Two Degrees Climate Target: Hell or Hallelujah

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Bachelor thesis
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Abstract

In 1996 the European Union and the United Nations Framework Convention on Climate Change (UNFCCC) adopted the 2°C climate target to prevent dangerous climate change and to limit the rise in global mean temperature to 2°C above the pre-industrial level. If this is possible to accomplish, with increasing emission of greenhouse gases, is hard to tell. There are today many uncertainties within the connections between the emission of greenhouse gases, the concentration of them in the atmosphere and the expected increase in temperature.
In this report the 2°C climate target is reviewed. By studying the available knowledge, the origin of the target and what might happen if temperature should rise with 2°C, an image filled with uncertainties, ambiguous definitions and moral dilemmas, revealed itself. This image indicated the complexity of the situation and the difficulties in formulating a climate target. After investigating different perspectives and possibilities a conclusion could be drawn, that the 2°C climate target is perhaps not the ultimate target but it is better than no target at all.

“It is perfectly obvious that the whole world is going to hell. The only possible chance that it might not is that we do not attempt to prevent it from doing so”

— Physicist Robert Oppenheimer

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1 Introduction

A couple of years ago I watched the movie "Day after tomorrow", a film about drastic climate change and what "might" happen if we continue down the road with increasing greenhouse gases emissions. I have seen it a couple of times since then and I have realised that there is a very strange feeling at the end of that movie. The film ends with pictures of the entire northern hemisphere covered with ice and snow. The main characters survived and the music and everything at the end, encouraged us to feel, "we made it, we survived!"

Let us stop and look at that again; the entire northern hemisphere is covered in ice and that is the situation when "we made it"? Then what would happen if we "failed"?
Plenty of the things happening in that movie are perhaps not grounded very much in reality but nonetheless the feeling at the end is what I want to emphasise. Because that feeling is not something unique for that movie, everyone wishes and hopes that we will "make it" just like they did. The thing is that we see ourselves as the "lucky ones," surviving a disaster. We are not any of those thousands of people that drown in New York when it was flooded or any of the thousands of people that probably would starve to death after a disaster of that magnitude. Everyone feels that we are going to make it and that feeling influences which decisions we make or don't make today. If you are going to survive anyway, why bother to do something about the climate?

Global warming is a very timely subject and a matter of great importance since it will affect every aspect of society. The debate is filled with a great range of arguments about what might happen and what needs to be done. Some scientists argue for the environment and the climate and tell you how our world might look like in the future, according to a whole range of complex climate models. The economists argue to preserve stability in the economic system, the oil or coal companies and producers argue for their case and the politicians are standing in the middle, trying to figuring everything out.

Because of my interest in the climate, I will in this work look closer at the 2°C climate target; a climate target that politicians for some reason have arrived at and is, by some, regarded as a suitable level to prevent dangerous climate effects. This report is divided into three parts. The first one gives a brief overview of climate change and then introduces the history of the 2°C climate target, climate targets in general and what they are. The second part will give a short introduction to the global mean temperature, and then explain the importance of climate sensitivity and the carbon cycle. These concepts are important to fully understand the arguments and difficulties presented in the third part where the 2°C climate target is discussed more in depth; is it reachable; is it a good target to aim at or should another target be adopted? To some of these questions there are no clear answers but my aim with this work is to present a picture based on scientific facts and personal conclusions on how we should tackle climate change.

1.1 Climate change

When talking about climate one is generally referring to the state of the atmosphere and other related components of the Earth system. Terms often used in situations to describe the climate are climatological mean, climate anomalies, climate variability and climate change. Fig 1.1 illustrates the difference between these different parameters.

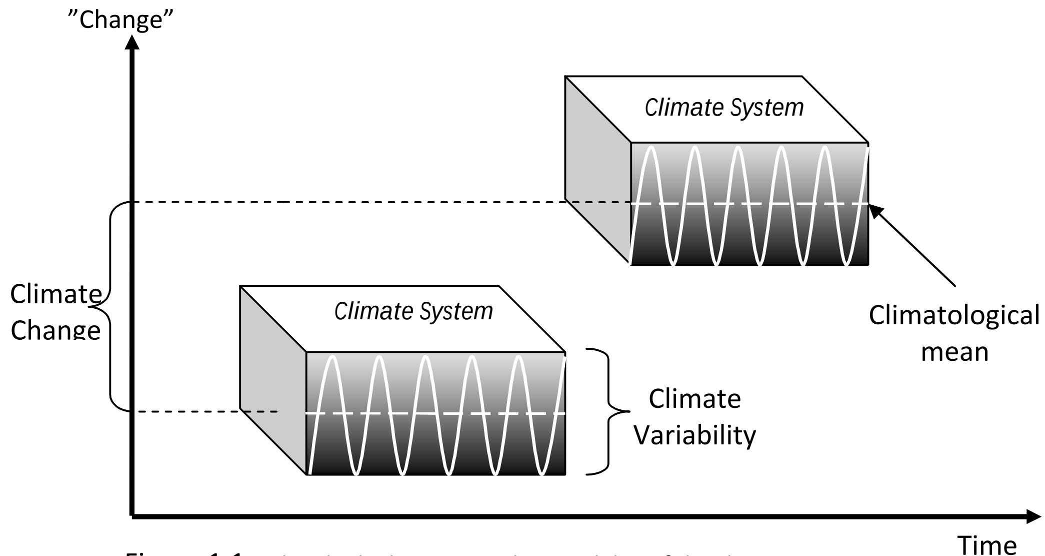

Figure 1.1: When looked over time the variability of the climate fluctuates around the climatological mean, but a climate change occur s when the entire system goes from one position to another.

Climatological mean is the state of the climate over a certain period of time. This includes both diurnal and seasonal variation and works like a period of reference, conventionally over a 30 year period. If, comparing your present data with that of the climatological mean, you find something that deviates from this mean; it is referred to as a climate anomaly. [1]

Climate variability is considered to be the long-term variability in the mean state either over a season, a year or a decade. Things that can cause such variation are for instance the phenomenon known as the El Niño Southern Oscillation (ENSO). A volcanic eruption or solar variation can also cause the climate to vary from one year to another. [1]

The climate variability changes over time between some limits.[1] When the climate is affected by a modification, these limits of the variability are altered. The climate system deviates from its previous values and will settle around some new values. If the result is that only the upper or lower limit of the variability is changed or like in figure 1.1, that the entire climate system is put in a new position, depends on different factors.

[1] The variation is not that regular as represented in figure 1.1.

Climate change is something that has been a part of this planet throughout its entire history. The planet has gone through some major changes and the climate has shifted between different states. Climatological investigations done on for instance ice cores give an indication of when different variations have occurred. Earlier shifts have taken place over thousands of years since they often had to do with the orbit around the sun, the radiation emitted from the sun etc. Climate change of that sort has happened before and will happen again. The reason why the changes experienced today are considered more serious is because the changes occur over a relative short range of time and will thereby affect human civilization.

When the term "climate change" or "global warming" is used in this work it is not referring to the natural variation of the climate. What is being discussed in this work are the effects caused by anthropogenic emission or other anthropogenic interference. The effects caused by humans, especially emission of greenhouse gases, are considered to be the cause of the changes in climate, measured and experienced today. Since many believe that humans are likely to be responsible, many also believe that if we are causing it, we can also fix it and this is what climate targets are invented for.

1.2 History of climate targets

One can have different types of climate targets, all interconnected to the relationship between emissions of greenhouse gases, concentrations of them in the atmosphere and the global mean temperature, as illustrated in figure 1.2.

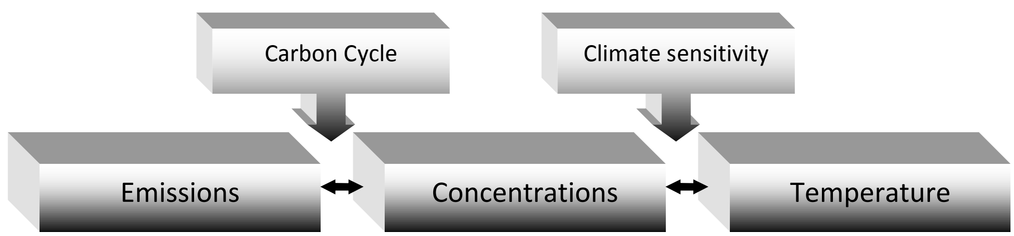

Figure 1.2: The connection between emission, concentration and temperature are not fully understood because of the uncertainties existing in the carbon cycle and the climate sensitivity.

Climate targets can be applied to any of these three. Either you formulate one that limits emissions, concentrations or temperature. An important issue is the uncertainty in the knowledge currently possessed by science of the connection between the different processes. Between emissions and concentrations, the uncertainty lies in the specific details in the carbon cycle (see section 2.2). Between concentrations and global mean temperature there instead is the problem of climate sensitivity (see section 2.1). A climate target formulated to limit any of them will result in uncertainty in the other two. If you for instance want to limit temperature you have no exact indication which level the concentration or emission should be on.

By the 1970s, perhaps even earlier, people were starting to understand that the modern, western human way of living damages the environment. Some scientists had raised the question much earlier but had often been rejected (as often the case when someone suggests a new view of the world). Predictions of increasing temperature caused a lot of worries, but also a lot of confusion when combined with reports of the cooling effects of particles and aerosols. One day the earth was getting warmer, the next humanity faced the risk of a new ice-age. Many had also a great difficulty in seeing how humans could affect the climate in the way suggested by scientists, a problem that to some extent still exists today. Despite the uncertainty in what was going on, the majority came to the conclusion that something needed to be done. [2]

Climate targets started to be discussed in the late 1980s and in the early 1990s. Two targets were formed during debates in Europe by 1987. The 2°C degree climate target was one of them and the other one said that a tolerable level of rise in global mean temperature would be 0.1°C per decade. International Project for Sustainable Energy Paths (IPSEP) published a report in 1989 in which two different climate targets for climate policy were presented. One was the just mentioned of a limited rise of 0.1°C per decade and the other of a maximum CO_2 concentration in the atmosphere of 400ppmv. That concentration was likely to give a rise in temperature between 1 and 3°C above pre-industrial temperatures. [3] [4]

The 2°C climate target is formulated to limit temperature. The intention of it is to prevent dangerous climate effects by preventing the global mean temperature to rise 2°C more than pre-industrial temperature. According to measurements temperature has risen 0.8°C since the beginning of the industrial revolution. [5]

The 2°C degree climate target was adopted by the European Union in 1996 and they have kept it during later statements both in 2005 and later also in 2011. It was also included in the so called Copenhagen Accord written in 2009 [6] and parties agreed to commit to it during the climate conference in Cancun, 2010. [7]
A review of this target is planned to take place during the period 2013-2015. That might lead to a sharpening of the temperature target since there are some who would like to see a 1.5°C climate target instead. [8]

This possibility of sharpening the target raises the question why the original level was put to 2°C? Why is it the “2°C” climate target? There is little scientific evidence for why that temperature should be the favoured one [4] so why is it not the 1.5 or 3 or 2.25°C climate target? The origin of the “2”, in the 2°C climate target is hard to find. The origin might be traced to the developed “traffic-light” system that a group of scientist created in the beginning of the 1990s. The colours represented different scenarios where green meant some degree of damage, yellow medium risks and red meant a serious disturbance of society. The border between the green and yellow were said to be a maximum temperature increase of 1°C (compared to pre-industrial levels) and the boundary between yellow and red were 2°C. Since the limit of 1°C was considered to already be out of reach the second option were 2°C. [9] Others talk about a legend, a story that the target emerged from a dinner conversation. [3] If this legend is true is a different question. The 2°C climate target might have started as an idea but it is today looked upon as a "maximum" level of global mean temperature increase.

Climate targets are criticized by some and acclaimed by others. Often they have unclear economic justifications and some economics have criticized the 2°C target for having a rather weak justification in cost-benefit analysis in studies of climate policy. [3] Climate targets initiate conversations and help to simplify things but sometimes they make it too simple and do not show the entire picture.

2 Theory

Often in discussions about climate change and global warming, the global mean temperature is frequently at the core of the debate. Discussions about how to limit the expected rise in temperature, how much it will rise and what effects a certain rise might cause are all being argued and reviewed. But the temperature is merely a result of the Earth energy balance.

For the temperature on Earth to remain constant, the energy that is received must match the energy that is emitted, otherwise the temperature will either rise or decrease over time. This is a process known as the Earths radiation balance and can be illustrated as in fig 2.1

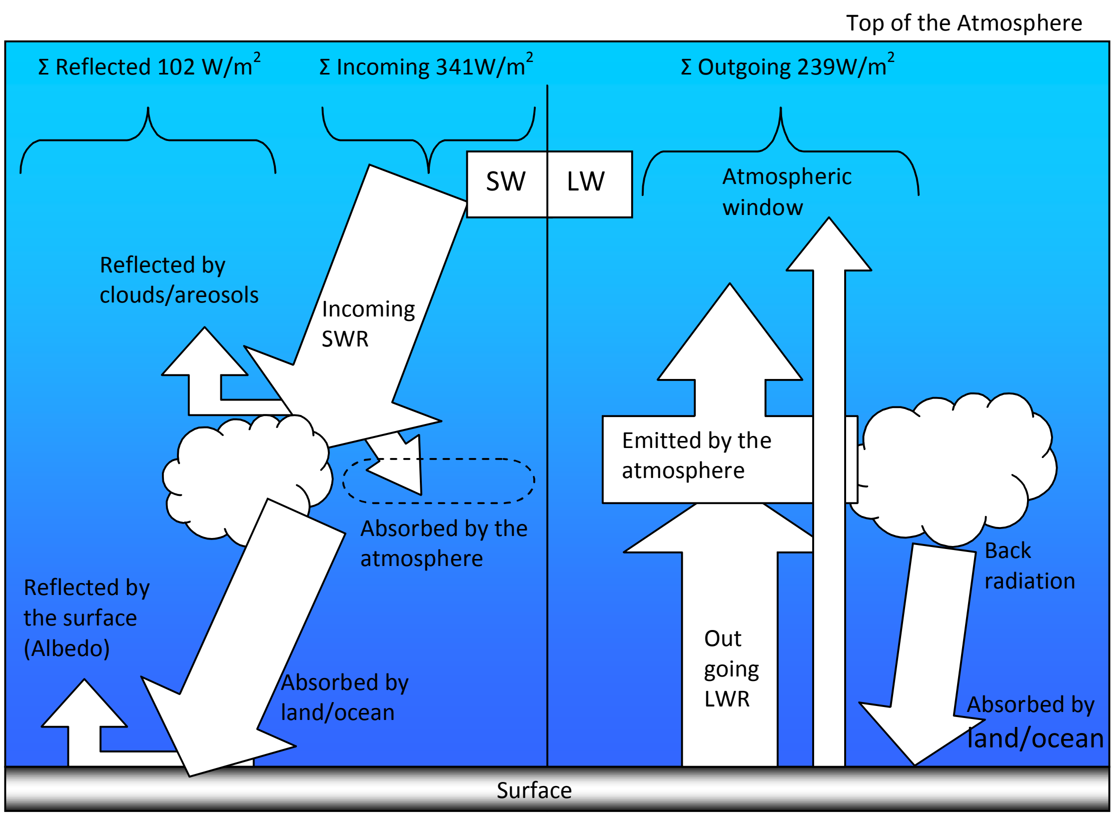

Figure 2.1: The radiation balance of the atmosphere represented with short-wave radiation (SWR) processes to the left and the long-wave radiation (LWR) processes to the right.

The shortwave radiation (SWR) from the sun is either reflected or absorbed by the atmosphere or the surface. Humans affect the balance in mainly two ways. One is by altering the albedo which changes the part of the SWR that is being reflected and the other is in the disturbance of the outgoing longwave radiation (LWR). The increased concentration of greenhouse gases changes the radiative properties of the atmosphere. The LWR is absorbed by the atmosphere which then emits radiation in every direction both into space and back towards Earth where it is absorbed again.

When it is said that the global mean temperature might rise with two degrees it does not imply that every location on earth will have a rise of two degrees. The average temperature is going to rise with two degrees but that does not imply that some places will not experience a greater or smaller increase in temperature. Areas over land and high northern latitudes are thought to experience a greater increase in temperature while southern oceans will experience less warming. [10] When a forcing[2] occurs the radiation balance is disturbed and a change in temperature will come as a result of that. The question is, how large will the change in temperature be and how will that change affect other areas of the climate system?

2.1 Climate Sensitivity

Conventionally, the climate sensitivity is defined as the equilibrium temperature response if the concentration of CO_2 in the atmosphere were to double. Despite that climate sensitivity is defined from the concentration of CO_2, a high value indicates a strong temperature response to whatever source of radiative forcing and a low value indicates the opposite. [3] [11] [12]

The first scientist who asked the question of what would happen to the climate if the concentration of CO_2 in the atmosphere were to double was the researcher S. Arrhenius at the end of the 19th century. He estimated the climate sensitivity to be 5.5°C. The Intergovernmental Panel of Climate Change (IPCC) has over the years presented values within a certain range where the latest value was presented in 2007. The climate sensitivity was given the value of 3°C, which is supposed to be the best estimation in the range of 2 to 4.5°C. [13] This range is thought to be the most likely interval. Conclusion has been drawn by combining different sources of information to get a better overall picture. Palaeoclimatic data, and volcanic eruptions have been combined with instrumental measurements and probability distributions calculated by computer models and the result point towards this 2 to 4.5°C interval. There are very few studies where the results differ substantially from the range. [14]

A mathematical expression for climate sensitivity looks like:

$$\lambda = \frac{dT_s}{dF} \qquad (2:1)$$

[2] Anything that might disturb the radiation balance

where λ is the climate sensitivity parameter, T_s the surface temperature and F the radiative forcing. [15]

Included in λ are different feed-back mechanisms. A feed-back mechanism is the climate response to a change and that response can either cause the change to be greater or smaller than it otherwise would have been. Feed-back mechanisms can be described as an enhanced or reduced variation of the climate as a consequence of an initial change in temperature. A couple of different examples are water vapour, clouds and ice-albedo. If the temperature increases, the atmosphere can “carry” more water and then increase the concentration of water vapour in the atmosphere. Since water vapour is a greenhouse gas, the increased concentration will increase the temperature even more. More water vapour might result in an increased concentration of clouds and depending on the optical thickness and the height of these clouds their contribution will either increase temperature (by absorbing the longwave radiation) or decreasing temperature (by reflecting the incoming shortwave radiation). An increased temperature means melting of the polar ice, the albedo is reduced and more energy is absorbed instead of being reflected by the snow and ice, resulting again in an increase in temperature. [12] [15]

There are mainly two different ways to estimate λ. The first one is through a general circulation model (GCM) to simulate the climate response to a change in the radiative forcing. The second way is by looking at climatological and historical data. In the data it has to be possible to deduce both the change in forcing and the change in temperature. [12]

The climate system is complex due to all the different components of it, which is also connected to each other. A change in one area might have certain influences in many other ones. Despite increased observational data and better computers, the uncertainties regarding climate sensitivity have not decreased significantly in past years. Trying to reduce the uncertainty in the different individual feed-back parameters to reduce the over all uncertainty in climate sensitivity has also proven only to give minor effects. [11]

The uncertainties regarding climate sensitivity existing today are a problem for climate targets of any kind. One can argue if this uncertainty is reason not to take action or if the available data provide us with enough information of where we are heading.
However, the uncertainty makes it difficult formulating climate targets but also in predictions of what kinds of climate changes a rise in temperature might lead to.

2.2 Carbon Cycle

Since the beginning of the industrial revolution the concentration of CO_2 in the atmosphere has increased. Measurements started by Charles D. Keeling on Hawaii in 1958 show a clear increase in the concentration. From different sources of investigation like ice cores, the pre-industrial level of CO_2 has been estimated to 280ppm and had rose to 375ppm by 2003. [16] By 2010 the level is estimated to be 390ppm. [17]

Figure 2.2 shows the increased concentration and the annual variation of CO_2 due to the growing season in the northern hemisphere, where a noticeable amount of CO_2 is absorbed every summer when the photosynthesis of plants is active. The data offer a clear indication of what has happened in the atmosphere since the 1960's. These records are considered to be very reliable since measurements are done on a location away from sources of interference and it provides a long measurement series of CO_2 concentrations in the atmosphere. [18]

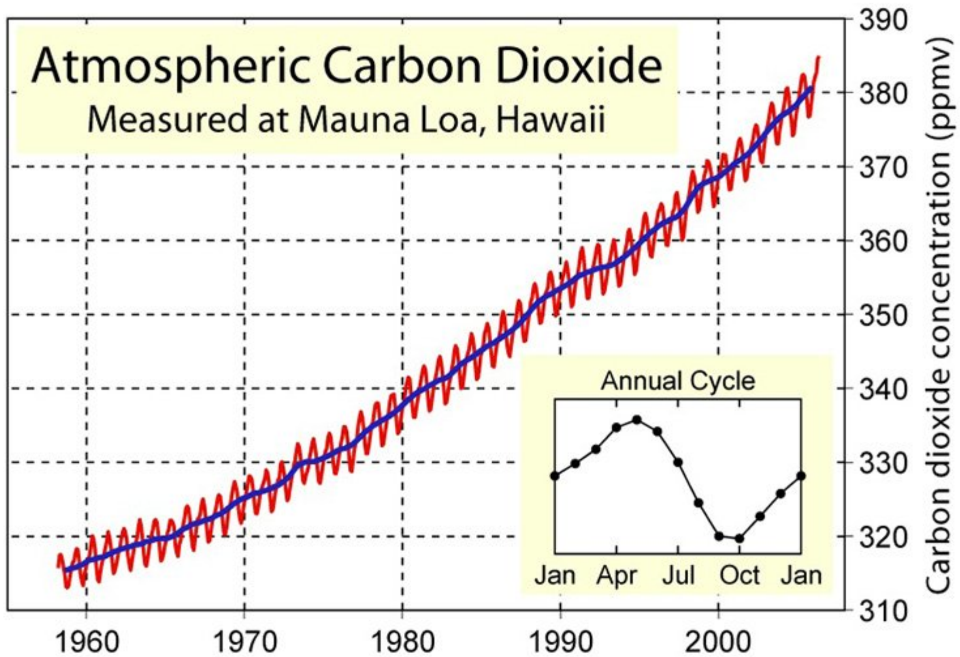

Figure 2.2: The concentration of CO_2 in the atmosphere measured on Hawaii from 1960 up till today. The red line represents the annual variation and the blue is the average increase in concentration. Source: http://www.eoearth.org/article/Carbon_cycle?topic=49505

We are but a tiny part of the entire global carbon circulation known as the carbon cycle. Figure 2.3 shows the major fluxes and also different sources and sinks. A source is either a place or a process that results in an emission of carbon and a sink is a place or process where uptake from the atmosphere takes place. Carbon can also be stored in different systems like the soil, the oceans or the atmosphere. A place of stored carbon is known as a reservoir which contains a large amount of carbon.

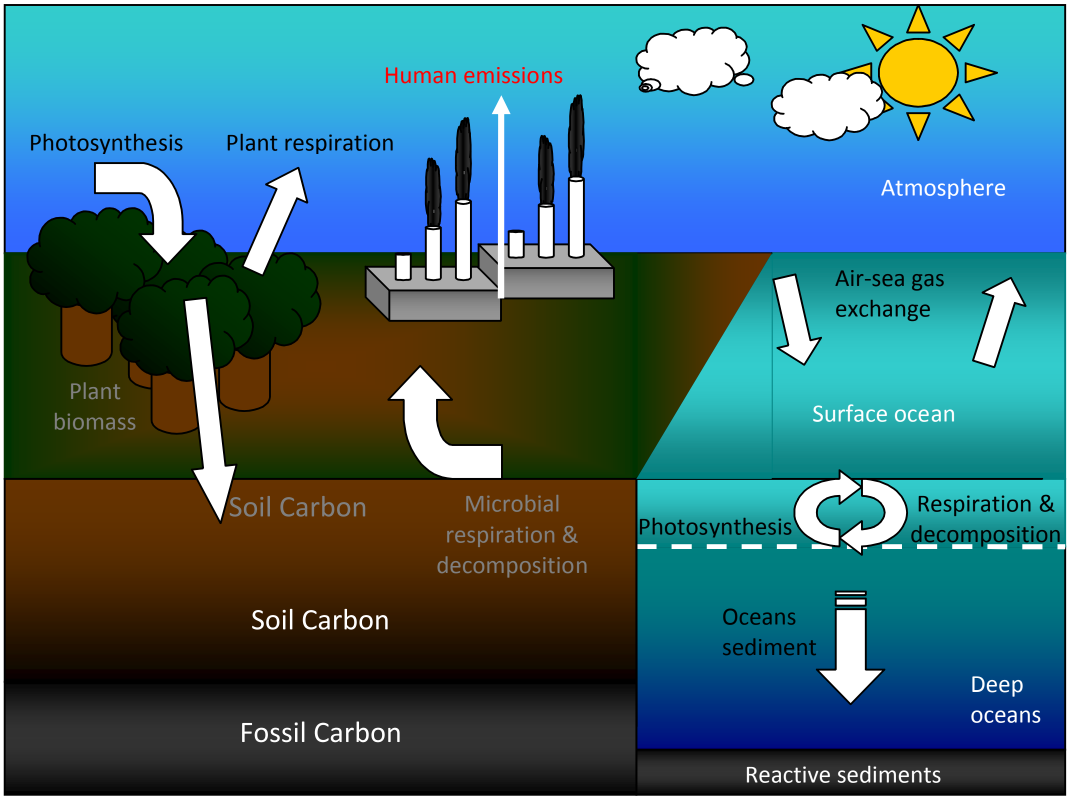

Figure 2.3: The carbon cycle illustrated with the major known fluxes. White text in the figure represents stored carbon, the black or grey the natural fluxes and the red one is human contributions.

A better understanding of the carbon cycle is today considered to be important because human lifestyle is a strong source in the carbon cycle; both because we are burning a huge amount of fossil fuels, but also through modified land use. In both cases we are disturbing the natural balances between the different reservoirs and the result is often that more carbon, in the form of CO_2, is released into the atmosphere. More CO_2 in the atmosphere leads to a rise in temperature.[3]

Modified land use can be performed in two different ways. The first one is through deforestation. Cutting down a forest or planting new trees in an area affects the fluxes in the carbon cycle. There is always a balance between photosynthesis, respiration and decomposition. The land biosphere is considered to be a carbon sink, which every year absorbs about 30% of anthropogenic emissions from combustion of fossil fuels and deforestation. The reason for this sink is an increase in net primary productivity (NPP) which comes as a result of different environmental features, one of which is the increase is temperature. The photosynthesis of plants is enhanced (up to a certain level) with rising temperature and CO_2 concentration. This rise increases the NPP and removes carbon from the atmosphere and stores it either in biomass or after some time in the soil. Figure 2.3 show that the soil is a reservoir of carbon. To consider the soil as a future option to store carbon is uncertain. An increase in temperature will increase the decomposition which releases carbon into the atmosphere again. Nature

[3] This is also true for other greenhouse gases such as N_2O and CH_4.

always endeavours to attain balance between the different fluxes but the magnitude and the local variations of these are not yet fully understood. [19]

The processes governing the oceans uptake of CO_2 can be described in three steps: 1) Dissolving of CO_2 in the ocean, 2) chemical interaction with seawater constituents and 3) transport into the deeper ocean, where 2) and 3) are the two steps removing CO_2 from the atmosphere. To predict the rate of the oceans uptake of CO_2 one need to have information about biological uptake in the oceans, oceanic transport and mixing processes, all of which today contain uncertainties. [16]

There are a couple of things regarding the carbon cycle that science would like to have more accurate information about: A more precise pre-industrial mixing ratio of CO_2, the total fuel emission, the transfer of CO_2 to the atmosphere as a result of deforestation, and the amount of carbon in the pre-industrial reservoirs are things that are considered important to learn more about. By doing this one can increase the knowledge of the anthropogenic impact on the carbon cycle and the climate. [16]

A better understanding of the carbon cycle will probably result in a better understanding between the emission and the concentration of CO_2 in the atmosphere. This connection is judged to be important in order to improve arguments regarding emission reduction policies, since there will then be a better understanding of the link between emission, concentration and temperature.

3 The two degrees climate target

The title of this work is “the two degrees climate target: hell or hallelujah” and the goal with it is to arrive at some sort of conclusion if this climate target is worth the attention it is given. In this section more questions will be asked than answers provided. The reason for this lies in the nature of science and in the origin of the problem. Because this problem gives rise to a couple of hard questions and as always in science, when you have answered one question, a lot many more can and should be asked to fully understand the situation.

Before I go on I would also like to emphasise and repeat things from section 1.2. I think there are two things to remember 1) there is very little scientific evidence for why 2°C should be the most preferable target and 2) there are uncertainties in the connection between the emission of greenhouse gases, the concentration of them in the atmosphere and the global mean temperature. These two things are important to keep in mind because they inform that this target has some factors of uncertainty and it is not a scientifically proven ultimate goal.

3.1 The 2°C climate target: what does it say?

The 2°C climate target is not a very clear target at all and not many people (if anyone) understand it to 100%. The origin and the temperature choice are already pointed out to be quite vague (see section 1.2). One could summarise the target in these points:

- The 2°C limit regards the increase in global mean temperature compared to the pre-industrial level.
- The 2°C climate target is projected as the goal to prevent dangerous anthropogenic interference.
- It is not a legally based target but rather a target that countries have agreed upon to be decent target to strive for.
- The target aims to restrain the long term changes which are not said to be limited by a certain time period.

These four points give a fairly good representation of what the target is all about but they still leave many questions unanswered. That in itself is not something unique to these points but is a problem with the target itself because it lacks descriptions and definitions in some areas, probably causing the confusion that surrounds the target. Questions that are problematic are for instance “what is meant by dangerous anthropogenic interference” and also “what happens if the target is not achieved?”

The first of these questions, the part regarding what are considered to be “dangerous,” is something that will be discussed more thoroughly in section 3.4. Many decisions are made to prevent these dangerous effects and if no one knows what they are then how could they be prevented?

Several investigations point in the direction that temperature might rise above 2°C, which raises the questions "what happens if the 2°C climate target is not achieved", "what happens if temperature rises more than 2°C?" Due to the fact that temperature might rise more than 2°C, discussions are initiated to include an acceptance for something called overshooting, which is a scenario for which the temperature changes, for a time to come, lies above the 2°C-limit. As long as temperature change, on the long-term starts to converge towards the 2°C level again, a period of overshooting is considered to be acceptable. How high the temperature might rise during this "overshooting period" or how long it is allowed to last is not clear.

Some might consider an overshooting a failure but it is important to remember that the 2°C level is not some "magical limit". The important things to avoid are the so called tipping points. There are different kinds of potential tipping points of which some can be regarded to be "points of no return" and should definitely be avoided, whereas others might cause severe alterations of the climate, but might be reversible.

An analogy of a chemical buffer can be used to illustrate the severity of a tipping point. If one pours an acid or base into a buffer, the pH-value will remain almost the same. Changes up to a certain level do not affect the pH and depending on the quality of the buffer different amount of acid/base can be added without any changes. Then a tipping point is reached where the slightest change will have a huge impact on the pH-value. Some areas of the climate system can be illustrated in the same way; a minor forcing might result in a comprehensive alteration due to the fact that a tipping point has been reached. The problem is that at current stage, the strength of the buffer is unknown which means that we don't know how far from tipping points we are.

If a tipping point were reached, a feed-back mechanism would cause the climate to undergo some major changes of which some might be permanent. There are however, great uncertainties surrounding different tipping points, what might happen, how fast the changes will happen and more seriously, when they might occur. There is no absolute safe level; there is still too much uncertainty involved, but the higher the CO_2 exposure, the greater the risks of facing a tipping point. [20]

3.2 Climate impacts due to emissions of a 2°C increase in temperature

Alterations in climate are something that have been observed over the last decades and because of the inertia in the climate system all changes have not yet manifested themselves. Additional changes will take place even if we were to stop all anthropogenic emission today. Predictions unfortunately point in the opposite direction with increasing emission over the years to come.

When talking about a rise in temperature of 2°C most people shrug there shoulders and do not understand the urgency of the situation. 2°C does not sound like much but it will nonetheless result in changes in climate which we have to deal with in some way or another. I prefer thinking of it in terms of body temperature. The human body is like the climate system, a balanced system where everything is connected to everything else. An increase in the average temperature in the body will give you a fever and that is not something to shrug your shoulders over. It is something serious and an indication that something is wrong. When you have fever, the body is put under a lot of stress and the same goes for the climate system when temperature rises. The analogy with the body fails on one point which is that when your fever has settled the body temperature is returned to the original value. The climate does not have a value like that but will instead balance around the new value.

As previously mentioned, the 2°C level is not a magical limit which if we stay beneath it everything is fine and if we cross it, something terrible will happen. A 2°C increase in global mean temperature will result in different climate changes of various magnitudes on a range of locations on Earth.

There are predictions made both on what might happen during the 21st century but also what might happen beyond this century. Observations that will be made during this century are likely to show a larger change than the observations done during the last one. How large the difference will be depends of which course the emissions take. In addition to the general warming and sea-level rise, heat waves and heavy precipitation events are very likely to become more frequent than before, sea ice are likely to shrink both around Antarctic and in the Artic. Tropical cyclones are likely to become more intense[4] due to the increasing sea surface temperature but there are uncertain predictions of what might happen to the frequency. Sea levels are expected to rise but due to limited understanding of the underlying effects driving sea level rises, reliable predictions are difficult to do. [21]

These changes will have different impacts on different parts of society which can be illustrated by figure 3.1. It is a figure that illustrates some examples of what can happen in different sectors with a temperature rise of 2°C relative to the pre-industrial level but also how the effects will amplify if temperature where to rise up to 5°C.

[4] More intense refers to stronger winds and heavier precipitation

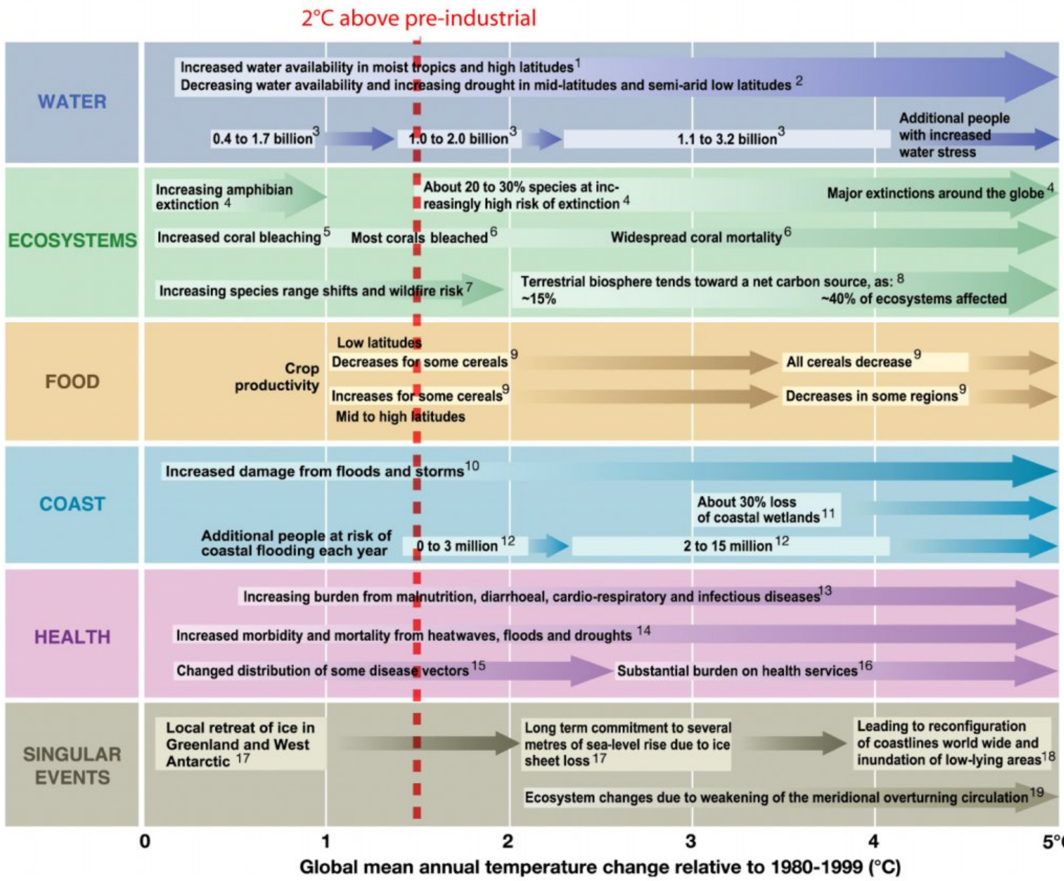

Figure 3.1: Different effects that might occur if temperature rose with 1-5°C with increasing effects with higher temperature. Since the change in temperature is relative to 1980-1999, the level where 2°C above pre-industrial level is marked in the figure is around 1.5°C.

Source: © EU The 2°C target, information reference document, background on impacts, emission pathways, mitigation options and costs. July 2008, p.13

Whether all these changes will cause severe damage if the temperature "only" rises 2°C is hard to tell. What has been investigated though is which areas that are more sensitive for changes. The Amazon due to the delicate balance in that ecosystem may be highly sensitive. Australia and Africa are also considered to be sensitive areas regarding both temperature and precipitation change. The southern part of South America is considered not to be as sensitive and the same goes for Central America. [22]

All the different potential changes will have a great impact on every society. All nations might not experience every change directly but through indirect impacts we will all be affected. We live on the same planet which means that the effects will be global and we will have to face all these changes together.

3.3 Can we meet the 2°C target?

As the 2°C climate target is formulated today, the question “if we can reach it” is a difficult question to answer, but in the same time it is not. The easy answer is that, if temperature stays below 2°C we have reached it and if it doesn’t, the target has been unsuccessful. The easy answer is either yes or no. But since there is no time-limit to the target, only an intention to in the long-term limit the temperature increase to no more than 2°C, the target might not fail even if a period of overshooting is experienced. This ambiguity makes it difficult to answer the question easily, but the answer to if we can meet the 2°C climate target is still either yes or no.

As to the question “if we can reach it”, a supplementary question should be asked. If the answer is “yes, we can reach it”, then the next question should be, “how can we reach it”? If the previous answer is “no”, then the next question is “why can’t we reach it”? Perhaps the question “can we reach it” needs to be changed to “what needs to be done” and can we do that before temperature exceeds the 2°C-limit? There is a consensus that to reach the 2°C target, severe reduction of emissions of greenhouse gases is necessary, but according to economics, politicians and scientist that may be both difficult and expensive.

The question has now been transformed into, “how much must we reduce the emissions”? This depends on how certain we want to be reaching the 2°C climate target. When performing predictions of what might happen in the future, answers with 100% accuracy are impossible, one only gets different probabilities depending on which scenario you are studying. There is uncertainty in climate science because of the uncertainties previously mentioned in the carbon cycle and climate sensitivity, total predictability is not possible. This does not mean that all predictions are wrong but they all contain a certain amount of uncertainty.

Estimations done show that there is a mean 82% risk of exceeding 2°C calculated from the formulation that a 2°C increase are supposed to be equivalent with a concentration of CO_2 of 550ppmv. If the aimed concentration instead were 450ppmv, there is still a mean 54% risk of exceeding the 2°C target. [3] Others consider a 2°C stabilization to be achievable if the concentrations of greenhouse gases are kept at the levels presented in table 3.1. [22] Together with those values are also the concentrations of the well-mixed greenhouse gases from 2010. Other investigations point in the direction that a peak in emissions is required by 2015 to limit temperature to less than 2°C above pre-industrial levels. If this peak takes place, there is a probability of 66% of achieving this climate target. [8]

Greenhouse gas	CO_2	Table 3.1 CH_4	N_2O	CFC-11	CFC-12
Concentration today [17]	390 ppm	1810 ppb	323 ppb	No data found	No data found
Concentration required [22]	418 ppm	2026 ppb	331 ppb	786 ppt	486 ppt

Table 3.1: The concentrations of greenhouse gases today, along with the estimated necessary stabilizations levels to achieve the 2°C target. The concentration of 418ppm can be compared to the value 550ppmv. 550ppmv was the original limit of the 2°C climate target formulated in 1996 but has been altered over the years. [3]

For there to be a 50% chance for temperature to remain below the 2°C-limit, the total emission of CO_2 (both from fossil sources and modified land use) in the years 2000-2049 will have to stay below 1440GtCO_2. To raise that probability to 75% the emissions must remain beneath 1000GtCO_2. During the years 2000-2006 approximately 234GtCO_2 were emitted and if the assumption is made that there will be a constant emission of 36GtCO_2 yr^{-1} up to 2049 the total emission by then will be 1815GtCO_2. [23]

Figure 3.2 illustrates that, depending on different scenarios, what needs to be done in order to reach the 2°C climate target. One scenario is that emissions from today increase as they did between the years 2005-2010 (the red line) and continues to do so until they peak. The relation between the x- and the y-axis show the rate of how much one must reduce the emission every year until 2100 to be able to reach the 2°C target. If one has the above scenario (the red line) and emission peak around the year 2020, the annual rate at which emission has to decrease is then ≈5.5% yr^{-1} until 2100. If the peak instead happens 2015 the decrease in emission will have to be around 4% yr^{-1}.

Another scenario is instead that the emissions stay constant at the level measured in 2010 up till the point where emission peaks (the yellow line). Lets again say that emission peak in 2020, the reduction rate now required has lowered to around 5.0%. If instead of a 2°C climate target, a target of 2.5°C should be considered, the reduction rates needed to fulfil that target are shown by the light and dark blue curves.

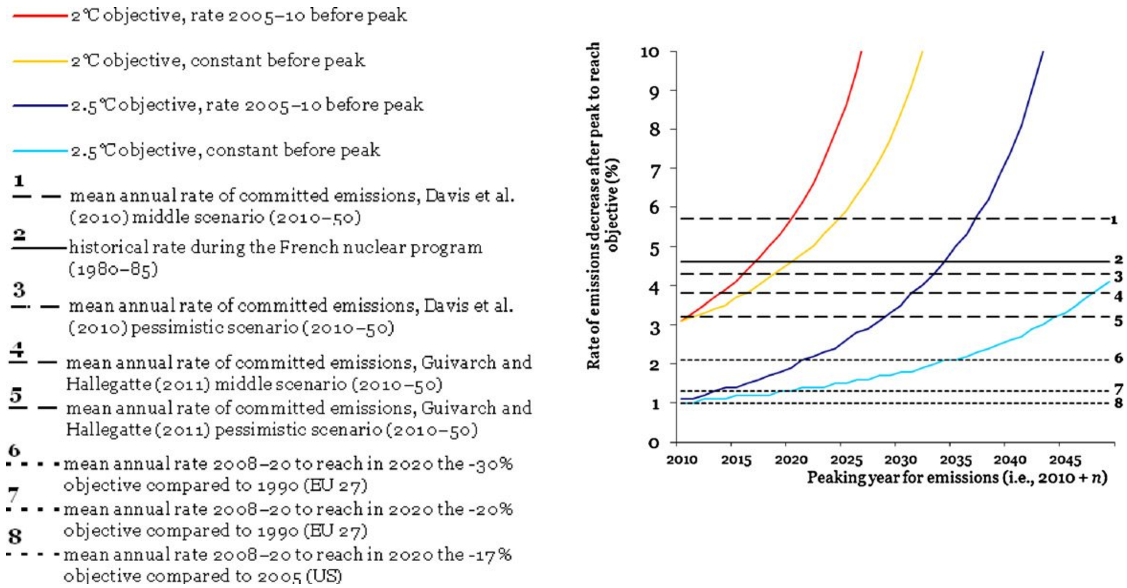

Figure 3.2: The different coloured lines represent different emission scenario: the red and yellow ones are connected to the 2°C target and the light and dark blue are connected to a 2.5°C target. Depending on the scenario different rates of decreasing emissions are required. The black horizontal lines represent different reduction targets according to predictions and historical observations.

Source: © Céline Guivach & Séphane Hallegatte, 2C or not 2C? Global Environmental Change 23 (2013) p.181

The black horizontal lines represent different reduction targets according to different predictions and historical observations. The European Union (EU) has decided to reduce their emission by 20% to 2020 compared to 1990. USA has a target to reduce their emission with 17% compared to 2005. These two targets correspond to an annual reduction of 1% and 1.3% per year (horizontal line number 8 and number 7). [24]

2050 is the year beyond 2020 often discussed and the emission will have to be reduced by 50-70% relative to the levels at 1990 for the 2°C climate target having a 66% chance of success. [5] [8]

Horizontal line number 2 is one that should be mentioned because it illustrates what is believed to be the largest observed decreasing rate that a country has ever performed over a couple of years. It was in France during the period of 1980 to 1985 when they were deploying nuclear power plants to "decarbonize" electricity production and through other energy efficiency measures they managed to reduce the emissions of CO_2 with 4.8% per year over that 5 year period.
[24]

It is quite obvious that if we are to reach the 2°C climate target we either should have peaked our emissions several years ago, or should put much more effort today in reducing our emissions. At current stages a climate target of 2.5°C would face a bigger chance of success than the 2°C has today.

The probability of reaching the 2°C climate target without a period of overshooting is looking rather slim. Does this mean that the target is never to be achieved? If overshooting is allowed then there of course is a better possibility, in the long to run to get the temperature curve to decrease and sink below the 2°C level. With the acceptance of overshooting the 2°C climate target can probably be achieved in the long perspective. But as the world looks like today with weak plans for emission reductions, remaining below 2°C is going to be a challenge of rare proportions.

3.4 Dangerous Anthropogenic Interference

The present formulation of the 2°C climate target refers to preventing dangerous climate change. The United Nations Framework Convention on Climate Change (UNFCCC) formed in 1992, has as its ultimate goal to stabilize the concentration of greenhouse gases on a level that would prevent Dangerous Anthropogenic Interference (DAI). The problem is that nobody knows what the word "dangerous" refers to. There is no clear definition of what can be regarded as a dangerous climate change. [25] There is however a framework, an outer limit where changes beyond that are considered to be dangerous. For instance if the global ecosystem is not given the time necessary to adapt, if food production is threatened or if the economic development is not allowed to proceed in a sustainable manner, then there is a dangerous anthropogenic interference. [26]

There are different attempts to define "dangerous" climate change more rigorously; quite often it is defined with the aid of global mean temperature but that is by some considered to be a weak definition. Of all the different climate variables that can cause the climate system to pass a critical threshold, the global mean temperature is hardly the parameter that actually causes the change. Regional temperature, changes in precipitation or other areas of the water cycle are likely to be the governed parameters. This implies that instead of temperature perhaps another parameter should be used. Some suggest radiative forcing[5], a parameter that governs many climatological features. [25]

Another definition of what can be considered to be dangerous is impacts that will affect food or water supply, human lives, ecosystems, or sustainable development in general. Different attempts to divide dangers into different groups have been done where "population at risk", "dollar lost", "local / regional / global impact", are examples of different groups. There is no limit how many groups the different impacts can be divided into and a definition of dangerous can still not be drawn from the various groups. For instance how large must a region be before a lack of food or water supply are considered dangerous? Is lack of water considered to be more dangerous than a lack of food? If a region experiences modest changes over many areas, is that less severe than a region that only experiences one severe event? [27]

An example that illustrates the difficulty in defining DAI is the melting of the Greenland ice sheet (GIS) or the West Antarctic ice sheet (WAIS) (or both of them). This would result in a major increase in sea-level and when asked, a majority would probably consider this to be a dangerous anthropogenic interference that should be avoided.

[5] A radiative forcing is a changed imposed on the Earth's radiation balance. An increased concentration of greenhouse gases or changes in the planetary albedo is examples of radiative forcing.

But since the ice sheets probably will melt slowly over several centuries and be completely gone in 1000 years, the feeling of dangerous almost disappears. [27] I believe this to be the result of the fact that we are not evolved to deal with these kinds of threats. We are evolved to deal with immediate danger, predators, fires, enemies, those kinds that happen now. Dangers that will reveal themselves slowly over decades or centuries to come are not something we are good at dealing with because we don't see the danger. This means that to be able to define what is dangerous, the time scale involved has to be considered.

Figure 3.1 illustrates different effects that might happen with a certain increase in temperature. Increased damage from floods and storms, millions of people experiencing water stress and an increasing amphibian extinction are all points that are located below the 2°C-limit. These are effects that will have an impact on human lives, costal regions and various ecosystems and can be seen as dangerous, but only if they affect food production, causes radical changes in ecosystems or hinder the economic development. If they don't these affects lie beneath the written limit of what is considered dangerous. Every effect that might happen is not dangerous according to the present definitions. Hurricanes, floods and heat-waves are things that are likely to be even more common but if they occur before the global mean temperature have risen to 2°C, or don't result in effects that have been categorised in article 2, [26] then these events are not dangerous since the climate target are written to prevent DAI. This is a problem that arises from the current formulation of the 2°C target.

Observations are already indicating that there are changes in ecosystems, heat-waves frequency and storm intensities. [28] This raises the question if we are already experiencing dangerous climate changes? If we are, then any climate target formulated to prevent DAI has already failed. If we are close to experiencing it then reaching a climate target formulated in that way may turn out to be very hard. This again depends on how one chooses to define DAI. [25]

Defining dangerous is not something that can't be done only by one country, one government or one institution. What is considered to be dangerous depends on the circumstances and what value you give different things. The definition of what is dangerous is something that at present state can't be put into a mathematical number or a detailed paragraph in a resolution, because it involves too many parameters like money, human lives, ecosystems and future generations.

Arguments often heard when it comes to prevent DAI are those that encourage you to feel for future generations. Many actions performed today are done to save future generations but the question is if things we today consider to be a problem may turn out to be a problem to future civilizations. When discussing these subjects we encounter some moral dilemmas and are forced to make some hard decisions. For example, should an effort be made to reduce ongoing wars and conflicts or should investments be made to reduce the damage of future floods? Questions of these kinds are bothersome and although one may consider the answer to be obvious, the questions can't be totally ignored. [29]

Defining DAI is a serious challenge and involves many parameters and a lot of different value judgement. The definitions of what is considered dangerous are difficult to formulate and might be a question that perhaps science should not even be involved in. The definitions should not be written during hasty circumstances and not by one group of expertise. One can argue if scientists should be involved in this group of experts and one can of course also ask if there are any experts actually capable of defining DAI with what we know today.

3.5 Advantages and disadvantages with climate targets

In this part of the work a more general discussion about the entire situation that surrounds climate targets will be presented. Arguments if we are going to reach the 2°C climate target, what might happen when we are struck by the dangerous climate change and the origin of climate targets, have already been presented in previous parts. In this one I try to present a picture of the different advantages and disadvantages that come with climate targets and especially the 2°C climate target.

Climate targets offer a simple explanation for people that lack proper knowledge and interest to understand the complexity and the meaning of complex computer models. They simplify information and make it accessible to more people. They present an opportunity for scientists, economists and policy makers to come together and talk on a more even basis, to come up with ideas and suggestions which path we should take and which target we should aim at when dealing with climate change.

The 2°C climate target is criticized, both by them who want to see a 1.5°C target but also by them who think that a 3 or 4°C target would be better. No matter the reasons one can always present different arguments about climate targets in general to try to advocate different ones and you can criticize the formulation in many different ways. This raises the question if climate targets are something worth having if they only steal a lot of time and energy that could be spent on something more valuable then pointless debates. What should we do, what plans should we have if climate targets are not an option? That is an interesting question, one which answer is obvious when one thinks it trough. In almost every situation you need a map, a plan of how to achieve your goals. It has not to be written in stone but you need to have some form of strategy and a goal, otherwise you don't do anything. You keep track of your money in the form of a budget, you write a note on what to buy when you go to the store and you apply in advance for courses you want to study. There is always a target and a plan how to get there. Simple or complicated, a target is needed, which answers the question that we need climate targets. The next question then is how should they be formulated to prevent time consuming arguments and if the 2°C climate target is formulated in a good way?

When formulating a target of any kind, the questions 1) what needs to be done in order to reach it, 2) when is it achieved and 3) what happens if it is not accomplished, all require answers. The current formulation of the 2°C target provides no clear answer to any of them. There are suggestions and recommendations of different emission paths to follow in order to stay below the 2°C-limit and there is high risk that an increase in temperature above the 2°C-limit might trigger climate changes beyond our handling, but does this answer any of the questions? In addition to these points a clear definition of what DAI represents is also missing. I think that in order to increase the influence of this climate target and to speed up the actions, these crucial issues need clarifications.

Today the 2°C climate target is formulated to limit temperature to prevent DAI but as mentioned in section 1.2 one can also choose to formulate one to limit either concentration or emission. The reason why the most famous of the targets are formulated to limit temperature which, I can only guess is because everyone has a feeling for temperature. A target to limit emission or concentration would show numbers that would not mean anything to ordinary people.
Figure 1.2 presented in section 1.2 shows a figure illustrating the connection between emission, concentration and temperature but that is only part of a bigger picture. A little better representation is perhaps shown in figure 3.2. The previous part is the same but a couple of other parts have been added to show another perspective of the situation.

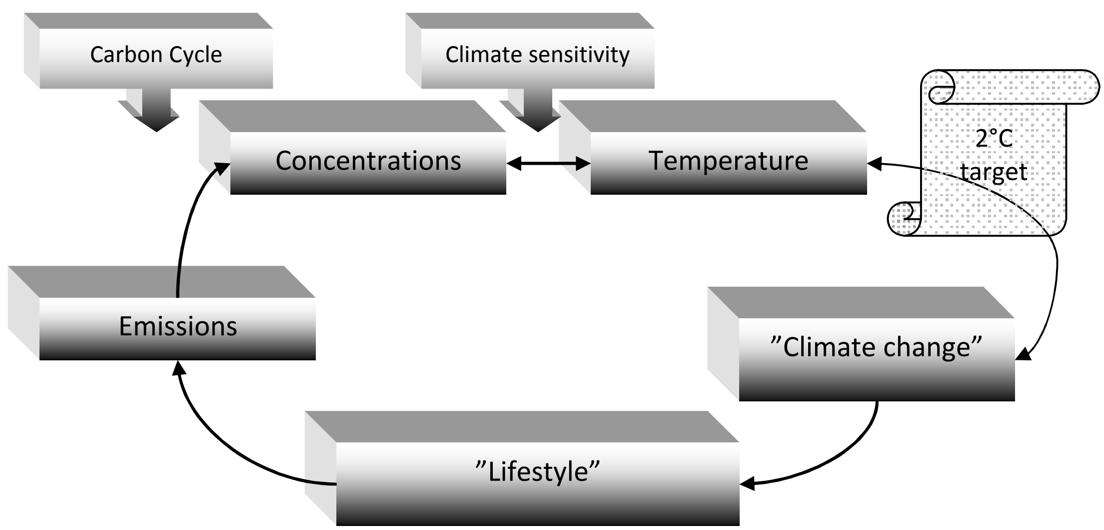

Figure 3.3: A new representation compared to fig 1.2. The 2°C climate target is formulated to limit dangerous climate change that rapidly would change our everyday life but it is our current style of life that is a major source behind the emissions that contribute to the increase in temperature.

It is not that obvious why temperature is the chosen parameter to limit when looking of this representation of the situation. Temperature will affect changes in climate and these changes are going to affect our future lifestyles but it is also our lifestyles today that are a huge factor behind the emissions of greenhouse gases. The uncertainty in the carbon cycle and climate sensitivity remains and the connection between temperature and climate change is also filled with uncertainty. “What”, “when” and “where” the effects will be most severe are factors that make the current formulation of the 2°C target complicated.

Boxes that also could be included in the figure are politics, economics and technological innovations. All these three things can be connected to the emission box. Policymaking by politicians (and voters) can regulate the emissions but since money is the driving force of the modern world, the economical view of the problem must be included and there is a balance between reducing emissions without damaging the economical growth. Technological innovations, new ways of producing energy to reduce the amount of CO_2 emitted for every service provided to the world population, are something we all seem to be waiting for. New inventions can only be achieved if money is invested today. When it all comes down to it the question is really where one should spend the money. Either it is spent on investments and actions trying to reduce emissions today or one will have to pay the bill of climate change tomorrow. Money will not be the only thing on that bill but the price will also have to be paid in destroyed ecosystems, lost biodiversity and human lives.

Climate targets are important and necessary but they have to be formulated in such a way that they include many aspects of the climate problem. Formulating the target only to limit temperature as is the case with the 2°C target can in itself be dangerous because it means that other climate effects can occur as long as temperature rise stay below the 2°C-limit compared to pre-industrial levels. Personally I think that a formulation that includes climate impacts as changed precipitation patterns, heat-waves and radiative forcing is better than limiting a target to include temperature only. The addition done in article 2 is good at setting the framework but there is still a grey area where events might be serious but not considered to be dangerous.

Another question is that, who is going to have the most influence in formulating the target. Should it be scientists who focus on the environment and possible climate impacts, economists focusing on the economy and economic growth or politicians with focus upon human lives and a sustainable society? A group of people with different areas of expertise would probably do a better job than a group consisting of only experts in one area because the formulation of a climate target is the most important part and that has to be given proper time.

Everybody wants to limit and prevent DAI but as previously mentioned nobody knows what that is. Today we use temperature as an attempt to limit that something. What is causing the problems is the emission of greenhouse gases but to reduce them we either have to change our lifestyles or invent new ways of "producing" energy (or doing both of them). Emissions can be regulated with a climate target but not the lifestyle of the population. I don't think that is something that could or should be written down in a climate target, that has do be dealt with in another way. The question we need to answer is not how to prevent DAI but instead how we can feed, transport and communicate for seven, eight or nine billion people in a sustainable way; the technology to do that does not exist yet. The answer to that question is one that we need to find if we are going to continue living on this planet. If we don't answer that, it doesn't matter how we define as dangerous climate change or formulate a climate target.

Climate targets help with negotiation for emission reducing policies but are also a way to inform the population of how the situation looks like and what is being done. Many are today aware of the fact that global warming is a threat we are facing. That understanding is reaching a new level among the general public but what is still missing is a sense of urgency. The focus climate targets often have on temperature might be a reason for this lacking feeling. Most people don't understand that if global mean temperature were to rise with 2°C it is more serious than it sounds. 2°C is an easy number to understand and it does not sound like much and here the simplicity of the climate target starts to work in the opposite way. It simplifies too much which robs the people of the feeling that this is a serious situation that needs to be fixed. It sends out some form of false certainty that "it is only 2°C, we got this under control" and "there is nothing to worry about."

In figure 3.4 I illustrate that climate targets in my opinion can be viewed in two different ways and they work in either a positive or a negative direction depending on how they are used. In the arena where scientist, economists and politicians are trying to arrive at some decisions, climate targets are good. They ease negotiation as already mentioned, but when they in some situations are used by politicians to improve their reputation and as something that they can "show off" for the population, then climate targets are not serving their original purpose anymore. Suddenly it has gone from something created to improve our odds of facing global warming to something that are used to increase reputation. Through the common whish of the media to turn everything into a disaster and politicians wish to give the impression that things are being done, the image presented to the population is often twisted, exaggerated or completely wrong.

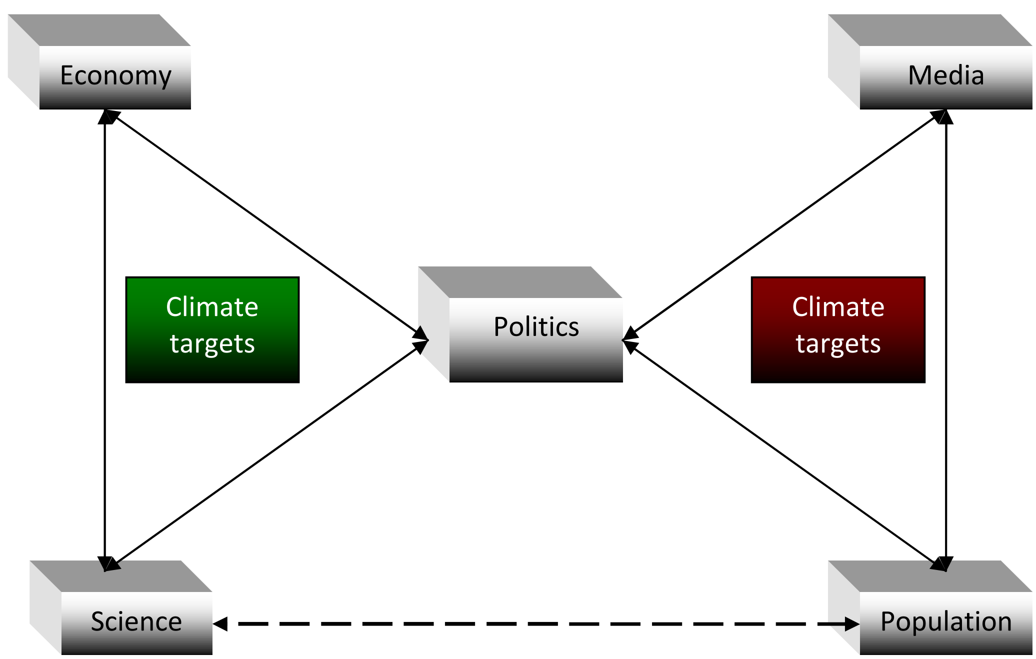

Figure 3.4: Climate targets are good when used to ease negations and performing policy making. When it comes to informing the population of the situation they can be exploited to increase the reputation of politicians instead of actually informing the severity of the situation.

Figure 3.4 shows a dashed arrow connecting the population with science. The arrow is pointing in both directions because I believe that information needs to go in both direction, it has to be a dialogue. Science needs to be better at presenting the data and the population needs develop a deeper interest and learn more about the underlying science instead of listening to the different prophecies of the media and the rather weak rhetoric used in the politics. If the population got a greater understanding of the complexity of the climate system, I believe better and quicker result in the climate debate would be achieved. Because we are the ones electing people into the political system and if we possess a basic understanding of the situation we can see trough irrelevant promises and elect people to the right place.

One can continue to view the climate problem from different perspectives and realise things to put on the scale either in favour or against a climate target. In what direction the scale will finally tip is not easy to make out in advance. The different perspectives presented here show that the 2°C climate target is not entirely good but neither entirely bad. The scale balances at the moment around a point in time when the decisions (or lack of decisions) in the years to come will show in what direction the balance might tip.

4 Conclusion

Climate targets in general are needed. They provide the map which we can follow and they will aid us in our struggle with climate change. Climate targets are a powerful tools when handled properly. They have to be formulated in a clear way that includes scientific evidence and reasoning, economic justification, assessments and political drive and motivation. If one of these is ignored or given too little or too much attention, time consuming debates are likely to surround the climate target instead of plans how to reduce our emissions.

The current formulation of the 2°C involves ambiguous statements and lack of clear definitions in some areas, especially those regarding DAI and the time plan when the target is accomplished. These are problems that ought to be solved if the target is going to go from what it is today into a legally based contract.

Something that would ease negotiations is if the uncertainties regarding the carbon cycle and climate sensitivity were reduced. These uncertainties are a problem but the solutions are not something we can wait for. Continued research is second nature but actions must be taken even if a precise connection between our emission and the expected rise in temperature does not currently exist.

Climate targets are good. The 2°C can be better. If the 2°C climate target will save us or guide us straight to the gates of hell is a question that has no answer. People often prefer to see everything in either black or white but when dealing with climate issues answers are rarely that simple. Including all the different factors, the complexity of the problem results in a situation where almost every action is neither black nor white but somewhat more like a grey probability distribution. I deduce that if the 2°C target gained a coherent formulation it would serve us better and we would have a more powerful tool facing the challenges ahead of us than we currently have.

This 2°C climate target is better than no target at all. Even if one could argue that a 2°C increase in temperature is putting a lot of stress on society and the population, it is still a target that initiates conversations about the climate. If it then turns out that this does not lead to anything and has been nothing more than some fancy words with little real value in them, then the cost of our indifferent behaviour will be revealed in the years and decades to come.

These are the conclusions arrived at after have considered present available knowledge, that the 2°C climate target is a good initiative which ignites the discussions but it is also in need of improvements. These conclusions might alter in time when new facts are presented either from the review of the 2°C target performed by 2015 or from IPCC reports released later this year. The scientific process is never to assume that a correct answer is given and always to be prepared to change the perspective when new discoveries are revealed.

To conclude this work I will end with a story that I heard from a man named Ernesto Sirolli. It was about a group of experts that had come together in the year 1860 to discuss the future of the city of New York. They were discussing different opportunities and difficulties and they were trying to figure out how the city might look like 100 years into the future. After the discussions they arrived at the unanimous conclusion that the city of New York would not exist in the year 1960; why? They had been looking at the curves of population growth and they realised that if the population kept rising at those levels, to move the population around in 1960 they would need 6 millions horses and the manure created by all those horses would be impossible to deal with. After looking at an old, inefficient, dirty technology they made predictions into the future. What happened? After 40 years, in the year 1900, there was somewhere around 1000 car manufacturing companies in the United States. A new technology had entered the arena and completely changed society.

Today the experts predict that New York might be flooded in 100 years, as a result of sea levels rising. The thing I want to stress here is that the future is unknown and nobody knows what is going to happen. The uncertainties exist and we are aware of them but this does not imply that we shouldn't do anything or continue as we always have. Every path we can take is covered in thick smog and we don't know what awaits us. What we do know is that we must make up our minds and chose one of the two alternatives every organism sometime is faced with; adapt to the changing environment or face its own destruction. I believe the choice is easy and with cautious steps, careful planning and confident actions I am convinced we can find our way through, and face a brighter tomorrow.

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