**Climate Change Analysis Report**

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BIS580 Business Decision Modeling

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**Executive Summary**

To investigate global energy and climate solutions, Climate Interactive and collaborators created the simulation program En-ROADS. It shows the impact of evolving technology and policies on global temperatures and carbon emissions, including taxation, subsidies, and carbon pricing. Evaluating different scenarios and analyzing their effects is made simple by En-ROADS's immediate, clear response. Regarding energy efficiency, renewable energy, carbon pricing, innovation, and global collaboration, this example emphasizes the significance of integrated policies. Investing in technology, expanding energy efficiency, encouraging international agreements, implementing carbon pricing, and raising subsidies for renewable energy sources are some of the main suggestions. The organization of climate plans is necessary, as these steps could significantly decrease emissions and stop the rise in global temperature by 2100.

**Introduction**

The climate of Earth has been highly observed by several scientific organizations throughout the past century. Solar radiation, ocean currents, volcanoes, and—most importantly—human activity that releases greenhouse gases have all been found to be major reasons for these changes. As NASA notes, human-caused emissions are disrupting the balance of the natural greenhouse effect, which is crucial for the habitation of our planet and storing heat in the atmosphere. Global warming is a major warming trend that has been caused by this. If global warming continues uncontrolled, scientists warn that irreversible damage and further negative impacts may result from temperatures rising over a key threshold of 2°C. It is therefore necessary to limit the increase in global temperature below this point to reduce the most severe effects of climate change.

It focuses on taking a thorough look at the climate change problem to address this major problem. To successfully address climate change, we want to provide practical solutions for changing mindsets, modifying rules, and making measured investments. We want to make a difference in a resilient and environmentally friendly future for our planet by evaluating the possible effectiveness of these actions in stopping climate change and reducing its negative impacts.

**Problem Statement**

The principal source of climate change is an increase in greenhouse gases, such as carbon dioxide (CO2). These gases can hold onto solar energy, which explains why Earth's temperature is rising. CO2 levels in premodern times were around 280 parts per million, or ppm. Natural gas extraction and the use of petroleum derivatives are two instances of human activities that have caused CO2 levels to rise to 410 parts per million. Earth's average surface temperature has increased by 1°C since the late 1800s. The frequency and intensity of heat waves, droughts, and wildfires have all changed as a result, as have sea levels, ocean acidity, and rainfall patterns.

The study examines multiple possibilities for configuration for reducing environmental change, such as evaluating carbon emissions, promoting renewable energy, taxing coal and gasoline, improving the energy efficiency of transportation, and lowering methane outflows. We want to identify the most effective strategies for reducing outflows of substances that deplete the ozone layer by examining the effects of different policies on the projected long-term rise in temperature by 2100. The aim is to provide experts with precise information on the optimal approach to halt climate change and ensure a sustainable future by reducing the anticipated rise in temperature and its harmful effects.

**Key Assumptions**

We make the following assumptions about the data: the dependent variable (2100 temperature increase) and the independent variables (carbon price, renewable energy subsidies, coal tax, oil tax, transportation energy efficiency, building energy efficiency, and methane reduction) are accurate and dependable. Additionally, to model these variables' impact on temperature rise, we suggest a linear link between them.

We keep other contributing variables as they are to concentrate on the consequences of a certain policy. It is predicted that by the year 2100, these policies will be put into place separately, continue to have the same impacts over time and produce the same results worldwide.

We predict that the climate system will react significantly to fluctuations in greenhouse gas emissions in the future, based on the most recent scientific data. It is believed that the suggested global emissions reduction plan, which makes use of additional renewable energy sources and carbon pricing, may be put into action with enough money and political support.   
 Finally, we expect that cutting emissions will have a noticeable effect on global temperatures and other climate indicators, even though these advantages might not be felt immediately. Considering how urgently climate change needs to be addressed, acting on these assumptions is both necessary and reasonable.

**Analysis**

By utilizing historical climate data, current policy and greenhouse gas emissions based on EN-roads we are analyzed the data and this data analyzed into 6 tools they are Decision Analysis, Linear Regression, Forecasting, Optimization, Probability and Statistics, Sensitive Analysis. Below part briefly describes each tool used by excel.

**Decision Analysis**

Decision analysis is a method used in decision-making processes to evaluate and compare various options or methods. Using the En-ROADS simulation model, a thorough decision analysis of several climate policy possibilities is presented in this document. The main goal of this analysis is to assess the degree to which various policy options are to reduce global sources energy for gas emissions like CO2, Methane, Coal, Oil, Bioenergy, Nuclear, Renewables.

By keeping the temperature at +2.0°C, evaluating the financial costs and advantages of each, detect possible dangers and possibilities, and offer practical recommendations for minimizing climate change. There is an initial increase in emissions or energy use, peaking around 2020. A significant decrease in emissions or energy consumption, indicating the effects of policy changes or an evolution toward more environmentally friendly energy sources between 2020-2050. After 2050, the long-term effects of sustained policy or technological developments are indicated by energy use or emissions stable or slightly increasing.

These projections allow decision-makers to plan for future energy needs, invest in sustainable energy technology, and develop plans to meet climate goals. Planning might help reduce possible problems associated with energy transitions, such as economic interruptions or energy shortages. Sustaining long-term growth and environmental goals will require funding for research and development of new energy technologies. The formula can be calculated as

* **EV= (Probability A × Expected Payoff A)+(Probability B × Expected Payoff B)**

**Sensitivity Graph**

The sensitivity graph highlights important changes in the energy combined by showing the estimated use of different energy sources from 2000 to 2100. Both coal and oil increased around 2015 and 2025, respectively, after beginning comparatively high in 2000, then rapidly falling and stabilizing at lower levels by the middle of the century. As until about 2025, gas is more stable. After that, it steadily drops and stabilizes.

In contrast, renewable energy sources have a low starting point but rapidly increase after 2020, taking the lead in energy production by 2040 and continuing to rise until they reach a high point by the end of the century. Nuclear energy and bioenergy both stay at comparatively low but stable levels over the course of the decade, with bioenergy showing some modest growth around 2030.

**Linear Regression**

Linear regression analysis uses another variable to predict the first one. The variable that is expected is called the dependent variable, and the variable that is used to create the prediction is called the independent variable.   
 This method uses one or more independent variables to estimate the values of a linear equation that most closely predicts the dependent variable. The best surface or straight line fit the data by linear regression by minimizing the difference between the expected and actual values.   
  
Analysis:   
 We are interested in determining the degree to which the baseline emissions and the emissions of greenhouse gases in the current scenario are related. The regression equation that the data produced is as follows:

Current Scenario emissions = 127.6808 - 1.4843 x Baseline Emissions

In this case, the emissions from the current scenario are the dependent variable, while the baseline emissions which are also measured in gigatons CO2 equivalent/year are the independent variable. The intercept of 127.6808 represents the expected current scenario emissions when baseline emissions are zero. The slope of -1.4843 shows that for every Gigaton CO2 equivalent/year increase in baseline emissions, current scenario emissions are predicted to decrease by around 1.4843 gigatons.

Simple linear regression R-squared values normally vary from 0 to 1, so the statistical summary's R-squared value of -0.7836 is unexpected. A negative R-squared score indicates that outliers or data scalability issues could be causing issues for the regression model. The model's parameters are provided by the t-statistics, p-values, standard errors, and coefficient estimates. The 95% confidence interval for the intercept's forecast, which ranges from 112.5252 to 142.8363, is 127.6808. The t-statistic is 16.716, the standard error is 7.638, and the p-value is 1.38 × 10⁻³⁰. The estimated slope is -1.4843, and the 95% confidence interval includes values between -1.7189 and -1.2496. Its p-value is 3.48 × 10⁻²², t-statistic is -12.549, and its standard error is 0.118.

The alternative hypothesis (H1) says that there is a relationship between baseline emissions and current scenario emissions, opposite to the null hypothesis (H0), which argues that there is no relationship at all. This is the slope's hypothesis test. With a p-value of 3.48 × 10⁻²² and a t-statistic of -12.549 for the slope, the relationship is statistically important and strongly opposes the null hypothesis.

Regression analysis results indicate a significant negative relationship between baseline emissions and current scenario emissions. According to this, emissions in the current scenario decrease as baseline emissions increase. The application of such observations is necessary to understand emission trends and develop effective emission reduction programs. In spite of this, the negative R-squared result suggests more investigation into the data, or the model used, as it may indicate the necessity for a different modeling approach or adjustments to the data. The total significant negative slope highlights the effect of baseline emissions on current scenario emissions, showing the importance of targeted emission reduction programs.

**Forecasting**

The process of predicting future patterns or occurrences by analyzing information and data from previous periods is known as forecasting. It involves determining the probability of future outcomes using a variety of statistical, mathematical, and computer techniques. Forecasting is a common tool used to help strategic planning and decision-making in a wide range of fields, including business, finance, economics, and weather prediction.

In this document, the Simple Moving Average (SMA) and Single Exponential Smoothing (SES) forecasting tools are used to analyze CO2 reduction data from 2000 to 2030. The ability to forecast future CO2 reduction and to analyze the pattern is critical for environmental management planning and making decisions.

The chart illustrates the actual CO2 reduction values, the SMA, and SES forecasts. The SMA line is smoother but lags, while the SES line closely follows the actual data trend.

**1.Simple Moving Average (SMA):**

The Simple Moving Average (SMA) is a method that calculates the average of a specified number of data points. Since a three-year SMA was used in this study, each expected result is the average of the CO2 reduction figures from the past three years.

**Calculation:** The average function in Excel may be used to determine the 3-year SMA. Assume that, beginning with cell B2 for the year 2000, your CO2 reduction data is in column B. Here's how to go about it: **SMA = Average/3** where Y, represents the CO2 reduction value.

**2.** **Single Exponential Smoothing (SES)**:

SES is a weighted moving average of historical observations, with the weights decreasing exponentially with the age of the observations, used in time series forecasting for multivariate data.

**Calculation:** To give more weight to recent observations, SES is used with a smoothing parameter (α) = 0.2. The graph indicates for the 5-year Weighted Moving Average (WMA) and the CO2 Reduction (Gt) from 2000 to 2030. CO2 reduction numbers are rising year, suggesting that carbon emissions are on the decline. This data is smoothed by the WMA, removing year-to-year variations to show a clearer underlying direction.

**WMA (5-year)** =AVERAGE/5

The lines show data on actual CO2 reduction as well as a future that is predicted from current trends. The projection, shown by the flat line, indicates that the rate of CO2 reduction might not increase further if no major adjustments are made. The forecast's range of uncertainty is shown by the confidence limits, which also include the lowest and highest projected values. Because it assists in projecting future events and provides information for policy choices, this type of forecasting is essential for environmental planning. For excel, the formula can be calculated for the current scenario i.**e. =FORECAST.ETS** and for calculating lower confidence bound (current scenario) the formula is i.e. **=C96-FORECAST.ETS.CONFINT** is calculated for the reduction of the lower CO2 reduction which reduces and for the upper confidence bound (current scenario) the formula i.e. **=C96+FORECAST.ETS.CONFINT** by using this formula the upper bound is calculated in the graph it shows increasing of CO2 reduction.

Excel can predict future values by requesting the chosen forecast period and previous data, which may help evaluate long-term environmental plans.

**Optimization**

In data modeling, optimization involves choosing the most effective way to organize and analyze data to meet specified aims, such as improved performance or accuracy. This method includes techniques for streamlining operations, reducing errors, and maximizing resource use, ultimately making data analysis faster and more effective.

In the context of climate change analysis, optimization is focused on finding the most efficient human behavioral and policy adjustments for reducing greenhouse gas emissions and keeping global temperature rise to 2°C by 2100. Optimization helps figure out the best combination of measures to achieve this goal efficiently and effectively, providing a sustainable future for the world.

The data collection was evaluated to identify variables that could influence the final temperature and help meet the 2°C target. Maximum values for each independent variable were chosen based on observations to ensure that the final temperature did not exceed the limitations. Each variable was carefully entered into the Enroads Model to determine its effect on the final temperature.

The solution was used to optimize the combination of variables that resulted in the target temperature of 2°C. The dependent variable (final temperature) was assigned to the objective cell, with constraints ensuring that the temperature remained an integer equal to or greater than the base temperatures calculated from the variables' maximum values. After the solution finished its computations, the disparities between the base and new temperature values were added to ensure that the target temperature of 2°C was met.

The final values derived from the solution were then reinstated into the En-ROADS Model to make sure that they delivered a temperature near 2°C.

**Probability and Statistics**

Predicting global mean temperature rise is critical for formulating climate policies to reduce the severe impacts of climate change. This research analyzes statistical probabilities relating to the expected increase of 2 degrees Celsius using hypothesis testing. The established null hypothesis (H0) posits that the predicted global mean temperature increase is exactly 2 degrees Celsius (H0: µ = 2), while the alternative hypothesis (Ha) contests this prediction (Ha: µ ≠ 2). To test these, a two-sample t-test with unequal variances and an ANOVA were applied to the data.

The t-test produced a p-value of approximately 0. Predicting global mean temperature rise is critical for formulating climate policies targeted at reducing the severe impacts of climate change. This research analyzes statistical probabilities relating to the expected increase of 2 degrees Celsius using hypothesis testing. The established null hypothesis (H0) posits that the predicted global mean temperature increase is exactly 2 degrees Celsius (H0: µ = 2), while the alternative hypothesis (Ha) contests this prediction (Ha: µ ≠ 2). To test these, a two-sample t-test with unequal variances and an ANOVA were applied to the data.

The t-test produced a p-value of approximately 0.963 for the two-tailed test, which is significantly higher than common levels of significance, leading to a retention of the null hypothesis. However, the applicability of the hypothesized mean difference to the actual expected temperature increase raises concerns. In contrast, the ANOVA outcomes signaled a statistically significant discrepancy between baseline and current scenario groups, indicated by an exceedingly low p-value of roughly 1.02E-41, which reflects a negation of the null hypothesis and denotes significant temperature changes. Confidence intervals from both groups bolster these findings by revealing non-overlapping ranges.

Considering the ANOVA results, the indication of a substantial deviation from the anticipated 2 degrees Celsius increase suggests an urgent scenario where actual temperature changes may exceed this boundary. The sensitivity of outcomes to carbon pricing adjustments imparts the importance of such policy tools, signifying the need for their decisive implementation. Coupled with this, the statistical significance of the results calls for a comprehensive strategy that includes the promotion of carbon dioxide removal (CDR) technologies through supportive global policies.

The data presents a persuasive likelihood that the global mean temperature rise could surpass the 2 degrees Celsius threshold, with significant policy ramifications. Establishing actionable policies supported by statistical evidence will involve a multifaceted approach that encompasses economic considerations and global fairness. While the statistical analysis provides clear indicators, the formation of policies must still accommodate the intricate socio-economic and geopolitical context to ensure a sustainable and climate-change-resilient future.

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**Carbon Dioxide Removal**

Reaching 40% of the maximum potential of net CO2 removal through (CDR) technologies including direct air capture and enhanced mineralization would need a comprehensive suite of global policies. These technologies are energy-intensive and costly; therefore, policies would need to focus on driving down costs, scaling up technology, ensuring the energy supply for these processes is sustainable, and providing economic incentives for their adoption. To reach 40% of the maximum potential for net CO2 removal, a robust framework of global policies must be set up to support and promote (CDR) technologies such as direct air capture and enhanced mineralization. Such policies should encompass increased governmental investment in research and development to innovate and refine these energy-intensive technologies, as well as financial incentives like subsidies, tax breaks, and grants to foster private sector engagement and reduce economic barriers.

Moreover, implementing carbon pricing mechanisms can catalyze industry investment in carbon capture and storage solutions by making emissions reduction financially attractive. Public-private partnerships will also be necessary to distribute the fiscal responsibilities and benefits of developing these technologies. Equally important is the commitment to green energy policies to ensure that the operation of CDR technologies is powered by sustainable energy sources, minimizing their environmental impact. In addition to facilitating the required carbon capture, transportation, and storage infrastructure, we must develop educational programs to cultivate a skilled workforce adept in these innovative technologies. International collaboration will be crucial to ensure that these initiatives gain traction globally, particularly within developing nations where economic constraints may impede progress. Encouraging the use of captured CO2 through the development of use markets can further support the economic viability of these technologies. Lastly, the adoption of land use policies that complement natural carbon sequestration efforts, coupled with vigilance to uphold sustainability and prevent environmental degradation, will round out a comprehensive approach to advancing CDR technology and mitigating climate change.

**Sensitive Analysis**

Sensitivity analysis is a method used to determine how modifications to input variables impact a model's or formula's output. Determining what components are most important involves altering the input parameters and analyzing the changes in the following results.

It is essential for risk management, decision-making, and strategic planning in financial modeling, such as cost projection, to understand these sensitivities. Stakeholders may use it to predict a variety of possible outcomes and modify their strategy accordingly. The impact of changes in four important factors—the coal tax, oil tax, renewable energy subsidies, and carbon price—was evaluated in this sensitivity analysis. We examined various degrees of variation for each element, holding all other factors constant, from significant increases up to 80% to major decreases down to -80%. This approach helps in separating each variable's impact on the result.  
The results showed an important sensitivity to changes in the coal tax. A 20% increase in the coal tax had a slightly different outcome than a 40% increase. On the other hand, value increases were more significant when the coal tax was reduced by 20% and 40%. It suggests that reduced coal taxes might have a significant effect on the measured outcomes since this suggests that the system is more sensitive to decreases in coal tax.

The results showed that adjustments to the oil tax had a comparatively consistent effect. The same results were obtained with variations ranging from -80% to +80%, indicating minimal variation across the various oil tax modification levels. This stability indicates that the results of the system are less dependent on variations in the oil tax, suggesting that there may be a flexible link between the rates of oil tax and the outcomes that will be tracked.

Moderate impacts were found in the sensitivity analysis of modifications in the renewable's subsidies. Values increased more when the subsidy was increased by 20% and 60%, while values decreased slightly when the subsidy was decreased by 40% and 60%. The results indicate that while subsidies for renewable energy do have an effect, it is not as great as increases in coal taxes. This may suggest that the current level of subsidies for renewable energy is approaching an ideal point, beyond which further increases or decreases have only a modest impact on the results.

The results were clearly and significantly impacted by variations in the price of carbon. Results consistently increased and became highly significant when the carbon price was raised by 20%, 40%, and 80%, whereas results significantly declined when the carbon price was lowered by 20%, 40%, and 60%. It is possible that carbon pricing is an important tool for altering the observed outcomes because of the significant sensitivity to changes in carbon prices that this shows.

|  |  |  |  |
| --- | --- | --- | --- |
| **Every variable altered** |  |  |  |
| 20% | 40% | -20% | -40% |
| 2.74 | 2.48 | 2.98 | 3.09 |
| 3.13 | 2.99 | 3.14 | 3.18 |
| 2.93 | 2.78 | 3.09 | 3.16 |
| 2.60 | 2.33 | 2.94 | 3.08 |
| 2.76 | 2.55 | 3.00 | 3.11 |
| 3.09 | 3.03 | 3.17 | 3.20 |
| 2.64 | 2.40 | 2.97 | 3.09 |
| 2.56 | 2.30 | 2.92 | 3.06 |
| 2.69 | 2.43 | 2.97 | 3.09 |
| 2.70 | 2.38 | 2.92 | 3.04 |
| 3.00 | 2.89 | 3.14 | 3.19 |
| 2.83 | 2.55 | 2.98 | 3.08 |
| 2.81 | 2.49 | 2.97 | 3.08 |
| 2.88 | 2.74 | 3.08 | 3.16 |
| 2.62 | 2.31 | 2.90 | 3.04 |
| 2.74 | 2.54 | 3.02 | 3.12 |
| 3.03 | 2.89 | 3.12 | 3.17 |
| 3.15 | 3.09 | 3.18 | 3.21 |
| 2.83 | 2.67 | 3.06 | 3.14 |
| 3.05 | 2.98 | 3.15 | 3.19 |
| 2.92 | 2.69 | 3.06 | 3.14 |
| 2.77 | 2.51 | 2.98 | 3.09 |
| 2.87 | 2.61 | 3.00 | 3.10 |
| 2.82 | 2.57 | 2.98 | 3.08 |
| 3.06 | 2.94 | 3.15 | 3.20 |
| 3.13 | 3.02 | 3.14 | 3.17 |
| 3.09 | 2.95 | 3.13 | 3.18 |
| 3.19 | 3.15 | 3.22 | 3.24 |
| 3.10 | 2.98 | 3.13 | 3.18 |
| 3.16 | 3.01 | 3.15 | 3.18 |
| 2.83 | 2.58 | 3.01 | 3.11 |
| 3.12 | 3.04 | 3.17 | 3.20 |
| 3.04 | 2.83 | 3.06 | 3.12 |
| 2.69 | 2.50 | 2.98 | 3.09 |
| 2.81 | 2.61 | 3.02 | 3.12 |
| 2.60 | 2.23 | 2.88 | 3.03 |
| 3.03 | 2.82 | 3.08 | 3.14 |
| 3.23 | 3.07 | 3.16 | 3.19 |
| 2.62 | 2.33 | 2.93 | 3.06 |
| 2.87 | 2.67 | 3.05 | 3.14 |
| 2.72 | 2.48 | 2.98 | 3.09 |
| 3.00 | 2.87 | 3.10 | 3.15 |
| 2.59 | 2.24 | 2.87 | 3.02 |
| 2.59 | 2.28 | 2.90 | 3.04 |
| 2.81 | 2.52 | 2.99 | 3.10 |
| 2.57 | 2.22 | 2.87 | 3.03 |
| 2.94 | 2.82 | 3.08 | 3.14 |
| 2.94 | 2.73 | 3.04 | 3.12 |
| 2.63 | 2.40 | 2.96 | 3.08 |
| 3.11 | 2.95 | 3.13 | 3.17 |
| 2.72 | 2.50 | 3.00 | 3.11 |
| 2.77 | 2.59 | 3.01 | 3.11 |
| 2.89 | 2.74 | 3.08 | 3.15 |
| 3.05 | 2.89 | 3.11 | 3.16 |
| 2.93 | 2.76 | 3.06 | 3.14 |
| 2.63 | 2.35 | 2.91 | 3.04 |
| 2.93 | 2.68 | 3.02 | 3.11 |
| 3.14 | 3.04 | 3.15 | 3.19 |
| 2.69 | 2.34 | 2.92 | 3.06 |
| 3.00 | 2.78 | 3.05 | 3.12 |
| 3.17 | 3.04 | 3.14 | 3.18 |
| 3.10 | 2.98 | 3.15 | 3.19 |
| 2.95 | 2.79 | 3.08 | 3.15 |
| 2.87 | 2.62 | 3.00 | 3.09 |
| 2.96 | 2.74 | 3.06 | 3.14 |
| 2.62 | 2.33 | 2.92 | 3.06 |
| 2.70 | 2.37 | 2.92 | 3.05 |
| 2.94 | 2.80 | 3.08 | 3.14 |
| 2.93 | 2.69 | 3.03 | 3.11 |
| 2.85 | 2.62 | 3.03 | 3.12 |
| 3.28 | 3.28 | 3.28 | 3.28 |

**Conclusions**

This report used the En-ROADS simulation model to explore the impact of various climate policies on global temperatures and greenhouse gas emissions. Analysis provides important insights into the effectiveness of various policies. Key findings highlight the crucial need for integrated climate policy to control global warming and reduce negative consequences. Integrated policies that promote renewable energy, carbon pricing, and energy efficiency are critical for decreasing emissions. Linear regression demonstrated that effective strategies reduce emissions despite higher baselines. Forecasting methods showed prospective CO2 reduction patterns, emphasizing the necessity for continuous policy adaptation. Optimization demonstrated that optimal policy combinations are critical for keeping temperature rise within the 2°C threshold. A statistical analysis proved the significance of carbon pricing and renewable energy subsidies. Sensitivity analysis revealed that tax and subsidy changes had a considerable impact on results, emphasizing the importance of proper policy calibration.

**Recommendations:**

Our team suggests many critical solutions for reducing climate change and promoting sustainability. Reducing reliance on carbon-intensive fuels is critical to reducing CO2 emissions. Promoting improvements in transportation technology, particularly electric vehicles (EVs), through incentives and infrastructure development, would significantly decrease emissions. Addressing the impact of population expansion on carbon emissions through sustainable development strategies is critical. To effectively reduce carbon emissions, a comprehensive strategy is needed, combining carbon pricing, renewable energy promotions, and severe energy efficiency regulations. Investing in renewable energy will reduce our dependency on fossil fuels. Improving energy efficiency in all areas will significantly reduce emissions. International cooperation and public awareness efforts are critical to global climate action. Policies will be more effective if they are monitored and adjusted extensively using scientific data. By implementing these recommendations, decision-makers may considerably reduce greenhouse gas emissions and limit global temperature rise, encouraging a more sustainable and resilient future for Earth.

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