Global Warming Chartbook

Last Fifty Years Extrapolated to Next Fifty Years

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Thesis

Global mean temperature is rising relentlessly in tandem with atmospheric carbon dioxide. We must accelerate the world energy transition from fossil fuels to renewables.

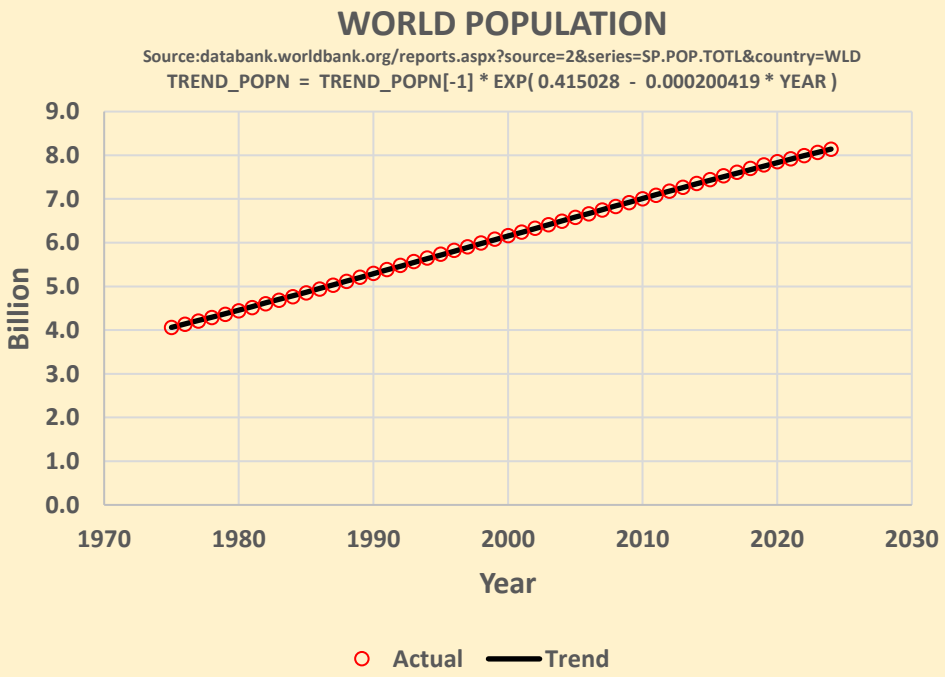
Approach (Updated to 2024)

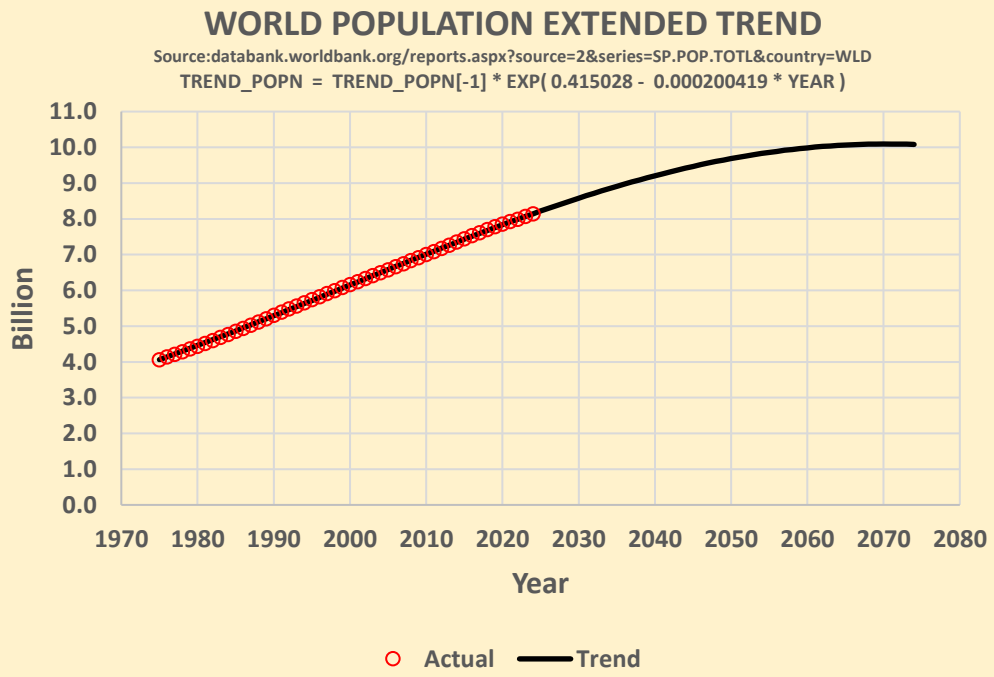
- **Simple trendlines estimated over last 50 years (1975-2024)**
  - **Global Population**
  - **Global Real GDP (2015 US$, Overall and Per Capita)**
  - **Global Atmospheric Carbon Dioxide Concentration (Parts Per Million)**
  - **Global Temperature Anomaly (Degrees Celsius, Relative to 1951-1980 Baseline)**

- **Business-as-Usual Trendlines extended over next 50 years (2025-2074)**
  - **Global population will rise from 8 billion to over 10 billion, peaking in 2070**
  - **Global real GDP will rise from $97 trillion to $268 trillion**
  - **Global real GDP per capita will rise from $11,876 to $26,553**
  - ***But*, global CO2 will rise from 425 PPM to 580 PPM**
  - ***And*, global temperature anomaly will rise from 1.29° C to 2.81° C**

- **Charts illustrate our quandary**

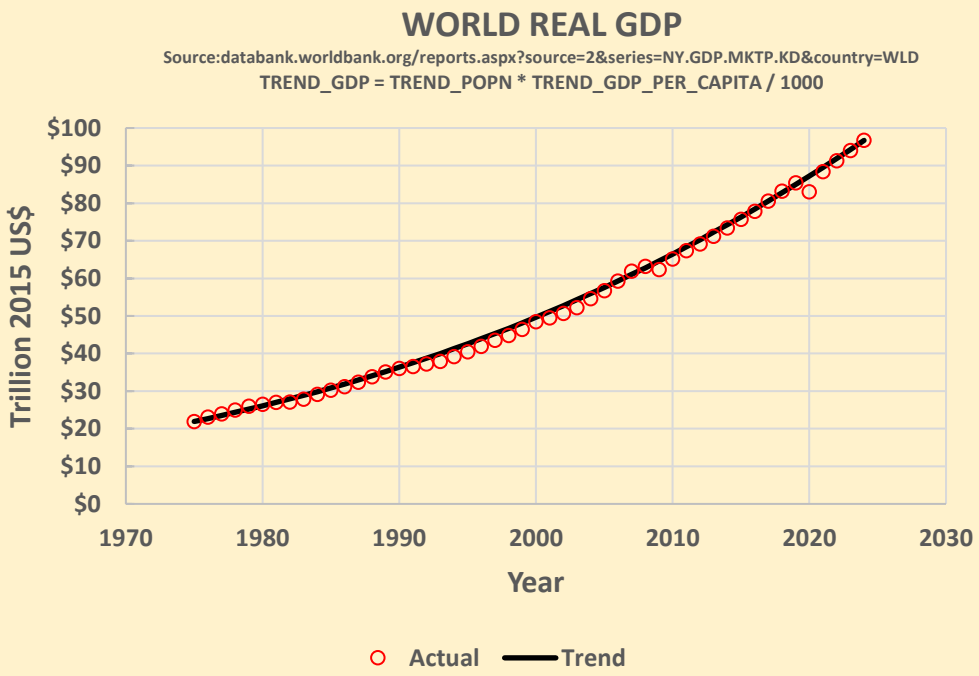
Population peaks over 10 billion in 2070

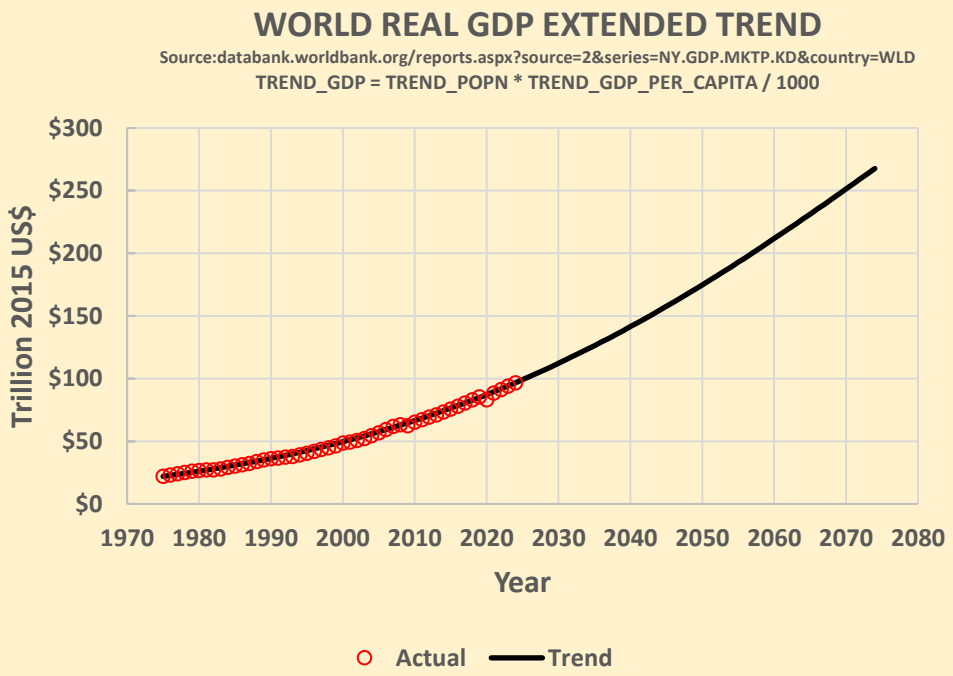




Population has the potential to grow exponentially. However, yearly percentage growth rates have steadily decreased since 1975. Assuming this continues, population will peak in 2070. This is good news although the planet is already overcrowded and new arrivals will want a better life.

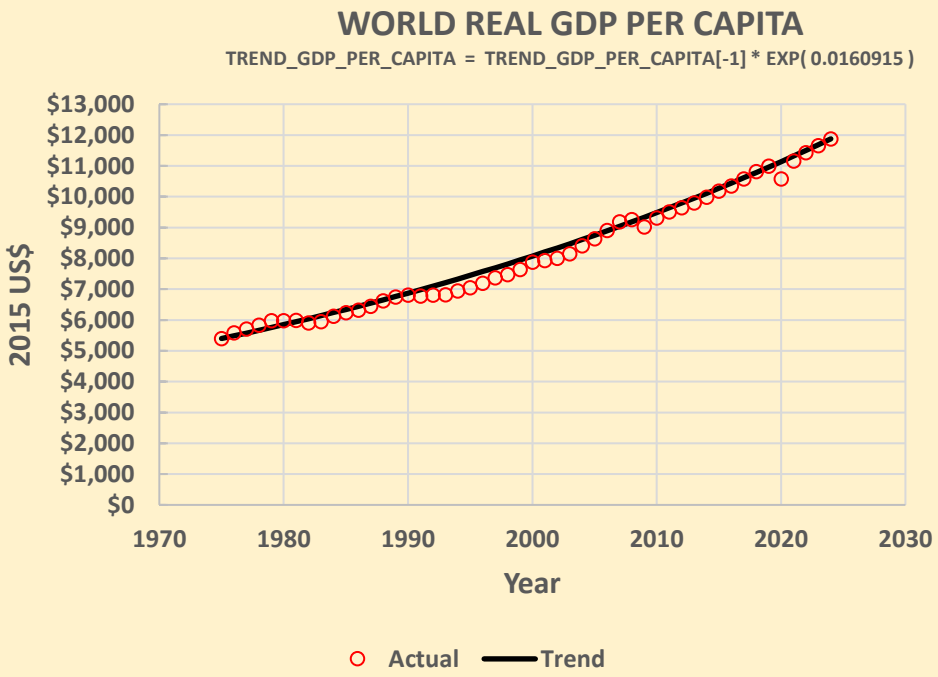
Real GDP exhibits strong growth

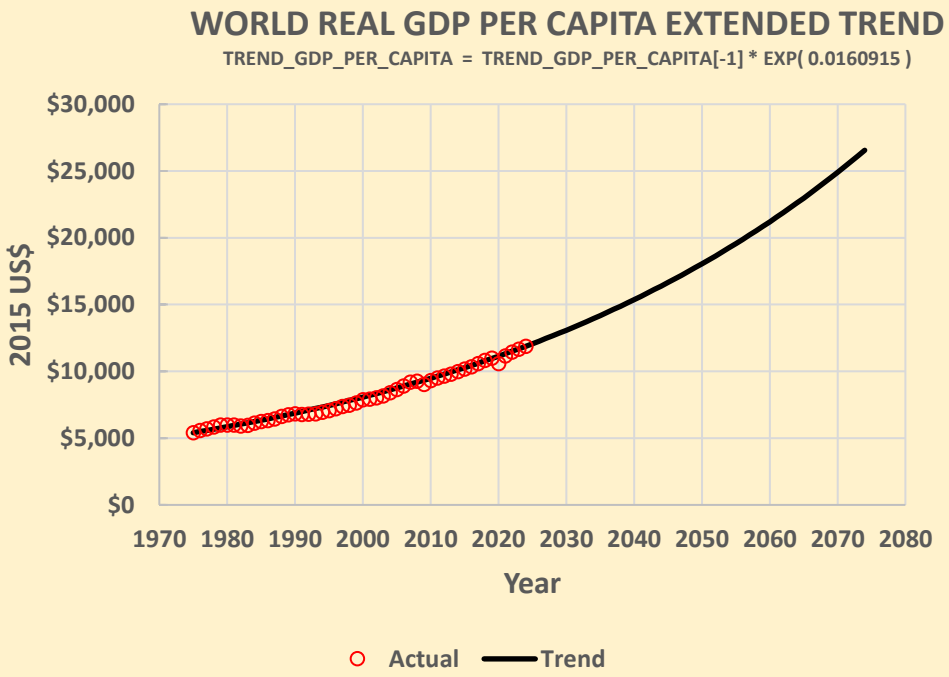




Notwithstanding various economic cycles, including the recent pandemic, world real GDP has followed a remarkably consistent growth path since 1975, largely driven by fossil fuels. However, extension of this trajectory to 2074 is highly questionable in view of environmental impacts.

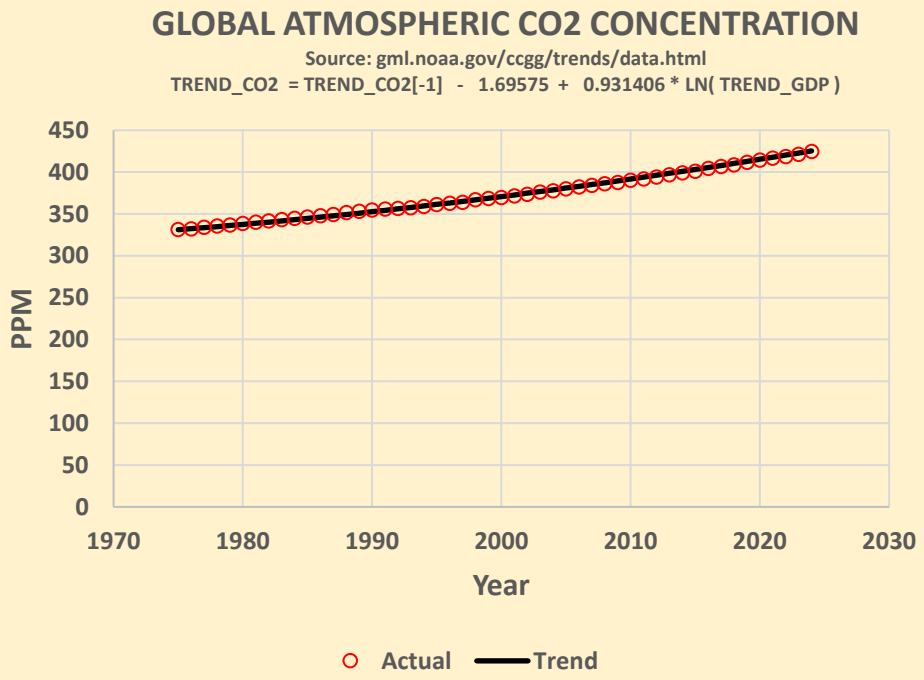
Real GDP per capita more than doubles

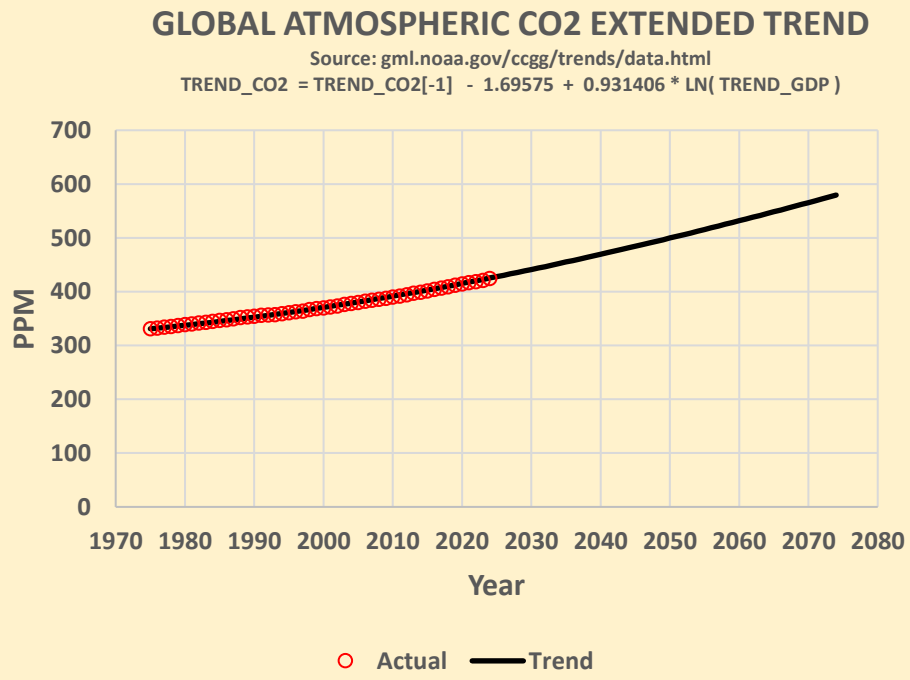




Real GDP per capita grows exponentially at 1.6% per year. This would be great without major environmental degradation! Once again, extension of this trajectory is highly questionable. We need to find a way to uplift the world population without poisoning the atmosphere and frying ourselves.

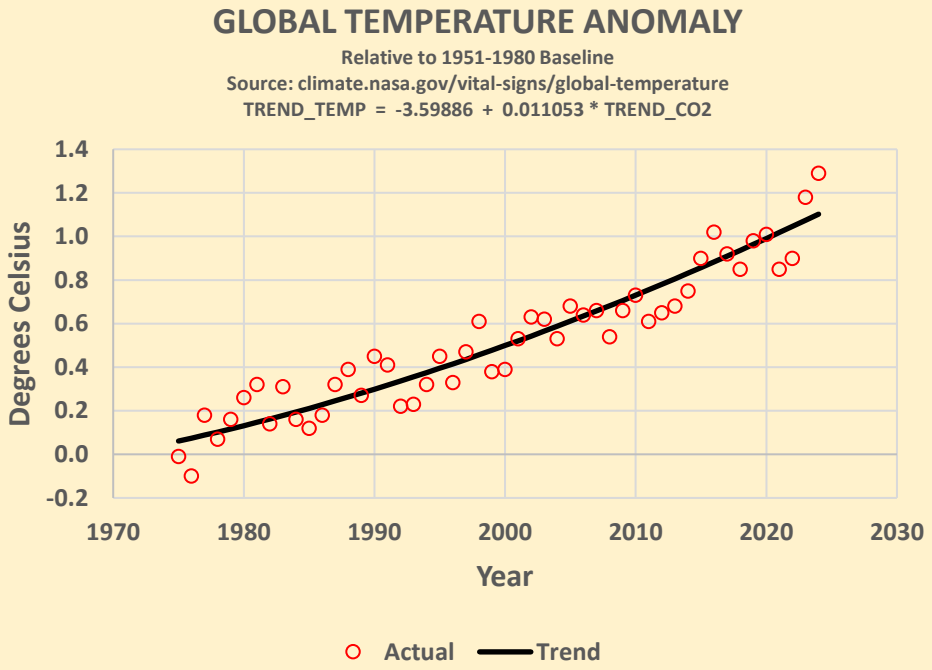
Unfortunately, CO2 increases significantly

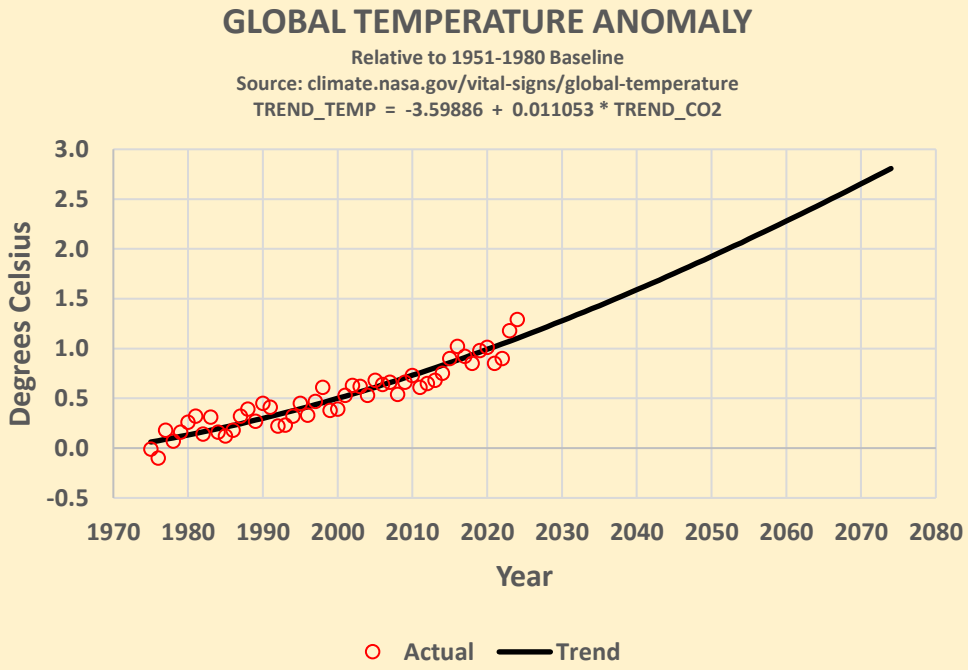




Causal relationships between economic output, carbon emissions, atmospheric greenhouse gas concentrations, and global warming are complex and nonlinear, but they are no longer in doubt. We are already in uncharted territory. Business as usual will make matters worse.

Moreover, temperature increases by 1.5° C





Given everything we're experiencing now (global melt, floods, superstorms, droughts, vast wildfires, extreme temperatures, wildlife extinctions), another 1.5° C is unacceptable. Feedback loops, like permafrost methane release, could accelerate global warming further.

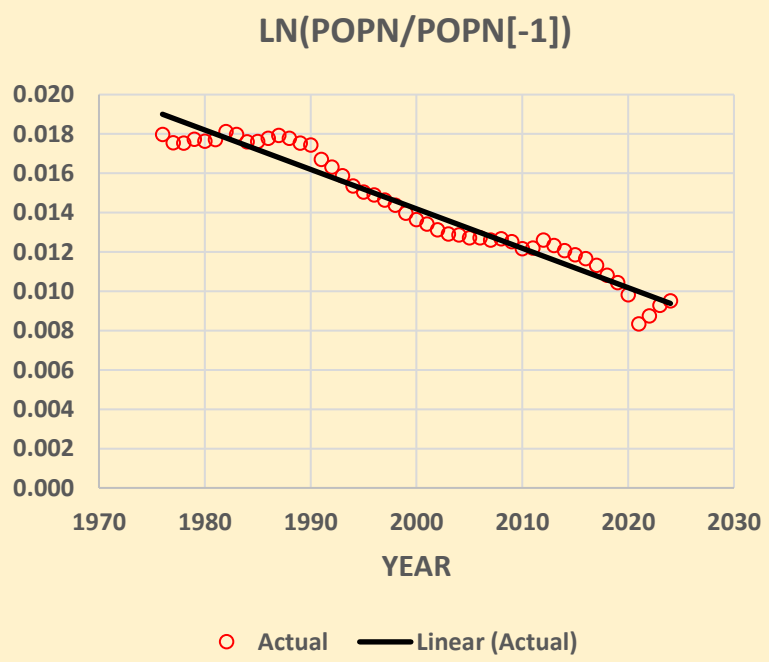
Conclusion

- We can’t allow another 1.5°, or worse, of global warming
- We must accelerate the transition from fossil fuels to renewables
- We must tax bad stuff (fossil fuels, carbon emissions) and fund good stuff (renewables, technological innovation)
- We must cap, and ultimately reverse, atmospheric CO2 concentration
- We must stabilize the Earth’s population, which is already too large
- We must develop the global economy within Nature’s limits
- We are environmental stewards for our descendants
- The future of the planet is in our hands
- Time is of the essence

Statistical Appendix

Regression model for LN(POPN/POPN[-1]) vs YEAR

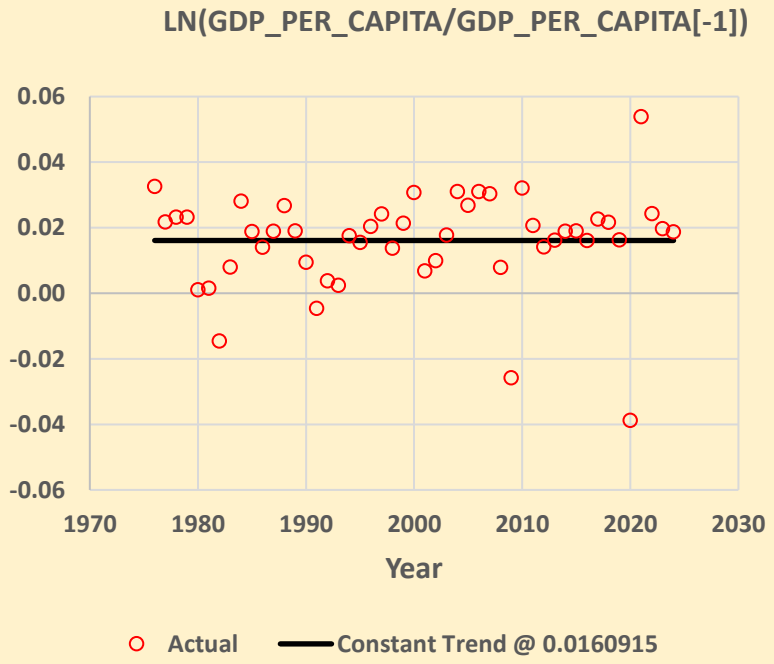
LN(POPN/POPN[-1])					
Regression Statistics					
Multiple R	0.973879904				
R Square	0.948442067				
Adjusted R Square	0.947345089				
Standard Error	0.000674753				
Observations	49				
ANOVA					
	df	*SS*	*MS*	*F*	***Significance F***
Regression	1	0.000393643	0.000393643	864.5958864	**6.50938E-32**
Residual	47	2.13987E-05	4.55291E-07		
Total	48	0.000415041			
	Coefficients	*Standard Error*	*t Stat*	***P-value***	
Intercept	**0.41502804**	0.0136324	30.44423861	**1.37592E-32**	
YEAR	**-0.000200419**	6.81603E-06	-29.4040114	**6.50938E-32**	



This model is not perfect but significant linear downtrend is a reasonable basis for extrapolation. Idea here is that annual population growth rate is diminishing over time.

Regression model for LN(GDP_PER_CAPITA/GDP_PER_CAPITA[-1]) vs YEAR

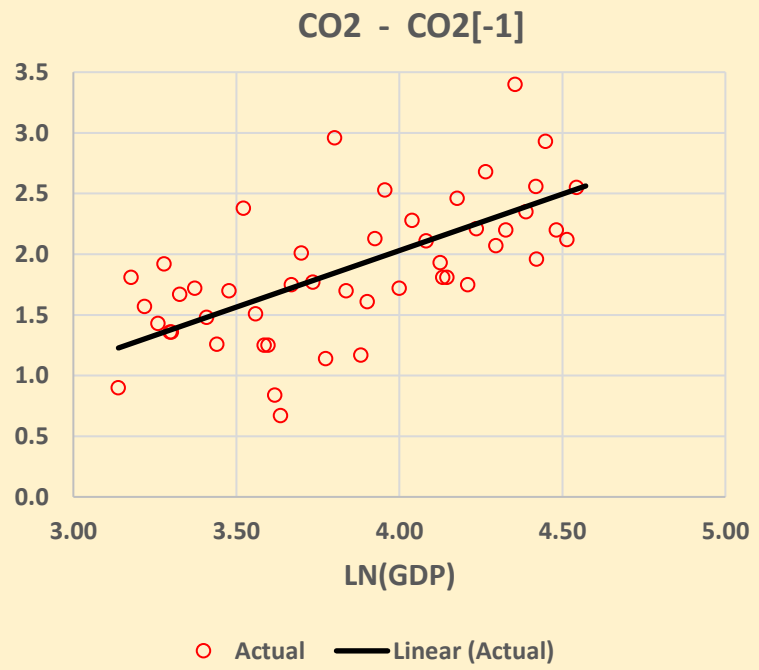
LN(GDP_PER_CAPITA/GDP_PER_CAPITA[-1])					
			INSIGNIFICANT REGRESSION USE SIMPLE AVERAGE INSTEAD		
Regression Statistics					
Multiple R	0.075976449				
R Square	0.005772421				
Adjusted R Square	-0.01538136				
Standard Error	0.015179624				
Observations	49				
ANOVA					
	df	*SS*	*MS*	*F*	***Significance F***
Regression	1	6.2877E-05	6.2877E-05	0.272878949	**0.603860709**
Residual	47	0.010829787	0.000230421		
Total	48	0.010892664			
	Coefficients	*Standard Error*	*t Stat*	***P-value***	
Intercept	**-0.14410867**	0.306682389	-0.469895498	**0.640602696**	
YEAR	**8.01001E-05**	0.000153337	0.522378167	**0.603860709**	



Time-trend is insignificant so we use the simple average for extrapolation. Idea here is that GDP per Capita annual growth rate is constant over time at EXP(0.0160915) – 1 = 1.622%.

Regression model for CO2 – CO2[-1] vs LN(GDP)

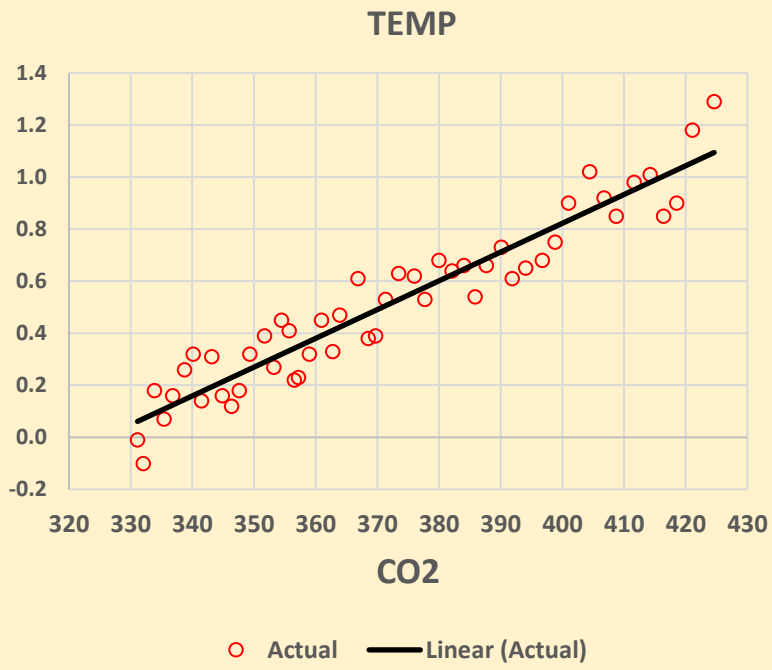
CO2 - CO2[-1]					
Regression Statistics					
Multiple R	0.655769543				
R Square	0.430033693				
Adjusted R Square	0.41790675				
Standard Error	0.466186668				
Observations	49				
ANOVA					
	df	*SS*	*MS*	*F*	***Significance F***
Regression	1	7.706742636	7.706742636	35.46101466	**3.14932E-07**
Residual	47	10.21451042	0.217330009		
Total	48	17.92125306			
	Coefficients	*Standard Error*	*t Stat*	***P-value***	
Intercept	**-1.6957464**	0.608784339	-2.785463237	**0.007682014**	
LN(GDP)	**0.931406385**	0.156409682	5.954915168	**3.14932E-07**	



Volatile scatter but significant uptrend is a reasonable basis for extrapolation. Idea here is that the change in atmospheric CO2 (i.e., annual emission) is nonlinearly related to real GDP, reflecting modest technological efficiencies over time.

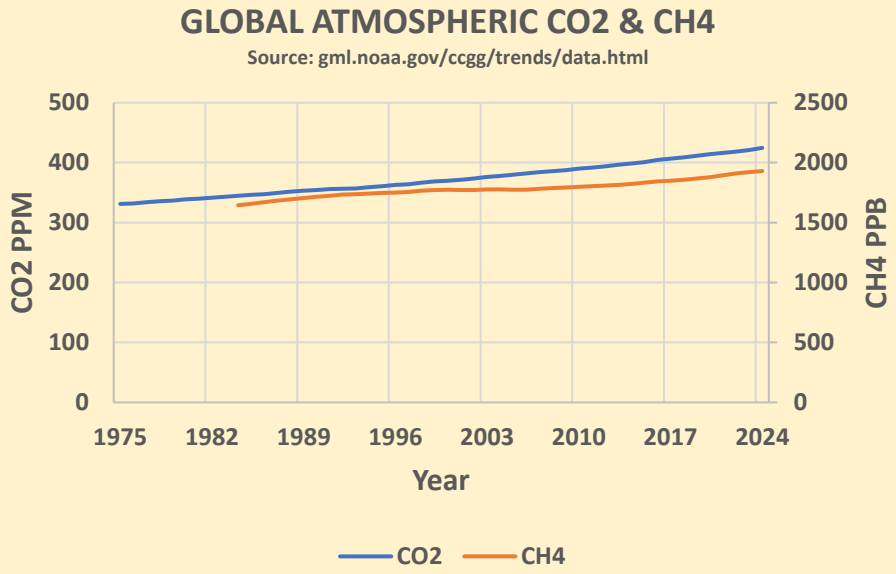
Regression model for TEMP vs CO2

TEMP					
Regression Statistics					
Multiple R	0.952988249				
R Square	0.908186602				
Adjusted R Square	0.906273823				
Standard Error	0.096799319				
Observations	50				
ANOVA					
	df	*SS*	*MS*	*F*	***Significance F***
Regression	1	4.448922808	4.448922808	474.7995147	**1.54469E-26**
Residual	48	0.449765192	0.009370108		
Total	49	4.898688			
	Coefficients	*Standard Error*	*t Stat*	***P-value***	
Intercept	**-3.59885533**	0.189374523	-19.00390441	**5.61898E-24**	
CO2	**0.011052721**	0.000507241	21.78989478	**1.54469E-26**	



Very tight model and significant uptrend is a reasonable basis for extrapolation. Idea here is that cumulative atmospheric CO2 has a linear impact on temperature.

Methane adds no predictive power



Methane (CH4) data is limited and wobbly. This greenhouse gas is a significant atmospheric pollutant, and it may become increasingly important in the future, but so far it is statistically insignificant as a temperature predictor, i.e., it adds no statistical precision beyond the single CO2 predictor. We are using atmospheric CO2 as a proxy for all greenhouse gases in our temperature regression model.