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Introduction

The partner for this project is Australian Centre for Education and Training – Global (ACET Global). ACET Global specialises in providing high quality and expert training to organisations both locally and internationally. Some areas that ACET global provides industry training in include leadership and management, marketing management, and others. ACET Global also offer guest lecturing in a range of fields to universities, and TAFE providers. All staff are current practitioners in their respective fields who deliver tailor made engaging lectures to students in the area of business management. ACET Global measure success not only by financial gain, but also social and environmental performance. As a part of these values, ACET global perform several external initiatives to contribute to community, social issues and contributing to environmental and sustainability projects. To give back to their community, ACET global has launched several non-profit projects to address varying societal problems that impact communities both locally and internationally. Current projects include the Global Peace Project, Global Sanitation and Sustainability Project, Global Road Safety Project, Global Entrepreneurship Project, Global Climate Action Project, Global Water Management Project, and Global Air Quality Project. The aim of each of these projects is to outline the issue being presented and provide various resources for readers to further investigate the issue, these take the form of reports, podcasts, videos, and infographics to deliver readers a variety of lasting information.

The initial aims of the project are to utilise data science techniques and report writing to diversify the current information presented on the Global Air Quality Project. Currently resources are limited to reports, infographics, and videos with limited exploration into existing data and visualisations related to their projects. ACET Global wishes to raise awareness of the importance and impact of air pollution through the visualisations and reports created by group members. As the air pollution project is in its infancy, there is little work completed past a general outline of the topic. Each group member was tasked with selecting and researching 2-3 topics related to air pollution in order to diversify the information on ACET Global's website. The topics covered included analysis of different pollution types and health impacts, continental differences in air pollution, the effect of international treaties of improving air quality, and case studies of cities with poor and good air quality and some of the causes of these. Through-out the course of the project, the aims remained the same, with only some refinement of selected topics occurring early in the project.

The deliverables for the project are a report encompassing each group members selected topics, data visualisations were applicable to be included in report or as standalone items on website pending ACET Global's wishes and a presentation to be given to ACET Global as well as recorded and submitted at the end of the project. Each group member was asked to compile their own report, visualisations and presentation so that ACET Global could collate information as they required. The total deliverables from the project are three reports and presentations including data visualisations.

Background

There following information gives gravity and understanding as to why mitigating air pollution and improving air quality is an important issue and why ACET Global chose to devote time and effort to developing resources that can be used to better the knowledge around air pollution. Air pollution causes approximately 7 million premature deaths per year from various physical impacts on people's health and over 90% of the world's population currently inhabits areas where the air quality exceeds WHO limits (World Health Organisation, 2021). The impacts of poor air quality are felt globally, and it is not an issue that impacts only specific regions. Due to the nature of air pollution, what is impacting one country can soon be spread to many others. In 2019, air pollution was the fourth leading cause of premature death globally, and the leading environmental cause(Health Effects Institute, 2020). Health impacts can include stroke, cancer, cardiovascular disease and respiratory illness (West et al., 2016). From this it becomes obvious that poor air quality is a threat to millions of people around the world, and one that many do not recognise as being especially pressing, it is for these reasons that ACET global has chosen to devote a project to consolidating a readily available suite of information for people to access in the hopes of developing their understanding and inspire change to help combat the threat of air pollution.

A general overview of air pollution and associated terms are provided below, so as to provide clarity and context to terms used throughout. Air pollution refers to emissions into the climate and atmosphere by several sources. These sources can be anthropogenic (human caused), biogenic(living natural causes) and geogenic (non-living natural causes), the most concerning of which are anthropogenic (Keywood MD, 2018). Emissions fall into two main categories, greenhouse gases and particulate matter, each with different sources and effects (Manisalidis et al., 2020). Greenhouse gases are the existence of trace amounts of gases such as carbon dioxide, carbon monoxide, ozone, nitrogen dioxide and methane that cause a warming effect on the earth(Casper, 2010, Environment Protection Authority Victoria, 2020, United States Environmental Protection Agency, 2021). The main sources of greenhouse gases are industry, vehicle emissions and the burning of fossil fuels. Particulate matter is the combination of solid and liquid particles in the air(Roser and Max, 2017). There are two main types of particulate matter, $PM_{2.5}$ and $PM_{10,}$ with numbers reflecting particle size in microns. The main sources of particulate matter are vehicle exhausts (Health Effects Institute, 2020).

Approach / Methodology

The methodology outlined to achieve the aims of the project are presented in a way that highlight methods that all group members performed while creating their individual reports and presentations. Individualised methodology sections are also provided to outline methods that individual members chose to perform as a part of their report development.

In order to ensure the topics chosen were going to add value and be novel to the information already supplied by ACET Global, a review of the information listed on the website and past reports was conducted to identify possible gaps. In doing so it was decided that more information could be provided regarding what constitutes air pollution, identifying regions that produced the most pollutants, investigating the impact international treaties on improving air quality, and case studies pertaining to certain aspects of air pollution such as identifying regions with the best and worst air quality . These topics fulfilled the aim of providing new information to ACET global as well as allowing for the creation of suitable data visualisation for the report and presentation. Through consultation with the supervisor from ACET global it was decided that the best opportunities for useful visualisation laid in the topics outlined above, as no previous work had been conducted by ACET global in these areas. The literature reviews were conducted by searching for scholarly articles in google scholar pertaining to air pollution, greenhouse gases, particulate matter, the health impacts of these and information relating to the selected case studies. Information from these articles were collated as background information and to form supporting sections of each member's report. As ACET global did not possess any data related to air pollution, it was required for each group member to source data for the topics outlined above that related to their topics of interest in order to create visualisations.

Several data science techniques were employed for data wrangling, tidying and visualisation. There was no requirement to share data amongst team members, so each member was responsible for collecting and curating their own data sets to suit their needs. After raw data had been sourced, it required extensive tidying before it could be visualised. Datasets created that pertained to continent data were initially recorded for individual countries, so countries were mapped to their corresponding continent before being aggregated to show the total average production of each pollutant by continent. Some filtering was required to remove countries who had no recorded values or could not be mapped to a continent (the result of out-of-date country names in data). Finally, data was filtered by date to ensure results were only for the time frame and region of interest. A clean dataset was written for each pollutant of interest by each team member. As data was often recorded daily certain data points were often missing from the collected data and to mitigate this, missing values were backfilled, this was done so as to not remove large portions of missing data. The above techniques were used to develop clean and complete data that could be used for visualisation. The outcome was tidy data for each continent or country for the selected time frame for each group member, these techniques were chosen as other methods may have resulted in omitting large portions of data or imputing missing values with different methods which were not appropriate given the data was time dependent. The techniques selected generated the most accurate and useful data for visualisations.

To demonstrate an example of the data used in the projects, Figure 1 shows an example of the G20 country data used for visualisations investigating the effect of the Paris Climate Agreement on air quality. The data for Australia is shown, where monthly average air quality index values for each pollutant recorded for the country. The air quality index value is based on the US EPA index value, and ranges from 0 to 300, where 0 is healthy air quality and 300 is extremely unhealthy. These values are uses as they standardise air quality to allow for comparison between countries and regions, whilst giving an indication of the severity of the air quality for each country. A dataset similar to this was produced by each team member with changes in country and pollutant depending on their area of research.

month	year	pm25	pm10	no2	co	country
5	2014	25.33333	10.500000	9.000000	2.000000	australia
6	2014	27.73333	11.116667	5.866667	1.616667	australia
7	2014	30.15054	12.661290	7.193548	2.032258	australia
8	2014	27.15054	10.709677	6.274194	1.451613	australia
9	2014	26.81111	12.666667	6.366667	1.250000	australia
10	2014	32.54839	17.967742	40.822581	2.370968	australia
11	2014	31.07778	17.600000	4.633333	1.583333	australia
12	2014	29.56322	15.224138	4.189655	1.068966	australia

Figure 1. Australian air quality data. Grouped by country and month for each year. Air quality is measured in Air Quality Index Value.

Once each team member had gathered and tidied the data required of their report, visualisations were created using R and the "ggplot" library. Members were free to choose which ever visualisation techniques they felt most comfortable using, as no hard constraints were placed on them by ACET global. Finally, each member compiled their research from literature reviews and visualisations into a final report and presentation that were submitted to ACET global to utilise how they wished as a part of the Global Air Quality Project website.

Luke's Methodology:

Visualisations related to regional air pollutant production were created using data from "Our World in Data", who have multiple repositories available for air pollutants by country. These repositories could be directly accessed in R using the "owidR" library. To investigate the impacts of international treaties on air quality, it was decided to research changes in air quality in the years after the Paris Climate Agreement (PCA) came into effect. A small-scale investigation was conducted by sampling the G20 nations from signatories and collecting air quality data where available. These countries were selected as it would allow for a selection of countries from all continents and being countries who are leaders on the world stage, it would allow for insights into the example that these countries were setting in regard to the efforts and reductions they were making. After researching data availability for pollutants for each G20 country it was decided that data would be obtained from the "World Air Quality Index Project". The data repository contained historical data for many pollutants from monitoring stations all over the world. In order to capture spatial variability in air quality, data for the three most populous cities in each country were downloaded, pending selection for having the required data for the selected pollutants and time frame.

Chih-Ying's Methodology:

Data used in the report is discussed below, with further information about the datasets provided in the corresponding number listed:

Data includes the air quality in Tasmania [1], and Delhi [2]. These were used to form the basis of case studies conducted to compare regions with good and poor air quality. The sources of air pollutants in Delhi [3], the number of deaths from different risk factors in India [4] and the total and per-capita economic loss due to premature deaths and morbidity from air pollution in India [5] were also gathered to explore the reasons and consequences of poor air quality in the Indian case study. The annual PM10 emissions and the number of exceedances from 1992 to 2003 [6] were gathered for Tasmania and the air quality before and after odd-even scheme in India were collected to investigate the impact of certain programs aimed to improve air quality (from 25 December, 2015 to 15 January, 2016).

[1] Data from EPA Tasmania includes year, city, P2.5 and PM10 concentration.

[2] Data from Kaggle includes date, city, P2.5, PM10, O3, NO, NO2, NOx, NH3, CO, SO2, O3, and AQI.

[3] Data from Ministry of Health industry includes season, P2.5, PM10, CO, NOx, sector, and percentage.

[4] Data from Kaggle includes country, code, year, the 26 different types of risk factors.

[5] Data from THE LANCET includes city, the total and per-capita economic loss from polluted air, the cost of premature deaths, morbidity due to air pollution.

[6] Data from Department of the Environment and Heritage includes year, the number of monitoring the data, the mean, minimum, maximum and the number of exceedances.

[7] Data from central pollution control board (CPCB) includes the locations of monitoring station and PM10, PM2.5, NO2, SO2 before, during and after odd-even scheme.

Yung Chen's Methodology:

Datasets were scraped from many websites including Kaggle, Our World in Data, and the World Health Organisation. After finding datasets, R was used to analyse each dataset and perform minor data tidying to ensure that data was in a usable state. It is important convey the messages in data in an easy to understand format for visitors to the website, so data was visualised mainly with line graphs as most of the data was time-series and as such this would be a concise way to convey messages to the audience. Visualizing the dataset with graphs helped to highlight the important information through different time periods.

Results, Evaluation & Analysis

As the aim was to produce varied insights regarding air pollution and air quality for ACET global to incorporate into an existing website, each team member researched and produced different results, each of which are presented below in an individual subsection. Members results include the data visualisations produced for ACET global and the key findings associated with these. These visualisations and findings will provide value to the existing information on ACET global's website as it currently does not contain any visual information and the diverse topics covered by the team are sure to aid in improving the understanding of visitors to the site. Please note that figure numbers only refer to those contained in each individual subsection.

Luke's Results:

There are two main sub-sections for the results found, identifying the historical leading continental producers of air pollutants, and identifying nations where the signing of the Paris Climate Agreement (PCA) has had the biggest impact. The final graphs used in the report and that will be incorporated into the website for each sub-section are presented below. The key findings from each figure are also discussed.

Leading Continental Producers:

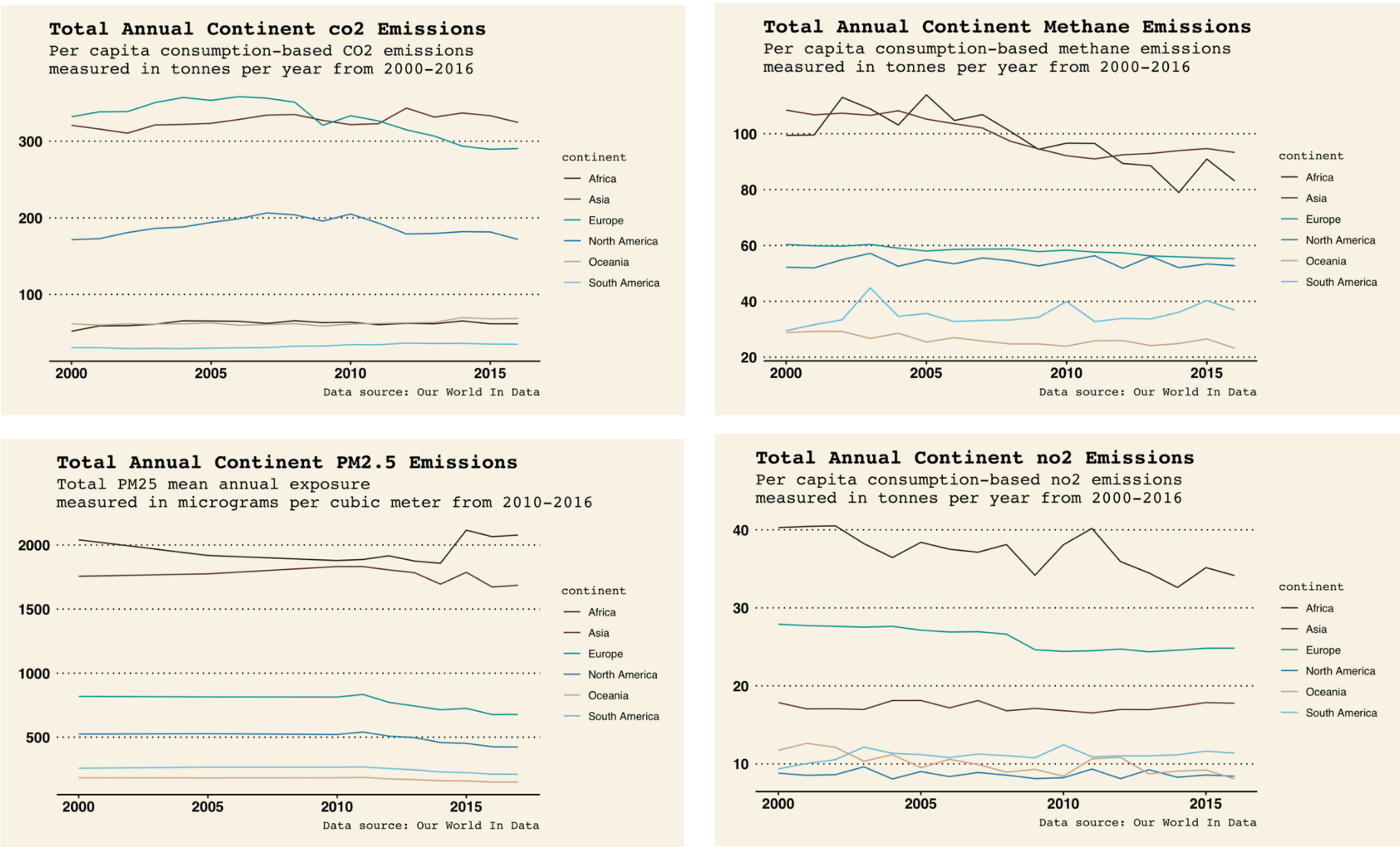

Figure 2. The total annual carbon dioxide, methane, $PM_{2.5}$ and nitrogen dioxide emissions by continent from 2000 – 2016. The amount of carbon dioxide, methane and nitrogen dioxide is measured in tonnes and standardized to per capita values. . The amount of $PM_{2.5}$ is measured in micrograms per cubic meter. Data was sourced from Our World In Data (Roser and Max, 2021)

Figure 2 shows that, globally, Asia and Europe are the leading contributors of carbon dioxide in the period from 2010 to 2016. Both continents produced over 300 tonnes of carbon dioxide for an extended time, with Europe dropping below that mark in the last few years. All continents appear to be relatively consistent in their carbon dioxide production from year to year, with slight fluctuations. It appears Europe's emissions levels have been steadily decreasing since 2008, making it the only continent with an obvious reduction in carbon dioxide emissions. Europe's emissions are mainly driven by the energy supply sector, industry, and transport, with these three sectors accounting for over 75% of European carbon dioxide emissions in 2015 (Tsiko et al., 2019). Similarly to Europe, Asian carbon dioxide emissions are also driven by transport sectors and energy production (Ohara et al., 2007). It has been noted that the downward trend in the years prior to 2010 may be due to the environmental measures put in place for the 2008 Beijing Olympics (Wu et al., 2011). Africa and Asia have been the two biggest producers of methane, both producing approximately 100 tonnes of methane in 2000, before showing a reduction towards 80-90 tonnes in 2016. Africa and Asia have shown the largest decline in methane emissions. Africa's methane production is due to microbial wetlands, agriculture and waste sources contributing the majority of their emissions (Lunt et al., 2021). Likewise, Asia's methane production is largely caused by agriculture, including the extensive use of rice paddies (Li et al., 2009), and the presence of tropical wetlands (Yin et al., 2020). The downward trend in methane production, beginning in 2005, for both Africa and Asia is once again attributed to changes made to meet Kyoto Protocol targets (Grubb et al., 1999). Africa and Asia have produced the highest amounts of $PM_{2.5}$, with both continents producing over 1500 micrograms per cubic meter. However, Africa, as the standalone, has shown a strong increase in the amount of $PM_{2.5}$ produced during the same time period, despite previously showing a steady decrease. The leading sources of $PM_{2.5}$ for Africa are domestic fuel burning, traffic emissions, and wind-blown dust (Wichmann, 2021, McDuffie et al., 2021). Similarly for Asia, $PM_{2.5}$ emissions were also attributed to fuel burning, dust, and vehicle emissions. Sea spray and industrial emissions also contributed to the total $PM_{2.5}$ emissions from Asia (Lurie et al., 2019). The reduction in $PM_{2.5}$ emissions for Europe, North America, Oceania and South America in recent years is, once again, a part of the strategies put in place by the Kyoto Protocol (Grubb et al., 1999). Africa was the biggest producer of nitrogen dioxide emissions, producing between 40 and 30 tonnes annually from 2000 to 2016. Whilst Africa may be the biggest producer, the continent showed the strongest decline in emissions of nitrogen dioxide. The high levels of nitrogen dioxide emissions by Africa have been attributed to the burning of vegetation and other biomass, with the observed reduction linked to a decline in those burnings (Hickman et al., 2021). The main sources of nitrogen dioxide emissions in Europe are vehicle emissions and fuel combustion. The reduction in European emissions in 2008-2009 has been attributed to the effect of the global recession in 2008, with emission levels not returning to those observed pre-recession (Castellanos and Boersma, 2012).

The results outlined above meet the aims of the project as they will give visitors to ACET global's website a better understanding of which continents have produced the most pollutants in recent years. The discussion of what causes these emissions for leading polluters also enable the reader to better understand what drives air pollutant production and how changes in policy can directly impact the state of pollutant production. The results also allow readers to compare different regions and appreciate that certain areas of the world are responsible for producing certain pollutants.

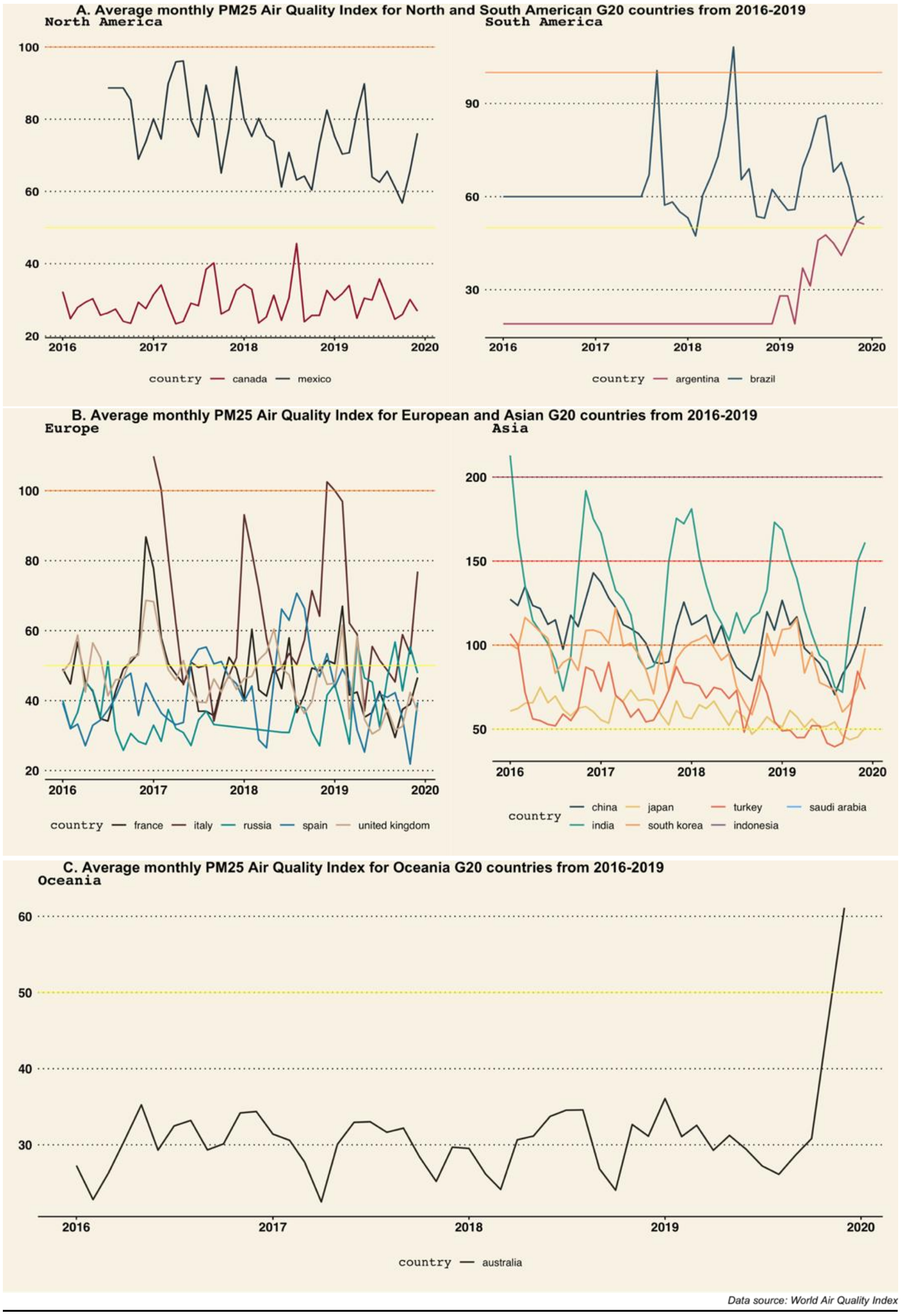

Figure 3. Shows the average monthly $PM_{2.5}$ Air Quality index from 2016 – 2019 for G20 nations where available. A) shows North and South American Countries. B) Shows European and Asian Countries. C) Shows Oceania countries. Coloured y-axis lines correlate to Air Quality Index level threshold. Data was sourced from the World Air Quality Index data repository (The World Air Quality Index Project, 2021)

When considering the $PM_{2.5}$ air quality, Mexico, India, and China showed consistent improvements in air quality for $PM_{2.5}$. Mexico is approaching $PM_{2.5}$ air quality below moderate levels, India is trending towards its peak levels being below unhealthy and China is making gradual progress towards $PM_{2.5}$ levels ranging in the moderate zone. Importantly, these countries have some of the worst $PM_{2.5}$ air quality in the world, so it is necessary to make changes that would lead to improved air quality. It is important to note that many of the G20 nations air quality for $PM_{2.5}$ were not at dangerous levels, therefore they are unlikely to implement strategies to address the air quality of this pollutant as there is little incentive or imminent danger. It is the countries levels are of concern and their changes since signing the PCA that are important to note, as seen with Mexico, India, and China.

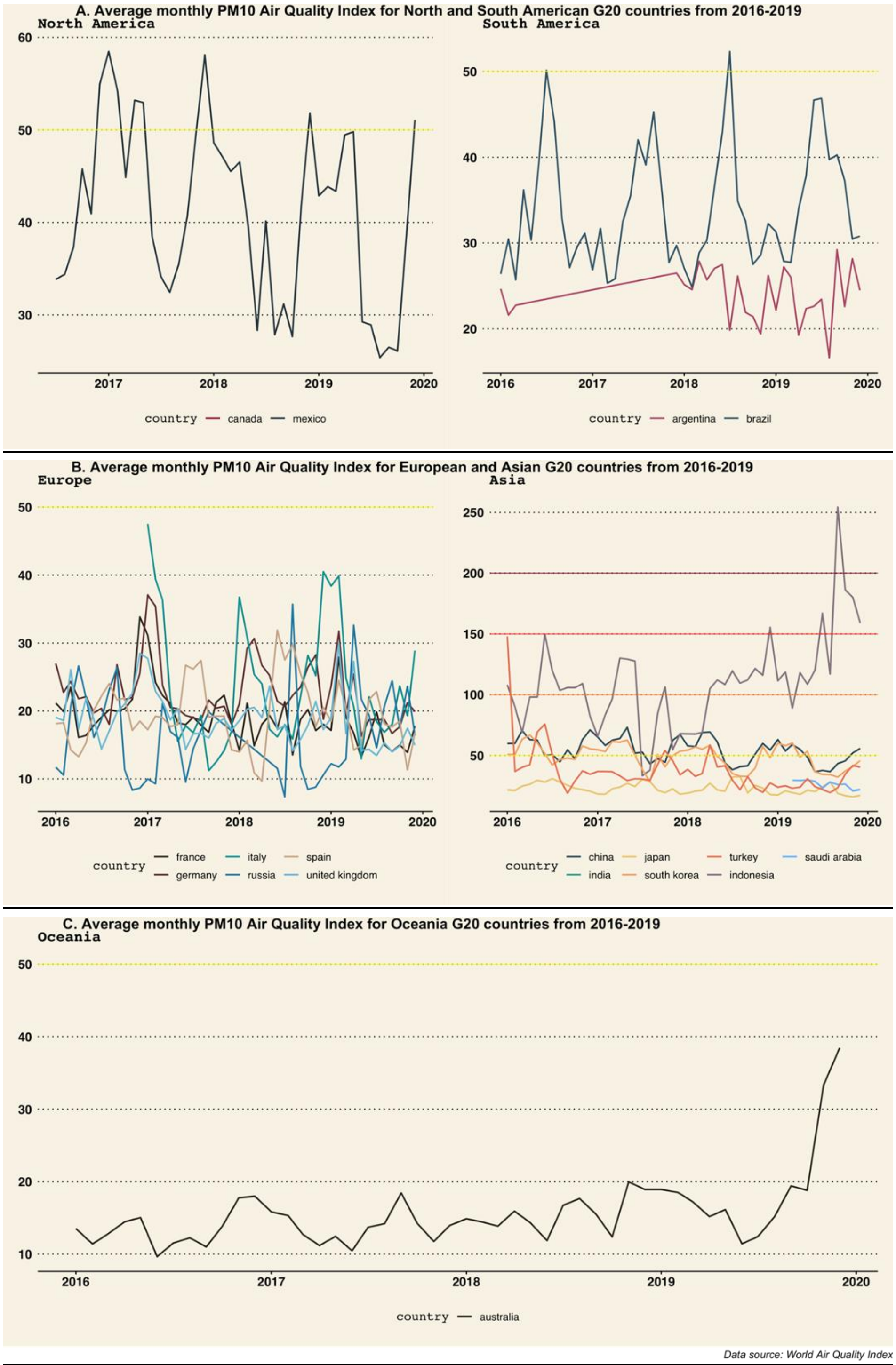

Figure 4. Shows the average monthly PM_{10} Air Quality index from 2016 – 2019 for G20 nations where available. A) shows North and South American Countries. B) Shows European and Asian Countries. C) Shows Oceania countries. Colored y-axis lines correlate to Air Quality Index level thresholds. Data was sourced from the World Air Quality Index data repository (The World Air Quality Index Project, 2021)

Similarly, with PM_{10} air quality, it is the G20 nations in Asia that are showing the strongest signs of reduction in the years following their signing. China, South Korea and Turkey have all managed to reduce index values to below moderate levels, although the improvement is not as dramatic as what is observed for $PM_{2.5}$ air quality. The most concerning observation from visualization regarding PM_{10} air quality is the sharp rise in Indonesia's PM_{10} emissions. Although they were initially tracking to improve air quality, in more recent years the air quality has worsened to unhealthy levels. Indonesian air quality has exceeded both the World Health Organisation and Indonesian standards, largely due to traffic emissions and biomass burning (Istiqomah and Marleni, 2020).

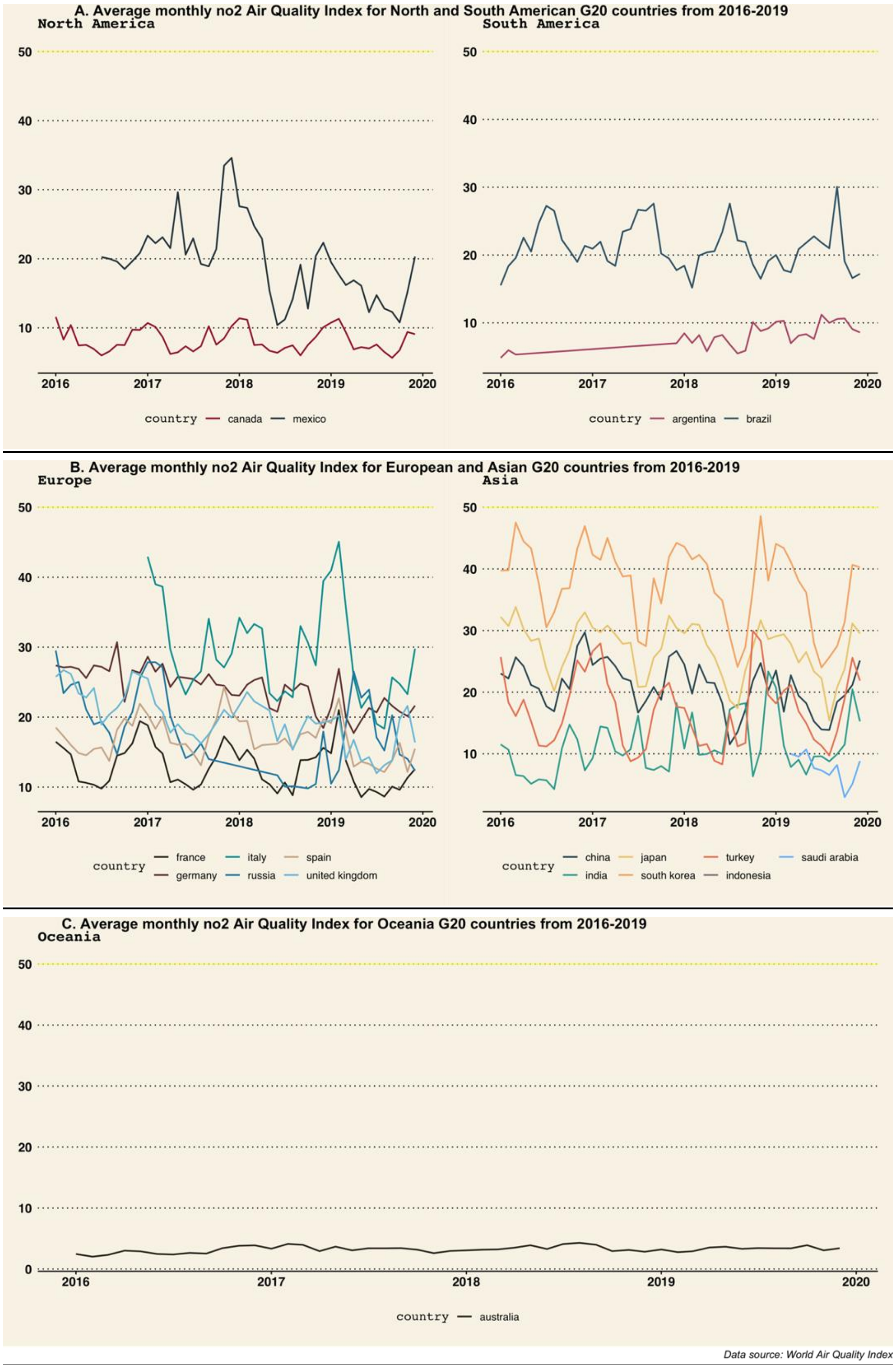

Figure 5. Shows the average monthly nitrogen dioxide Air Quality index from 2016 – 2019 for G20 nations where available. A) shows North and South American Countries. B) Shows European and Asian Countries. C) Shows Oceania countries. Colored y-axis lines correlate to Air Quality Index level thresholds. Data was sourced from the World Air Quality Index data repository (The World Air Quality Index Project, 2021)

For nitrogen dioxide air quality, it is difficult to discern the effects of the PCA, largely because of the relatively low index levels observed globally. Of the G20 countries presented South Korea was the only nation close to breaching the moderate air quality level for nitrogen dioxide. Since the signing of the PCA though, South Korea has made steady improvements in the air quality for nitrogen dioxide, with the most recent peak index being 40 and lowest 35. Other countries to show improvements in nitrogen dioxide air quality were Germany and the United Kingdom. Whilst neither of these countries had concerning levels, they have both been able to reduce their nitrogen dioxide air quality since signing the PCA. Reductions in countries where the air quality levels are not concerning shows that strategies implemented to meet PCA goals can be far-reaching, and signs of improvement can be found in areas that may not be the most pressing or urgent for countries to address.

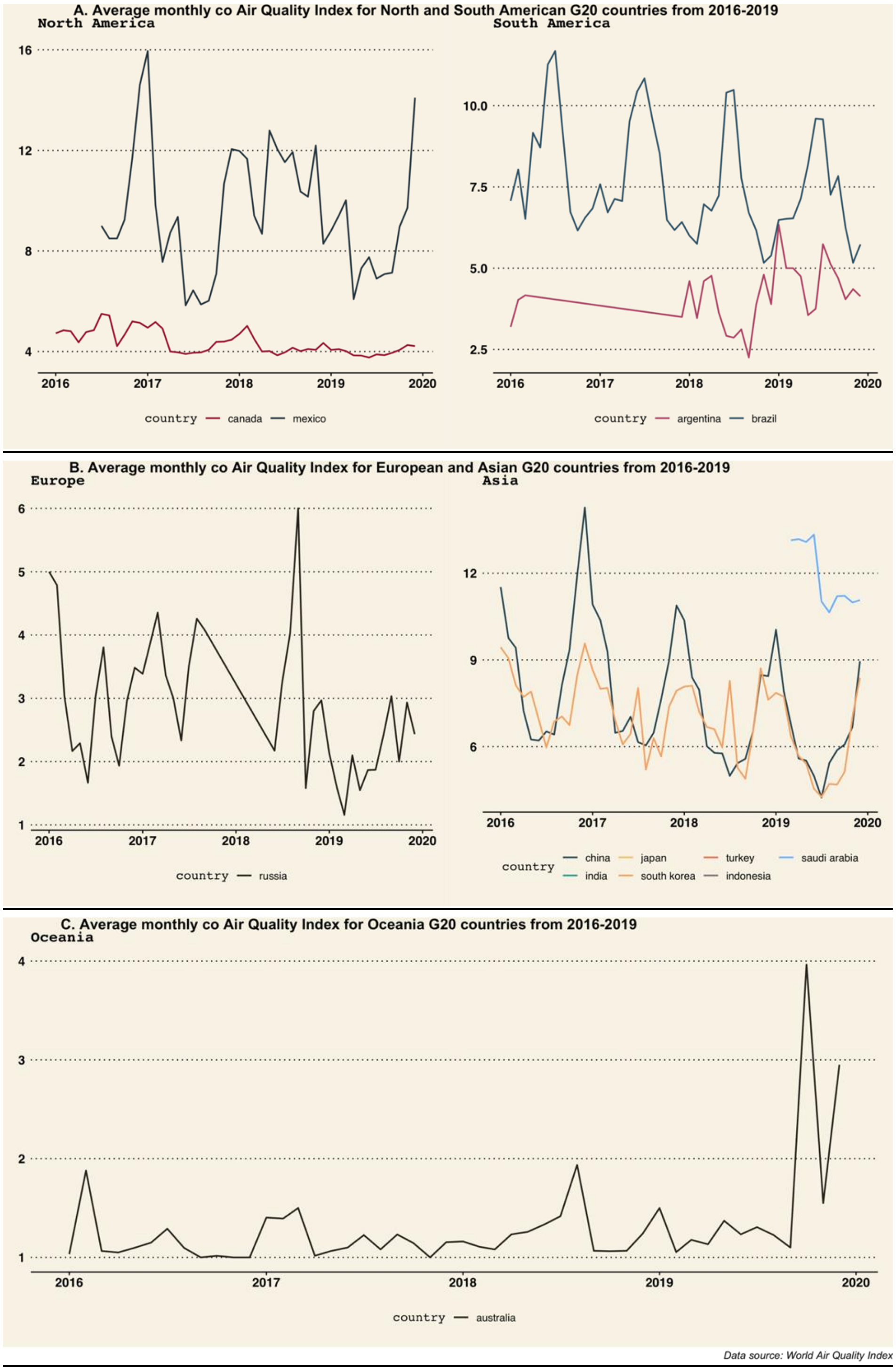

Figure 6. Shows the average monthly carbon monoxide Air Quality index from 2016 – 2019 for G20 nations where available. A) shows North and South American Countries. B) Shows European and Asian Countries. C) Shows Oceania countries. Data was sourced from the World Air Quality Index data repository (The World Air Quality Index Project, 2021)

The effect of the PCA on carbon monoxide air quality is also difficult to discern. Many of the G20 nations did not have publicly available records of air quality for this pollutant and those that did exhibit extremely low index values – therefore, little change was observed. Of the countries presented, Brazil, China and South Korea all showed signs of improving air quality in the three years after the PCA came into effect. These countries were able to reduce their peak index value to below 10 by the end of 2019. Due to the high air quality for carbon monoxide globally, it is unlikely that countries are developing specific strategies to combat this pollutant, and reductions observed are more likely the result of strategies implemented to meet other PCA goals or reductions.

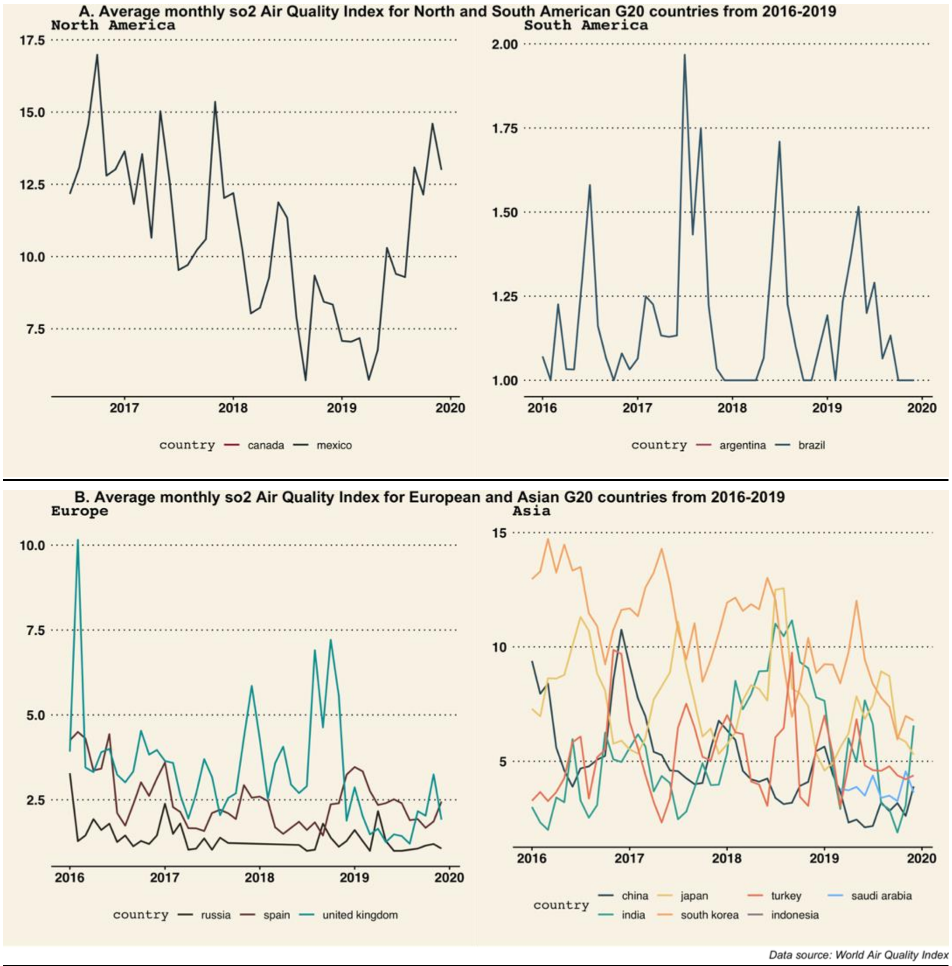

Figure 7. Shows the average monthly sulfur dioxide Air Quality index from 2016 – 2019 for G20 nations where available. A) shows North and South American Countries. B) Shows European and Asian Countries. Data was sourced from the World Air Quality Index data repository (The World Air Quality Index Project, 2021)

Similar observations can be made for the air quality of sulphur dioxide. One noteworthy observation is the increase in sulphur dioxide index level in Mexico from 2019. Despite improving air quality in the years prior, air quality recently decreased. A possible explanation for this is the prevalence of oil fields in Mexico giving rise to sulphur dioxide hotspots in the country (Dahiya and Myllyvirta, 2020). No countries had poor air quality levels, but a few were still able to show improvements in the sulphur dioxide air quality over time. The United Kingdom and South Korea again showed air quality improvement from 2016 to 2019. Again, these improvements are likely the by-product of measures aimed to reduce other pollutants as a part of the PCA, but reinforces the importance and effect that the PCA can have. By requiring strategies to reduce other pollutants, progress can be made elsewhere even if this is not the intended outcome.

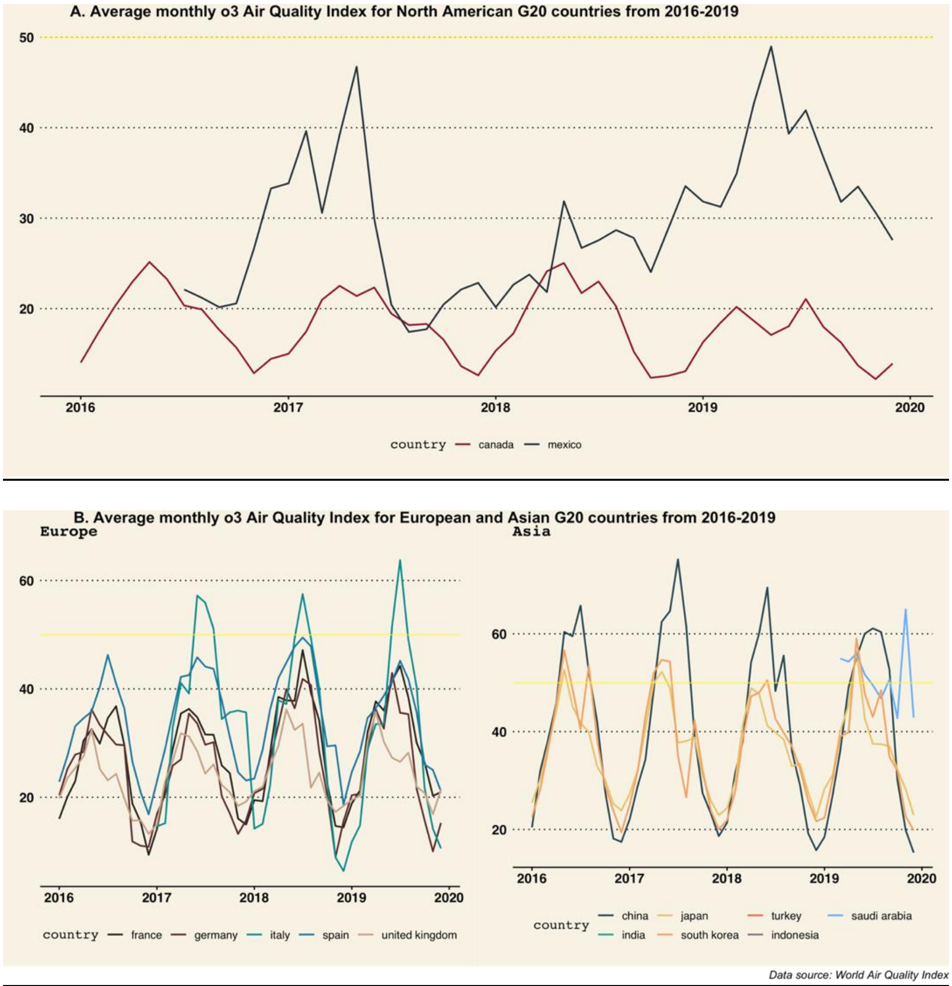

Figure 8. Shows the average monthly ozone Air Quality index from 2016 – 2019 for G20 nations where available. A) shows North American Countries. B) Shows European and Asian Countries. Colored y-axis lines correlate to Air Quality Index level thresholds as outlined in figure 5. Data was sourced from the World Air Quality Index data repository (The World Air Quality Index Project, 2021)

No countries appear to be making drastic improvements in their ozone air quality. Rather, most countries are holding relatively stable air quality levels when accounting for seasonal variation. This is despite several countries peaking above the moderate threshold (Italy, China, South Korea and Japan). Whilst this level of ozone air quality is not hazardous, it does show that there is still scope for improvement when tackling air pollution and that no single strategy is able to result in an improvement in air quality across all variables. There may a need for further refinement in strategies being implemented to help improve ozone air quality, as currently it is either holding or worsening. It is suggested that countries implement more targeted approaches to improving air quality and reducing emissions, reducing strategies that focus on overall goals.

The figures above illustrate that, whilst many of the nations presented were able to improve their air quality for many of the pollutants considered in the years after signing the Paris Climate Agreement, some nations were unable to do so. It is worth noting these nations and considering actions they may be able to take to show improvement akin to others. Nations that were able to improve their air quality across most pollutants include Mexico, Italy, China, South Korea, the United Kingdom and Germany. Of the countries considered, these are the ones that are making the most active contributions to improve their air quality and reduce air pollution. Of those making significant headway, South Korea must be commended for its significant and constant improvement in air quality of all pollutants. South Korea has tightened regulations around environmental inspections of businesses, imposing significant criminal sanctions for non-compliance, progressively restricted air quality standards, and begun monitoring major industrial emitters. Further to this, South Korea includes stakeholders and the general public in consultations regarding changes to air quality bill drafting (Trnka, 2020). Implementing measures such as these is what has resulted in the improved air quality witnessed in South Korea. Conversely, some nations have failed to show such an improvement, Argentina, Brazil, Russia, Indonesia, and India can still do more to improve their air quality. These countries showed decreases in air quality or showed an improvement but remain at unsatisfactory levels. Of these, India and Indonesia are of the most pressing concern, showing unhealthy air levels. These levels are only for several pollutants, indicating that they may benefit from targeted responses to address these issues. India however has shown some consideration to further improving air quality. The National Clean Air Programme (NCAP) follows a traditional policy framework and some improvements have been made as a result, however further recommendations for the NCAP have been made, including tightening of air quality regulations, heavier investment in public transport and increased exposure of regulatory data to the public (Santosh 2021). The possibility of incorporating similar measures as those implemented by South Korea may also benefit not only India, but other nations that could yet still further improve their air quality through diminishing air pollutant production.

The results of the investigation into the impacts of the Paris Climate Agreement are of value to ACET Global as they show that international treaties can be effective in combating air pollution. It is important that website visitors have an appreciation that large scale treaties are not just a political move to save face, but rather an effort by nations to combat a pressing issue. The results allow users to identify and appreciate countries who are making significant changes to improve air quality, whilst also highlighting those who are not. The results also provide the user with supporting information to understand what strategies countries are implementing so as to improve air quality. Information such as this is helpful to deepen and broaden understanding of air pollution for visitors to ACET global's website.

<u>Chih-Ying's Results:</u>

The report briefly explains, what policies can be applied to reduce air pollution and how effective measures these measures may be, as well as case study comparisons of regions with good (Tasmania) and poor (India) air quality. The report includes visualisation of the concentrations of PM2.5 in cities in Tasmania and Delhi (Figure 1 & Figure 2) to compare and contrast how air pollution can vary globally. The cost of air pollution in different countries is shown in Figure 3, representing the cost in percentage of each countries GDP. The impact of specific policies aimed to reduce air pollution are shown in Figure 4 and Figure 5. Figure 4 shows the changes in $PM_{2.5}$ emissions in Delhi before and after the implementation of the odd-even scheme, which limited the number of cars present on roads each day. Figure 5 shows the changes in PM_{10} in Launceston after the implementation of the Wood Heater Replacement Program.

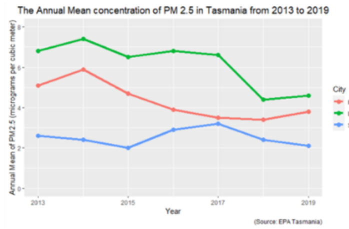

Figure 1. Annual Mean PM2.5 in Tasmania from 2013 to 2019

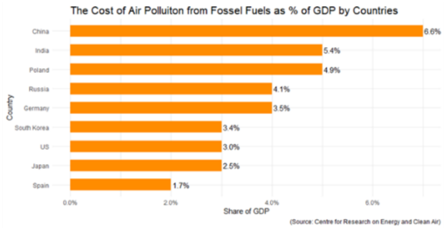

Figure 3. The cost from fossil fuels shares of GDP in different countries

Figure 5. Annual mean PM10 in Launceston from 1997 to 2003

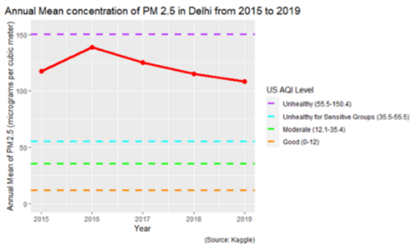

Figure 2. Annual Mean PM2.5 in Delhi from 2015 to 2019

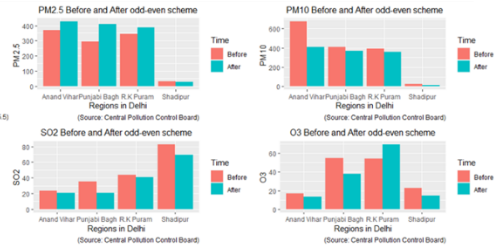

Figure 4. Pollutants before and after odd-even scheme

Main findings from the report and visualisations are summaries below:

- Air pollution can be created locally, and it also can be spread from other regions due to the weather patterns, such as Delhi in summer.
- The main sources of air pollution in Tasmania are domestic wood heating, planned burning and wildfires, whilst in Delhi it is road dust, vehicle exhaust and industrial emission. This shows that there is no one fix for air pollution as the sources are varied regionally.
- Air pollution has an ever-increasing negative impact on human life around the globe, and the regions with good air quality are no exception. The number of people who have died as a result of lung cancer caused by air pollution has increased in the last decade.
- The emission of pollutants not only causes a negative impact on public health, but it also has detrimental economic consequences, resulting in a decrease in labour productivity and an increase in health care costs and absence from work due to air pollution related illness.
- Fortunately, government policies play an important role in the improvement of air pollution. Education programs for example, help the public clearly understand the problem, increase awareness of air pollution, and change the public's attitude and behaviour on environmental protection.

These results are valuable to ACET global as providing useful resources about air pollution to the public helps readers appreciate the harmful effects of air pollution and brings attention to the actions people can take to tackle the problem of air pollution. It is vital visitors understand the importance for governments to alter their policies, it is hoped visitors will feel empowered to ensure their governments are aware of the many ways to improve air quality, including investing in renewable energy, promoting green transportation, and creating technologies that reduce pollutants. The information and research conducted throughout the report and visualisations will provide valuable scope and new information that is currently not available from ACET global.

Yung-Chen's Results:

Figure 1 shows the countries with the worst ambient air quality in the world. In Egypt, about 120 deaths per 1000 people were because of ambient air pollution in 2017, which is about 12% of all deaths in Egypt, and is the highest worldwide. Furthermore, it is shown that the death rate of ambient air pollution tends to be highest across the developing countries, including many countries across Asia such as China, India and Nepal. The main source of air pollution in Egypt is particulate matter, which mostly comes from the transportation industry and burning of waste material. Additionally, as Egypt is surrounded by desert, large amounts of dust are blown into cities, contributing to poor air quality. Unfortunately, the situation is compounded by the lack of rain as increased rainfall decreases the levels of dust present. Consequently, both natural and man-made influences exacerbate ambient air pollution in Egypt, making it the country with the worst ambient air quality.

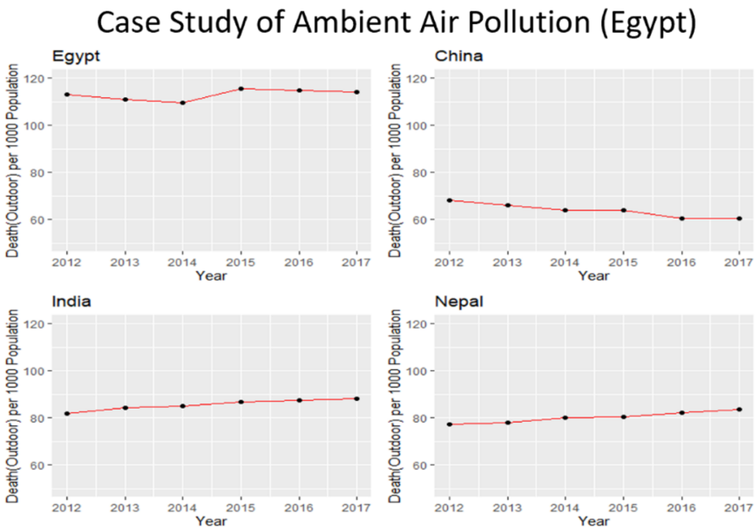

Figure 1. Number of deaths per 1000 people in Egypt, China, India and Nepal

Figure 2 illustrates the countries with the worst household air quality in the world. Household air pollution is caused by burning solid fuels– such as firewood and crop waste. Household air pollution is one of the world's biggest problems especially in undeveloped countries whose people have no access to safe and clean fuels for cooking. In 2017 in Papua New Guinea, about 109 deaths per 1000 people were caused by household air pollution, which accounts for close to 11% of the countries total deaths, it is the worst household air quality around the world. The death rate of household air pollution is relatively high in undeveloped countries such as, the Central African Republic, Solomon Islands and Somalia. This is because the people there are not able to afford clean fuels such as biogas, liquefied petroleum gas, electricity, and natural gas used for cooking and heating. In Papua New Guinea, only 63% of population have access to electricity. Household air pollution produced by rudimentary cookstoves is toxic and the WHO estimates it leads to around four million deaths every year, which exceeds the number of deaths caused by malaria, tuberculosis and AIDS combined.

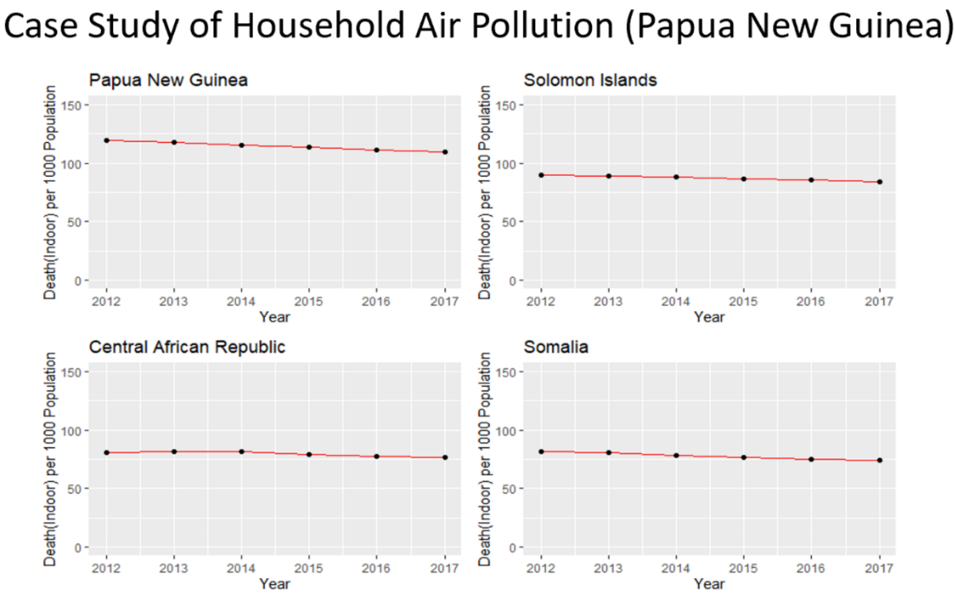

Figure 2. Deaths per 1000 people caused by household air pollution in Papua New Guinea, Solomon Islands, Central African Republic and Somalia.

Figure 3 demonstrates the impact of using clean fuels in Maldives on reducing deaths. As can be seen, the Maldives have a growing number of people who can get access to clean fuels, and this coincides with a reduction in the number of people dying from outdoor air pollution related causes.

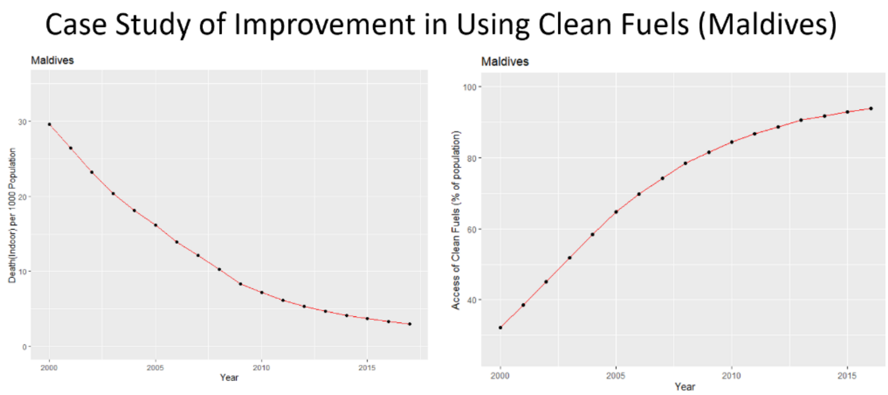

Figure 3. The number of deaths per 1000 people from outdoor air pollution in the Maldives and the percentage of population who have access to clean fuels.

The results above meet the aims of the project as the impacts of indoor and outdoor air pollution related deaths are yet to be covered on the website. These results will allow readers to develop an appreciation of how serious air pollution can be in certain regions of the world, by highlighting the number of deaths caused by air pollution, visitors will be able to understand the severity, especially visitors from regions such as Australia where air pollution is not often associated with deaths. The results also show that change can have a drastic impact on benefiting people's lives, this is important to instil in readers, as ACET global does not wish to report purely foreboding results, but rather illustrate some of the positives around the globe that demonstrate that air pollution can be combatted.

Conclusion

Over the course of the project, the team researched a wide variety of topics that will compliment not only each other's work, but also the existing work present on ACET global's website. The topics covered will meet the aim of enhancing and deepening visitors to the website's knowledge of air pollution, how policy can impact air quality, locations around the globe who have good and poor air quality and highlighting different strategies that can improve air quality. The complimentary visualisations produced will enhance the user experience of ACET's website as they will be able to quickly identify important messages and pieces of information relating to air pollution. Although the work conducted by the group is an excellent foundation for ACET global, future research they may wish to conduct could include investigating the impact of COVID-19 on global air quality, research into the latest technologies being used to combat air pollution and an in-depth analysis of Australia's policies and strategies related to air pollution. These topics would continue to build upon the work done by the group and allow the suit of information at ACET global's disposal to continue to grow to further educate the wider community.

Appendix

Roles and Responsibilities

Luke Howard – s3846238:

- Researched the following topics for report and presentation for ACET global:
  - What constitutes air pollution? Provided a thorough background understanding of the different types of air pollution, their sources, and the health impacts they can have.
  - The historical emissions of pollutants by different continents.
  - Gathered information on the Paris Climate Agreement to provide a basic understanding of its aims and how it relates to improving air quality.
- Produced data visualisations for:
  - Historical continental pollutant emissions. Gathered data for emissions of carbon dioxide, methane, $PM_{2.5}$ and nitrogen dioxide. Tidied this data and aggregated it from country to continent level emissions. Finally plotted per capita emissions for each pollutant and continent.
  - Air quality of G20 countries for years after signing the Paris Climate Agreement. Gathered data from the World Air Quality Index Project for several cities from each country of interest. Combined these datasets to countries average monthly emissions for each pollutant. Separated country data sets so that each pollutant had its own data set. Finally, produced data visualisations of the changes of air quality through time for each country, presented by continent
- Produced written report for ACET global as instructed, to be used in broadening the information of the Global Air Quality Project
- Presented findings of report to ACET global in presentation
- Produced recorded presentation of findings to compliment report, to serve as reference for future ACET global work.
- Compiled reports and presentations for RMIT assignments

Chih-Ying Ho - s3816723:

- Researched the following topics for report and presentation for ACET global:
  - Case studies regarding cities with good and poor air quality
  - Investigated specific strategies implemented by certain cities to improve air quality
  - Investigated the economic impact of air pollution
- Produced visualisation related to report topics
- Produced written report for ACET global as instructed, to be used in broadening the information of the Global Air Quality Project
- Presented findings of report to ACET global in presentation
- Produced recorded presentation of findings to compliment report, to serve as reference for future ACET global work.

Yung-Chen Niu - s3817129:

- Researched the following topics for report and presentation for ACET global:
  - Identified countries with the worst indoor and outdoor ambient air pollution, measured by number of deaths
  - Conducted a case study on the impact of access to clean fuels on reducing air pollution related deaths in the Maldives
- Produced visualisation related to report topics

- Produced written report for ACET global as instructed, to be used in broadening the information of the Global Air Quality Project
- Presented findings of report to ACET global in presentation
- Produced recorded presentation of findings to compliment report, to serve as reference for future ACET global work.

<u>How we worked</u>

Due to the constraints of covid-19 and various Victorian lockdowns, the team was unfortunately not able to meet face-to-face at any time. To compensate for the inability to work directly with one another several strategies were put in place to ensure collaboration amongst the group. The first of these was to use Freedcamp as a project management system. This allowed for direct communication between team members through the use of discussion forums. We were also able to communicate with our project leader on this format. Further to this, our project leader could assign tasks to be completed which made ensuring the project was completed in a timely manner very easy, along with the submission of weekly task logs to ensure that tasks were completed on time. To compliment the discussions occurring on Freedcamp, the team also met on Zoom three times a week. Team meetings occurred on Mondays, Wednesdays and Fridays, with each meeting serving a different purpose. The Monday meetings would be a chance for all interns to meet across the different streams and discuss any issues they may be having, as well as an opportunity for our project leader to update us on the tasks for the week and keep touch on how everyone was progressing. The Wednesday meeting served the purpose of the team members presenting their findings, data visualisations and reports as they were completed. This provided the opportunity for feedback from our project member and other group members, this was the best opportunity for collaboration on each other's work throughout the week. Finally, the Friday meeting was a final opportunity to touch base with our project leader about any issues and queries we had; these meetings were often quite brief. As each member was tasked with creating their own report and presentation for this project, we often worked individually for extended periods of time, but would use the tools provided to us to ask questions and provide feedback about our own research, where to find suitable data and how to improve our visualisations. Although we did not get the opportunity to work with one another face-to-face, the tools given to us still fostered collaboration and teamwork in what were largely individual projects.

<u>Self-reflection (Individualised)</u>

<u>Luke's Reflection</u>

Through the process of researching, writing reports and presentations as well as developing data visualisations, I encountered difficulties and learned new skills that allowed me to produced work that I am extremely proud of. There are several things that I learned throughout the work integrated learning project that I did not know prior to beginning it, some of it related to data science techniques and others related to how to work on a project in a collaborative and business environment. With regards to new techniques learned, most of these related to how to best prepare data for visualisation and how to produce effective and simple visualisations that conveyed the messages I wanted to deliver. The first problem I faced was how to best account for missing data in the G20 country air quality data. These values arose from failed readings from the monitoring stations used by the Air Quality Index Project. Initially I tried to visualise this data by removing missing values, however this resulted in unsatisfactory visualisations that did not accurately show the changes in air pollution through time. After some research and consideration, I decided to use a forward filling approach to replace missing values, this allowed for all data to be used and create a more accurate picture of how air pollution changed for the G20 countries. The visualisations created with this data were far more satisfactory. More lessons learned occurred when producing the data visualisations for the report. Initial attempts at visualisations included trying to plot all

G20 countries on one plot as was done with the continent's graphs. This did not produce the desired result, as it was impossible to discern countries from each other. This forced me to reconsider how to best present the information. I decided that individual graphs presenting countries from the same continents would be appropriate. This allowed for comparison of countries within the same geographical range as well as compare differences between different continents. After researching different use cases of R's ggplot library, I found that multiple plots could be presented together using "ggarrange", this allowed for further labelling and organisation of plots than the standard ggplot library. Doing this allowed me to separate out the countries into a concise and easy to understand visualisation. Another challenge faced was developing an appropriate palette to use for the visualisations. As the standard palettes available are not particularly appealing I spent a lot of time researching suitable palettes that would be both visually appealing yet take into consideration certain visual impairments such as colour blindness. Many iterations of data visualisations were produced to ensure that an appropriate palette was used. Although the static plots produced were suitable for the report and presentation, if I were re-do this project, I would of also developed some interactive plots (produced with Plotly or another such library) that could be used solely on the website. This would increase user interactivity and allow for users to focus in on information such as certain countries or time frames of interest to them, this would also aid in solving the problem of having too many countries presented in single visualisations.

Outside of the lessons learned while developing visualisations, I also learned how to collaborate efficiently and effectively in a virtual environment in a professional setting. As this was my first involvement in a project conducted by a business and not simply a university assignment, I had to learn what was expected of me in terms of behaviour and work-load. The first weeks were helpful in me developing the understanding of what was required of me, having discussions with my project leader about expectations really helped me learn what they were wanting from me and what they hoped to achieve for the project. I learned that ensuring there is a clear definition of goals and expectations is vital to ensuring I am completing the expected work and that the business is not expecting too much of me. Having this understanding made for a very comfortable experience and I believe resulted in informative work. If given the opportunity to work on a project like this in the future, I would strongly recommend that the team work on a single report. Although I understand why we were asked to largely work individually in order to create the maximum amount of content possible, I believe that a single report would have allowed for more time to create even better visualisations, as I would not have needed large portions of my time conducting literature reviews for all sections of the report. If a single report were to have been produced, each member could have focused on one section, resulting in more time for data collection and visualisation refinement, which would have resulted in less content but of a higher quality.

I found this opportunity to work with ACET global very insightful and an excellent opportunity to put my skills into use in a professional environment. I have gained a better understanding of what is expected and required to complete a project and learned many useful lessons that I will carry forward into my career from this point.

Chih-Ying's Reflection:

This project helped me improve my critical thinking and learn about my strengths and weaknesses. I also learned how to write an organized report, how to complete tasks in a timely manner, how to communicate with others. I'm good at visualizing data, but I'm not good at effectively communicating and clearly understanding the question while writing the reports. At the beginning of the internship, I tried to work on the effect of air pollution on mental health, but it was difficult to collect the data that shows the direct connection between the air pollution and mental health. So, I change my topic to the regions with good and poor air quality.

Yung Chen’s Reflection:

It is a great experience having an internship at ACET Global. The internship helped me to develop my time management skill and ability to analyse questions. Additionally, I gained insight about the challenges of reducing the air pollution during this project, and it reminded me that the issue of air pollution should not be underrated.

I was originally trying to analyse the main causes for air pollution as my main topic. Therefore, I initially chose Europe as my target as they are one of the leading polluters and I looked into leading causes of air pollution deaths, which appeared to be the transport industry. However, I found it difficult to collect the datasets I needed to conduct a proper investigation and analysis. In week 4 of my internship, I decided to narrow down my range and focus on ambient and household air pollution. This helped me to collect the datasets that I needed, as data pertaining to this topic was more readily available. I was able to visualize the number of deaths in terms of ambient and household air pollution and investigate the triggers for each.

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