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To Transition to a Green Economy: Understanding World CO_2 Greenhouse Gas Solutions to Climate Change

Neil Tamhankar[1] and Smile Dube[#]

[1]Laurel Springs School, Ojai, CA, USA
[#]Advisor

ABSTRACT

The importance of shifting to a green economy is clearly established within the UN Social Development Goal (SDG) 13. SDG 13 focuses on combating climate change and its impacts; the UN reports that over 197 parties have signed the UN document. However, the green economy definition is so broad that it encompasses all 17 SDGs. A feasible approach in this paper is to limit our discussion to CO_2, which accounts for almost 75% of greenhouse gases. Methane, nitrous oxide (NO_x), and fluorinated gases account for 14%, 8%, and 1% respectively. Thus, we use world data from the World Development Indicators to examine the main sources of CO_2 from 1960 to 2014. We find the persistence of CO_2 over the years, which indicates that most countries have failed to limit the output of CO_2 and other greenhouse gases. The conclusions drawn are stronger within an econometric model relating CO_2 to GDP by employing an Environmental Kuznets (EKC) model for each region of the world. NO_x emissions are also discussed later in the paper as another application of the EKC model.

Introduction

A green economy is an economy that operates in a sustainable manner, emits less pollution, and minimizes waste. How can greening the economy slow down climate change? What are the most important parts? How much money and resources would it cost? Climate change is an existential threat and greening the economy can stop it. Greening the economy is critical to stopping climate change as it removes factors that are changing our climate. For example, an ideal green economy has little to no pollution. Pollution, of course, is a major contributing factor to global warming and our changing climate. Greening the economy also reduces overconsumption, another prime cause of climate change.

Given the diversity of the world and specific features found in each country, particularly their economic development, it is impossible to devise or suggest a single model of a green economy. However, it is possible to suggest measures that emphasize sustainable development which might help an economy transition to a green economy. The shift to a green economy should achieve a balance between natural resource consumption and environmental protection while retaining social equity and the well-being of society. In addition to green policies at the macro level, the emphasis of SDG 13 on climate change is one of the most important goals as it is related to the other 16 SDGs. The focus on CO_2 emissions in this paper is driven by three features. First, the source of CO_2 is the burning of fossil fuels like coal, gas, and oil plus an increasing amount of deforestation. In these activities is the human involvement in the rise of CO_2 emissions. Second, CO_2 emissions are easier to measure at country, regional and global level. The global data from World Development Indicators on CO_2 is used here to show the growth of CO_2 emissions

since 1960.[1] Finally, it is difficult to estimate long-term emissions for methane, nitrous oxide, and fluorinated greenhouses gases. The data on these gases is available since the 1990s. Thus, most studies on climate change or the greening of an economy tend to use CO_2 emissions data. This paper is no exception to this trend (see Figures 1 to 4 below).

Greening the economy will significantly slow down climate change. With a decreased, more sustainable human impact on the environment, the climate is less likely to drastically change. The most important parts of a green economy are related to fossil fuels. If the massive subsidies to the fossil fuel industry are removed and instead placed on the renewable energy industry, there will be a massive decrease in pollution as energy companies shift more quickly to renewable energy. The most important forms of renewable energy are solar, wind, and nuclear. Baldwin and Lenton (2020) found that the total cost of government subsidies to the fossil fuel industry was estimated to be 6.5% of the global GDP. The subsidies removed from the fossil fuel industry can pay for the shift to a green economy, and further revenue can be raised by imposing taxes on the fossil fuel industry. They found that between 10% to 30% of fossil fuel subsidies would be enough to transition the world to a low-carbon economy in their IISD report.

The UK has already implemented a green subsidy program called the Renewables Obligation (RO) program. The program came into effect in 2002 and placed an obligation on UK electricity suppliers to acquire more of their electricity from renewable sources. Renewables Obligation Certificates (ROCs) are issued to suppliers who meet the quota of renewable energy production. If suppliers do not have enough ROCs by the end of each year, they must pay out of pocket for the certificate deficit as a penalty. This is a great incentive for electricity suppliers to switch to renewable energy. Another example of a green subsidy program is ECO (Energy Company Obligation) in the UK that is focused on energy efficiency and fuel poverty. It places the burden on the suppliers of improving the energy systems in people's homes. The increased efficiency both reduces carbon emissions and costs for households.

Green subsidies aren't the only economic actions governments can take. They can issue tradable pollution permits, which are permits given to polluting firms. The permit gives a limit on the amount of pollution the firm can produce. If the firm goes over the limit, it must buy more permits from either the government or other firms, creating a market with supply and demand for the permits. This method gives the government control over emissions and provides incentive for firms to not go over their limits.

Literature Review

The literature on the green economy is vast and it is found in journals in economics, political science, ecological and environmental studies, and books that reflect these disciplines. The objectives in a green economy can be organized to achieve environmental and sustainability goals. Bassi (2015) emphasized taking a systemic approach that takes physical capital, human capital, social capital, and natural capital into account. He discussed the social ramifications of climate change, like increasing income inequality and unemployment, and how a green economy can prevent such consequences. He suggested methods of shifting to a green economy such as green investment and government regulation. He proposed that industrial sectors (which are the most carbon intensive) need to move to more energy efficient technologies to reduce their impact on the environment.

Bernauer and Betzold (2012) differed from Bassi (2015) as they focused on how civil organizations can contribute to environmental policy. They advocated that governments should outsource the implementation of environmental policies to nongovernmental organizations (NGOs). NGOs may be more effective in implementing policies because they have a presence on the ground and a lot of experience working with communities. However, they offered some criticisms of civil organizations in that they lack legitimacy and accountability.

[1] There is very detailed data by country and region which could be used to tell regional variations in CO_2. Such data could also be used to estimate the contribution of variables to CO_2 emissions.

Tol (2009) claimed that CO_2 emissions are the key cause of climate change while also being a major byproduct of energy and food production. He further suggested that CO_2 emissions are in every facet of life; companies, farms, and households all produce emissions.

Caldeira and Brown (2019) stated that global economic production heavily relies on fossil fuels. He claimed that increases in GDP and economic expansion lead to higher levels of consumption of energy, producing more CO_2 emissions. He proposed investing in infrastructure, increasing economic productivity, and researching clean energy sources as solutions.

Quéré et al (2020) claimed that during the initial quarantine of the COVID-19 pandemic, CO_2 emissions temporarily decreased due to a reduced energy demand. For example, people working from home would no longer have to fill their gas tanks, greatly reducing demand for gas.

Carney (2019) emphasizes ESG (Environmental, Social, and Governance) investing to strengthen companies that protect the environment and weaken companies that hurt the environment. By investing in companies with positive environmental and social effects, companies are incentivized to be more environmentally and socially aware. He also claims that investing in green bonds, which are sold to raise money for protecting the environment, can have a key role in fighting climate change.

Almaraz et al (2018) claimed that NO_x, or nitrogen oxides, are a deadly component of air pollution and are primarily produced from agricultural sources. Agricultural soils are the main source of nitrogen oxides. Making fertilizer more efficient will decrease NO_x emissions from soil. Reductions in NO_x emissions will improve the air quality. Reducing these types of emissions by investing in the agricultural industry is a key part of creating a green economy.

Och (2017) sought to test the Kuznets Curve Hypothesis (KCH) in Mongolia. In other words, she investigated whether Mongolia's nitrous oxide emissions could be characterized by the environmental KCH in a model of economic growth. The KCH is a U-shaped curve relationship between pollutants and per capita income (= GDP/Population). Accordingly, the theory postulates that environmental pressure increases up to a certain level as income per capita grows until it reaches a certain threshold. Thereafter, pollution tends to decrease. She reported that about 40% of NO_x emissions are from human activity (the other 60% are natural in Mongolia since the country has very little agriculture and industries save for the polluting oil fields). The main source of these emissions is agricultural synthetic fertilizers. A reduction of agricultural fertilizers use will help offset NO_x emissions. The paper also focuses on environmental education to teach people about sustainable energy. These solutions are closely related to the promotion of a green economy.

Sinha and Bhatt (2017) also studied the Environmental Kuznets Curve (EKC) in India and concluded that economic growth and negative environmental effects are closely linked. However, once income rises to a certain threshold for India, the model predicted that the economy would start shifting towards cleaner resources that will benefit the environment. Developing and developed countries all rely on electricity to fuel economic growth. Electricity is often produced by coal, creating large amounts of emissions. A core tenet of the green economy is the complete replacement of pollution-emitting energy sources with green energy sources like wind and solar.

Song et al. (2013) stated that pollution reduction should not be achieved at the cost of economic growth. They also used the EKC to describe the tradeoff between economic growth and the environment. One interesting point is that once economic growth reaches a certain level, the environment sees some improvements (according to the EKC model). They gave the example of China as overly reliant on coal as an energy source. They suggested clean energy policies and waste management policies to limit negative effects on the environment.

Diao et al. (2018) postulated that NO_x emissions have widespread negative social and economic effects, as well as health effects because they contribute to air pollution. Increases in GDP and energy consumption (both necessary for economic growth and societal advancement) lead to increases in NO_x emissions. For example, the development of the steel industry and other heavy industries produces large amounts of NO_x. The key challenge is finding a way to continue economic growth while having no adverse effect on the environment (sustainable economic growth).

To further refine these ideas, Ge et al. (2018) studied China's urbanization and concluded that it caused NO_x emissions to soar as it shifted from an agricultural economy to an industrial economy. They suggested that the environment cannot handle negative long-term effects of these emissions, which need to be reduced as soon as possible. The main solution is to quickly invest in controlling pollution and shifting to non-polluting energy sources. Additionally, they said that governments should decelerate the growth of cities (a major contributor to emissions) and encourage residents to use green transportation. These solutions tie in with greening the economy, especially in investing in green energy sources and green infrastructure.

Guo et al. (2016) agreed with Ge et al. (2018) that urbanization, while promoting economic growth and development, also yields environmental pollution that can devastate the natural environment. In China, they suggested that the rapid economic growth has led to large amounts of pollution that has undermined the quality of life of city residents. The stimulation of industrial production directly created air and water pollutants that are detrimental to human health. A green economy requires sustainable industrial production that produces little pollution.

Another study by Zhao et al. (2013) on NO_x pollutants in China agreed that the primary NO_x gases are contributors to air pollution, and they are driven by the fast growth of energy consumption. Economic development and urbanization in China have increased NO_x emissions. Energy saving policies, like lifestyle changes and energy efficiency improvements, can decrease these emissions. Energy saving measures are a crucial part of greening the economy.

Grossman and Krueger (1995) investigated whether economic growth inflicts harm on the environment and found that economic growth does not inflict unavoidable harm on the environment. Initially, when GDP increases, the environmental quality decreases. However, once GDP reaches a certain point, environmental quality starts to increase. Therefore, it is possible that increasing the income of a country's citizens to a certain point can prevent environmental degradation. By creating well-paying, sustainable jobs that spur economic growth, there might not be a huge tradeoff between economic growth and sound environment.

Baldwin and Lenton (2020) also tackled the green economy question. They suggested methods for solving the climate crisis such as the governments' responses to the pandemic and the ozone layer crisis in the 1980s. Judging by the success of these responses, they indicated that governments could act against climate change. They began with detailing the causes of the climate crisis, particularly excessive fossil fuel consumption. They discussed how governments effectively saved the ozone layer by ratifying the Montreal Protocol in the UN in 1987. They also analyzed how governments focused on pure science when combating both the pandemic and the ozone layer crisis, showing that they can undertake the task of limiting climate change. They provided specific economic actions governments could take to control climate change such as removing fossil fuel subsidies and placing subsidies on renewable energy sources. They discussed the Paris Agreement (2015) as a first step towards solving the climate crisis but not enough on its own. Baldwin and Lenton (2020) included a lot of valuable information in their paper, and I believe that it shows that a concerted effort from governments to shift to a green economy can stop climate change.

Methods

The data on NO_x, CO_2, and other emissions came from the World Development Indicators database and Our World In Data, another online database. The World Development Indicators database is provided by the World Bank and has data on every country, albeit with varying amounts of coverage per country. In this paper, I have included world data on total CO_2 emissions, CO_2 emissions from electricity and heat production as a percentage of total fuel combustion, CO_2 emissions from liquid fuel consumption, and CO_2 emissions from transport as a percentage of total fuel combustion. I was able to find all the data from 1960 to recent years for the last three categories from the World Development Indicators database. However, for total CO_2 emissions, the World Development Indicators database lacked data between 1960 and 1990. I got that data from the Our World In Data database. For the World Development Indicators database, I found the data I needed by choosing "World" in the country section, choosing the four CO_2 categories in the series section, and choosing every year from 1960 to 2019 in the time section. To find the data from

1960 to 1990 for total world CO_2 emissions in the Our World In Data database, I went to the Our World In Data website, which led me to their GitHub repository with CO_2 data. Then, I downloaded their CSV and extracted the necessary data. I placed all of this CO_2 data into graphs which illustrate how CO_2 emissions have evolved over time.

Results

As discussed in the introduction, we focused on the CO_2 data to examine the impediments to a green economy. The data from World Development Indicators is available by (a) country, (b) regions/continents of the world, (c) island groups, (d) country poverty groupings (income) and (e) global level. Groupings (a) to (d) give the longest data that can be used in econometric models such as the environmental Kuznets Curve Hypothesis (KCH) or any other model. Grouping (e) can also be used in such work but the researcher would have to assemble panels of data to obtain enough observation points for decent econometric results. This paper used data (e) to present figures from various sources of CO_2 to show the evolution of CO_2 from 1960 to 2014. Figure 1 shows that World CO_2 emissions have been steadily increasing for the past 60 years. The increase is noticeable from 1990 to 2010 and much more since 2010. It would be interesting to net out (subtract China & Indian CO_2 from World CO_2) to see whether one could single out these faster developing countries with huge populations. An even better picture could emerge if all developing country CO_2 emissions were subtracted from World CO_2 to ascertain the role of poor versus rich countries in the greening of economies.

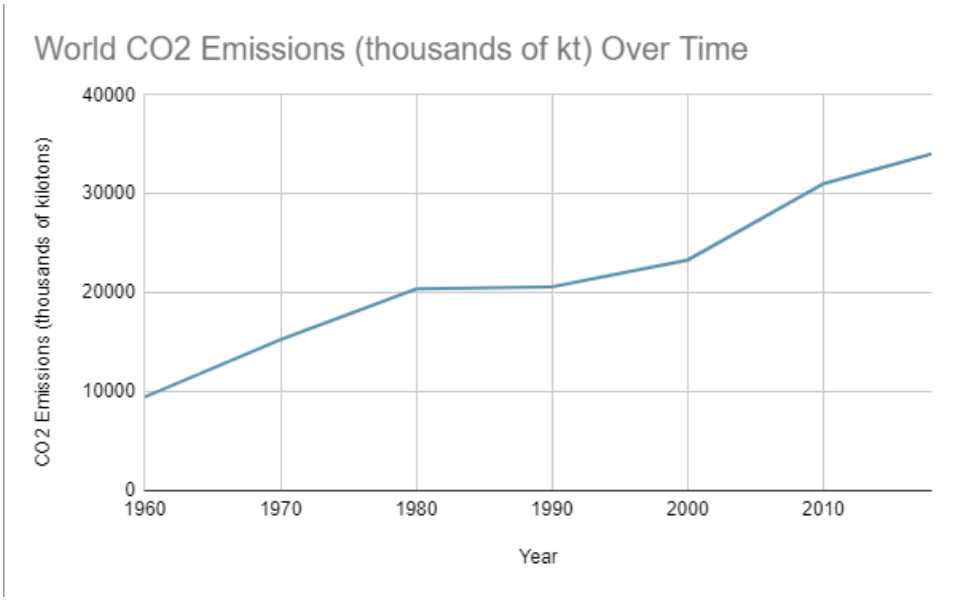

Figure 1. World CO_2 Emissions (thousands of kt) Over Time

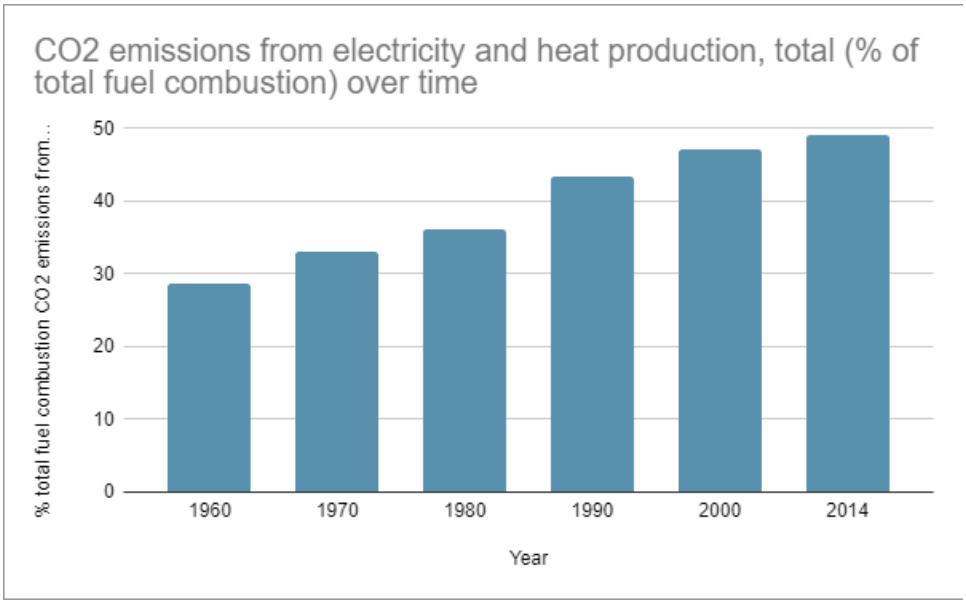

Figure 2. CO_2 emissions from electricity and heat production, total (% of total fuel combustion) over time

Note that CO_2 emissions from electricity and heat production have stayed below 50% of total fuel combustion, while steadily increasing since 1960. There is sufficient knowledge at this time to approximate how much coal, gas, and oil is burned by industry and people each year. For example, we know the amount of CO_2 released into the atmosphere to produce a unit from a fuel source (example, a kilowatt-hour from coal, gas). These units, called "emission factors", allow researchers to then multiply the amount of energy produced from electricity and heat production from coal, oil, and gas to get a good measure of CO_2 represented in Figure 2. The numbers have slowly increased over time from 30% in 1960 to 49% in 2014.

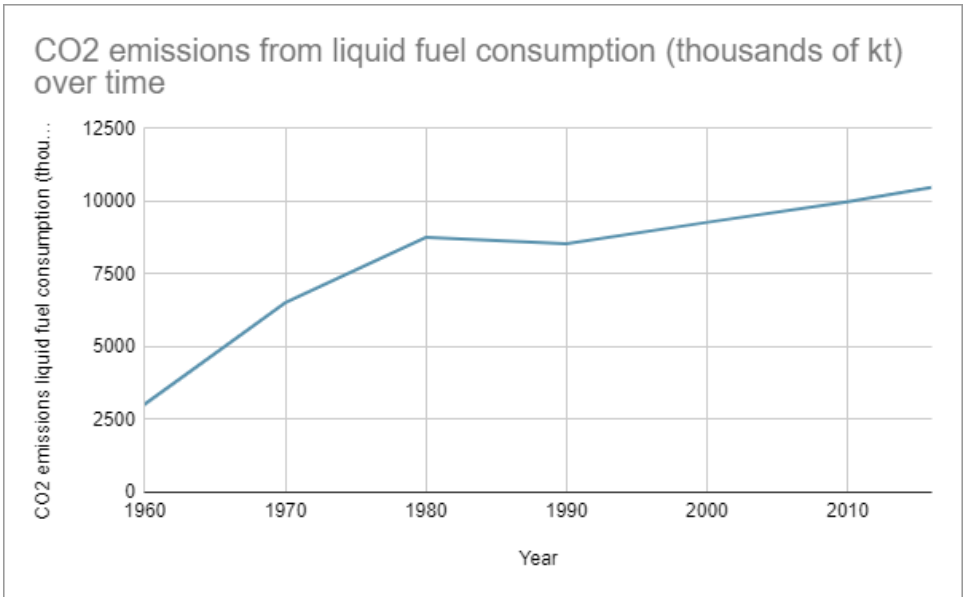

Figure 3. CO_2 emissions from liquid fuel consumption (thousands of kt)

In Figure 3, liquid fuel means fuel like oil, diesel, and any other petroleum fuels. Emissions from these fuels have increased over time. The tonnage of CO_2 increased from 2500 in 1960 to 7700 by 1980. It stayed flat between 1980 and 1990 before beginning a steady rise from 7700 in 1990 to over 10,000 by 2000.

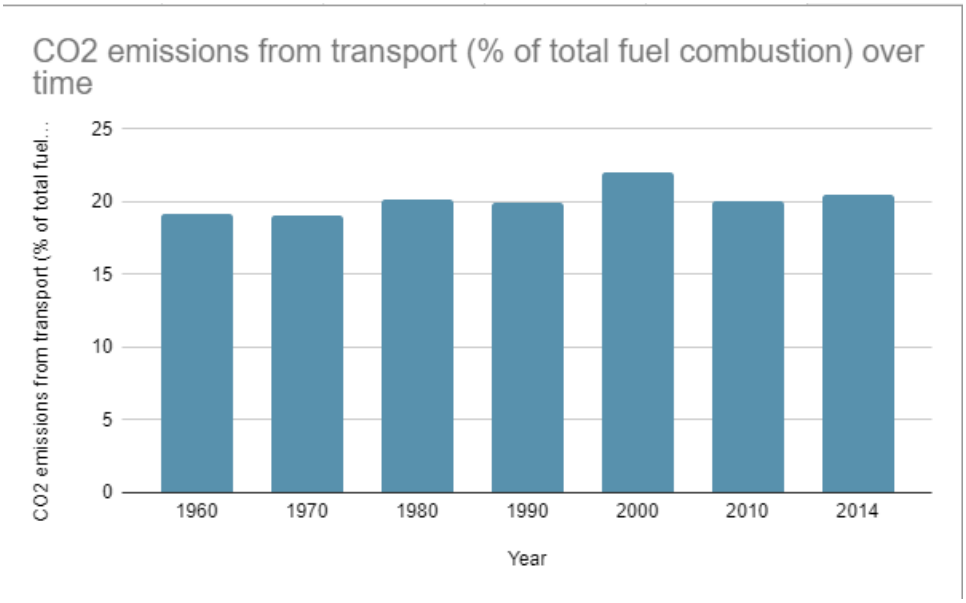

Figure 4. CO_2 emissions from transport (% of total fuel combustion) over time

In Figure 4, CO_2 emissions from transport have stayed below 20% of total fuel combustion and have had little variation over time except for year 2000, when CO_2 emissions from transportation reached 22% of total CO_2 emissions from fuel combustion. Gases from planes, autos, tractors, trucks and types of soot tend to increase warming and hence contribute to global warming and act as an impediment to economies attempting a transition to a green economy.

Graphs (1) to (4) show how dire the situation is. They show that world CO_2 emissions have more than tripled since 1960, that CO_2 emissions from electricity/heat production and CO_2 emissions from liquid fuel consumption have been steadily increasing, and that CO_2 emissions from transportation have stayed relatively stable.

To transition to a green economy, the infrastructure must change drastically, including changes in transportation, energy, waste management, and a change in rampant consumerism in Western culture. This includes changing the infrastructure of our cities, which are responsible for 60% of the world's greenhouse gas emissions.

Sustainable consumption is also a key component of greening the economy. Some important steps the government can take are putting a focus on the environment in schools, more effective eco-labelling, encouraging eco-friendly products to be sold in stores, and developing programs for sustainable food, transportation, and housing.

Discussion

The data shows a clear and present danger to our world. CO_2 emissions in energy consumption have risen over the decades while CO_2 emissions from transportation have stayed relatively stable. World CO_2 emissions have tripled since 1960. These emissions must be reduced immediately to avert a climate disaster. However, the Kuznets Curve shows that increasing GDP and the general wealth of a nation can eventually reduce negative environmental effects.

According to these findings, transitioning to a green economy is possible. A rapid change of government subsidies from the fossil fuel industry to the renewable energy industry will substantially reduce emissions as companies have more incentive to switch to renewable energy sources. The money that was previously being spent on the fossil fuel industry in the form of subsidies could be used to pay for shifting our society to a more sustainable way of life. For example, it could pay for producing new, cleaner technology or building more sustainable buildings.

It is imperative to rebuild our infrastructure to be more sustainable. For example, cities should be designed in ways to encourage people to use bicycles as transportation (larger bike lanes, bike parking racks throughout the

city, etc.) From now on, buildings should also be made more sustainably. They should be made to reduce pollution/waste and be energy efficient - hopefully running on completely renewable energy.

Consumerism is one of the main reasons humans are in this situation. Wasteful consumption of resources is inherently unsustainable, and that behavior must be changed immediately if we want to prevent future crises. The private sector benefits greatly from consumerism, so it is up to the government to educate the public about the negative effects of their choices. The government can enact policies to strengthen eco-labels on eco-friendly products or put warning labels on products that have negative environmental effects. Additionally, the government should take immediate action to put a focus on the environment in schools. If children learn the environmental effects of their actions at a young age, they may make better consumption choices as adults. The government should encourage eco-friendly food sources and sustainable housing that runs on clean energy.

Conclusion

According to SDG 13, shifting to a green economy is of utmost importance to combating climate change. The green economy is a sustainable economy that operates without waste or negative externalities. Greening the economy includes shifting from fossil fuels to renewable energy sources, changing the infrastructure to be more sustainable, advocating for sustainable consumption of resources, and increasing fertilizer efficiency to decrease NO_x emissions. The data clearly shows that rising CO_2 emissions must be curtailed immediately to combat climate change.

Greening the economy is an effective tactic for combating climate change. Removing subsidies from the fossil fuel industry will greatly decrease emissions and help pay for shifting to a green economy. A change in the infrastructure of our cities, to make them more sustainable, is an equally important component of a green economy. And finally, changing the culture of our society to be less wasteful in our consumption of resources will ensure that any similar crises will not arise in the future.

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