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# A BASIC MODEL OF GLOBAL WARMING

*As the kick-off article of Business, Economics, Sustainability, Leadership and Innovation, this brief manuscript reviews and analyzes global human population, $CO_2$ and global temperatures. The first section characterizes population dynamics historically, currently and future projections as presented by the United Nations (2017). The second section examines the economy, the physics of combustion supporting the economy, and global $CO_2$ emissions, also as a time series. The third section examines global temperatures. The article closes out with suggestions for future research in nonlinear climate change modeling and applied research in energy system improvements and policy to avoid a climate catastrophe.*

***Keywords***: *climate change,* $CO_2$, *Population, energy system improvement.*

## INTRODUCTION

Two extensive and recent scientific reports on climate change have been released about global warming. The United Nations Climate Change Report (2018) and the United States Government Global Change Research Program (2018) both agree that global warming is not only a result of combustion but that the speed and severity of global warming are not following a gradual linear path. Rather, they say that climate change is accelerating, and the effects are upon us now. Both reports go on to say that if we, inhabitants of the earth, fail to change our combustion-based energy systems quickly (less than 15 years), climate will markedly interfere with our life support systems that we rely upon for our fundamental existence. This kick-off article will be followed by several other articles that suggest exactly when and where the catastrophe happens, how to delay and possibly circumvent the impending catastrophe.

It should be obvious to even the casual observer that we cannot continue with our inefficient, unintelligent and unconstrained nonrenewable power systems. An extraordinary amount of evidence (Hansen et.al 2017; Hansen et.al 2016; Jacobsen 2011; Song et.al 2017; Taylor et.al 2015; Taylor et.al 2015; Temby et.al 2017) suggests that if we continue business as usual given growing populations that are dependent upon fossil fueled economies to increase standards of living through old production and consumption technology natural systems will fail to support us.

This work models the principal components of climate change and looks at their basic relationships with the most reliable and valid data available to date. From analytical results we should consider and act on how to make the necessary changes to avoid a catastrophic tipping point in climate change that would have severe negative consequences on our vital life supporting ecosystems. A set of fundamental propositions are made: 1) there will be a significant positive relationship between population and $CO_2$, 2) there will be a significant positive relationship between earth temperature and $CO_2$. I further propose that upon examination, the slope of the curve is steeper as the time series observations exclude the more distant past and considers the more recent decades of relationships of carbon dioxide over time, temperature over time as well as population over time.

NOTE: My next article looks at a nonlinear model and hypothesizes that data will display sudden change. The cusp catastrophe model (Thom, 1975) is well known in physics, biology and social science (Zeeman 1977) for sudden and dramatic change as opposed to a general linear model where proportion in variation across the variables hold constant. The cusp catastrophe model has three variables where two are independent or are predictor variables and one dependent variable. All three variables have specific characteristics where the first independent is asymmetric, the second independent displays a bifurcation and the dependent has a sudden change with a region of least probable behavior. I have set the asymmetric variable as population, the bifurcation variable is $CO_2$ and lastly, set the dependent variable as earth temperature. The cusp catastrophe model takes fundamental thermodynamics into account.

## METHODS

Three primary data sources were used for the three variables: 1) population, 2) $CO_2$ and 3) earth temperature and all three aligned for annual observations on a spreadsheet. Population data is from the United Nations Department of Economic and Social Affairs (2017) and is measured as per/person as the living making allowances for births and deaths as a differential in the given year. Their most current revision was the 2017 release of world population prospects and the update included current conditions as well as future projections. The UN updates their public domain population spreadsheets each passing year. With roughly 83 million people most currently (2017) being added to the population annually, the upward trajectory slightly slows but continuing growth. The United Nations department releasing the reports and spreadsheets is part of the World Population Prospects: The 2017 Revision of the Department of Economic and Social Affairs. The important difference between the 2017 release and the prior release is the increase in population projection. The older version estimated less than 10 billion people on earth in 2100 but the current version projects 11.2 billion by 2100. Other important markers along the trajectory are 8.6 billion by 2030 and 9.8 billion by 2050, all an increase from the prior published world population projection estimates. The data used for the models contained within this paper reading are only up to 2017 and not the future projected estimates. In other words, I only used past data because past data is not estimated but validated by direct measurement. Carbon dioxide data is also observed annually. Data was collected by the National Carbon Dioxide Information Analysis Center (2017), Oak Ridge National Laboratory, US Department of Energy (DOE). Similar to the United Nations, the US DOE has professional statisticians that collect data from the observation points across the globe. I also confirmed with data from NASA, Goddard Institute (2017), Earth Policy Institute, Worldwatch Institute, Signposts 2017) from 1960 to 2017 and lastly NOAA/ESRL, Atmospheric Carbon Dioxide - Mauna Loa (2018).

Units of measure are annual in parts per million (PPM) and smart sensors are used that assure sensor calibration feedback loops and data point transmission to collection servers for direct reports. Pretechnological sensor data collection instrumentation, digital and otherwise, are from ice core samples. Data used for earth temperature were also verified with multiple well-respected scientific sources. Temperature is from NASA, Goddard Institute (2017), Earth Policy Institute, Worldwatch Institute, Signposts from 1960 to 2017 and lastly NOAA/ESRL, Atmospheric Carbon Dioxide - Mauna Loa (2018) all warehouse temperature. Units of measure are measured in annual observations and the actual units are of temperature are in Centigrade not Fahrenheit. Smart sensors are used that assure sensor calibration feedback loops and data point transmission to collection servers for direct reports. Again, pre-technological (digital) instrumentation relies upon data from ice core sample composition.

### Population Dynamics

The latest official updated United Nation's projection for Earth's human population is estimated to be 11.2 billion before 2100 as reflected in figure 1 below.

Not only is the population growing, it is geographically changing. There is a global mass migration taking place this century and the scale of the migration is quite different than in the last century. Most of the growth is taking place in the developing countries and the movement is from rural areas to urban mega cities in costal zones.

Growth and migration are at a critical intersection. While the population of the earth is increasing and migration to cities is increasing, standards of living are also increasing. One observable indication of increasing living standards is how people commute in developing nations and the third world.

Transportation systems account for about 27.5% of greenhouse gas emissions. However, the volume of petroleum used to move ourselves and our physical objects is increasing because consumerism is also on the rise. From rural poverty to bigger spaces to live with more durable goods inside bigger living quarters is fashionably desirable. This is especially true in developing nations where bicycles have given way to motorcycles that have given way to automobiles. Air travel is more common among the general global population than ever before.

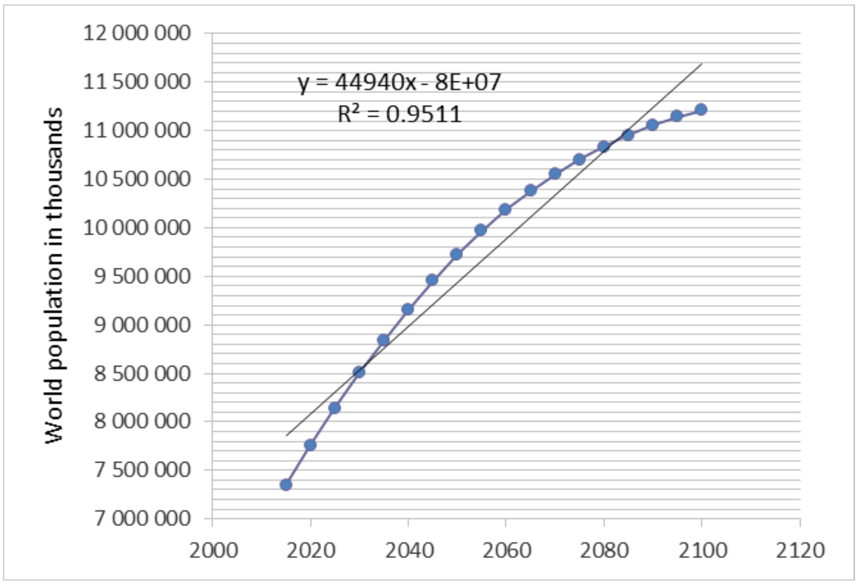


***Fig. 1.*** *Global population estimate based upon latest UN data*

General consumer goods, housing and technology are increasing as well as their subjective service life replacements. The replacement of material possessions has gone from necessity replacements to what is commonly referred to as upgrades. Indeed, stainless steel appliances, granite countertops, oversized wash machines and 72-inch televisions placed in yet larger living spaces is a fast spreading worldwide phenomenon (Jacobsen 2011). In fact, cities that were once fishing villages are now megacities with skyscrapers and advanced infrastructure systems. Yet, living in cities is more sustainable than living in rural spaces for the already developed nations.

In 2016, an estimated 54.5 percent of the earth's population lived in cities. The UN Department of Economic and Social Affairs (2017) estimates that in 2030, 60 percent of the world's population will live in cities. According to the last several decades of data, the world's population has increased by roughly 74 million people but is increasing at over 44 million, on average, a year over the entire trajectory until 2100 (table 1). Over the recent past, the growth has been equal to an increase of approximately 1 billion people every 13 years. You could think of it as an increase of over 6 million people per month, or 1.4 million a week (Jacobsen 2011).

In 2018, 55% of the world's population lives in urban areas, a proportion that is expected to increase to 68% by 2050 (UN, 2018). Projections show that urbanization, the gradual shift in residence of the human population from rural to urban areas, combined with the overall growth of the world's population could add another 2.5 billion people to urban areas by 2050, with close to 90% of this increase taking place in Asia and Africa, according to the new United Nations data set launched in 2018. Developing countries absorb, and will continue to absorb, nearly all of the world's population increases between today and 2100. Meanwhile, very rural populations are scarcely growing at all and by 2030, more than half of all Asians and Africans will live in urban areas.

*The Economy, Physics of Combustion, and $CO_2$ Emission*

Aside from people, energy is the most important driver of our economic systems (Jacobsen 2011). With AI on the rise, people (labor) will become less and less part of the production function. Everything is brought to us courtesy of energy. We live, work and play in energy constructed residential, commercial and industrial facilities that also use energy to keep us thermally comfortable, lit at night and during the day, help us communicate and do our work. I could easily argue that energy is becoming even more important as we become ingulfed in AI, big data and machine learning because they are all digital and once up and running, exclusively energy dependent. The materials and systems we use are made from petrochemicals and require processes that depend on energy. The water we drink, clean and cook with is electrically filtered, sensed, piped and pumped to us. We even kill each other with energy bombs and guns. Our food is fundamentally energy and from a physics view, everything is fundamentally energy. Yet, we risk our security and well-being by relying on politically charged energy with limited availability and nonrenewable. The shift to more reliable, stable and renewable energy powered systems is necessary because we have created a world where we will not survive without gigawatts of energy at all times. Table 1 below specifies the $CO_2$ outcome from complete combustion and respective heat values of gasoline, coal and natural gas. The kWh is based upon estimates from an average grid system with multiple inputs and outputs in the USA.

| **Type of Fuel** | **$CO_2$ (Kgs.)** | **$CO_2$ (Lbs.)** | **Btu** |
|---|---|---|---|
| 1 gallon of gasoline | 8.9 | 19.62 | 114,100 |
| 1 pound of coal[1] | 1.3 | 2.86 | 14,000 |
| 1 ton of coal | 2,594.55 | 5,720 | 28,000,000 |
| 1,000 cubic feet of natural gas | 54.7 | 120.59 | 100,000 |
| 1 kWh of electricity | .61 | 1.34 | 3,412 |

***Tab. 1.*** *Several standard carbon dioxide and heat of common fuels*

Source: US Energy Information Administration Carbon dioxide ($CO_2$) forms during coal combustion when one atom of carbon (C) unites with two atoms of oxygen (O) from the air. Because the atomic weight of carbon is 12 and that of oxygen is 16, the atomic weight of carbon dioxide is 44. Based on that ratio, and assuming complete combustion, 1 pound of carbon combines with 2.667 pounds of oxygen to produce 3.667 pounds of carbon dioxide. For example, coal with a carbon content of 78 percent and a heating value of 14,000 Btu per pound emits about 204.3 pounds of carbon dioxide per million Btu when completely burned. Complete combustion of 1 short ton (2,000 pounds) of this coal will generate about 5,720 pounds (2.86 short tons) of carbon dioxide (source: Energy Information Administration).

NOTE: It's shocking that so many people graduate from universities energy illiterate. Perhaps this is why we take it for granted or why we do not change our sources fast enough and do little to protect our long-term interests in a sustainable way.

*Combustion*

When I taught and practiced power engineering none of these big picture issues ever emerged in powerplants or boiler room conversations. Improvements were made operationally with new technology that made the work easier for the operators or higher efficiency with better technical calibrations of equipment and systems to save money on fuel or increase the service life of the equipment with better maintenance practices, thereby saving money. I read combustion engineering textbooks that covered a variety of fuels and combustion conditions, systems and processes but nothing about social or environmental outcomes.

*Chemistry of Combustion*

When matter undergoes a chemical change, the same collection of atoms is present before and after the change. Obviously, combustion is a chemical reaction that changes the arrangement of atoms. The law of conservation states that atoms are neither created nor destroyed during chemical reactions. Stoichiometry is the measurement of the elements and it is useful to learn at least some the fundamentals.

When you look at a burning (combustion) reaction, you will find an equal number of atoms on each side of the combustion process. An arrow represents before and after combustion and when you consider how many atoms are inherent to Carbon, Hydrogen and Oxygen for different elements you will find the same amount before and after combustion. The reason I bring this up is that you have more $CO_2$ after combustion by weight on the right side than you have fuel by weight on the left side because it takes approximately 12 time the volume of oxygen to have complete combustion. Hence, seemingly more coming out than going in. But as we can see, the same amount that enters the process, leaves the process. The laws of thermodynamics have many applications to business and economics and we should all learn more about thermodynamics in economics and business curriculum in our universities to fully understand what is taking place.

$$C_8H_{18} + CO_2 \rightarrow CO_2 + H_2O$$

The + sign is read as reacts with and the $\rightarrow$ sign is read as produces.

The world's commercial and industrial economies are largely dependent upon combustion processes. Combustion is the principle cause of new $CO_2$ going back to the beginning of the industrial age. Figure 2 below shows the distribution of $CO_2$ over 1017 years and we see a point of inflection (pointed out by the arrow) at 1779 at 281 ppm, the very beginnings if the industrial age. Measuring $CO_2$ before 1880, is not representative of the trend we see leading up to 2018.

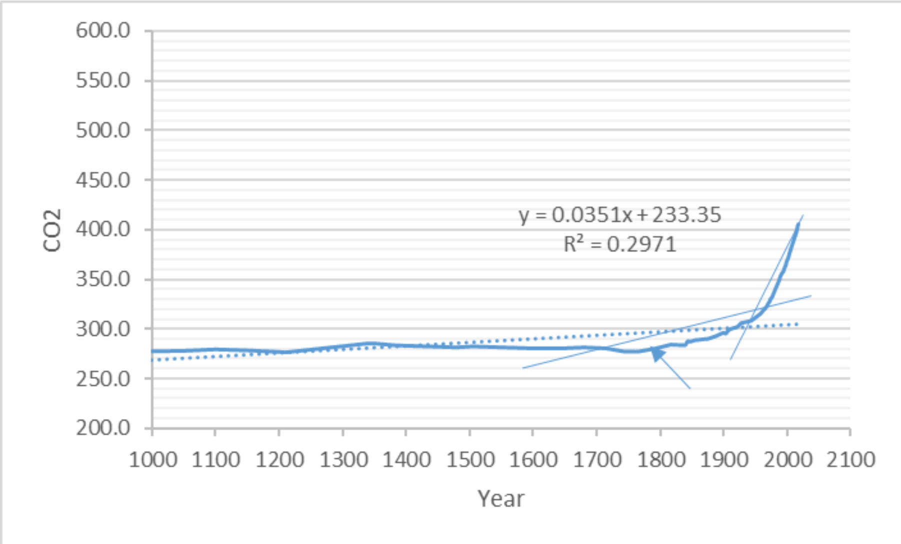


***Fig. 2.*** *Annual observations of CO2 levels going back 2017 years*

In figure 2, we see three lines of best fit (linear systems). The first (dotted) line is over the entire time-period and has a slight positive slope where it's increase is at a rate of .035 ppm for every year passing. The second is where we see an increased responsiveness with a steeper slope and the last line completely departs from the previous behavior with a strong inwardness, suggesting an exponent as most representative of conditions after the year 1800. In my next article we examine nonlinearity.

*Temperature*

We can observe in figure 3 below, from 1880 to 1970, temperature increased but the increase is less than between 1970 and 2017 where it changes slope. In spite of the massive and further increasing heat absorption at the north and south poles and mountaintop icepacks, temperature is escalating, and the escalation is increasing.

Starting from the first point of inflection (responsiveness to $CO_2$) in Figure 2, in the year 1880, figure 3 above begins measuring the distribution of temperature in Celsius annually and it is exhibiting a fairly linear behavior ($R^2 = .78$). As a function of time we see an increase.

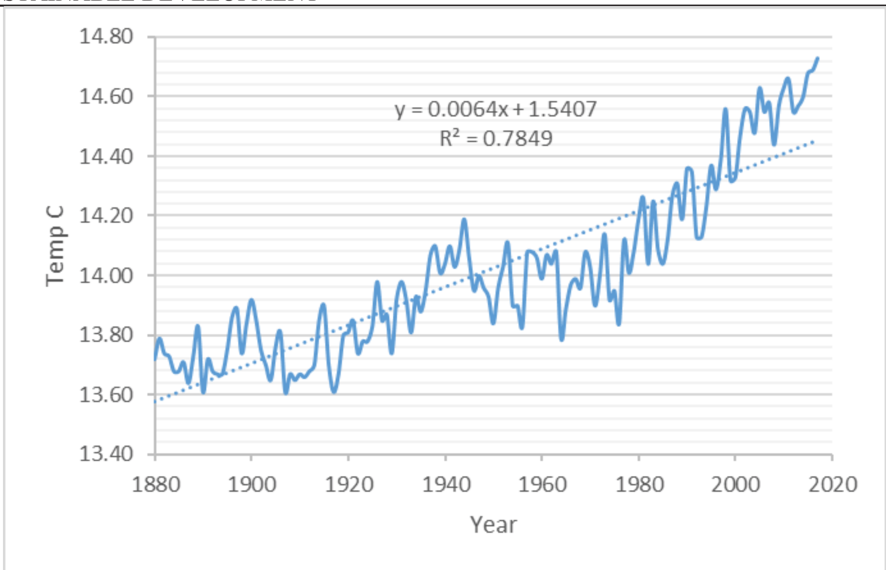


***Fig. 3.*** *Earth's average surface temperature from 1880 through 2017*

## ANALYSIS AND RESULTS

The basic model of analysis is temperature as a function of $CO_2$ and is expressed as:

$$t\ f\ CO_2$$

where *t* is earth average earth surface temperature in C° and $CO_2$ is carbon dioxide in ppm

Below in figure 4 we have set temperature as a function of $CO_2$ starting with the year of 1880 and ending with 2017. Obviously, there is a steady increase in each variable concurrent across the distributions.

Temperature has changed in the past. However, on an entirely different time scale. For example, every 23,000 years there is glacial interglacial cycle attributed to the wobble of the earth at it rotates around the sun. Each annual contribution is 1/23,000 of the entire wobble, so you can easily calculate that the glacial interglacial periods have no association with the warming we are experiencing now because the timescale for the rate of change is exceedingly far apart.

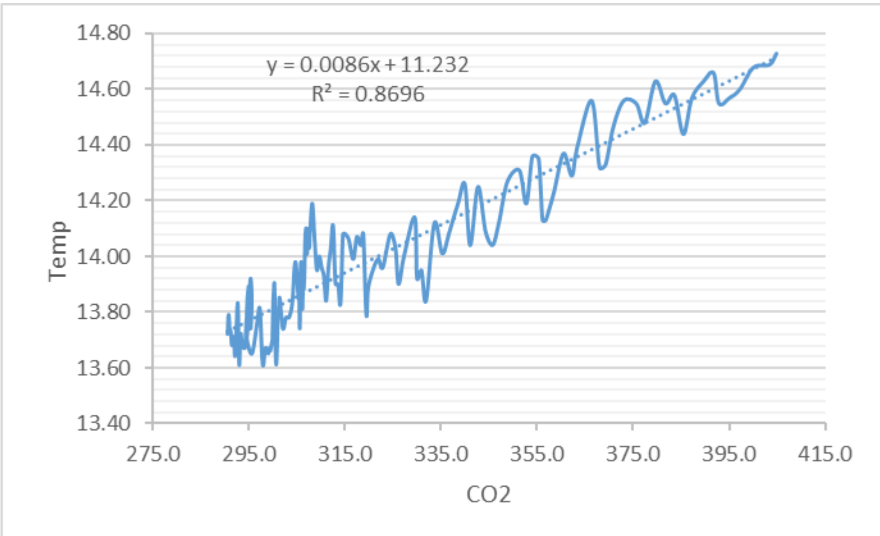


***Fig. 4.*** *Temperature as a function of $CO_2$*

Returning to the trend of the relationship between $CO_2$ and temperature from 1880 through 2017 (table 2), we see a coefficient of about .008 and the significance level (P-value) is essentially zero while a linear system seemingly prevails so prediction may be simplified.

| *Regression Statistics* | | | | |
|---|---|---|---|---|
| Multiple R | 0.932549746 | | | |
| R Square | 0.869649029 | | | |
| Adjusted R Square | 0.868690566 | | | |
| Standard Error | 0.104702223 | | | |
| Observations | 138 | | | |
| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
| Intercept | 11.23221752 | 0.092853263 | 120.9673972 | 2.5171E-140 |
| CO2 ppm | 0.008597292 | 0.000285415 | 30.12203626 | 4.9204E-62 |

*Source: NASA, Goddard Institute, http://www.giss.nasa.gov. and Earth Policy Institute, with long term historical data from Worldwatch Institute, Signposts, CD-Rom (Washington, DC); 1960 to 2017 from NOAA/ESRL, "Atmospheric Carbon Dioxide - Mauna Loa," at www.esrl.noaa.gov/gmd/ccgg/trends/co2_data_mlo.html.*

***Tab. 2.*** *Regression output for earth temperature (C) as a function of CO2 (ppm)*

For every 1 ppm of $CO_2$ there is a corresponding 0.0086°C change in temperature. Almost 87% of the relationship between $CO_2$ and earth's temperature fits the linear model, and the risk of rejecting the null hypothesis when it is actually true is 4.9E-62. However, as we have found again, these more historic distributions and respective findings do not fully represent our current state. Let's examine more current data representative of more recent time, which is at the core of this study.

We have examined the middle slope on figure 2, let us look closer at the final slope on figure 5 that spans from 1964 to 2017. We see that there is a significant relationship between $CO_2$ and Earth's surface temperature but, the latter part of the time series is more representative of our current conditions and the coefficient increased by .001103. Even though we see higher temperature responses to $CO_2$, we have not taken into account the fundamentals of heat with respect to change of state.

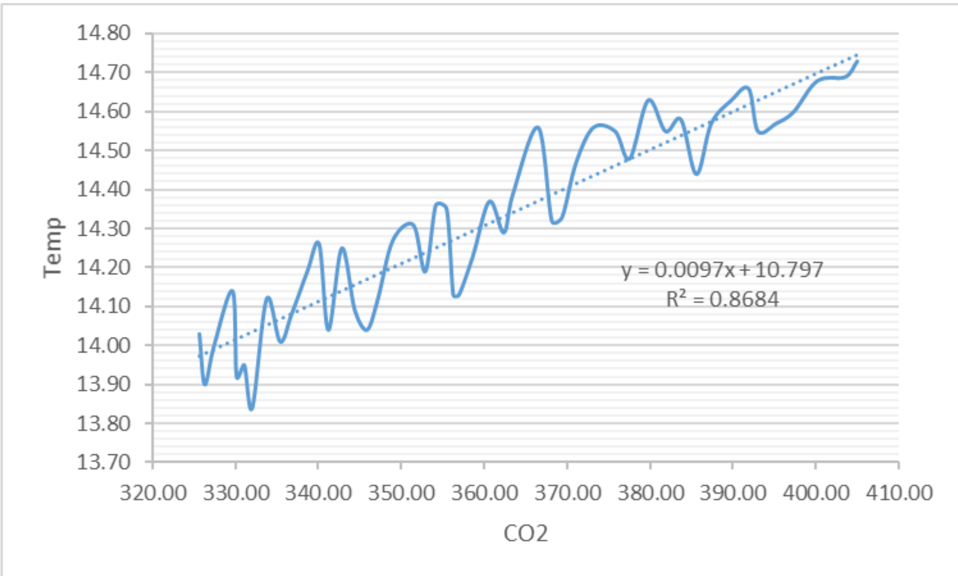


***Fig. 5.*** *Regression model of temperature as a function of CO2 from 1964 to 2017*

**DISCUSSION**

This article was composed to simplify a topic that might be viewed as complex. I am suggesting that people may dismiss or even avoid what they perceive as overly complex. I may assume that everyone understands it and is able to discuss the most salient details but this might be unlikely. It is this sprit I ran a few simple models that are only part of the global warming phenomenon. The stabilization of energy stocks, flows and prices facilitated an acceleration of products and services nationally and internationally, further stressing ecosystems while leading up to the great electrification boom we are witnessing now. Air travel is on the rise and is a significant contributor to emissions. My flight from Chicago to Shanghai used approximately 50,000 gallons of jet fuel and increases my footprint more than all other aspects of my life. As we gear up for electric self-navigating cars, trucks and planes, drone driven warehousing and delivery, furthering artificial intelligence, consisting largely of instructions for electrical and electronic actuation systems, the demand for power is and will continue to increase. Economic decisions and actions are increasingly a function of electrons, not people. At the low end (table 3) of the scale (1.1 to 2.8C CI) we see an apparent disruptive change to ecosystems. Certain corrective actions we take now may circumvent severe negative consequences. For example, at the high end of the table 3 scale (2.6 to 5.9C CI), we see severe catastrophic change that may essentially disrupt water and agriculture systems that impact socio-political systems.

| **2100 Values** | **Temp. Increase Over Preindustrial (90% C.I.)** | | | | **Atmospheric CO2** | | **Atmospheric CO2e** | |
|---|---|---|---|---|---|---|---|---|
| **AU** | 4.5°C | 8.1°F | (2.6°C-5.9°C) | (4.8°F-10.5°F) | 910 | ppm | 1250 | Ppm |
| **INDC Strict** | 3.5°C | 6.3°F | (2°C-4.6°C) | (3.6°F-8.2°F) | 675 | ppm | 860 | Ppm |
| **Ratchet 1** | 3.2°C | 5.8°F | (1.9°C-4.3°C) | (3.4°F-7.7°F) | 635 | ppm | 790 | ppm |
| **Ratchet 2** | 3°C | 5.4°F | (1.7°C-4°C) | (3.1°F-7.1°F) | 605 | ppm | 715 | ppm |
| **Ratchet 3** | 2.6°C | 4.6°F | (1.4°C-3.5°C) | (2.6°F-6.2°F) | 550 | ppm | 610 | ppm |
| **2 Degree Path** | 2°C | 3.6°F | (1.1°C-2.8°C) | (2°F-5°F) | 480 | ppm | 490 | ppm |

*Source: http://climatescoreboard.com and Carbon Dioxide Analysis Center, Oak Ridge National Laboratory, US Department of Energy*

***Tab. 3.*** *Temperature and CO2 ppm estimates for 2100*

## FUTURE RESEARCH

It is possible to circumvent this apparent catastrophe. However, it involves three major changes in how we 1) see ourselves as one surviving populous on Earth 2) design and operate our residential, commercial and industrial economies and 3) accelerate the diffusion of clean energy technological developments. Infrastructure is a principal component of the economy (Zhang 1991) and the scale of intelligent, renewable and more efficient systems requires new infrastructure. Unlike a standard linear model or the normal S-curve (Valente 1995) of the diffusion (cumulative adoptions) of innovations (Rogers 2003), the sudden shift in Earth's surface temperature from $CO_2$ increases over a short period of time suggest that the distribution of clean technology adoptions throughout our infrastructures requires a sudden shift in adoptions (Jacobsen 2007) in order to offset this increasing demand for energy, according to the United Nations (2018) report.

*Nonlinear Global Warming Model*

Nonlinearity is simply when a variable follows a path that deviates from a straight line. It is not often observed in the real world because nature and other systems do not align for our observational convenience. Indeed, nonlinearity is the rule where linearity is actually the exception. The systems we have examined in this article were based upon their linear relationship and largely displayed (see $R^2$) this proportional variation across variables.

The most salient points of nonlinearity occurs at 32 F or 0 C° degrees. Melting ice at the poles and mountain ice pack is as a sudden jump in the heat absorption takes place as white snow-covered ice turns to a very dark or black. Black surface absorbs heat at a much higher rate and an acceleration in Earth's temperature takes place. It requires an additional 144 Btu to melt one pound of ice to one pound of water at 32 degrees F° or 0 C° at atmospheric pressure. Therefore, depending on how many pounds of ice exist (presently, 10 percent of land area on Earth is covered with glacial ice, including glaciers, ice caps, and the ice sheets of Greenland and Antarctica. Glacierized areas cover over 15 million square kilometers or 5.8 million square miles) temperature change will slow at 32 while a change of state takes place but, not all at once. We are actually in a slow period of temperature change while the ice absorbs heat to change state. This is one of the reasons why it is difficult to identify a specific date. One thing is certain however, if we do little to nothing, the time interval between 2035 and 2050 is well past the point of no return.

The rotunda under land and ocean has vast reserves of methane frozen below the seabed. Permafrost, tundra soil frozen year-round covering almost one-fifth of Earth's land surface, runs anywhere from 50 to 600 meters (160 to 2,000 feet) deep. Entombed in that freezer is carbon from plant and animal matter accumulated over a long history. As soil thaws, ancient deposits decompose, attacked by microbes, producing carbon dioxide and when in water, methane. Both are greenhouse gases, but methane is many times more powerful in warming the atmosphere. Therefore, it is suggested to find a better fitting model of the climate change phenomenon. The research model should take into account the thermodynamic properties of temperature change and the change water/ice state while considering heat absorption under conditions of change in $CO_2$ and population. The new model may consider that one varying element rarely mediates 100% of another element and that there are likely to be many varying factors that should be considered when examining the behavior of a single variable and that it is more likely that these relationships are nonlinear than linear. This expanded view is the basis of systems thinking. Most scientists look at the world in this way but now the manager, business person and worker should have a sense of causality such that connections between elements may have feedbacks that accelerate or slow a given process, that small movements in one place may result in sudden dramatic shifts somewhere else and that critical values exist in self organizing systems. Indeed, I will be developing this kind of model in a companion article.

*In Conclusion*

While sustainability may mean many things to many people, everyone seems to agree that when you sustain something you are making it last. By this simple concept we must consider ecosystem longevity. However, growth in the economic since, is the increased physical scale of matter/energy that sustains economic activity such as production and consumption indefinitely. Although in economics, consumption is a misrepresentation because products are never consumed, they lose quality and/or degrade to a less useful state. There is no real consumption or production of matter/energy in the physical sense, output is really a process where low entropy materials are transformed into products and when spent, the matter/energy is reused somewhere else and the rest is high entropy waste. Production starts out with depletion and ends up with pollution while growth is the quantitative increase in the physical scale of production, so to speak (Daly, 1996). The qualitative improvement in the physical transformation process is a result of technology and/or understanding of the purpose of the transformation and this is referred to as development. ***Sustainable development is really an action resulting from a deeper understanding of technological processes over the long run.*** Nonetheless, no matter how we use resources their sum remains constant as it is explained by the law of conservation of energy and matter (Jacobsen 2010). Our most salient global problem is that combustion obeys the laws of thermodynamics (Jacobsen 2010). Therefore, the only solution to the problem is the international diffusion of conserving, efficient and renewable energy technological advances.

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***Якобсен Дж. Дж.***

## Узагальнена модель глобального потепління

*Як стаття, що розпочинає видання журналу «Бізнес, економіка, сталий розвиток, лідерство та інновації», цей короткий рукопис розглядає та аналізує світову людську популяцію, СО2 та глобальні температури. Перший розділ присвячено дослідженню динаміки чисельності населення, аналізу історичних, поточних та майбутніх прогнозів, що складені Організацією Об'єднаних Націй (2017). Другий розділ розглядає економіку, зокрема, фізику горіння, що підтримує економіку, і глобальні викиди СО2, а також флуктуації їх в часі. Третій розділ присвяено дослідженню глобальних температур. Стаття закінчується пропозиціями щодо майбутніх досліджень в області нелінійного моделювання зміни клімату та прикладних досліджень у поліпшенні енергетичної системи та політиці уникнення кліматичної катастрофи.*
***Ключові слова:*** *зміни клімату, СО2, населення, вдосконалення енергетичної системи.*