Communicating Climate Change

Exploring the data behind the temperature rise

<u>Group 1 - Reaktor</u>

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1. ABSTRACT

This project, a collaboration between Aalto University and Reaktor, is focused on the problem of communicating climate change to a predominantly Nordic audience. It achieved this by building interactive and exploratory visualizations to let people explore the data and by publishing them on a public website. Additionally, a simple multivariate linear regression model was built to predict emissions five years into the future which made decently plausible predictions.

2. BACKGROUND & MOTIVATION

Climate change, mainly due to carbon dioxide (CO2) and methane emissions, is one of the largest challenges that humanity is currently facing. As population and consumption will continue to increase in the future, so will emissions. Meaning the challenge is far from over and will likely get worse before getting better [1].

If not addressed and limited, climate change will cause widespread social, economic and ecosystem damage [1]. As greenhouse gas emissions are distributed globally and over a wide range of societal activities, it needs to be addressed from a global point of view.

The current political goal is to limit global warming caused by emissions to 1.5 degrees. It has been assessed that this would require a general global carbon neutrality by 2050 and negative emission soon after that [1].

While that goal is still far from achieved there is an increasing momentum of decreasing emissions. Europe as an example has been able to cut its total emissions almost yearly since the 1990s. In addition, several countries both within and outside of Europe have pledged carbon neutrality with varying target years [2][3].

In the Glasgow climate conference in November of 2021 a new global agreement, the Glasgow Climate Pact, was reached. In the agreement 197 countries pledged to cut the emission of CO2 to limit temperature rise to 1.5 degrees. On a better note, for the first time, there was an explicit plan to reduce the use of coal by phasing it out. The pact pledged to increase financial aid to developing countries to help them cope with both the effects of climate change and the switch to clean energy [4].

3. GOALS OF PROJECT

The goal of the project is to find ways to communicate climate change in a clear and impactful way with an interactive web page [13].

The focus is especially on capturing the emission reduction momentum by visualizing greenhouse emissions, in particular CO2, and the explaining factors by first exploring the past and then into the future.

The target audience for the project and the web page is described as predominantly Nordic. However, as climate change is a global challenge, the challenge is addressed on a global level with opportunities to focus on the Nordic countries. The report also includes a Nordic deep dive to further address the target audience.

The exploration and the effect of carbon tariffs and credits and whether they are an effective measure in limiting emissions is also briefly discussed in the report.

The web page is meant to be designed in a way that it could be used smoothly both on bigger screens as well as mobile devices. The data and models are also meant to be automatically updated.

4. DATA

This chapter will focus first on the data that was used during this project and then on uncertainties in the data.

4.1. Data sources

The data sources used were public sources. The data used is mostly CO2 emission data with a couple of exceptions.

One of the key data sources throughout the project was Our World in Data's (OWID) dataset on CO2 and other greenhouse gas emissions [11]. This dataset is a collection of data from Gapminder Carbon Watch, World Bank, Climate Watch Portal, etc. processed in a cohesive and accessible format.

Our data source for worldwide temperature was the NASA Goddard Institute for Space Studies (GISS) [8]. The data in the dataset we used is taken from meteorological stations and averaged over the globe and over the year, going from 1880 until the present. Within that timeframe, no data is missing.

4.2. Data Processing

All the datasets were pre-processed quite well, so there was no need for any big changes. Many of the countries lacked data for the early years in 1900s, but since that data was not used in the models it was not an issue.

The following tables show a glimpse of the data used in the project:

Land-Ocean: Global Means

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	J-D	D-N	DJF	MAM	JJA	SON
1880	-.18	-.24	-.08	-.16	-.09	-.21	-.18	-.10	-.14	-.23	-.21	-.17	-.16	***	***	-.11	-.16	-.19
1881	-.19	-.13	.04	.06	.07	-.18	.01	-.03	-.14	-.21	-.17	-.06	-.08	-.09	-.16	.06	-.06	-.18
1882	.17	.14	.05	-.15	-.13	-.22	-.16	-.07	-.14	-.23	-.16	-.36	-.10	-.08	.08	-.08	-.15	-.18
1883	-.29	-.36	-.12	-.18	-.17	-.07	-.07	-.13	-.21	-.11	-.23	-.11	-.17	-.19	-.33	-.16	-.09	-.19
1884	-.12	-.08	-.36	-.40	-.33	-.34	-.32	-.27	-.27	-.25	-.33	-.30	-.28	-.26	-.10	-.36	-.31	-.28
1885	-.58	-.33	-.26	-.41	-.45	-.43	-.33	-.31	-.28	-.23	-.23	-.10	-.33	-.35	-.40	-.37	-.36	-.25
1886	-.43	-.50	-.42	-.27	-.24	-.34	-.17	-.30	-.23	-.27	-.26	-.25	-.31	-.30	-.34	-.31	-.27	-.26
1887	-.71	-.56	-.35	-.34	-.30	-.24	-.25	-.35	-.25	-.35	-.26	-.32	-.36	-.35	-.51	-.33	-.28	-.29
1888	-.34	-.35	-.41	-.20	-.22	-.17	-.10	-.15	-.11	.02	.03	-.04	-.17	-.19	-.34	-.27	-.14	-.02

Table 1. Temperature Dataset from GISS.

	iso_code	country	year	co2	co2_growth_prct	cumulative_co2	co2_per_capita	methane	methane_per_capita	population	energy_per_capita
0	AFG	Afghanistan	1949	0.015	NaN	0.015	0.002	NaN	NaN	7624058.0	NaN
1	AFG	Afghanistan	1950	0.084	475.00	0.099	0.011	NaN	NaN	7752117.0	NaN
2	AFG	Afghanistan	1951	0.092	8.70	0.191	0.012	NaN	NaN	7840151.0	NaN
3	AFG	Afghanistan	1952	0.092	0.00	0.282	0.012	NaN	NaN	7935996.0	NaN
4	AFG	Afghanistan	1953	0.106	16.00	0.388	0.013	NaN	NaN	8039684.0	NaN
...	...	...	...	...	...	...	...	...	...	...	...
25189	ZWE	Zimbabwe	2006	10.365	-3.11	641.225	0.853	10.38	0.854	12155496.0	3923.549
25190	ZWE	Zimbabwe	2007	9.835	-5.12	651.060	0.802	10.69	0.872	12255920.0	3901.841
25191	ZWE	Zimbabwe	2008	7.720	-21.51	658.780	0.624	11.01	0.889	12379553.0	3334.178
25192	ZWE	Zimbabwe	2009	5.476	-29.06	664.257	0.437	11.35	0.906	12526964.0	3281.868
25193	ZWE	Zimbabwe	2010	7.878	43.86	672.135	0.620	11.87	0.935	12697728.0	3669.757

Table 2. Emissions Dataset from OWID.

	Sub-sub-sector	Sub-sector	Sector	Share of global greenhouse gas emissions (%)
0	Road	Transport	Energy	11.9
1	Aviation	Transport	Energy	1.9
2	Rail	Transport	Energy	0.4
3	Pipeline	Transport	Energy	0.3
4	Ship	Transport	Energy	1.7
5	Residential	Energy in buildings (elec and heat)	Energy	10.9
6	Commercial	Energy in buildings (elec and heat)	Energy	6.6
7	Iron & Steel	Energy in industry	Energy	7.2
8	Non-ferous metals	Energy in industry	Energy	0.7
9	Machinery	Energy in industry	Energy	0.5

Table 3. Emissions by Sector Dataset from OWID

Table 2 only shows the most relevant columns in the dataset since the original dataset contained 58 columns and showing all of them here would make it unreadable.

4.3. Uncertainties in data

As mentioned earlier, the data used in the project is mainly CO2 emission data in different formats. CO2 emission data is mostly based directly on energy use reports. [5]

Due to that there are two key sources of uncertainties in C02 emission data: Incorrect reporting of energy consumption and incorrect assumption of emissions factors used for fuel burning (meaning the assumed carbon content of burned fuel, which is directly used for calculating emissions). Incorrect reporting of energy consumption is typically low and comparably negligible. The uncertainty of incorrect assumption of emissions factors used for fuel burning ranges between 2-

5% worldwide – in individual cases it can even be much higher than that - and is the main issue of the two. [6]

Even though CO2 emission datasets from various sources are often based on the same energy use reports, they somewhat differ from each other. Reasons for these differences besides the two key uncertainties described above are differences in which emission sources are considered (e.g., the production of cement or waste combustion), differences in the approach – some organizations base their data on reports of individual consumption, some on the data from individual economic sectors - and different and inconsistent primary energy equivalencies. [5] These factors can make it challenging to compare data from different datasets – there is not really a way for us to say whether one source is more accurate than another.

5. METHODS

The datasets were gathered as csv files for easier access and faster processing.

The project mostly focused on visualizing available data to provide valuable insights into global, local, and sector-wise trends. The visualizations were built in python [14], using the plotly [15] library and deployed with streamlit [16]. An emphasis was put on the interactivity of the visualizations, to allow users to play around with the data themselves and come to their own conclusion.

The interactivity was achieved by, for example, allowing users to select specific parts of the data (such as a country) to focus on, and enabling them to "travel through time" to see how the trend has evolved over time. Different visualizations had diverse ways of exploring them, but the above two were the most common techniques to be applied.

Apart from the data visualization, the project also tried to predict future emissions (up to 5 years) based on the available data. Several methods were tried regarding this, with a particular emphasis on keeping the model as simple as possible.

Using the correlation matrix as a guide, we identified three variables to be highly correlated with CO2 emissions: Population, GDP per capita, and energy per capita. GDP and energy were chosen to be per-capita since the population already contained the information about the magnitude of the country and taking the total GDP and total energy for each country would have inserted that information about the country multiple times in the data, giving it an unnecessarily higher weight.

A total of three models were tried out: Simple univariate linear regression, multivariate linear regression, and Facebook Prophet [17].

The Prophet model was tested because it is often used to predict time-series data. However, this model excels at predicting seasonal trends but emissions data, on a large scale, does not show "seasonality". As a result, the Prophet model only performed on par with univariate linear regression.

The final chosen model was multivariate linear regression because of its apparent good performance paired with simplicity and explainability. The explaining variables for the CO2 model were chosen to be population, energy consumption per capita, and year. For the methane model, the explaining variables were population and year. This choice was made by testing the performance of the models and making sure that for all relevant countries these variables exist in the data. The explaining variables were shifted with respect to the response variable by a number of years necessary to obtain predictions 5 years into the future. This shift could be larger than 5 years in case the newest data was not available for all explaining variables.

We also decided to explicitly visualize the uncertainty (epistemic and aleatoric) associated with the models. Epistemic uncertainty refers to the uncertainty in the already measured values for CO2. According to our sources the estimates can be off by up to 5%. Epistemic uncertainty also stems from not making use of all possible explanatory variables, but this part of uncertainty was not modelled explicitly (notable omissions include emission goals and carbon tax). Aleatoric uncertainty stems from not being able to predict the emissions exactly due to random events that the model cannot predict (such as the COVID pandemic). This uncertainty was estimated using the statsmodels [18] Python package which gave confidence intervals for the predictions on top of which the 5% was added.

6. RESULTS

The following chapter will go through the findings and results of the project similarly to the web site (link here).

6.1. The temperature is rising

Human-induced global warming reached about 1°C (likely between 0.8 and 1.2°C) above pre-industrial levels in 2017 as visible in figure 1, with a 0.2°C increase per decade. Most land regions are warming up faster than the global average - depending on the considered temperature dataset, 20-40% of the world population live in regions that had already experienced warming of more than 1.5°C in at least one season by the decade 2006-2015. [7]

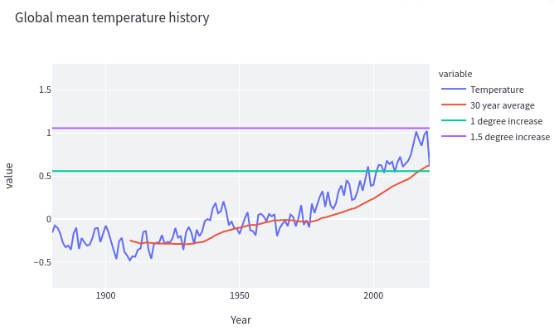

Figure 1. Global mean temperature history.

Global warming is defined in the IPCC (Intergovernmental Panel on Climate Change) report as an increase in combined air temperature of land regions and surface temperature of water-covered regions averaged over the globe and a 30-year period, usually relative to the period 1850-1900. By that measure, warming from pre-industrial levels to the decade 2006-2015 is assessed to be approximately 0.87°C. [7]

The red line in figure 1 shows the global temperature over the previous 30 years while the straight lines represent a 1 °C and 1.5 °C increase from pre-industrial levels. Note that the figure is merely an approximation for the sake of visualization: in practice, there is no exact pre-industrial temperature to work with - even the methods of calculating it differ greatly - and therefore also no exact temperature we could label as 1.5 °C increase. We did not look too deeply into this matter since it is not the main concern of the project.

6.2. Here is why it matters

Currently, climate change has most significantly impacted natural systems as visualized in figure 2. This includes situations such as melting ice, changing precipitation, which affect water resource quality and quantity. It has also caused terrestrial, freshwater, and marine species to alter their habits.

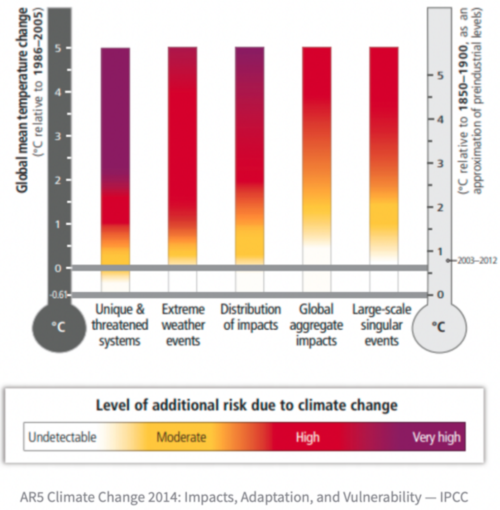

Figure 2. Impacts, Adaptation and Vulnerability.

The consequences of emission rise follow a snowball effect. That is, it exhibits a positive feedback loop that severely magnifies the consequences over time. Some of these include negative effects on human health (especially so for marginalized communities), economic inequality, impact from extreme events such as heat waves, droughts, cyclones, etc.

Some second-order consequences of these events are disruption of food production and water supply, alteration of ecosystems, violent conflict, etc. These are further intensified due to our lack of preparedness regarding them.

6.3. Emissions Worldwide have been growing

Ever since the industrial revolution, the amount of greenhouse gases released into the atmosphere has been rapidly increasing. However, each country is distinct, has developed at a different pace and has tried to reach different emission goals. To introduce the reader to the emissions data and tell the history of GHG (Greenhouse Gas) emissions in each country, 3 different visualizations have been used.

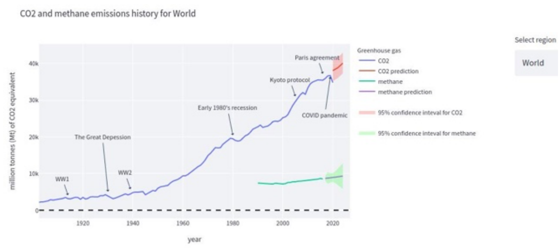

Figure 3. CO2 and methane emissions history for World.

Figure 3 shows a line plot of the emissions of CO2 and methane since 1850 for the World or a selected country. The plot includes emission predictions 5 years into the future along with their 95% confidence intervals. It also annotates some historical events that had an influence on emissions. This plot is meant to give a general overview for the reader.

Years into the future	CO2 MAPE (%)	Methane MAPE (%)
1	7	4
2	10	5
3	12	6
4	14	8
5	16	10

Table 4. Mean absolute percentage error of the CO2 and methane prediction models with a shift of 6 years.

When testing the predictions on past data, the performance of the models was measured using mean absolute percentage error (MAPE). The further the prediction is into the future the more time it has to deviate from the trend in the training data. Therefore, the MAPE is reported for each timestep from the last training data point and can be found in Table 4.

Figure 4 displays an interactive heat map of the world with options to select what value is shown (CO2 per capita, total CO2 or CO2 growth percentage). There is also a slider for selecting the year for which the map is drawn.

This figure is meant to show the differences quickly and intuitively between countries and continents. The reader can easily distinguish which countries are the main CO2 polluters, but can also focus on the countries that he/she is interested in.

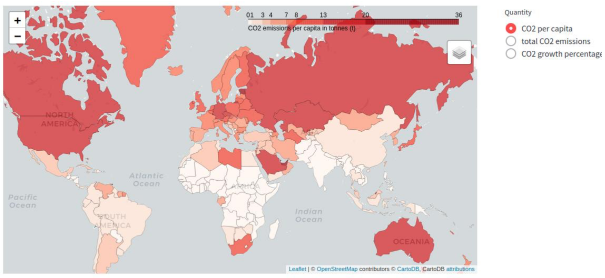

Figure 4. CO2 emissions: Per capita, total and growth percentage.

Figure 5 is not as intuitive but can provide even more interesting insights. It is a scatter plot of the total CO2 output of a country vs the percentage change in a specific year.

Thanks to this the reader can see what proportion of countries are decreasing their CO2 emissions. It also shows that the 3-5 most polluting countries have a huge influence on the entire world as their emissions are orders of magnitude above most other countries.

The color of the points shows how wealthy the country is using GDP per capita. The figure allows for selecting the year and displays the country names when hovering over a point.

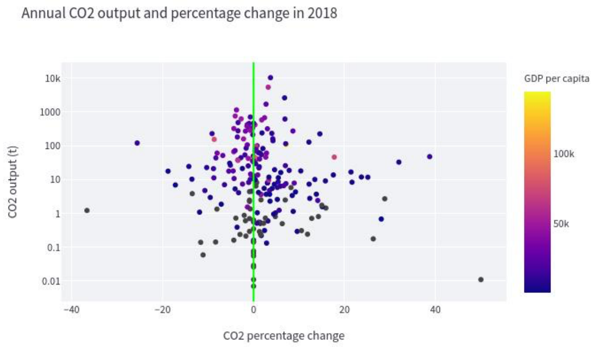

Figure 5. Annual CO2 output and percentage change in 2018.

6.4. Sources of emissions

Figure 6. Global emissions by sector.

Global emissions can be grouped according to their source sectors. One way to do this is the following where 4 different sources are identified as visible in figure 6 and those then broken into further sub-sectors and sub-sub-sectors. The figure above shows the sub-sectors for energy, but the sub-sub-sectors for the rest as for them the sub-sectors are equal to the sectors. These four sectors are from the largest to the smallest: Energy related emission, agriculture, forestry, and land use related emissions, industrial process related emissions and waste related emissions.

As mentioned, energy is with 73,2% the largest source of emissions. 54% of energy related emissions come from energy in industry, 22,1% from transportation, and 23,9% from energy usage in buildings both commercial and residential. Transportation related emissions are mainly from roads. This is visible in the figure above as the circles are relative to the proportion of total emissions.

The remaining 26,8% of the emissions are as following: 18,4% of emissions come from agriculture, forestry & land use which mainly consists of livestock, manure, rice cultivation, agricultural soils, and crop related emissions. Industrial processes, cement and chemical & petrochemical, account for 5,2% of the emissions and waste, wastewater, and landfills, for 3,2%.

6.5. What can be done

There are various ways to reduce global warming - we can replace high-emitting fuels such as coal, oil and gas with more climate-friendly alternatives like solar power, wind power, or nuclear power. We can also work on making our buildings, technology and infrastructure more energy-efficient, both in production and in usage. [8]

Another approach is to try to remove CO2 that is already in the atmosphere, for example by reforesting the earth – tropical forests once covered 12% of the earth's landmass, now they only cover 5% -, by changing farming practices to store more carbon in the soil or through direct air capture technology. However, it is unlikely that these methods will be able to remove carbon dioxide faster than it is currently being produced. [8]

As individuals, we can impact climate change through our choices as consumers by means such as following a plant-rich diet, choosing climate-friendly means of transportation, energy and heating options, avoiding food waste and unnecessary trips. Additionally, individuals can influence policies on a local and national level through political participation.

Similarly, companies can impact climate change by reducing the emissions produced by their operations through various measures, such as minimizing transport distances and using carbon-neutral energy sources.

A promising method to curb climate change on a societal level involves encouraging individuals and companies to reduce their own emissions by introducing carbon taxes – by placing a tax or fee on the use of fossil fuels, production and consumption choices leading to higher emissions become more expensive, raising the incentive to switch to more climate-friendly alternatives. [9]

7. ETHICAL ISSUES

Ethical issues regarding communicating climate change can be divided into two separate ethical questions:

1. Overall ethical issues regarding climate change
2. Ethical issues regarding the approach of this project

Where the latter can further be broken down into ethical issues of the data and methods used.

The following chapter will discuss both.

7.1. Overall ethical issues

The impacts of climate change, both those already visible, but also the future ones, create an ethical dilemma as the impacts are often not direct and do not target those responsible for them most of the time. Responsibility as such is also not easily determined due to the lack of visible evidence on the impact of climate change on humans' lives since a deep understanding of the climate change problem is required in order to determine moral concern.

Still, climate change raises serious ethical issues. For example, global climate change will negatively impact lower classes, reduce the quality of life of future generations and threaten plants and animals.

To mitigate the impact of climate change, governments will eventually have to compromise to an extent to stabilize the amount of greenhouse gases in the atmosphere.

For that reason, our responsibilities as to other forms of life, to future generations and to the poor, who will suffer the most from human-induced climate change is one of the concerning ethical questions.

There are also many ethical questions regarding the duties of developed nations to poorer nations or if it is reasonable for any nation to refuse to take actions against climate change until there is a least-cost solution.

Nonetheless climate change itself constitutes an ethical challenge. There is no simple basis for an ethical response to the challenge.

7.2. Project specific ethical issues

As mentioned, project specific ethical issues can be divided into two: data and method related.

As all predictions about future climate change trends start with gathering factual data at a certain place over an extended period, the ethical issues regarding data will cumulate in the methods as well. While ethical issues in methods will not cumulate in ethical issues in data.

The main issue with data is incomplete factual data on aspects of climate change. In other words, the uncertainties caused by observation gaps. Some of the observations are also estimates rather than absolute truths.

Observation gaps include gaps regarding certain geographical areas of the world, in particular the climate data in southern countries and continents. Relative to the abundance of data about climate conditions in the Northern hemisphere, the data about climate conditions in the Southern hemisphere appears to be thin (IPCC 2007d: 32). This is especially noticeable the older the data is that is being investigated and could affect prediction about climate change and its trends.

As these countries are already the countries most affected by climate change with fewer capabilities to fight it and thus only increasing the gap between developing and developed countries in regards of climate change. Thus, it is not only a data issue, but also an ethical issue.

8. NORDIC JOINT POLICIES

Nordic countries have taken many effective actions to support the transition of a sustainable low-carbon society. These policies help economic development, generate jobs, and improve living standard. Between 1990 and 2011, greenhouse gas emissions in the Nordic region were lowered by 9% while GDP rises 55%. [10]

8.1. Efficient energy solutions against cold weather

Due to the nature of cold weather, long logistic distance to sparsely populated residence areas, energy consumption and greenhouse gas emission rates per capita are higher in Nordic countries. Nordic governments have been promoting innovation in low-energy construction and district heating systems to reduce annual carbon dioxide emissions from average 0.8 tonnes to 0.2 tonnes of C02 per capita, through clean energy research programmes and industrial investments in energy-saving and low-carbon technologies.

8.2. Renewable energy exploitation

Nordic countries have been implementing numerous renewal energy sources including hydropower, wind power, geothermal energy, and forest biomass. Together these sources made up 63% electricity generation and 30% energy consumption in 2010. Norway and Sweden lead hydropower. Finland focuses on biomass. Denmark favors wind power. Iceland is full of geothermal energy.

8.3. Wide social awareness and acceptance

Nordic governments conduct various policies to promote social awareness of environmental issues and acceptance of green energy. Municipalities define targets and launch local initiatives. There are social welfare policies that support low-income households to have clean energy from biofuels, heat pumps and other greener alternatives compared to fossil fuels.

8.4. Pioneering in green technology

In order to help Nordic countries, gain leadership in green technology, governments have been promoting R&D investments in clean energy sources and energy-saving technologies. Local market initiatives help creating jobs and export products and services. Public sectors from transportation, buildings, and catering act as buyers to promote sales, while joint financing institutions like Nordic Environment Finance Corporation and the Nordic Development Fund assist businesses strategically.

8.5. Forests as carbon sinks

Large forest areas of Nordic countries contribute critically to global carbon sink. The growing forest biomass and forest soils help reduce greenhouse gas emissions in Nordic. Over the past 24 years, carbon sequestration has been significantly growing. Compared to 1990, net carbon emissions are now 25% lower.

9. CONCLUSION

The project's overall goal was to communicate climate change to a Nordic audience in an intuitive and interactive way. This was done by making the plots modifiable such that users could choose to explore the data themselves. Additionally, a simple multivariate linear regression model was built to predict emissions five years into the future.

10. FUTURE PROSPECTS

The following years will show how strong the increasing momentum of decreasing emissions will be, which will make it considerably easier to predict future emissions. It will also relieve what the factors are that help decrease emissions the most, but also what features those countries have.

The emission data used in the visualizations on our website is not stored locally but downloaded directly from Our World in Data every time the website is loaded (and then cached for performance reasons). Therefore, these visualizations will stay up to date in the future as well without us having to manually update them. The temperature data is stored in a local file but can easily be updated manually with new data.

As for the prediction models, an obvious next step would be to try out more complex (but still explainable!) models such as polynomial regression and time series autoregressive model - to capture the nonlinearities in the data more accurately. Another approach would be to get a gears-level understanding of the explanatory variables and preprocess them more effectively such that the models can more easily exploit their relations and the information contained in them.

Another avenue for improvement would be to highlight notable events in climate history along with the visualized data. This could for example highlight the Paris Agreement, political will, carbon taxes, and other events that potentially would have had a non-trivial impact on the emission data.

11. PROJECT

The first part of the following chapter will focus on describing each student's role in the implementation of the project. The second part of the following chapter will include an assessment of the difficulty of the project.

11.1. Roles of students

The project was implemented in a very agile way, meaning that the ways of work were changed as needed as were the roles of each student. There were no fixed roles for the time of project, instead the roles changed even weekly.

The work usually went along these lines on a weekly level:

Each week there was a weekly meeting with just the team to recap on what each member had done during the last week and where the project is currently at. Based on that it was determined what needed to be done during the next week and how that work will be divided. Most of the time the work itself was done individually, but when needed also smaller teams worked on a particular part of the project. In addition, also the presenter for that week's presentation was chosen during that meeting and a rough draft for the presentation was created. This meeting was most of the time on Wednesday.

Additionally, there was a meeting on Thursdays where also the teaching assistant, Alena Shchevyeva and Saku Suuriniemi, the company representative from Reaktor's side of the project were present. For this meeting the group had on most weeks prepared some questions in advance that Saku then answered. Saku Suuriniemi often also provided additional comments to the project to drive it into the right direction. These comments as well as the answers to the questions were very helpful throughout the project.

The individual roles for each group member are described below.

Mikolaj Wojnicki worked on searching for useful data sources and interesting visualizations online as well as exploratory data analysis and initial Streamlit testing. Later he focused on visualization of the GHG emission data, creating predictive models for emissions using mainly linear regression as well as Facebook's Prophet model and finally using the results to write corresponding sections on the website and the report.

Verna Niva worked on the overall storyline with Aayush and how to communicate climate change. This included benchmarking other similar projects and reports and refining the focuses of the project. Simultaneously data sources were researched and tested to see if they would work for the purpose. She also worked on sector analysis and writing the report as well as the slides.

Aayush Kucheria initially scoured for public data we could use, then carried out exploratory data analysis, and was later focused on getting the website up and running. He also contributed to crafting the storyline along with Verna and helped with other miscellaneous stuff as it cropped up.

Hanne Sauer looked into potential data sources and using streamlit, and worked on implementing visualizations on the website. She also researched background information such as uncertainties in data and past global warming and wrote or contributed to corresponding sections on the website and the report.

Khue Nguyen experimented with building different interactive visualizations, worked on a mini project that we decided not to include in the final project, and also contributed to the website.

Bui My also experimented with building different interactive visualizations and worked (along with Khue) on a mini project that we decided not to include in the final project. She also researched climate initiatives in the Nordics.

11.2. Assessment of project

The two key challenges of the project were an overly broad assignment description, *communicating climate change*, and the variety of data.

The first meant that it required a bit more time at the beginning of the project to define the scope of the project and what to include in the project. Or more precisely, what not to include as it seemed like there were endless options.

The latter meant that there are endless articles, reports, data bases and visualizations regarding climate change and those needed to be limited to a manageable number of data sources and reliable data sources. Thus, public data sources like Our World in Data were used.

Making visualization itself and building the website were, while time consuming, much easier once the scope and story line were agreed on.

The forecasting of climate change proved to be rather difficult as mentioned there is currently an emission reduction momentum which makes it hard for the models to capture that instead of the growth that has been going on for years. It was also challenging to make use of the numerous economic, political, and geographical factors that affect emissions as it is difficult to collect the required data and make uncertainty predictions for complex models.

12. Sources

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