagne-aviation.fr/Pionniers/page%20landelle.htm, visited: 2015.03.16.)

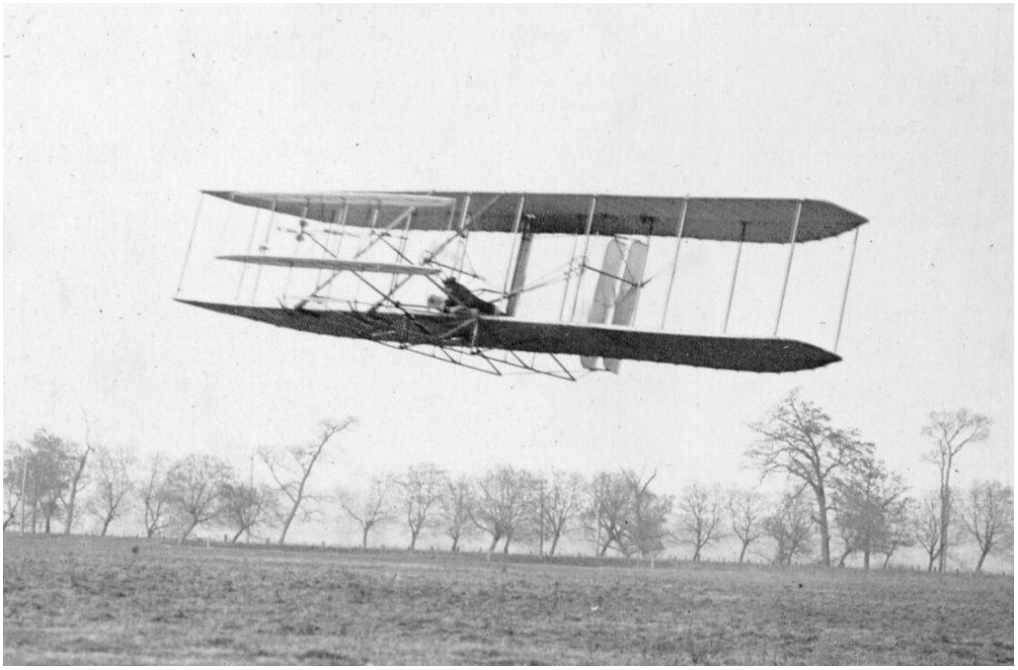
[98] Cook L., Carol. "90.07.06: The Aerospace Industry: Its History and How it Affects the U.S. Economy." Yale University. Yale-New Haven Teachers Institute. 2011., Chapter IV. (available at: http://www.yale.edu/ynhti/curriculum/units/1990/7/90.07.06.x.html#e, visited: 2015.03.29.)

Their longest trial ride from among the about 105 was 5 minutes long then.[99] Many count it as the birth of modern aviation and aviation industry, or the flying "heavier-than-air machine" with the introduction of flight control.

At the same time, the "invention" could not be only attributed to Americans, as a number of engineers and inventors had been working on airplanes in parallel in different regions of the world, and some developments are product of their aspirations. All in all, different machines already existed at the time of Wright brothers, although there contributions cannot be debated on a sole basis.[100]

The beginning was not smooth. For the huge surprise of the *Wright brothers*, despite several letters to the government and the congress, the US refused to consider the development of aircrafts, until Theodore Roosevelt took the presidency. His administration supported the investment in motorized machinery, which enabled the Wright brothers to launch their first official demonstration flight in 1908. In 1909 *Blériot* flown over the English Channel, for the first time with an aircraft heavier-than-air, hence becoming one of the early pioneers to spread aviation.[101]

[99] Ibid. ch. V.
[100] Archer, Susan Kelly. Was the Airplane an American Invention? (2014) International Journal of Humanities and Social Science. Vol. 4, No. 13; November 2014.
[101] The New 'Daily Mail' Prizes." Flight, Volume 5, Issue 223 (available at: http://www.flightglobal.com/pdfarchive/view/1913/1913%20-%200387.html, visited: 2015.03.28.)



1. Picture: Wright Flyer II. 1904. Source: Wrigth Broters website (available at: http://www.wright-brothers.org/Information_Desk/Just_the_Facts/Airplanes/Wright_Airplane_images/1904_Flyer_II/1904_Flyer_Flight_16Nov.jpg)

The first aircrafts to be built were ordered by the military, and with the introduction of more advanced engines, airplanes could technically evolve within a shorter period of time.[102] As a matter of fact, military began to use aircrafts soon after their invention, first in Italy, in 1911 in the Turkish war.[103]

It also means that commercial aviation did not really exist back then. World War I., on the other hand, largely catalyzed production in aircraft and demand grew significantly and in the US they introduced the airmail service.

[102] Cook, ch. V.
[103] Ferdinando Pedriali. "Aerei italiani in Libia (1911–1912)". *Storia Militare*, N° 170/novembre 2007,p.31–40

The models had also been demonstrated in other countries, which helped the industry to be created in countries like France, developing enhancing their own machines with the flight control system inspired by the Work of the Wright brothers.[104]

Interesting facts to mention is that, at the very beginning, it was impossible to carry out night maneuvers with the aircrafts. Only a bit later they equipped them with beams so that they provided visibility at night. The first planes were made of wood, which was later switched to aluminum in the period between the World Wars. The very first scheduled commercial airline to fly was established in 1914, operating in Florida, between Tampa and St. Petersburg.[105]

During the times of war, Europe invested enormous sums in research and development activities. Aviation has become the most rapidly incrementing industries with sharply improving technological solutions implemented ever before in history. Some of the pioneer planes of the era were: Wright Flyer (considered to be the first airplane), Santos-Dumont No. 14-bis, Voisin-Farman, Blériot XI, Curtiss Model E flying boat.[106] Regarding the significant first producers, providing military aircraft for the WWI, Fokker and Havilland (DH) can be mentioned.[107]

[104] Crouch, Tom D. Bilstein, Roger E.. History of flight. Aviation. Encyclopaedia Britannica. (available at: http://www.britannica.com/EBchecked/topic/210191/history-of-flight/260581/Other-aviation-pioneers, visited: 2015.03.28.)

[105] see: Smithonian National Air and Space Museum website. The early years of air transportation 1914-1927. (available at: https://airandspace.si.edu/exhibitions/america-by-air/online/early_years/early_years01.cfm, visited: 2015.03.29.)

[106] Ibid.

[107] See eg.: Treadwell, Terry C. Classic World War I Aircraft Profiles, Volume 1: Fokker Fighters,SE5 & 5A,Siemens Schuckert British & American DH4,Curtiss Jenny,Spad Fighters,de Havilland DH1 & DH2. (2005) Cerberus Publishing.

2. Picture: Fokker D VII. Source: NASA

In 1925, the government privatized airmail operations that can be considered as the beginning of airline industry in the US.[108] WWI, on the other hand restructured transportation options. Due to the political circumstances and the massive destruction of railways especially in Europe, demand for alternative solutions raised. It called for the opening of the first commercial flights and airlines, operated with extra military "biplanes", for instance, the DH-4, propelled by piston engines. These enabled long-range flights, and deeply transformed passenger mobility options.[109]

Aircrafts and their technology proved to be more and more reliable that is well demonstrated by early record data, such as the first non-stop flight between New York and Paris, through over 33 hrs, carried out by *Charles Lindbergh* in 1927 on a single-engine airplane. *Amelia Earhart*, in 1932 has become the first woman pilot who crossed the Atlantic. For those, who have seen the Aviator movie with Leonardo DiCaprio, the name, *Howard Hughes* should ring a bell. Apart from being responsible for important advancements in aviation technology, with a group of four, he drove a global flight with a Lockheed in less

[108] Cook, ch V.
[109] Boyne, Walter James. history of flight. 2015. Encyclopædia Britannica Online. (available at: http://www.britannica.com/EBchecked/topic/210191/history-of-flight/260581/Other-aviation-pioneers, visited: 2015. 05.10.)

than four days. Speed of aircrafts enhanced simultaneously, with the ability to achieve a speed of 550 km or 340 miles/h by the 30's.[110] During the same period of time, jet engines' (the parallel invention of *Hans von Ohain* (Germany) and *Frank Whittle* (England) launched a great advance in the technology. Commercial aviation always followed military aviation in technology, and it was one of the motors for development.

Within this first era in aviation, huge manufacturers of the century emerged. Here I mention some those most important.

With now over 100 years of experience in aviation, *Fokker*, the Dutch company was established in 1911. In WWI it supplied the German army with its airplanes. Its golden ages were in the 20's 30's, when they managed to reach 40% of the US market, and also had dominant position in Europe hand in hand with Junkers. It went bankrupt in 1996 and was acquired by *Stork*, turning into a "specialist supplier". By today, some of its models are still in service worldwide, including the Fokker 100.[111]

De Havilland was a British established company, founded in 1920 by aircraft designer Geoffrey de Havilland, designing military and commercial planes. It had its separate branches (or subsidiaries) in Canada, Australia and New Zealand. They conducted important development in aircraft engines, being competitors for great names as *Rolls Royce*. One of their biggest events was the launch of de Havilland DH 106 comet was the first produced commercial jet aircraft equipped with Havilland Ghost turbojet engines. [112] The Canadian branch (first sold to Boeing, later became part of Bombardier) introduced the famous DHC-8 (Q400) model in the 80's, which is now one of the most popular turboprop airliner.

[110] Lindbergh, Charles A. "WE" (with an appendix entitled "A Little of what the World thought of Lindbergh" by Fitzhugh Green, pp. 233–318). New York & London: G.P. Putnam's Sons (The Knickerbocker Press), July 1927. pp. 218-222

[111] see.: Fokker webpage. History of the Company. (available at: http://www.fokker.com/company/history, visited: 2015.05.10.)

[112] see: De Havilland Aviation website. The history of De Havilland. (available at: http://www.dehavillandaviation.co.uk/History/history.htm, visited: 2015.05.03.)

Douglas Aircraft Company was a US-based company, established in 1921. They served an important role in the circumnavigation of the world, such as in significant developments in military aviation. They introduced the aircraft named "the plane that change the world", the DC-3, a twin-engine propeller driven airliner. It has become the most popular aircraft soon after its introduction in 1936 by American Airlines, able to carry 21 passengers. One of their notorious models was the DC-9. In 1967 it joined *McDonall Airlines* (founded in 1939, famous for being a significant aircraft manufacturer during the World War II, being able to be the constructor for the first NASA spaceship program, the Mercury) and formed the *McDonall Douglas Company*, finally merging with *Boeing* in 1997.[113]

Boeing was established in 1916 by *William E. Boeing* in Seattle. It has important history not only in commercial and military aviation, but also in space programs. It also served during the World Wars and introduced the first "modern passenger airliner", the B-247 in 1933, with full metal design, retractable landing gear and wing with full cantilever, with ability to carry 10 passengers. In 1938, with the introduction of Boeing 307 Stratoliner (first flown by airline TWA) the company again made history. It was the first commercial aircraft which used pressurization. It highly evolved aviation and made it possible to fly over 20 000 feet, avoiding severe turbulences and "air/motion sickness" at previous heights of 10 000 feet. Today its headquarters is now in Chicago, US. One of their world famous models is the B-747 (jumbo jet). Boeing is the biggest aircraft producer apart from Airbus in our days. [114]

Apart from great manufacturers, some well-known airlines also were founded, such as the Dutch *KLM*, in 1919, proudly claiming now the title of the eldest airline of the world. As early as the 1930's it was able to operate weekly flights to Jakarta.[115] Following the Dutch, in

[113] see.: Cunningham, Frank. Sky Master: The Story of Donald Douglas and the Douglas Aircraft Company. Pittsburgh, Pennsylvania: Dorrance and Company, 1943. OCLC 14152627
[114] see: Boeing website. (available at: http://www.boeing.com/history/ visited: 2015.05.03.)
[115] KLM website. History. (available at: http://www.klm.com/corporate/en/about-klm/history/, visited: 2015.04.29)

1926, the Germans opened their airline, the *Lufthansa*, still one of the most successful companies of our age.[116]

The USSR, considering the new technological development, aviation, as a thing that should be developed by the proletariat, established its own airline, the now notorious *Aeroflot* in 1929.[117] In interesting fact about the airline, although being one of the eldest and most well-known airlines of the world, it had a relatively poor safety record in the 80's 90's, which is why it received the cognomen "Aeroflop" by travelers, and still quite a few people keep using this name.

In the USA, *United Airlines,* one of the world's biggest airlines, was established also in 1929, by the founder of Boeing and Frederick Rentschler. Nevertheless, they consider 1926 as the inauguration momentum of the company, serving then as an "airmailer" with a biplane.[118]

Airlines has become extremely important in the first half of the 20th century, especially for countries that had colonies back then, as a useful mean to keep connected to their far-away lands. Hence, developing national airlines for Britain, France and the Netherlands was a priority.[119]

World War II and the following Cold War were again great inducers for advancements of aviation. More and more airlines and producers appeared on the market, including now the biggest, *Airbus* and technology improved in an unimaginable space.

Safety of airplanes that was a primer worry previously, enhanced a lot, making flying the safest and fastest means of public transport and trade vehicle in our age.

[116] Lufthansa website. History. (available at: http://www.lufthansagroup.com/en/company/history.html, visited: 2015.04.29.)
[117] Boyne. Encyclopaedia Britannica.
[118] Star Alliance website. United. (available at: http://www.staralliance.com/en/about/airlines/united_airlines/, visited: 2015.05.01.)
[119] ibid.

From the sixties with the introduction of computers a rapid boom began in aviation as well. Different sensitive safety systems, complex electronic devices, computerization and modern radar and sensor systems had been introduced that helped the industry to be even more competitive and to produce enormous income.

From a bicycle-like machine, the most advanced vehicle emerged that requires sophisticated and complicated engineering to be able to serve the demand and expectation of millions. New famous models of airplanes, such as the supersonic Concorde and Boeing 747 or the Airbus A380 were introduced. Broad body airplanes with the capacity to carry hundreds a passengers and large cargo conquered the market of long-haul flights. Charter planes began to operate for touristic purposes travelling to holiday destinations, and lately, low cost carriers (LCCs) appeared, offering often friendly prices, accentuating competition. It also meant that the increased number of airplanes had increased emission of CO_2 and greater demand for fuel.

All this happened within a century, with the greatest growth beginning after the 50's. The number of aircrafts and passengers multiplied, such as the income they generated. The structure of the market has become diverse and it constantly keeps changing. From a luxury product of the previous years, air service has become a widely affordable alternative to travel and to transport, hence now its role is crucial in the economy.

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