

Measures Taken to Reduce the Dominant Air Pollutant

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Abstract. In recent years, with the growing concentration of air pollutants, as for how to improve the air quality, draws the attention from all over the world. In general, there are two sources of air pollutants, one is natural disasters, the other is improper human activities. The air pollution caused by human activities, has emerged as a huge challenge on various aspects, including climate change, health impact to human body, living conditions for flora and fauna, ecosystems damage and the economy loss. In comparison, the solutions to reduce the density of pollutants and improve the air quality are divided into separate aspects which are intersected with different social and environmental situations. The aim of setting and publishing of the laws and legislations is to regulate the daily human behaviors which are possible to cause the air pollution. The analysis for the consistence of the major air pollutants will be beneficial to figure out the direction of how to improve the air quality and how hazard of each air pollutant would be. For instance, PM_{2.5} will primarily cause the decrease of the clearance in the air, further cause the increasing of human diseases such as respiratory and cardiovascular diseases. The utilization of advanced technology would not only improve the efficiency of reducing the air pollutions, but also make the future disasters more foreseeable so that it is now possible to prevent and block them. All these listings are aiming to find the future trend of air quality and improve the measures we are taking currently.

Keywords: Air pollutant, hazardous, source, measurement, technological ways.

1. Introduction

Recently, with the rapid development of industrial production and technology, various kinds of air pollutants density have been increasing sharply. According to the statistic collected from Environmental Protection Agency (EPA), the global carbon dioxide (CO₂) emission in 2023 has been increased 90% comparing to 1970. Among these new increases in carbon emissions, electricity and heat production, industry and technological cultivation are occupied for 25%, 21% and 24%. Also, CO₂ emission from transportation is accounted for 15% of the total amount (Fig. 1) [1].

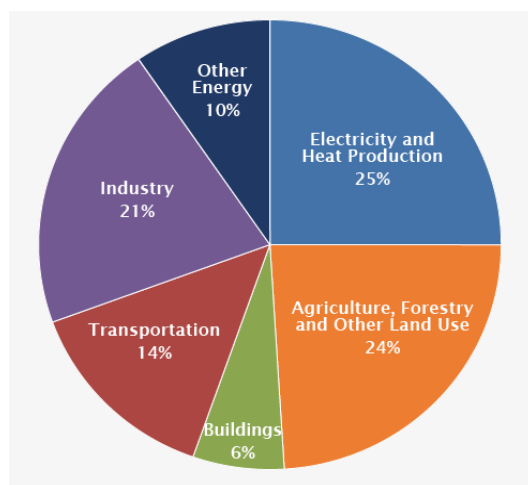


Figure 1. Global CO₂ Emissions by Economic Sector. https://www.epa.gov/sites/default/files/2016-05/global_emissions_sector_2015.png

Moreover, other than CO₂, nitrogen oxides (NO_x), carbon monoxide (CO), sulfur dioxide (SO₂), Particulate Matters (PM_{2.5} and PM₁₀), Ozone (O₃) and Lead (Pb) are the current dominant air

pollutants. Regarding on the criteria from EPA, all these six substances are identified as dominant air pollutants.

CO is a colorless and odorless gaseous pollutant which can be generated from the incomplete combustion of the fuels which contain carbon element. Factors such as insufficient supplement of fuel or oxygen (O₂) and low combustion temperature or time will increase the possibility of incomplete combustion. Traditional fossil fuels such as coal, natural gas and gasoline and other energy sources such as biogas and firewood are all carbon-containing. The increasing amount of NO_x in the air not only has significant impact to the environment, but more hazardous to air quality because of it could synthesize substances that would cause light pollution. As for PM_{2.5} and PM₁₀, they could penetrate human skin easily and reduce the visibility of the nearby atmosphere. SO₂ concentration can make the air becoming stinky. More importantly, it would cause synthesize sulfur-containing acid. Ground level O₃ can be formed through various sources such as complex photochemical reactions involving precursor pollutants, primarily NO_x and volatile organic compounds (VOCs), in the presence of sunlight. has a role of both primary and secondary pollution. The excessive amount of Pb could remain toxic in nature, air and human body and such toxicity will cause an ineliminable impact.

Overall, all the dominant air pollutants will either have a huge variety of sources or have the potential to lead to a severe negative impact not only to the air quality, but to the environment and society. This paper briefly introduces the major source of each dominant air pollutant, its negative effect, measures taken to control and reduce the concentration, benefit which good air quality could bring and analysis the future trend of air quality.

2. Major Sources of Air Pollutants

For all the dominant air pollutants, their primary sources will be multi-aspects, complex, hidden and even possible to differ them into plenty of stages. Thus, pending the development of a governance program, specifying the major sources would be not only helpful to reduce the complexity to the further research, but also allows for the development of precise treatment programs for pollutant sources. Overall, without the emission released by the natural surroundings, the major human activities which are potential to generate variety of air pollutants are industrial production, transportation, electricity generation and human caused forest fires.

2.1. Industrial Production

2.1.1. Fuels combustion

While the factories running their machines, the burning of the fuel such as the coal, oil and natural gas is inevitable, which is inevitable. The combustion products would not only contain the listed six dominant pollutants, but also contains Volatile Organic Compounds (VOCs), which is a hazardous chemical which will form the ground-level ozone in the air.

2.1.2. Dust and particulate emissions

For instance, during the process of mining and the construction of architecture, when handling the material, it would bring out the air pollutants especially particular matters (PM_{2.5} and PM₁₀), which would bring one of the greatest health impacts. Besides the health impact by human intaking them, the pollution which is from dust and particular in the air would also affect by dust cycle and interact with climate according to the research carried out by World Meteorological Organization (WMO). Combined with gravity, the existing aerosol, and the existed turbulence, once the dust or the particulate escapes from the surface, they will be transported and dried by the turbulence and part of them would finally drop into the ground-level atmosphere by its gravity. Thus, they would be wide-spreading and reduce the clearance of the air. As in the last paragraph mentioned, part of the dust and particulate will finally drop into the ground-level, there is another part will stay with the aerosol which will further form the clouds. Further, it will cause the increasing possibility of the ice crystal droplets from the clouds, which would be harmful to the animal habitat.

2.2. Transportation

If there is demand of travelling, delivery service and cargo service, there will be various pollutants such as CO, NO_x, PM and VOCs into the atmosphere. The certain sources including tailpipe emissions and the generation of secondary pollutant. Between both major pollutant source related to transportation, the tailpipe emission is the dominant because it would lead tremendous further polluting sources such as vehicular idling and traffic congestion.

2.3. Electricity Generation

As one of the biggest demands in the human society, huge number of pollutants such as O₃ and carbon oxide, which would be intake by the nearby atmosphere. Even though a variety of clean or renewable electricity production methods are utilized including biomass, hydro/wind power, geothermal and nuclear power. Due to the restriction that caused by geography factor and hidden secondary emission. For instance, during the construction of hydropower plant, the submerged flora would have the potential to generate methane (CH₄), which is one of the greenhouse gases (GHGs) much more powerful than CO₂ for leading the greenhouse effect.

2.4. Forest Fire

Recently, there was forest fire happening nearby New York City (NYC), the visibility of the atmosphere reduced rapidly in a short period so that certain research and detections of the air quality were carried out by several institutions such as EPA government. From the Fig. 2, the increasing numbers of forest fire would cause dramatically increase of PM2.5 density.

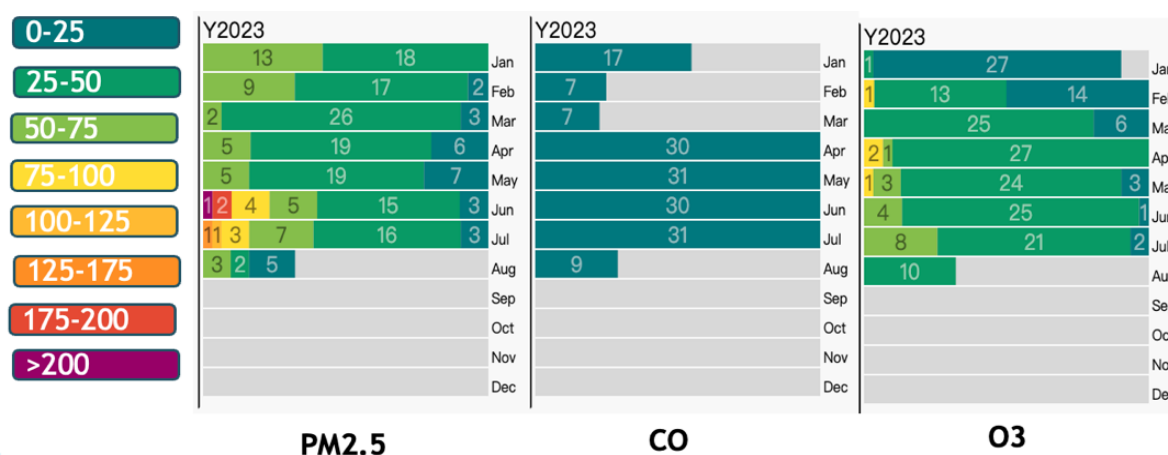


Figure 2. Air Quality index (AQI) each month in 2023, NYC.
<https://aqicn.org/city/usa/newyork/ps-274>

3. Negative Impact Air Pollutants

The major sources of the pollutants are figured out in the previous section. Therefore, the next step is to analysis the impact of air pollutants such as what could each air pollutant bring negative impact on human body, how does it affect the climate and in which way it would be harmful to human society. In this section, the article will mainly show the impact on human health and life, economy, environment such as flora and fauna.

3.1. Impact of NO_x

Table 1 shows all forms of NO_x. However, the most common two of the nitrogen oxides are nitric oxide (NO) and NO₂. Regarding on their impact on human health, the major effects are respiratory problems and lung function reduction. When human breathe in NO_x, the respiratory system would regard it as a foreign scent, then it would cause symptoms such as shortness of breath, sneezing and tight feeling in the chest. Further it would lead respiratory diseases such as asthma and bronchitis.

Table 1. Nitrogen Oxides

Formula	Name	Nitrogen Valence	Properties
N ₂ O	nitrous oxide	1	colourless gas water soluble
NO N ₂ O ₂	nitric oxide dinitrogen dioxide	2	colourless gas slightly water soluble
N ₂ O ₃	dinitrogen trioxide	3	black solid water soluble, decomposes in water
NO ₂ , N ₂ O ₄	nitrogen dioxide dinitrogen tetroxide	4	red-brown gas very water soluble, decomposes in water
N ₂ O ₅	dinitrogen pentoxide	5	white solid very water soluble, decomposes in water

More importantly, the ground air level NO_x would straight lead to light pollution, and it has the potential to react with flowing VOCs and generate ground level O₃ under the sunlight (equation (1)). Worse still, NO_x is also a major air pollutant that causes the acid rain (equations (2)-(4)). The ammonium nitrate (HNO₃) and the nitrous acid (HNO₂) would not only lead to acid smog, but damage to vegetation and architecture.



3.2. Impact of CO₂

CO₂ is the most familiar GHG in people's mind, plays a crucial role in the atmosphere. However, the excessive amount of CO₂ would lead to severe greenhouse effect. It specifically manifests as temperature rising at the first stage, further cause ice melting especially in North/South pole and the top of the snow mountains. Meanwhile, it could also cause extreme weather such as hurricanes and heavy rain falls.

Moreover, ocean acidification has a tight relationship with the increasing amount of CO₂. At primary, the direct solvency of CO₂ would form chloride in the seawater. However, the more severe impact is the interruption of the marine food chains and the coral bleaching. While the living condition of the marine and coral has been deteriorated, fewer marine plant exist underwater then less CO₂ could be absorbed by the photosynthesis process. With more CO₂ resolved in the ocean, the positive feedback loop would form which would result in the acceleration of acidification.

3.3. Impact of SO₂

Similar with NO_x, SO₂ also has the potential to form the oxalate (H₂SO₄), which is one of the bases of acid rain by reaction with water after being oxidized, as shown in equations (5)-(6). H₂SO₄ is a highly corrosive chemical, which would not only corrode architectures, but harmful to human health such as skin and eye irritation and cardiovascular diseases.



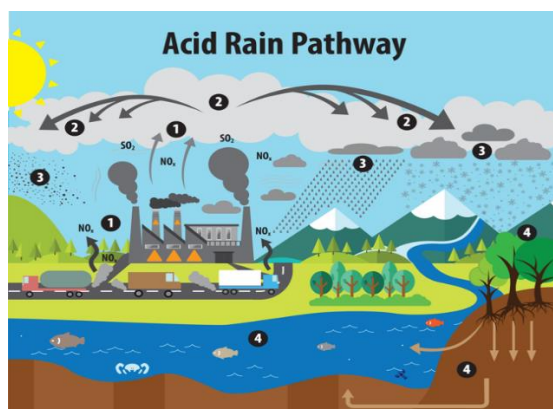


Figure 2. The acid rain formation and pathway. <https://www.epa.gov/sites/default/files/2020-05/acidrainpathway.png>

3.4. Impact of PM_{2.5/10}

PM_{2.5/10} refers to particulate matter which has a diameter smaller than 2.5/10 micrometers. The increasing density of the PM_{2.5/10} would not only lead to health effect through interrupting human respiratory function, but reduce the air visibility, carry more toxic contamination such as heavy metal to water and soil, damage to the climate by affecting the clouds formation and reduce the ecosystem capacity by reducing the area of habitats of sensitive vegetation and animals.

3.5. Impact of Ozone (O₃)

Ozone is known as the perfect shield for human by blocking the excessive infrared and ultraviolet radiation. However, it becomes a major pollutant in the ground level atmosphere because it would be hazardous to both human health and atmosphere. Moreover, ozone is one of the rarely seen secondary pollutants because it has been majorly synthesized by the existing VOCs and NO_x in the air. Fig. 3 shows the formation of ground-air level ozone. The excessive amount of ozone would irritate human eyes, nose and throat. Further it will lead to diseases such as asthma, bronchitis and cardiovascular. Meanwhile, if human is exposed to surroundings which contain high-level ozone density, the risk of getting lung disease would increase dramatically.

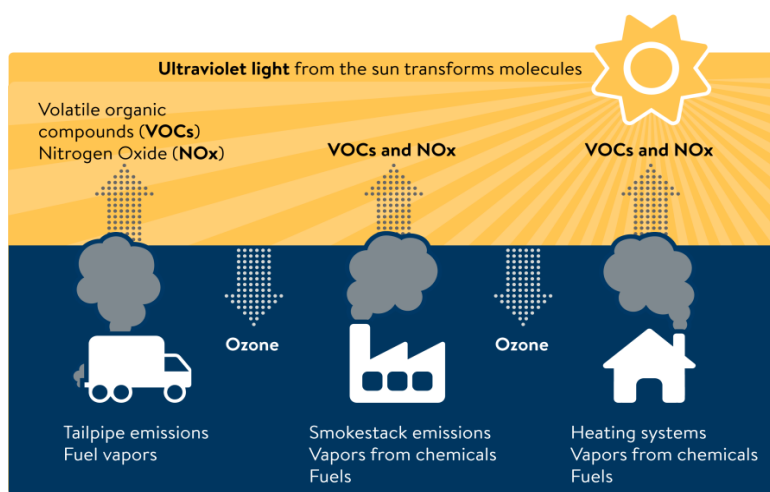


Figure 3. Major formation of ozone. <https://www.pca.state.mn.us/pollutants-and-contaminants/ozone>

Overall, all the air pollutants have some common hazard to the environment and human health, for instance they would all cause diseases related to lungs and respiratory systems or reduce their function. Each air pollutant will also have their own specific impacts. Therefore, these commonalities should be taken into account when formulating an approach to air quality management, but they should also be tailored to their individual characteristics.

4. Efforts to Control and Reduce Air Pollutants

Nowadays, there are increasing number of citizens appealing for an effective effort to stop polluting the air and improve the air quality. By applying the certain laws and regulations for all the air pollutants would not only help refresh the air but regulates the human beings and reduce the human activities which pollutes the air, which are beneficial for maintaining the social sustainability. However, with more industries are generating the pollutants and larger scale of production, there is an increasing demand of the technological methods to both prevent pollutants into the environment and reduce the air pollutants in a much more effective way.

4.1. Regulations Related to Air Pollutants

Regulations are for monitoring the data of air condition, managing and ruling human behaviors and activities and protecting public health.

4.1.1. Grand regulation

As for the model of the regulations, Clean Air Act (CAA) enacted in 1990 by EPA agency not only includes the criteria for all the air pollutants, but set regulations and restrictions for human behaviors, transportation and industrial production [3]. Table 2 shows all the criteria for the major air pollutants. According to the Table 2, CAA provides two different standards, primary and secondary standard [4]. Primary standards provide protection for public health, which including the health condition of “sensitive” population such as children and elderly and secondary standards public welfare such as protections against damage to flora and fauna habitats.

Table 2. CAA Criteria for Each Air Pollutant (2023) [2].

Pollutant	Primary/Secondary	Averaging Time	Level	Form
Carbon Monoxide (CO)	primary	8 hours	9 ppm	Not to be exceeded more than once per year
Tubular or column-type	120	1 hour	35 ppm	[11]
Lead (Pb)	primary and secondary	Rolling 3-month average	0.15 µg/m ³	Not to be exceeded
Nitrogen Dioxide (NO ₂)	primary	1 hour	100 ppb	98th percentile of 1-hour daily maximum concentrations, averaged over 3 years
Multi-anode (vertically arranged)	primary and secondary	1 year	53 ppb	Annual Mean

4.1.2. Regulations related to human behaviors

Other than the grand regulation such as CAA which provide specified criteria and standards for each dominant air pollutant, the human society also requires regulations for the daily human activities. As an example, regulations related to prevent forest fires are widely followed because forest fires would lead to the dramatical addition of PM2.5 in the atmosphere and visibility reduction. Human behaviors and activities which could cause forest fire are unattended campfires, improper discarded cigarette ends, operation of vehicles and burning vegetation. For preventing the forest fires, the Stage I and II of Fire Restrictions have been carried out by Forest Service (FS).

Under the Stage I fire restrictions, campfires are restricted for personally owned charcoal grills, fire pans and wood fuels, only the fire structures provided by owner are allowed. Meanwhile, under the Stage II fire restrictions, all forms of campfires are forbidden. If one of both restrictions has been violated, a penalty of \$5000 for individuals and \$10000 for corporations will be at least generated. In addition, a 6-month imprisonment would also be carried out and this could be up to 12 months.

Additionally, there are more regulations for controlling vehicle and industry emission, waste management and fuel quality. However, the government and certain institutions are supposed to enlarge the power declaration to draw more attention, and this will be helpful to form the basic consciousness of reducing air pollutants for all the citizens.

4.2. Technological Methods

To improve the efficiency of improving the air quality and manage the pollution from large scale of industrial production. Utilization of modern technology would be the best option to achieve this goal. Moreover, it is also possible to spread the information on time, forecast what kind of effect could air pollutants bring to human and society and effectively prevent the coming disasters.

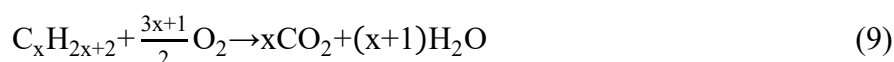
4.2.1. Utilization of catalytic converters

Catalytic converter, a device which could extract harmful gases in the byproduct of industrial production then burn them up, further turn the harmful gases into harmless gases. It is widely established on vehicles and devices in the factory. Table 3 is the characteristics of a Well-Designed Catalytic Converter [5].

Table 3. Characteristics of a Well-Designed Catalytic Converter. DPM is Diesel particulate matter, HC is Hydrocarbon.

Pollutants	Proportion of reduction
CO	Reduced by 80%– 95%
HC	Reduced by 85%–90%
DPM	Reduced by 25%–35%
Odor control	Very good
Influence on engine	Low-pressure drop; no fuel penalty

In conclusion, a well-designed catalytic converter would be able to eliminate majority air pollutants which are generated from inadequate fuel combustion through the oxidation, especially reduce the amount of CO, NO and hydrocarbon compounds (HC compounds) into CO₂, NO₂, CO₂ and water [6]. Although the oxidation of CO and HC compounds still generate CO₂, it turns the toxic gas such as CO and NO_x into non-toxic N₂ and CO₂ and turn HC to CO₂, HC is a much more powerful greenhouse gas than CO₂.



4.2.2. Utilization of viscoelastic fluid

Viscoelastic fluid is a combination of Ammonium polyphosphate (APP) and plant-based cellulose or colloidal silica particle [7]. APP is not only an elastic material but can be added into the surface of the woods and separate trees from oxygen and sparks, this could effectively prevent trees and even forests from burning and when it is burnt, the combustion product would only contain water vapor and fire-extinguishing residue. Therefore, APP has the potential to be the most effective material to prevent unexpected forest fires and further prevent excessive PM_{2.5} entering the atmosphere. However, the drawback of APP is that it lacks viscosity so that it could only stick to the tree surface for several days. Thus, people added up cellulose or colloidal silica particle to increase the viscosity so that the combination product, which is so called viscoelastic fluid could stick to the surface for seasons long. To sum up, the combination of the modern technology or its product would provide various benefits, including simplifying the process of improving air quality, more easily to apply to reality and spread the information to everywhere [8]. Most significantly, it provides possibility to turn the pollutants into usage effectively. Fig. 4 is how viscoelastic fluid prevent forest fires.

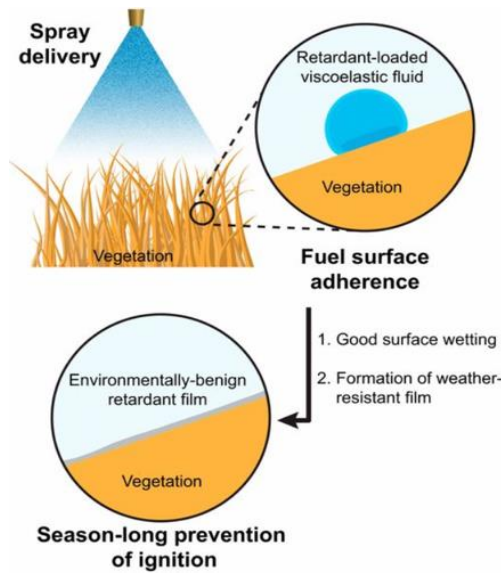


Figure 4. How viscoelastic fluid prevent forest fires.

<https://www.semanticscholar.org/paper/Wildfire-prevention-through-prophylactic-treatment-Yu-Hernandez/83950de665d9fb8034f68f469708844d6363cadf>

4.3. Utilization of clean energy

Technology would not only improve the method for controlling and preventing more pollutants enter the atmosphere but stimulating the energy utilization from traditional and contaminating fossil fuels to a series of clean and renewable energy sources. Thus, the meaning for taking research on clean energy is that while ensuring that the needs of productive human life are met, less polluted emissions are released. Fig. 5 displays the increasing trend of utilization of clean energy for generating electricity. With cleaner energy sources and more advanced technology, the production chains will become less harmful and more efficient. By replacing clean and renewable energy, air pollution will be significantly reduced and further the goal of establishing a robust and sustainable environment will be achieved.

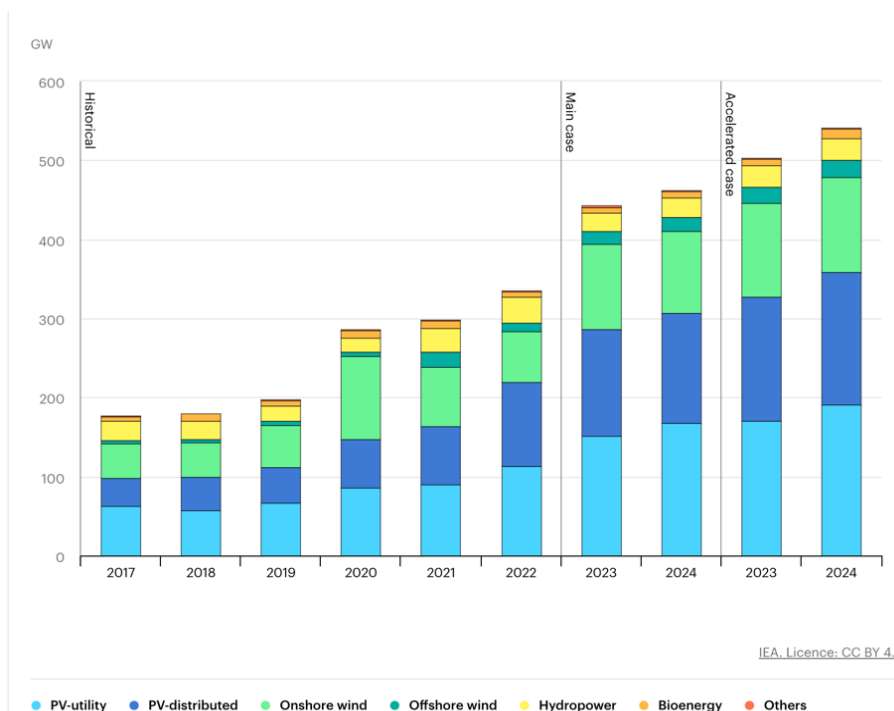


Figure 5. Data of net renewable electricity capacity from 2017-2024, global.

<https://www.iea.org/energy-system/renewables>

5. Future Trend of Air Quality and Positive Effect

With the raising awareness of air quality, the related regulation such as CAA has been put into use and people have made a great progress for achieving the standards set by CAA [9]. Better still, people have made sufficient research on analyzing the constitution of air pollutants and successfully figured out six of them which would cause the worst effect and more importantly, technology has been gradually utilized to accelerate the process of all the actions which are beneficial for the air we breathe. Here is the result of the declining air pollutant concentration after applying CAA since the year 1970. With the air becoming cleaner, less cost will be paid for the environmental and human health problems that are caused by the air pollutants, and it will further lead to the growing of Gross Domestic Product (GDP) by increasing productivity, drawing more tourism businesses, and reducing environmental cost [10]. With the GDP growing in a rapid pace, there are increasing number of vehicles and population simultaneously. It represents that the improvement of the air quality can reduce the premature death and involve greater energy efficiency [11]. In addition, there are more benefit which good air quality could bring such as climate mitigation and life quality enhancement.

6. Conclusion

CAA is a regulation related to various aspects, which are aiming to protect and improve the atmosphere regarding on the entire nation. It not only contains the categorization of every pollutant by the chemical structure, formation, the way to pollute the air and impact. It could be helpful for understand the emission sources in order to further formulate the policies. In general, emissions of air pollution come from stationary fuel combustion source, industrial processes, vehicles on the highway and non-road mobilities. As for the utilization of modern technology, the catalytic converters can reduce the insufficient combustion products and the new fireproof material, viscoelastic fluid could protect the inflammable nature being burnt and more importantly, block more PM_{2.5} enter the atmosphere. Thus, it is beneficial to utilize technology to provide more advanced methods for reduce the air pollution because it will not only make all the process become more effective but provide all the possibilities for various new methods. The transfer of energy consumption from fossil fuel to clean and renewable energy would be the key point of improving the air quality because less harmful pollutants will be produced. With the combination of technology, regulations and the usage of renewable energy, the future economy will grow because there will be reduction for the extra cost and more advanced methods to clean up the air and protect the environment will be explored.

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