Who am I to talk about climate change?

My name is Phil Beauchamp. I graduated from the University of California at San Diego, in 1971, with a bachelor's degree in Chemistry. I entered the United States Army in 1971 and served for 3 years. After the Army I attended Cal Poly Pomona, graduating in 1977 with a master's degree in chemistry. I then attended University of California at Irvine, where I obtained my Ph.D. in organic chemistry in 1981. That same year I obtained a tenure track professor position at Cal Poly Pomona, where I taught chemistry for 31 years, officially retiring in 2012. While at Cal Poly, I was in charge of the Nuclear Magnetic Resonance (NMR) instrument for about 25 years (NMR is similar to MRI used in medicine). NMR uses the radiowave region of the electromagnetic spectrum to study the structure of organic and biological molecules. The electromagnetic spectrum divides energy waves according to energy (x-rays > ultraviolet (UV) > visible > infrared (IR) > microwaves (μ) > radiowaves). Three of these, UV, visible and IR, are often included in discussions about Climate Change. Throughout my college career my main research focus was on determining the chemical structure of natural compounds isolated from plants by my colleague, Vasu Dev, using spectroscopy (NMR, IR and MS). Even though retired, I still continue to teach organic chemistry at Cal Poly half time, and I have 2 courses in the fall 2019 semester with 230 students.

About 4 years ago I read my first book on climate change (CC) and immediately became concerned about this subject. The more I read, the more concerned I became. I recently finished my 36th book on climate change and I am convinced, as a scientist, that this is as important to the future survival of the human race as controlling nuclear weapons and bioterrorism.

I wrote the" Oreo Parable of Climate Change" for a high school science teacher friend to introduce Climate Change and science to her students, which she shared with fellow teachers. It seems to work as a good introduction for Climate Change and gets the conversation going.

At the end of the document below, I introduce the Citizens Climate Lobby (CCL) who proposed a bill before Congress, House Resolution 763, that would add a carbon tax to fossil fuels sold in the United States ($15 / ton of carbon dioxide equivalent in the first year). The money collected would be redistributed back to all Americans equally (it works out to about $350, or so, for each person). The goal is to incentivize the rapid reduction of fossil fuels and switch to alternative sources of energy. This short document merely serves as a brief introduction to a very serious problem for the future of earth. You, and your family, are part of that future. Join a chapter of the CCL in your area to better understand this problem and be part of the solution. Thanks for reading.

An Oreo Parable of Climate Change

Phil Beauchamp

Energy is something every life form needs, every moment of every day. Humans get our energy by eating food and combusting it to carbon dioxide and water. Eat too few calories and you are underweight; eat too many calories and you are overweight. To completely determine what your calorie requirements are, you could keep a log book of your daily activities and what you eat.

Let's say you wanted to figure out what were your daily calorie needs, so you could live a healthy life. To determine this scientifically, you would have to start keeping a record of every type and precise amount of food and drink you consumed every day to know exactly how many calories went into your body. As a good scientist, you might want to consider additional variables such as how much protein, carbohydrates, fats, vitamins, minerals and fiber you consumed, but for this parable let's go with just the calories. You would also have to keep a record of all of your daily activities every day to know how many calories you burned. In other words, you would have to become a scientist and collect a lot of data over an extended period of time.

So many factors make it all sort of complicated, so you might need to do different versions of this experiment, limiting the variables in any one experiment. A single day's worth of data would not answer the question. Even one week of data would not be enough, because of natural fluctuations that occur in life. How much water do you drink, how much sweat do you lose, when do you go to the bathroom and what time of the day is it? Did you weigh yourself when you woke up or after a meal, with your clothes on or off? Is it a holiday celebration or a busy workday? As you can see, there are many variables. That's the way it is in most science experiments. It's not like flipping a coin and seeing heads or tails.

Let's say you started off with a healthy weight of 130 pounds and over a few months determined that your body requires 2,000 calories per day. You limit yourself to 2,000 calories a day for an entire year, and faithfully keep your same exercise schedule. To your great delight, your weight doesn't fluctuate a single pound. You have used science to improve your life.

One day a "friend" introduces you to Oreo cookies. You love them and start eating 1 Oreo cookie every day as a treat. Somehow you avoid the temptation of binging on an entire pack of Oreos all at once. In case you were wondering, an Oreo cookie has about 50 calories, so now you are eating 2050 calories per day. This doesn't seem like a big deal because 50 calories is hardly anything. Just in case, you do the research and find that 1 pound is about 3500 calories (borrowing

research data of other scientists). How long would it take to gain 1 pound, and really, who would even notice a single pound? This turns out to be a simple calculation. It would take (3500 calories/pound)x(1 pound)x(1 day/50 calories) = 70 days, and you wouldn't even notice if you did gain 1 pound.

A year goes by and your Oreo a day becomes an entrenched habit, and you are 5 pounds heavier. You have to loosen your belt 1 notch, but still nothing to worry about. Your habit continues, and suddenly, it's 10 years later and you are 50 pounds heavier. You notice downsides of the extra weight: diabetes, heart disease, high blood pressure and you get tired more easily. Yet, it was just one little cookie a day that got you into this potentially life-threatening situation.

You know what should have happened. You could have eaten 50 calories less in your daily diet, or you could eat 350 calories less one day a week, or you could exercise 50 extra calories every day. There are lots of ways you could have modified your lifestyle to eat the 1 Oreo a day and still maintain your healthy weight, if you understand the energy inputs and outputs.

If you did happen to find yourself 50 pounds overweight, you would have (50 pounds)x(3500 calories/pound) = 175,000 calories to lose. You couldn't lose that weight in a day, a week or a month. If you completely quit eating, and still had a basal metabolism of 2,000 calories per day, it would take you about 87 days to lose 50 pounds. That's almost 3 months of starvation.

Of course, when you starve yourself, your body slows its metabolism to try and keep you alive. This means it would actually take longer to lose the weight because the calories you burn goes down. Also, during starvation your body starts to break down protein to maintain glucose levels so your brain cells don't die. If part of the protein comes from your heart, it might stop beating and you would die. Starvation is a very poor strategy to achieve a long term healthy lifestyle. On the other hand, if you cut out 500 calories a day, it would take about one year to lose the 50 pounds. That means no cheating, every day for a year. You would need discipline of steel, but it would be worth it to get back to a healthy weight and lifestyle, where you want to be.

The Oreo Parable was deliberately written to postpone discussing the darker realities of Climate Change. I have read 36 books on Climate Change, and the path we are on can get us down. Not many people want to consider the consequences of going down this path, which is why I wrote the Oreo Parable as a gentler introduction to Climate Change.

This simplistic parable captures what we are doing to our world, using an everyday problem many of us have struggled with. "Discipline of steel," that's what's needed to address Climate Change. Fossil fuels (coal, oil and natural gas) are the Oreos and carbon dioxide is the calories. Carbon dioxide has become the poster boy for Climate Change, but it does not work alone. Water, methane and other greenhouse gases are important accomplices in causing Climate Change.

It is good to have concern about the future, but to act on that concern, there needs to be hope that we can change what we are doing. Climate Change sounds an alarm that calls us to action to save our world. It is up to us to answer that call. Future generations will thank us.

Carbon dioxide is a trigger that starts a lot of other balls rolling as it increases its concentration in the atmosphere. Carbon dioxide in the atmosphere absorbs infrared energy (heat), which, in turn, warms the air and water. Water is also a green house gas and when the oceans warm, the vapor pressure goes up and there is more water in the atmosphere, which also heats the atmosphere. We need some of this heat to have a livable world, but too much is a problem.

As humans we tend to think in hours, days, weeks and months, but Climate Change requires that we think in decades, centuries and millennia to understand what is happening. The geological records tell us that CO2 and temperature have risen and fallen many times over millions of years for a variety of reasons, continually changing the climate on earth (Milankovich cycles, volcanoes, rapid growth of various life forms, deforestation, ocean currents, plate tectonics, etc.),. When CO2 levels are higher, the earth gets warm enough that tropical jungles can grow at the poles. When CO2 levels are lower, the earth gets cold enough that glaciers extend over most of earth (called 'snowball earth'). Over the past few million years the temperature difference between hottest and coldest has only been around 10^{o}C (18^{o}F). Humans' use of fossil fuels has raised the earth's temperature about 1^{o}C in the past 200 years and an additional 1-4^{o}C increase is predicted in the next 100 years based on how fast we are adding CO2 to the atmosphere.

About 12,000 years ago, climate hit a sweet spot for Homo sapiens (us). CO2 levels were about 280 ppm and the average temperature was about 15^{o}C (59^{o}F). That gave us a window in time to become what we are today. We changed from hunter-gatherers roaming the earth, to living in

communities with shared responsibilities that allowed us to invent agriculture, domesticate various animals, develop language, writing, religion, culture and more. We had time to think and create, ultimately becoming what we are today.

The levels of CO2 remained relatively constant at 280 ppm throughout this period, until about 1770 when James Watt invented an improved steam engine by using coal as a magical source of energy. Burning coal makes CO2 and H2O, which is added to the atmosphere. Over the next 215 years CO2 levels increased to 350 ppm in 1985, an increase of about 70 ppm (an average increase of 0.3 ppm/year). Along the way, we added oil and natural gas as additional fossil fuels. Since 1985 we have increased our use of fossil fuels, and in 2019 CO2 levels hit about 415 ppm, an increase of an additional 65 ppm in only 34 years (an average increase of 1.9 ppm/year). This past year CO2 levels went up over 3 ppm in 1 year, the largest increase on record. Multiply that out by 10, 20, 30, 40, 50 years and you can see where we are going. We need to completely stop, but instead we are speeding up.

A warmer earth melts ice and warmer water expands, both of which raise sea levels. Rising sea levels causes flooding of coastal cities and island states; corrupts fresh water tables and rice growing deltas with salt water; and alters migration patterns and habitat conditions of animal and plant life. Sadly, loss of animal and plant diversity has already occurred. Extinction rates are running over 100 times the usual rate.

Extra CO2 also dissolves in the oceans and has already increased their acidity by 30%. Continuing increases in acidity are endangering coral reefs (0.1% of the area of the oceans), which harbor about 25% of all marine species in the oceans, an important source of food and diversity for a rapidly increasing population.

Droughts, fires, flooding and storm events are becoming more severe. This impacts food production and land use around the world at a time we desperately need more food. It can also cause human migrations of millions of people, as recently occurred in Syria. Some estimates exceed 100 million people forced to migrate in the coming decades. Many other consequences follow from these changes, but are not fully discussed here.

In fact, we have reached a point where even a decade is too long to delay action. We need immediate simple steps to get started, and then hope that those steps will inspire further action to reduce the more extreme consequences of Climate Change. There are many realistic options, and we have to figure out ways to move them to the top of our “to do” list.

When I talk to people about Climate Change, I find all kinds of responses. Some people are passionately working for solutions (see CCL topic below). Some people are very concerned and wonder what we can do to help. Some people believe CC is real, but they don't think they can find time in their busy lives to offer help. Some people are curious and want to know more because they haven't thought much about it. Some people are very fearful and don't want to think about it because it increases their anxiety and/or makes them depressed. Some people don't want to think about inconveniencing their comfortable lifestyle, so CC is best kept out of sight and out of mind. Some people are hostile and angry about CC and unwilling to listen. They challenge every fact with an argument about why it is not true, despite abundant scientific evidence supporting CC.

There are good reasons why people don't want to hear about CC. It is a complex and multifaceted subject that has been studied from every angle of science and other disciplines. CC involves geology, physics, chemistry, biology, psychology, economics, computer science and especially politics. The message of CC is alarming. CC requires self sacrifice, societal sacrifice and a radical change in our way of life. The problems of CC are so big that corrective actions taken by one person are too small to have any significant impact, and they are so slow (on a human time scale) that we don't believe anything is really happening. So we think, "Why bother?"

What is actually required is a concerted world-wide effort, from all of us, to eliminate the primary uses of fossil fuels as rapidly as possible. Unfortunately, fossil fuels also happen to be the life blood of modern society. Remember in the Oreo Parable, starvation wasn't a good strategy. We need a plan that sustains our way of life, while it rapidly reduces our dependence on fossil fuels.

We all know how hard it is to change an ingrained habit. The habits of fossil fuels are buried so deeply inside of us that they occupy every part of our being and the societies we live in. Also, changing the infrastructure supplying our energy is super expensive, and very inconvenient. It will take a considerable amount of time (some estimates are 3 decades) and will power to transition away from fossil fuels. We hope we have the will power, but time is something we don't have much of to make the monumental changes necessary.

Four decades ago, we could have adopted a more reasonable schedule of change, but that time has passed. The fossil fuel industry deliberately misled us, telling us there wasn't really a problem to confuse the issue in order to prevent change and continue their cash flow. We were content to believe them to continue our comfortable lifestyles. Now it's crunch time. We don't have a moment to delay, because the effort needed is so great. So what do we do?

First, we need to believe there are real solutions and acquire an optimism that gives us the energy to work towards those solutions. Fortunately, there are several alternatives for renewable sources of energy and we need to take advantage of them. The most commonly discussed are listed below, but this list is not exhaustive.

1. Biomass is organic material from plants and animals. Because it was living material, it is part of the carbon cycle and is in equilibrium with Nature. When it is burned, it returns the carbon dioxide that it took from the atmosphere, so no new carbon is added, it's just recycled. Biomass could come from wood waste, agriculture crop waste, food waste, animal manure and human sewage waste. It can be burned or converted to biofuels. Corn and sugar cane are currently used to make ethanol as a gasoline additive. However, the energy used to grow them, process them and transport them is just about the same as the energy they provide, so they don't really provide "extra" energy. Microorganisms (algae and bacteria) are being genetically engineered to make organic molecules used for fuel or petrochemical products and they require much less land, but we still have to feed them. These are small contributions that won't solve our energy problems, but they contribute towards a solution.

2. Hydropower is one of the oldest renewable energy sources that generates electricity. It uses water and the energy of gravity to turn massive turbines that produce electricity. In 2018, hydropower supplied 7% of the total utility-scale electricity and is currently the largest renewable energy source in the US. It's relative percent contribution has dropped over time because there are other alternatives that have grown and expanded. Most hydroelectric dams are built on large rivers which limits their future growth. Almost all of these power plants were built before the mid 1970s. A combination strategy is to use wind or solar to generate electricity, to pump water up into a reservoir that can then be used like a giant battery to allow the water for flow downhill to turn the turbine. There are certain to be other strategies to use hydropower, if we do the research.

3. Geothermal heat can be used to heat buildings, heat water for bathing or to boil water. It can also run turbines to make electricity or store it in hydroelectric 'batteries' (reservoirs). Geothermal uses heat from the earth's mantle, where temperatures range from about 400^{o}F in the upper boundary to $7{,}200^{o}$F at the mantle-core boundary. It is renewable because the earth's core is always giving off heat. Geothermal is limited because conditions have to be just right to capture this energy (location, depth to drill, etc.).

4. Wind is caused by uneven heating of the earth's surface. During the day, land tends to heat up faster and expand pulling in air from the ocean. At night, land tends to cool faster and the winds tend to reverse. Mountains, valleys and plateaus are other variables to be considered. Today, wind energy is used mainly to generate electricity, although windmills have been used for centuries to pump water out of the ground, and are still common on farms and ranches. The cost of wind electricity has dropped so much and so fast that wind is passing up coal as a source of electricity. Some people object to the large wind mill blades that can kill large bird species. However, CC, itself, threatens the survival of many life forms on earth. If fossil fuel subsidies were eliminated (globally estimated at $1-5 trillion), wind energy could easily compete with fossil fuels. One down side is that the wind has to be blowing for electricity to be generated. If

large storage batteries (or hydroelectric reservoirs) can be invented, excess electricity generated when the wind was blowing could be stored to use later.

5. Solar energy has probably been used for as long as humans have walked the earth. It can be used to dry clothes, heat a home or a green house, heat water for bathing or swimming pools, send messages or start fires using reflective surfaces, and more recently, for generating electricity. Solar photovoltaic devices change sunlight directly into electricity. They can also power smaller electronic devices, like lights, clocks and calculators. Arrays of panels can supply electricity to an entire house or cover many acres to supply 1000s of homes. Of course, solar only works when the sun is shining. That will depend on the time of day, the weather and the location of the solar cells. A large surface area is needed because the light energy reaching the earth is small. Large batteries or pumping water uphill into a reservoir are ways to store energy for when the sun is not shining. Research on these possibilities is on-going, but needs to be accelerated. The price of solar has fallen so much and so fast that it has become competitive with fossil fuels, without the FF subsidies.

6. Hydrogen fuel cells have the potential to solve some of the biggest energy problems, ranging from buildings to transportation. Hydrogen, H2, is the most abundant element in the universe and there are tremendous reserves bound up in water, H2O. Water electrolysis can generate hydrogen gas and oxygen gas from water, and could be run using solar or wind electricity. Bacteria have been making hydrogen since life began. We may be able to improve bacteria's hydrogen producing properties using genetic engineering. Hydrogen combustion is clean, the oxidation product being water, and it has high energy content. No carbon dioxide is produced. Hydrogen fuel cells can be used in a variety of applications. Fuel cell electric cars are somewhat similar to gasoline vehicles and can have a driving range up to 300 miles and be refueled in minutes. Several states (CA, HI) and countries (Japan and Germany) already have refueling stations, but we would need to build out the infrastructure to support hydrogen fuel. There are several problems to be worked out, but hydrogen has a promising future, if we do the research.

7. Nuclear must be considered. In 2016 there were 99 commercial reactors in the United States. They supplied 19.7% of our total electricity, 60% of emission free electricity in the US. The US supplies 33% of the world's nuclear energy. Nuclear power plants have a lifetime of around 40 years. Nuclear does not emit CO2 except in the construction, mining, transport and storage processes. Building plants is very expensive, but maintenance and production costs are not. Modern plants are safer and do not depend on external electricity or water supplies for cooling. Reactors can be installed underground for additional security. Uranium is not considered a renewable resource, but Plutonium can extend the lifetime considerably and thereby make less hazardous waste (100s instead of 1000s of years). Three names elicit alarm: Three Mile Island, Chernobyl and Fukushima. These past disasters should be compared to continued use of fossil fuels. In 2010, alone, it estimated that 4.5 million deaths were attributed to fossil fuel pollution worldwide, mostly due to coal, while in comparison, 9,000 deaths were attributed to Chernobyl. Probably the strongest arguments against nuclear are terrorism and storage of waste products that can last 1000s of years. Considering that Climate Change also has the potential to alter the course of civilization forever, we should consider using nuclear energy in the mean time.

8. Energy conservation reduces fossil fuel needs. We can adjust daily errands to make a single trip, turn off lights and appliances when not being used, hang dry clothes when possible, use LED light bulbs, use smart power strips, use a programmable thermostat, use energy efficient appliances, use less hot water, insulate the hot water heater and turn down the thermostat, weatherize our homes, use energy efficient windows and upgrade our heating and air conditioning systems. Not only will we save money, we will help protect the environment. On an individual scale, the energy savings are small, but serve as an act of commitment to save our earth. On a global scale energy savings can be significant.

Despair, confusion and apathy prevent change and encourage modes of thinking that lead us to believe that the problems we face are unsolvable and therefore that nothing we do matters. The fossil fuel industry has been fostering such attitudes for 40 years to prevent any progress towards alternative energy sources. For our own survival, and that of the rest of life on earth, we need to shut them down.

What we really need are solutions in order to increase optimism and activate participation by individual citizens. An optimism that is neither foolish nor silent can be revolutionary. Real solutions are available, as mentioned above. We need to take full advantage of them to change our world for the better. Belief unleashes the power of people to act from their highest principles. Belief provides an energy born of hope. Shared belief in a better future can unify us and create an explosive political force of change.

CCL and H.R. 763

Citizens Climate Lobby (CCL) is a nonpartisan organization having over 540 chapters spread throughout the United States and the world. The CCL was founded in 2007 and has proposed to create a revenue neutral carbon fee and dividend. CCL is working to get a carbon dividend bill passed in congress, House Resolution 763. This bill offers a first step at reducing our use of fossil fuels. Participation in CCL promotes awareness that can lead to understanding, belief and the political will to make a difference in CC. Participation only asks that you share with family and friends, and lobby your congressional representatives with letters, calls and emails.

H.R. 763, introduced on 1/24/2019, is called the "**Energy Innovation and Carbon Dividend Act of 2019**." It imposes a fee on the carbon content of fuels, including crude oil, natural gas, coal, or any other product derived from those fuels that emit greenhouse gases into the atmosphere. The fee is imposed on the producers or importers of the fuels and is equal to the greenhouse gas content of the fuel multiplied by a carbon fee rate. The rate begins at $15 per ton of

CO2 equivalent emitted in 2019, and increases by $10 each year (see calculation below). The fee is subject to further adjustments based on our progress in meeting specified emissions reduction targets (it goes down if we make progress in reducing fossil fuels).

The bill also imposes a specified fee on fluorinated greenhouse gases, which are present at much lower levels, but are 1000s of times more intense infrared absorbers. The bill has exemptions for fuels used in agriculture and the Armed Forces.

There are rebates for facilities that capture and sequester carbon dioxide (hard to do right now, but maybe possible with more research). There are border adjustment provisions that require fees or refunds for carbon-intensive products that are exported to or imported from countries that do not have carbon pricing mechanisms (this forces nonparticipating nations that trade with us to share the costs).

The fees are deposited into a Carbon Dividend Trust Fund and used for dividend payments to U.S. citizens and lawful residents, minus a fee for administration expenses. This would reward those who conserve and penalize those who waste fossil fuels. The bill also suspends the current regulations that limit greenhouse gas emissions unless the emission targets established by this bill are not reached after a specified time period.

A bill such as this impacts every part of our market economy and would ensure that every person is participating in efforts to reduce Climate Change and to be a part of saving our world. Again, if you want to participate, share your concerns with family and friends and write to your Congress person and Senators to encourage passage of this bill.

Finally, **H.R. 763** proposes that all existing subsidies of fossil fuels, including tax credits, be phased out over the 5 years following enactment. We shouldn't be giving money to industries that have been deliberately misleading us for decades, thereby helping us get into this situation.

Sample Calculation

H.R. 763 proposes to charge $15 per ton of CO2 equivalent and raise that by $10 per ton in each subsequent year. The fee would continue to rise until the total CO2 equivalent emissions have been reduced to 10% of US CO2 emissions in 1990. Last year 7 gigatons of CO2 were released into the atmosphere by the United States. For the whole world it was almost 40 gigatons of CO2 (giga = 1 billion). An approximate calculation for the first year fees would generate (7×10^9 tons CO2) x

($15/ton) = $105,000,000,000 ($105 billions). Dividing that amount among the 250,000,000 adult citizens comes out to $420 per person (minus administrative expenses).

The fees would be levied on fossil fuel sellers based on how much fossil fuel they sold, presumably raising the costs of products sold and passing the costs on to the consumers. Those buying products using lots of fossil fuels would pay more money. Those purchasing goods using less fossil fuels would pay less money.

Each year there would be an additional $10 per ton, which adds a total of $70,000,000,000 ($280 per person), assuming CO2 emissions stay constant. Of course, we hope CO2 emissions will actually drop.

Using the assumptions above, constant CO2 levels would make the 'per person' second year total $700, $980 in the third year, $1,260 in the fourth year and $1,540 in the fifth year. Those amounts would go down if fossil fuel use actually declined. The goal is that at some point the incentive to cut use of fossil fuels will become strong enough to reach the goal of reducing fossil fuels to 10% of the 1990 levels. Remember, those dividends would go to all citizens equally.

The main reason to do this is to rapidly change our thinking and our habits. Instead of being paralyzed by fear and apathy, we will become energized by hope and belief in a better future.

Please feel free to share this document if you feel others may be interested in knowing more about CC and save our earth.

Link to Citizens Climate Lobby (CCL)
https://citizensclimatelobby.org/

Bipartisan carbon fee bill (CCL)
https://citizensclimatelobby.org/carbon-fee-bill/

Link to House Resolution 763
https://www.congress.gov/bill/116th-congress/house-bill/763

Here’s a picture of most of the CC related books I have read.