Air Pollution on a U.S. Scale

New Mexico

Supercomputing Challenge

Final Report

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Team 72

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Executive Summary

This program is focused on the idea of Carbon Dioxide pollution, and how it affects the environment (i.e. global warming, air quality, and climate change). We are trying to solve this problem by switching the three large polluters in the US (transportation, industry, and commercial energy) from using fossil fuels, to running off renewable energy. Our program change two main factors, the rate at which polluters convert, and the demand for products created by the polluters (factory goods, electricity, etc.) or the polluter itself (cars, boats, planes, etc). The program will use these two variables to run different models of the future and see how CO2 pollution affects our environment. By running this program we are hoping to find the slowest rate people could convert to renewable, and the highest usage of products, but still have a future with good air quality, low ppm of co2, and low-temperature change.

From running the program we determined that we could switch at a medium conversion rate, or 59553 cars, 6 factories, and .8 power plants converting to renewable sources each day, with medium to high usage (which is equivalent or a decent bit more than what we use now), and still have good numbers for ppm, and temperature. Anything higher than this (slower conversion and/or higher usage) would have devastating effects to human health and the environment. Anything lower (faster conversion rate and/or lower usage) would work, and work better, but would be harder to implement and harder to get people on board with it.

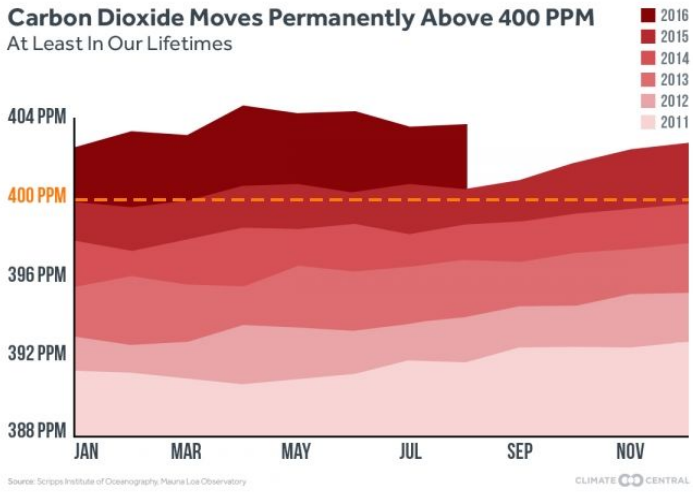
Introduction

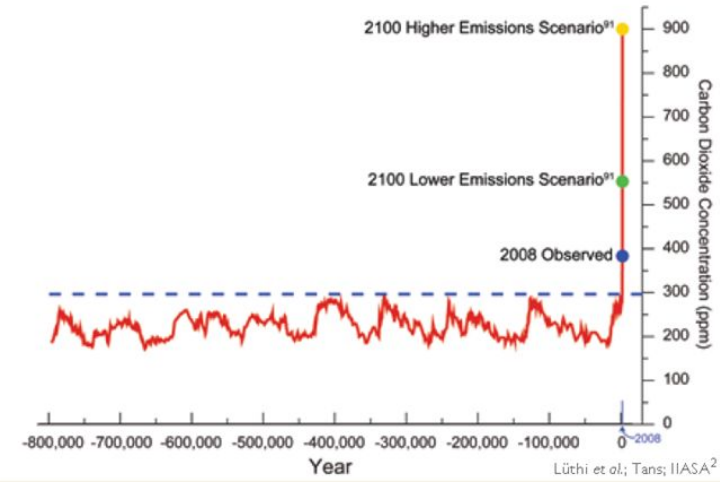
Global warming and air pollution are becoming a more and more prevalent issue in today's society and politics. The increasingly dangerous amounts of Carbon Dioxide being released into our environment through the burning of fossil fuels poses not only an immediate threat to our health but also devastating effects on the environment in the long term. With this program, we will attempt to offer a solution to the extensive use of fossil fuels by converting the United States main polluters to renewable energy sources such as electric cars, wind turbines, solar panels, etc. The program offers different speeds at which the U.S. will convert to renewable energy sources to see how this will effect Carbon Dioxide pollution in the future. It also presents what the average temperature and air quality will be in the future with different rates of pollution. While this program may not offer a perfect solution to the problem, it does offer different scenarios so we can see some of the effects this problem might have if not solved.

The increasing development of these renewable sources continues and will continue, to make this problem easier to solve. As the technology needed to extract energy from these renewable sources gets cheaper, it becomes more likely that a company would switch from fossil fuels, or could be convinced to switch. This technology is also constantly being expanded upon and improved which makes it more and more efficient. This makes allows it to produce more energy so that it is an actual alternative for fossil fuels and sometimes even produces more energy than fossil fuels. As time goes on this problem will only become more solvable however by then it may be too late to undo the damage that this pollution has done on our environment. This means that we need a solution now using the resources we have, not waiting for better ones to be developed in the future.

Problem

As previously stated, global warming and air pollution are a prevalent issue in today's world and politics. The burning of fossil fuels produces Carbon Dioxide which, while a necessary compound in our atmosphere, is an air pollutant in excess amounts and contributes to global warming. Three of the largest producers of Carbon Dioxide in the US are electricity (commercial and resident power, etc.), transportation (cars, trains, boats, etc.), and industry (manufacturing, factories, etc.). These things all run off of fossil fuel produced electricity which is a nonrenewable power source and creates CO2. In 2016, for the first time in known history, the atmospheric Carbon Dioxide level surpassed 400 ppm of CO2 (Graph by Kahn, Brian “climate central”, 27 Sept. 2016). With the low level of emissions predictions, we are expected to hit 550 ppm of CO2, and with high-level emission prediction, we are expected to hit 900 ppm (Graph by Unknown “Only Zero Carbon”) . This is triple what the levels have been stabilized at for thousands of years. Because this milestone is still recent, the long term effects of this concentration of Carbon Dioxide are still somewhat unknown. However, from the effects that have already come, we know these levels will be harmful.

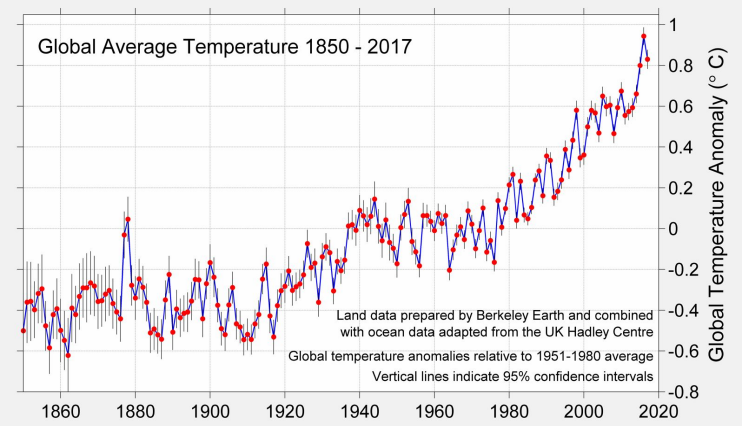


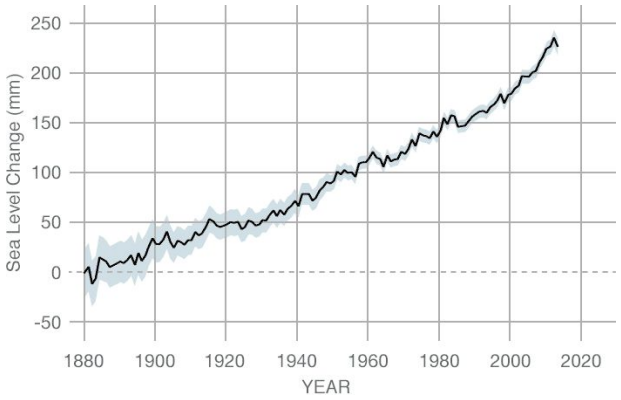


The atmospheric ppm of Carbon Dioxide reaching levels this high poses health risks to humans. While ppm at 900 is still considered safe it can cause drowsiness.

Furthermore, these predicted levels are for atmospheric Carbon Dioxide so levels being at 900 poses more serious issues than just drowsiness. This is because 900 ppm is what the levels will be at outside in open spaces, however in closed spaces that aren't as well ventilated ppm levels will be higher and could cause more serious side effects like headaches, loss of attention, and heart palpitations.

Not only does the increasing atmospheric ppm of Carbon Dioxide pose health risks to humans, but it could also have detrimental effects on the environment. Carbon Dioxide is a greenhouse gas, so contributes to global warming (Graph by *Berkeley Earth*, 18 Jan. 2018). Greenhouse gasses lead to global warming by piling up in the troposphere and the ozone layer. Then rays from the sun come down to earth like normal, however, when they try to exit the atmosphere the greenhouse gasses reflect the rays and cause them to stay on earth. This raises the global temperature which has drastic effects on earth. Global warming is having many serious effects on our environment at the moment. The rising global temperatures are melting the ice caps. This is contributing to the loss of habitat for many polar animals and a rise in ocean levels (Graph by NASA, 24 Sept. 2018). The rising ocean levels cause flooding in ocean towns and increased natural disasters like hurricanes, tsunamis, etc. The increasing temperatures and ocean levels are also causing climate change which is worsening droughts in many dry regions of the US. The climate change caused by greenhouse gases is changing regions of the US and could make some places unlivable due to things like flooding, drought, etc.





Solution

Our proposed solution to this program is to make the three largest polluters in the US run off of renewable sources. In our model this solution is only applied to the three largest polluters (Transportation, Industry, electricity), however, it can be applied to other, smaller, polluters in just the same way. Changing these polluters to renewable sources such as solar power, wind power, geothermal power, etc. can reduce or even completely eliminate the amounts of CO2 they produce. Our solution is to convert these polluters over a period of time with a similar amount converting each day. We model different speeds at which these polluters convert to see what the rates they could convert at but still have good air quality, low ppm, and low-temperature change. With this program, we should be able to determine the slowest speed at which the polluters could convert and the pollution in the future be at a good state.

Basically, the solution to the problem is the speed at which polluters will switch to renewable sources. While the faster conversion rates and lower usage rates offer better results for the environment, they do not offer a very realistic solution. This is because it is unrealistic to expect all organization and people to switch to a renewable source in a short amount of time unless something actually forced them too (like a national Law). Instead, the scenarios that fall somewhere in between, with moderate lengths of conversions and usage, but still a relatively good outlook for the future. The ppm and temperature may be a little higher in these scenarios, however, it is more realistic and possible to get the polluters to switch in a moderate time span.

Program

In our program, we attempt to model the Carbon Dioxide created by the three largest polluters in the US, electricity, transportation, and industry. We used numbers and data collected by the EPA, NASA, National Parks Services, and other organizations to base our program and make the pollution as accurate to the real world as possible. All numbers used in the model a based off data from reliable, or mostly reliable sources from the internet. Our program uses some randomness to create variation in the results that accounts for unpredictable things like, car crashes, factory closures/openings, disasters that cause the release of CO2 (Wildfires), etc.

This program will focus on three main factors to determine the state of Carbon Dioxide pollution in the future. It will focus on the atmospheric ppm of CO2, air quality, and temperature. With these measurements, we will be able to determine some of the effects it will have on humans and how dangerous these pollution rates really are. Temperature and Air quality a directly related to the atmospheric ppm of CO2, so with gathering the ppm of CO2 we can determine these other variables. This also means that an increase in the atmospheric ppm of CO2 is one of the main causes of things like global warming, climate change, worsening air quality, etc. With the numerous technological advancements happening in the 21st century, many solutions to these problems are arising. Renewable energy sources are becoming more and more efficient, and reliable, and even a better option to fossil fuels. The problem with these renewable sources is that the initial costs for organizations to switch to these renewable sources is high and in the short term it saves them more money to stay with using fossil fuels, however, in the long term, it is more cost effective, and better for the environment to use renewable sources. This program is based on the idea that everyone will switch to renewable sources, they will just do it at different rates. For the sake of saving time we only ran the program for 100 years (in the program) for each test.

Results

Low Conversion Rates (rate that polluters turn renewable)

	Very Low Demand	Low Demand	Medium Demand	High Demand	Very High Demand
PPM	1: 640.14 2: 667.32 3: 631.66 Average: 646.37	692.11 673.41 658.56 Average: 674.69	880.61 863.7 835.67 Average: 859.99	846.87 868.6 772.21 Average: 829.23	1057.52 1085.9 1148.3 Average: 1097.24
Air Quality	1: Fair 2: Fair 3: Fair	Fair Fair Fair	Fair Fair Fair	Fair Fair Fair	Poor Poor Poor
Temperature(C)	1: 13.7 2: 14 3: 13.7 Average: 13.8	14.3 14.1 13.9 Average: 14.1	16.1 16.0 15.7 Average: 15.94	15.8 16.0 15.1 Average: 15.63	17.9 18.2 18.8 Average: 18.3

Medium Conversion Rates

	Very Low Demand	Low Demand	Medium Demand	High Demand	Very High Demand
PPM	1: 487.8 2: 483.4 3: 492.28 Average: 487.83	484.9 490.0 491.61 Average: 488.84	561.6 557.0 572.34 Average: 563.65	538.5 520.9 532.4 Average: 530.6	634 606.3 628.71 Average: 623
Air Quality	1: Good 2: Good 3: Good	Good Good Good	Good Good Good	Good Good Good	Fair Fair Fair
Temperature(C)	1: 12.2 2: 12.2 3: 12.3 Average: 12.23	12.2 12.2 12.3 Average: 12.23	13.0 12.9 13.1 Average: 13.33	12.7 12.5 12.7 Average: 12.63	13.7 13.4 13.6 Average: 13.57

High Conversion Rates

	Very Low Demand	Low Demand	Medium Demand	High Demand	Very High Demand
PPM	1: 458.4	457.78	497.5	489.98	554.6

	2: 455.4 3: 460.9 Average: 458.23	452.4 457.09 Average: 455.74	500.3 500.2 Average: 499.33	481.0 474.52 Average: 485.49	545.2 528.48 Average: 542.76
Air Quality	1: Good 2: Good 3: Good	Good Good Good	Good Good Good	Good Good Good	Good Good Good
Temperature	1: 11.9 2: 11.9 3: 11.9 Average: 11.9	11.9 11.9 11.9 Average: 11.9	12.3 12.3 12.3 Average: 12.3	12.2 12.1 12.1 Average: 12.15	12.8 12.8 12.6 Average: 12.73

As shown by the tables above, no low conversion rate scenarios will lead to a future with a good ppm, little temperature change, and good air quality. In terms of low conversion rates, even with very low usage of the polluters, the ppm is still above 600, and air quality is fair, not good. In this, there is also a temperature change of 2.3 degrees Celsius. This is just with low usage, and so with this low conversion rate and medium, high, very high usage the outlook is even worse. With very high usage the atmospheric ppm will be 1097, which will make the air quality poor. A ppm this high is linked to complaints of drowsiness and stuffy air. This is what the air will be like outside so it will be even worse in places with bad air exchange and have more serious side effects. It also has a temperature change of 6.8 degrees. This scenario is obviously not viable for the future of our earth and health, and so a low conversion rate would not solve the solution. The medium conversion rates are viable to some extent, but for it to work it relies on very low to high demand/usage. With medium and high demand, and medium conversion rates the ppm stays below 600 ppm but is still pretty high. There is a temperature change of 1.1-1.5, but the air quality is still good. This means that these scenarios could work with little more impact on our health or the environment, however, it would be better to have lower ppm and less temperature change. This means that anything lower than these will also work, and work better because they either have a faster conversion rate, lower usage, or both. There are many scenarios that work however the most realistic probably medium conversion with medium or high demand.

Conclusion

In conclusion, the medium conversion rate with medium or high usage is the slowest we could convert to renewable energy and still a bright outlook for the future or the environment and humans health, pertaining to air quality and co2 ppm. The medium conversion rate is approximately equivalent switching 59553 cars, 6 factories, and .8 power plants, to renewable sources each day. This sounds like a lot but compared to how many there really are and how big the United States it, it is not that much and is doable. This is also equivalent to being 100% renewable in approximately 70 years, and when put like that is sounds much more doable. Anything lower than this will work even better however it is unrealistic to expect everyone to switch at an even faster rate, especially with what it costs to go renewable at this moment. It is also unrealistic to expect people to use these things a lot less than we do now (medium being how much we use now) so it is most realistic to expect usage in the medium to high category.

This program did not on its own solve the problem, however, it did give us an idea of what needs to be done to solve it. We can use the information gathered and come up with an actual plan to get everyone on renewable energy. This program gave us an idea of what the timeline needs to be for switching to renewable but the hardest part to actually solving the problem lies ahead. We, everyone in the US, need to work together to switch to renewable. We need to get the people reluctant to switch, to see the true nature of this problem and realize that if it is not solved it will affect everything in serious ways. The nature of this solution is really simple, we just need to work together to get everyone on renewable energy, however, making people work together is harder than it should be. So, we cannot make this happen just by using this program, but some of the data collected in the program helps us to know what really needs to be done.

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Bibliography

- Kahn, Brian. “The World Passes 400 PPM Threshold. Permanently.” *Climate Central*, 27 Sept. 2016, https://www.climatecentral.org/news/world-passes-400-ppm-threshold-Permanently-20738
- *Atmospheric Carbon Dioxide*, www.onlyzerocarbon.org/co2_levels.html.
- “Global Temperature Report for 2017.” *Berkeley Earth*, 18 Jan. 2018,http://berkeleyearth.org/global-temperatures-2017/
- “Sea Level | NASA Global Climate Change.” *NASA*, NASA, 24 Sept. 2018, https://climate.nasa.gov/vital-signs/sea-level/
- “Sources of Greenhouse Gas Emissions.” *EPA*, Environmental Protection Agency, 9 Oct. 2018, www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.
- “Carbon Dioxide Concentration | NASA Global Climate Change.” *NASA*, NASA, 17 May 2017, https://climate.nasa.gov/vital-signs/carbon-dioxide/.
- “Global Climate Change Impacts in the United States 2009 Report Legacy Site.” *800,000 Year Record of CO2 Concentration | Global Climate Change Impacts in the United States 2009 Report Legacy Site*, https://nca2009.globalchange.gov/800000-year-record-co2-concentration/index.html.
- “How Is Air Quality Measured?” *How Is Air Quality Measured? | NOAA SciJinks – All About Weather*, https://scijinks.gov/air-quality/.
- “How the World Passed a Carbon Threshold and Why It Matters.” *Yale E360*, https://e360.yale.edu/features/how-the-world-passed-a-carbon-threshold-400ppm-and-why-it-matters.
- “Rising CO2 Levels Could Push 'Hundreds of Millions' into Malnutrition by 2050.” *Carbon Brief*, 5 Sept. 2018,www.carbonbrief.org/rising-co2-levels-could-push-hundreds-of-millions-into-malnutrition-by-2050.

- “U.S. Emissions.” *Center for Climate and Energy Solutions*, 31 Oct. 2017, www.c2es.org/content/u-s-emissions/.
- “What Passing a Key CO2 Mark Means to Climate Scientists.” *Climate Central*, 20 Nov. 2015, www.climatecentral.org/news/co2-400-ppm-scientists-meaning-19713.
- “What Are Safe Levels of CO and CO2 in Rooms?” *Kane International Limited*, www.kane.co.uk/knowledge-centre/what-are-safe-levels-of-co-and-co2-in-rooms.
- “ZGw063RY - Wall Mount CO2 Monitor.” *ZyAura*, www.zyaura.com/products/ZGw063.asp.