INTRODUCTION

Scientists have stated that the tipping point into ecological and environmental devastation is a 2°C increase in the average global temperature compared to the pre-industrial baseline. They have strongly urged that we avoid even the 1.5°C threshold, as its effects may take centuries to recover from.

To stay below the 1.5°C limit, countries would have to reduce the amount of greenhouse gases (GHGs) they emit each year, working to avoid a global concentration limit set by scientists. This is the basis for the Paris Agreement, a treaty adopted in December 2015 by 197 United Nations countries pledging to fight climate change. Each party submitted emission reduction goals in Intended Nationally Determined Contributions (INDCs) before and Nationally Determined Contributions (NDCs) after its adoption.

The trajectory of historical data was extrapolated forward to 2030 to provide projections of GHG emissions for comparison with the goals of the Paris Agreement. The difference is measured as the emissions gap.

The analysis conducted with this data focused on historical global greenhouse gas emissions and identifying the largest contributors to greenhouse gas emissions, both historically and currently. The countries of focus were identified based on their behavior as top emitters in 2015. The top 10 emitters in 2015 will be a primary focus of this analysis.

BACKGROUND & THEORY

It is understood that annual GHG emissions have accelerated exponentially across the globe since the pre-industrial period (1850 – 1900). In 1992, the United Nations drafted its Framework Convention on Climate Change (UNFCCC), an agreement to limit the increase in GHGs in the atmosphere. Each successive treaty was more aggressive and urgent in its goals. However, we continued to see rising atmospheric GHG concentrations, greater yearly emissions, and accelerating climate change effects during that time. The Paris Agreement, crafted in 2015, is the most recent of these treaties.

The Paris Agreement signatories had to submit plans for how and by how much they would lower their GHG emissions through 2020, 2030, and 2050. Such plans, or Intended Nationally Determined Contributions (INDCs) and Nationally Determined Contributions (NDCs) for pre- and post-Agreement plans, respectively, would be reviewed and revised based on the nations' achievements toward their GHG target. While NDCs include more than just GHG emission reduction targets, they will be the focus of this project.

This project aimed to examine how well the parties that signed the Paris Agreement are meeting their goals. Based on what they need to reduce to by a particular year versus where they are now, are they on track to limit warming? Which countries have the greatest impacts on the global limit goal?

HYPOTHESIS

- I expect most nations will fall short of their reduction goals. Their predicted emissions for 2030 will exceed the pledged emissions cap. However, emissions will be lower than those of their pre-2016 business-as-usual (BAU) trajectories.
- Larger countries, such as the United States, will significantly impact global emissions. I suspect many of these larger nations will not meet their goals.
- I predict that the gap between actual and pledged emissions for 2030 will be lower than it would have been without the adoption of the Paris Agreement for industrialized nations.
- I expect the actual global emissions gap for 2020 to be significant, as will the estimated gap for 2030.

- I believe that the top emitters will include the United States, China, and India based on population and economic activity.

DATA

The data for this project contains historical GHG emissions from all countries (PIK PRIMAP historical emissions dataset[i]). It includes all Kyoto Protocol GHGs: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6). The data excludes emissions from Land Use, Land Use Change, and Forestry (LULUCF)[ii].

Additional datasets were created containing the Nationally Determined Contributions of the countries investigated and the global benchmarks established by scientists necessary to stay under the 1.5 and 2°C thresholds.[iii] [iv] The data was collected from various sources and underwent any transformations needed to get the required metrics.

ANALYSIS

EMISSIONS FROM 1850 TO PRESENT

When attempting to lower global GHG emissions, it is important to know which countries have the greatest impact. Ten countries have the greatest cumulative emissions from 1850 to 2020 (in descending order): The United States, China, Russia, India, Germany, the United Kingdom, Japan, France, Ukraine, and Brazil. Figure 2 shows the share of global emissions each of these ten countries make up each year, with all other countries grouped as "All Others", from 1950 – 2020.

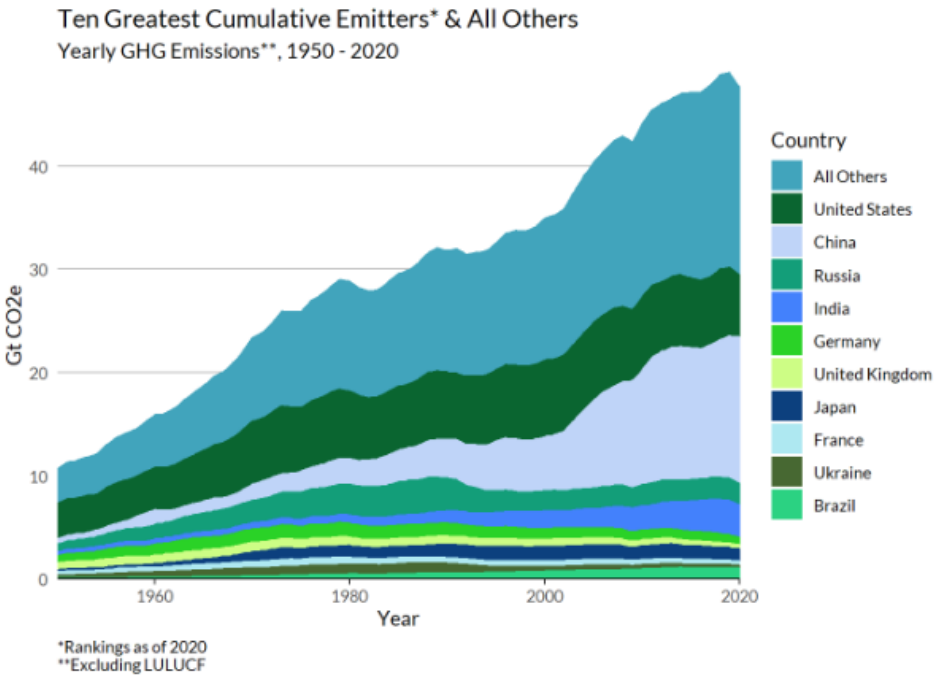

Figure 1

These ten countries accounted for roughly 50% or more of yearly global emissions in this period. (The widening or narrowing of each country's area on the graph reflects increases or decreases in annual emissions over time.)

A few other features are noticeable when evaluating cumulative historical emissions since 1850:

The United States saw its most significant changes from the 1870s to the early 1970s. The United States' relatively consistent yearly emissions over the last 40 years reflects how the composition of its economic activity has not significantly changed in the last half-century.

Fellow early-industrializers made the list, including France, Germany, and the United Kingdom. These three countries have made visible decreases in the last few years.

By contrast, China – and India, to a lesser extent – show increases over the same period, rising significantly around the turn of the 21st century. These emission increases reflect the countries' efforts to rapidly industrialize in recent decades and open their economies to global markets.

Population plays an essential role as well. If this data were represented in emissions per capita, it could significantly change the composition of these rankings. A large share of the emissions from the United States, China, and India are likely, in part, due to their large populations.

The United States is the largest single contributor to Earth's greenhouse gas concentrations since 1850, with the combination of early industrialization, a large economy, and a large population likely contributing.

The United States, France, Germany, the United Kingdom, and similar countries with high historical emissions must play a large leadership role in the global effort to reduce GHG emissions.

Table 1. Top 10 Cumulative Emitters, 1850 – 2020

Country	Total excl. LULUCF summed	Total incl. LULUCF summed	LULUCF summed
United States	557.11	592.42	35.31
China	363.95	426.10	62.15
Russia	175.73	186.76	11.03
India	119.19	149.72	30.54
Germany	115.40	114.59	-0.81
United Kingdom	99.21	102.52	3.31
Japan	76.41	75.43	-0.98
France	59.75	56.54	-3.21
Ukraine	51.48	57.27	5.79
Brazil	49.03	130.26	81.23

2015 EMISSIONS

The nations of focus for the projections were identified as the highest emitters when the Paris Agreement was signed. Comparing the largest cumulative emitters since 1850 to the largest emitters of 2015, we see some countries appear on both lists. In 2015, the ten countries that emitted the most GHGs were, in descending order: China, the United States, India, Russia, Japan, Brazil, Iran, Germany, Indonesia, and Saudi Arabia.

Table 2. 2015 Top Emitters

Country	Total excl. LULUCF summed	Total incl. LULUCF summed	LULUCF summed
China	12.79	11.94	-0.85
United States	6.78	6.05	-0.74
India	2.92	2.62	-0.30
Russia	2.06	1.46	-0.61
Japan	1.32	1.27	-0.06
Brazil	1.17	1.39	0.22
Iran	0.93	0.95	0.02
Germany	0.90	0.88	-0.02
Indonesia	0.83	1.48	0.65
Saudi Arabia	0.75	0.74	-0.01

Together, these "Top Contributors" made up nearly 2/3 (64.5%) of global emissions that year (Figure 3). This effect is noticeable in the data – aggregated historical emissions of those ten mirrors the global emissions data nearly perfectly since 1900. Since 1980, this group of countries has constituted roughly the same percentage of global emissions each year, reflecting the massive effect these countries have on the aggregate.

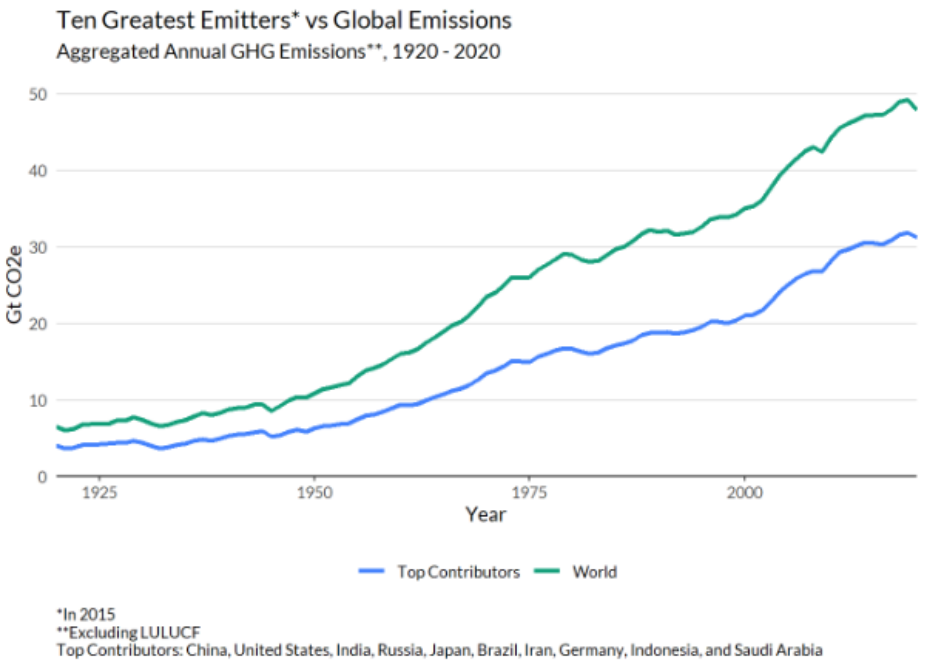

Figure 2

EMISSIONS FROM 2015 TO 2030

The Top Contributors submitted INDCs in the fall of 2015 as part of their intention to sign the Paris Agreement that November. These INDCs and their later NDCs were aggregated to evaluate their combined proposed trajectory (with immediate implementation) (Figure 4). Historical data for the sum of the Top Contributors and the global total were used to predict each grouping's yearly emission trajectory for 2021 through 2030.

First, a BAU line, reflecting behavior before 2016, was predicted to estimate emissions if pre-INDC policies were maintained.

Next, 2015 to 2020 served as each group's post-INDC and NDC policy behavior period. That data was extrapolated to predict what emission levels are expected to be in the 2020 - 2030 period if the post-Paris Agreement behavior remains unchanged.

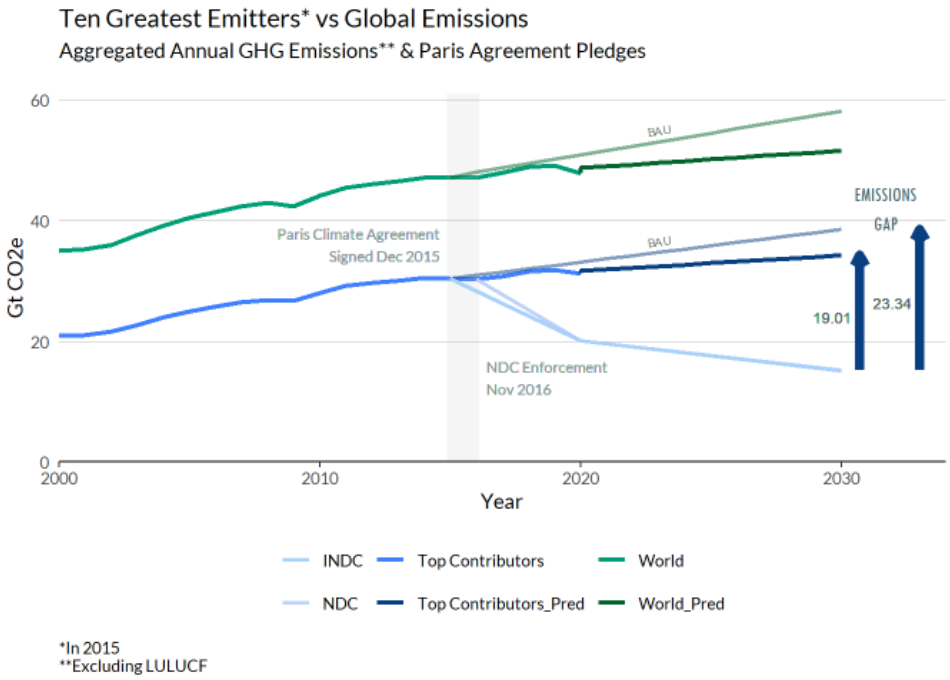

Figure 3

In Figure 4, the collective pre-2020 goals for the Top Contributors can be seen on the INDC and NDC lines at the year 2020. This connection links their behavior when they were making their post-2020 pledges to their shortcomings in meeting their pre-2020 pledges.

For the years 2016 to 2020, the Top Contributors' and global emissions were lower than their business-as-usual predictions were estimated to be. However, the decrease in yearly emissions came nowhere near as low as needed to reach 2020 pledges.

When aggregating the pledges for the period ending in 2020, their yearly emissions were meant to be lowered to 20.06 Gt of CO2 equivalent by 2020. The collected data from that year shows that the actual aggregate was 31.18 Gt of CO2 equivalent – more than 10 Gt more than the goal. Furthermore, it appears they are far from being on track to reach 2030 pledges.

The INDC and NDCs these countries submitted were significantly more ambitious than their pre-2020 targets: 15.15 and 15.25 Gt CO2e before 2030, respectively.[v] However, estimates show that emissions will continue to increase from 2020 to 2030. The gap between actual emission and target emission levels will be even larger in 2030 than the gap for 2020.

Estimates put emissions for the year 2030 at 19.01 Gt CO2 equivalent higher than pledged (34.26 Gt against 15.25 Gt). However, this gap is smaller than the gap between pledged emissions and BAU emissions for the year 2030 (23.34 Gt).

The Top Contributors are estimated to fail to meet the pledges of their current NDCs for the year 2030. Plans will need to be considerably more aggressive in the next round of NDCs. Actions must be more urgent throughout the decade if members hope to close the gap.

PATHWAYS OF GLOBAL WARMING

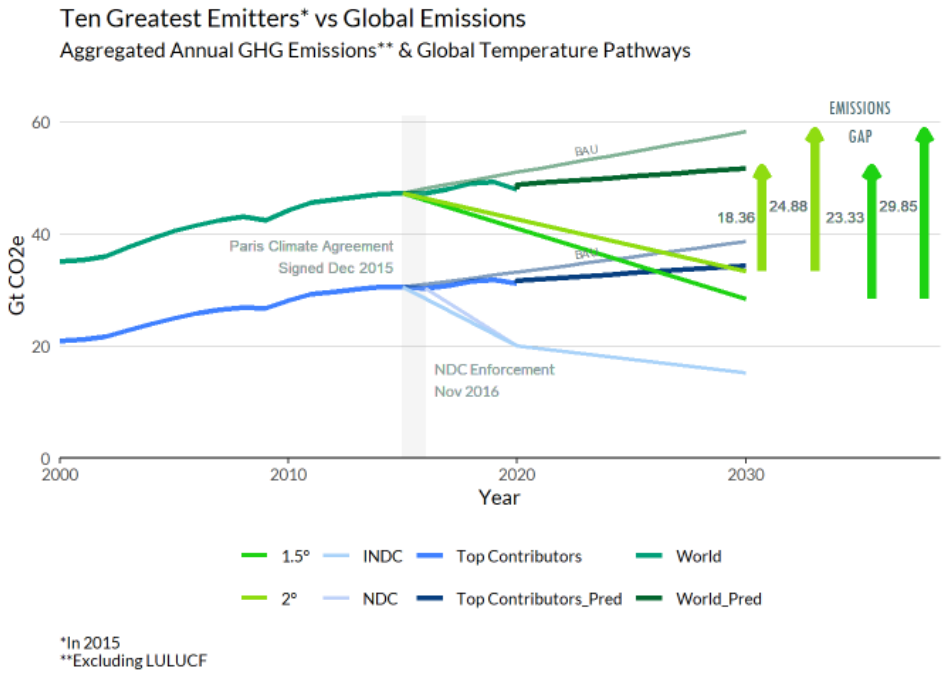

Figure 4

As previously stated, the main goal of the Paris Agreement is to limit global warming to 2°C while making best efforts to stay below 1.5°C, compared with pre-industrial levels. In its Fifth Assessment Report[vi], the Intergovernmental Panel on Climate Change (IPCC) predicts GHG concentrations for these degree paths based on likelihood of occurring.

Figure 5 shows the 1.5°C path with a 50% or more chance of occurring and 2°C path with 66% or more chance of occurring.

- These paths require a 72% reduction in global GHG concentration for 1.5°C and 49.5% (42-57%) reduction for 2°C by 2050 compared to 2010 levels.

- That means that global emissions in 2030 would need to be 28.28 Gt CO2e to be along the 1.5°C pathway and 33.26 Gt CO2e to be along the 2°C pathway.

Like the gap between the NDC target and Top Contributors' predicted emissions, there is a large gap between the pathways and predicted global emissions in the year 2030 (23.33 Gt more for 1.5°C and 18.36 Gt more for 2°C).

The predicted emissions through 2030 (51.61 Gt for 1.5°C and 58.14 Gt for 2°C in 2030) are lower than those predicted for the BAU trajectory. The emissions gap for the BAU trajectory is significant (29.85 for 1.5°C, 24.88 for 2°C).

Table 3. Goal Emissions, Predicted Emissions, and Predicted Emissions Gaps in 2030

Group	Pathway	Emissons (Gt)	Surplus from Goal (Gt)
World	1.5°	28.28	
World	2°	33.26	
Top Contributors	NDC	15.25	
World	Predicted	51.61	18.35, 23.33
Top Contributors	Predicted	34.26	19.01
World	BAU	58.14	24.88, 29.86
Top Contributors	BAU	38.59	23.34

KEY TAKEAWAYS

The data reflects that, on the aggregate, countries that have signed onto the Paris Agreement are not doing enough so far to limit warming below 2°C. The largest emitters have not enacted policy changes that put them on track to meet the goals of their NDCs.

These nations are also not expected to reach peak emissions before 2030. The longer it takes for emissions to peak, the more difficult it will be to reach net zero goals and stay on track to limit warming.

On an international scale, industrialized and wealthy countries, particularly those that are the greatest emitters, should lead the way in investing in developing nations and the Global South. As a leader in wealth and emissions, this is especially true for the United States. On the national front, domestic policy must reflect this approach.

Those already disadvantaged, both inter- and intra-nationally, will face the brunt of global warming's effects. Nations' leaders must ensure an equitable approach to climate adaptation and emission reduction efforts.

CONCLUSION

Climate change is an imminent global crisis that we are already facing the costly effects of. Scientists state that if we cannot keep global warming below 1.5°C, we will see catastrophic environmental consequences.

Governments and corporations must address and combat climate change through policies curbing GHG emissions. These policies require innovative technologies, changing the status quo, and massive investments in both. Transitions to renewable energy away from fossil fuel combustion is a great first step. Many developing nations will require international financial support to make these transitions.

Governments often step in to fill gaps where corporations see no benefit to an action. This is where strong pro-environmental policies and regulations need to come in. Still, corporations must move to green, sustainable actions and technologies. Voters in the former case and consumers in the latter hold some power to encourage those changes. There must be a multi-pronged approach across industries, sectors, and levels of government. All are needed to fight for those who will be hurt first and greatest, and time is running out.

APPENDIX

[i] Link to & information about the dataset: Gütschow, J.; Pflüger, M. (2021): The PRIMAP-hist national historical emissions time series v2.3.1 (1750-2019). zenodo. doi:10.5281/zenodo.5494497.

[ii] This sector covers GHG emissions and removals from human-induced land use, including deforestation, reforestation, and afforestation; cropland, grazing land, and forest management; and revegetation. This is important for affecting the amount of carbon dioxide in the atmosphere, but there is no common framework for LULUCF accounting. Many INDCs and NDCs, along with the data provided by governments, lack mention of the necessary assumptions and methods applied to collecting LULUCF data, presenting an issue in consistently tracking international LULUCF data. Even when mentioned, many different methods are used to collect this data, adding to the inconsistency. For this reason, the totals used for analysis exclude LULUCF in this project. The effect of this exclusion was evaluated, and it was found that after 2000, there is not a pronounced effect on the data. As seen in Figure 1, the slopes (direction) for the data including and excluding LULUCF emissions are virtually the same. Therefore, this author feels confident that it has no significant impact on the underlying assumptions and analysis.

[iii] Sources for NDCs: Climate Watch NCD Tracker Custom Comparison, Climate Watch Explore NDCs,

[iv] Sources for pathways: IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

[v] Russia is the only country that submitted an NDC with a less aggressive goal than its INDC, from a maximum effort of 75 Gt CO2e to 70 Gt CO2e.

[vi] This report was the basis for the Paris Agreements; the Sixth Assessment Report was released this year and will be the basis for the next round of NDCs.