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Saint Greta and Climate Change Problem

=== 1. Why? ===

Any major event triggers three informational echoes.

The first is the soonest to arrive yet is the least meaningful. It is prompted by immediate emotions such as fear, empathy, or anger. Its dirty tid engulfs the Internet for days, obliterating the very possibility of a thoughtful discussion. Often it carries quite ridiculous ideas. Such that banni plastic straws or switching to biodegradable plastics would slow down climate change (it's the opposite). Or that personal sacrifices like drivin less would help (a tiny, barely measurable dent at best). Or that switching to a Tesla would reduce carbon footprint (it will, but only about as much as switching to a Prius).

Next comes the Critiques wave. It spans weeks and is made of responses generally more skeptical and analytical. These people point out -- usually rightfully -- inconsistencies and controversies within the event that prompted the frenzy, as well as of the first wave. In our case, they would say that sailing a yacht while hiring other people to cross the ocean on a plane isn't really a showcase for reducing CO_2 emission. Or tha making "personal sacrifices", if taken at blatant face value, should start with avoiding aluminum, not living in buildings made with steel and concrete, and generally abandoning the produce of modern farming. Often, based on such observations, they would dismiss the initial event a rubbish, and brand everyone who continues talking about it as idiots. This is quite wrong though, at least in the Greta's case -- because, no matter how childish her presentation was, the problem behind it ***is*** real.

After that wave slumps away, a third and fainter one might present itself to a careful observer. It speaks with voices of people who try to look problems from all sides and consider all constraints, even mutually contradicting ones. Normally they aren't very audible. But, disturbed by no and persistence of the first two waves, they may start looking at the issue. And ***that*** is the value of what Greta did. By stirring the pile of emotions and opinions, she triggered, indirectly, the thought process of elaborate and careful thinkers.

Some of these people are called in when CEOs and presidents need to develop their own position (rather than convince someone else) on a problem. What would those people say? Disclaimer: I am ***not*** one of them. But I can try to make an educated guess. And I hope that, while are reading this, a dialog like the below is unfolding somewhere on our planet...

=== 2. A Strange Conversation ===

The President (**P**):

- Tell me please, is CO_2 concentration in the atmosphere truly growing?

- Yes, Mr. President, it is growing. Anyone with $200 can buy a detector, measure the current concentration and compare it to the values printe in the books of 1950s.

P:

- And what about climate change?

A:

- Mr. President, with the amount of CO_2 currently in the atmosphere **some** temperature rise is inevitable. This happens via a simple greenhous effect. Every graduate atmospheric physics student can estimate the size of that effect at roughly +1 C degree using basic textbook physics. On does not need a pile of scientific evidence for that. Calculations of this kind also work for atmospheres of Mars and Venus.

P:

- So how can that be dangerous? After all, if the temperature increases by one degree, our country would seem only to benefit.

A:

- Mr. President, the primary danger is not that one degree from the greenhouse effect. The primary danger is in feedback loops. We cannot predict how they would respond to such a ***rapid*** climate change, which has not been known to happen so fast in the Earth's history yet. It m be that the temperature would change way further than comfortable +1 degree.

P:

- Feedback loops? What are they?

A:

- For example, increased temperature accelerates organics decomposition in soil and swamps. That results in more CO_2 entering the atmosphe and thus even more warming. Through this effect, the warming self-enhances. That is called a positive feedback loop.

As an example of a negative feedback loop, consider that hotter weather means more water evaporation hence more clouds hence more reflection back to space, hence a negative push on the temperature.

There are at least dozens of such loops. Of many, we simply are not aware. Other we do recognize but predicting their response with the required precision is a very challenging task. We don't really know where the combined effect of all of them would take us. Effectively, we are betting on a roulette. Maybe nothing would happen. Or maybe nothing would remain of our civilization in 100 years. It is a gamble.

P:

- Suppose we lived in an ideal world, where a coordinated action could be achieved with all other Big Countries. What could we do to prevent the disaster, then?

A:

- Mr. President, providing such an advice is impossible without considering political matters, which would exceed the scope of my responsibilit However, if you ask, the only thing I beg you **NOT** to do is to try to reduce CO_2 emissions now.

[Several jaws break wide open. The assistant nearly trips over the carpet. You can almost ***hear*** everybody in the room thinking: 'Did he lose mind???']

A:

- Mr. President, before you decided that you misheard me, or that I lost my mind, let me repeat that we should **NOT** focus on reducing CO_2 emissions. Not at least as the ***primary*** goal. If you give me three minutes, I would be happy to explain.

P:

- Go ahead, please.

A:

- Let me start by stating that CO_2 is produced by multiple and very different industries, with none of them alone contributing more than a quarter of all emissions (https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data#Sector).

Suppose we focus on just one industry -- say, transportation -- and completely cut its CO_2 output. That'd suppress CO_2 flow by 14%. What happens next? Other industries will keep growing as they have been in the past. At the current pace, they will take back that 1.14x CO_2 reduct in a matter of just a few years. After that, we'd be back at the original problem.

Therefore, it does not make sense to focus on any ***one*** industry.

What if we cut CO_2 across all of them?

If we do that by simply scaling them back, we'd cause an irrecoverable catastrophe far surpassing the Great Depression or the demise of the USSR. Millions of people will starve out across the world if agriculture production (crops and livestock) diminishes. Yet agriculture is responsibl for 24% of greenhouse gas emission. Industry contributes another 21%. A large part of it is cement, aluminum and steel production, which provide the basis for most construction, machinery, roads and bridges. Cutting it would be a disaster. The situation is virtually the same across most industries. Scale something back -- and people will start dying. While ***some*** of the CO_2 we make supports luxury, most of it serves basi living needs.

Thus, it seems that we need not just cut CO_2 emissions across all the board but do that in such a smart and creative way as not to reduce corresponding industries outputs. But those are ***very*** diverse industries. To do so, we would need 2-5 breakthrough inventions completely changing the shape of our civilization, and we'd need them on a very short term. Given that it took decades of R&D to come up with what we have today, the task appears unfeasible.

Yet there is probably one way out of it. Fortunately, we do not need to re-invent ***all*** industries. It is enough to reinvent only one of them: energy production.

Suppose we had a way to increase the current energy output by a factor of 10x, without hurting the environment proportionally and without relying upon fossil fuel. How that ability could be utilized?

First and most importantly, it would enable CO_2 capture from the atmosphere. Today, we obtain 1 unit of chemical energy per 1 kg of CO_2 fron burnt fuel. If we were to capture that CO_2 and tie it chemically into something non-volatile, we'd have to spend energy. Since that would also require a chemical reaction, it would cost, roughly, the same 1 unit of energy. Thus, today permanent CO_2 capture is a (nearly) net zero proposition. But if our energy budget grows 10x, spending 10% of it on correcting past mistakes would not sound like too much of a tax.

Second, it would enable advances in many industrial technologies. For starters, one does not really need carbon to make Iron. It's just the mos convenient way in use today. With abundance of cheap energy, one can simply heat ***any*** ore enough for it to decompose into the elements a collect them as the output, be that Iron, Aluminum or Praseodymium.

Smart people may notice that making 10x more energy would warm up the planet by a direct action, with no CO_2 involvement. True, but by a mere 0.25 degrees. That is much better than what we are facing now.

But to develop a new energy capability, we must not undermine industrial, scientific, and energy potential we have today. Instead, we should apply it at full force to make a breakthrough in energy generation.

There is at least one historical precedent when a country, faced with environmental threat, made a leap forward instead of scaling back, and won. I am talking about the United Kingdom and their deforestation problem (https://en.wikipedia.org/wiki/Forestry_in_the_United_Kingdom#Background).

At the break of 1100 AD, 15% of UK was covered with woodland. Then that forest started being rapidly consumed for firewood, industry, construction and, most importantly, fleet. By 1900, their forestry area shrank to a tiny 5%. I'm sure there were people thinking: 'Maybe we should stop all this. Maybe we need to scale back'. I am glad they did not do that. Building a powerful fleet is what made the Great Britain a world class nation and let it develop a modern industry. Later, the strength of that industry enabled the 20th century reforestation program at reasonable and supportable burden to that industry. As a result, the UK forestry coverage is 10% today and it keeps increasing.

To summarize, Mr. President, I firmly believe there is no way back. There is no possibility of sustainability right now. Instead, we should press forward to achieve it, and do that fast.

R:

- Thank you for explaining your position. And what is the new energy source you are referring to?

A:

- I am talking about thermonuclear energy, also known as fusion. This is *__the only__* energy source known with virtually unlimited capacity and virtually no environmental impact, if implemented properly. Yes, it is not ready for production yet. While working on it, we will need to rely heavily upon other renewable sources, primarily on wind and solar energy. And we must act fast. If the climate change backlashes, or if any ot reason causes us to lose the momentum and the intellectual power needed to reach this goal, we may *__never__* be able to recover again.

=== 3. What Can You Do? ===

Of course, that dialog is purely imaginary. I can only hope that kind of a conversation is happening somewhere. It is unlikely that any of the wo leaders would read this text. Rather, I'm writing it for you. So *__now__* it is the time to talk about sacrifices, though you may be surprised by the twist this will take.

Consider ITER (https://en.wikipedia.org/wiki/ITER, https://www.iter.org/). It is the largest experimental facility designed to test key principles energy production via controlled fusion. Yes, it is *__experimental__*, so things there may or may not work exactly as expected. But most physicist would agree that ITER is a very important step towards developing controlled fusion. Now let's look at some basic facts about ITER:

> Officially initiated: 1988
> Construction started: 2008
> The first fusion experiment planned: 2035
> Cost: €20 billion (as of 2016, estimate, construction only)

Read that. 47 years -- nearly two human generations! -- from the initiation to launch? Something must be broken here. But wait. There is more Compare ITER's cost to the following figures:

> Cocaine consumption in North America in 2008 *__per year__* (https://www.unodc.org/documents/wdr/WDR_2010/1.3_The_globa_cocaine_market.pdf): $38 billion
> US wine market, *__per year__* (https://www.prnewswire.com/news-releases/total-us-wine-market-tops-70-billion-300779605.html): $70 billion

Judging by these figures alone, an average American seems to be much more concerned with getting boozed rather than with climate change

what? Who said, 'Stop drinking?' That's not what I propose. I believe most people are good and mean good. The *__proper__* conclusions to dr from this comparison are:

1. A typical American has very little idea of where to direct their efforts of saving the climate. Virtually none of their efforts, money, and voices makes any difference. This is irrespective of ITER.

2. Yet it does not take a super-sacrifice to make a change. If (miraculously) each American gave $100 to ITER, that would've fulfilled all planned budget of that facility for 17 years of construction.

No, I'm not saying "donate to ITER" (though you should do so if you feel like that). ITER is only one of the approaches and is not a guarantee. B there are many alternative pathways to developing controlled fusion. Some of them will work, because the underlying *__physical__* principles ar well understood and correct. It is mostly a matter of practical research and engineering. It should not take cancelling forever all your Hawaii vacations, or confiscating $100K per person, to achieve that goal.

So, what can *__you__*, as a world citizen, do?

0. Of course, you should recycle, keep toxic waste isolated, protect forests, and drive electric if you feel like that. But those measures alone ha only little effect on climate change, even if everybody does that.

1. Require that proposals on dealing with the climate problem are quantitative. That they provide the numbers on the relative change in CO_2 concentration or emission expected if a proposal is accepted. That's because the game we are forced to play is also quantitative and measured well in % of CO_2 in the air. If a proposal cannot quantify how it would affect that figure, there must be something fishy about it.

2. Educate yourself. If the matter seems too complex, ask physicists or climatologists, not journalists or politicians. They would be overwhelmingly happy to explain. If you don't have time, at least read the facts from the next section.

3. Educate your children. Teach them critical thinking, emotion control, math and multiple languages, so that they aren't easily hypnotized by media and aren't limited by just one country education system.

4. Support building more wind and solar power plants. They work today and have enough capacity to generate 2-5x more energy (per year) th what we make now, thus providing us with a "bridge" to work on controlled fusion or any other alternative. Not least important, they can redu the current CO_2 output by 20-50% and maintain that relative reduction for decades while supporting globally growing energy demand.

5. Support the research on new energy sources, and on controlled fusion specifically. This is a long-term part of the plan.

6. Demand all the above from the politicians by voting, writing letters, and expressing your feedback.

Speaking realistically, will anything happen if you do that? It may or it may not. We should not underestimate the complexity of the game politicians have to play. For example:

> To apply sanctions to an environmental pollutant, you need an overwhelmingly strong economy. But no economy can be overwhelming it is vulnerable to external dependencies like food or energy! And 30% of energy is produced from coal. So, paradoxically, you may need some coal industry to push for reducing coal consumption!
> The louder you speak about climate change, the greater are the chances that ***someone else*** would cut the emissions and hurt their economy, giving your country an advance. In that respect, I am very interested to know who is sponsoring Greta.
> Finally, if anyone invents working fusion, they reap almost no benefits. The knowledge would soon become nearly public, and many wo start using it. No surprise, nobody wants to be the one who pays for this quite expensive lunch for the whole crowd. That might be another reason why controlled fusion has constantly been "15 years away" for the past 70 years.

However, earlier or later ***some*** country would have enough political willpower to implement fusion. At minimum, you can send your kids the for having a future. That's why there is item #3 on the list.

=== 4. Facts ===

A true scientific paper is supposed to have a list of references. Fortunately, this paper is not of that kind. Instead, it lists only some fun (and no so fun) facts:

(1) Biodegradable plastics decompose quickly. Then, they release their carbon back into the atmosphere. If you primarily care about ***capturin*** carbon, you should opt for the most permanent and least degradable plastics (and make sure they are not burnt).

(2) Personal transportation contributes only 7-10% to global greenhouse gas emission (https://www.epa.gov/ghgemissions/sources-greenhous gas-emissions#transportation). If you all stop driving, the difference will be consumed by other industries within just a couple of years.

(3) Yes, there are greenhouse gases other than CO_2 contributing to climate change (https://www.epa.gov/ghgemissions/global-greenhouse-ga emissions-data). But of those artificially produced, carbon dioxide (CO_2) predominates by the effect, thus it makes sense to focus mostly on it when discussing measures and actions.

(4) While some CO_2 emission supports luxury, most of it supports basic living (https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data, scroll to "Global Emissions by Economic Sector").

(5) To appreciate the intricacy and complexity of known climate feedback loops net, read this (https://earthhow.com/climate-feedback-loops/) Or just take a glance at this picture if you have only 30 seconds (https://en.wikipedia.org/wiki/Climate_change_feedback#/media/File:Gore_inconvenient_truth_loops.png). Climate change ***is*** complex. It i very easy to suggest "simple, quick, and wrong" solutions for it.

(6) Teslas run on electricity. Does that mean their use produces no CO_2 emission? Not at all. 64% (https://en.wikipedia.org/wiki/World_energy_consumption#Electricity_generation) of world electricity originates from burning fossil fuel. Yes, the state of Washington relies primarily on hydro. But unless you are suggesting that Teslas are banned for the less lucky rest of the world, you should use the global energy figure. CO_2 does not recognize boundaries.

Does Tesla truly spend 2.2x less energy per mile than a hybrid gasoline car, as this (https://en.wikipedia.org/wiki/Electric_car_energy_efficienc Wikipedia page suggest? Not either. The page is misleading in a very bad way. It does not mention that for every unit of electricity that Tesla spends, there is roughly 0.64/0.4 = 1.6 units of fossil fuel energy burnt at the power plant to make that electricity. And 59% of that fuel is coal with carbon footprint 1.5x worse than that of gasoline. Thus, the end difference, while probably still in favor to Tesla, is closer to 1.3x in terms energy use, and even less so in terms of carbon footprint.

Does Tesla make less CO_2 than a regular gasoline car? Yes, by a factor of 2-5x, like that of a Prius. The benefit results primarily from regenerati

noticeable positive difference.

(7) A somewhat crude and not exactly precise, but reasonable and consistent estimate of the current CO_2 greenhouse effect: http://www.realclimate.org/index.php/archives/2006/01/calculating-the-greenhouse-effect/

(8) As of 2017 China contributes 29% to the world's CO_2 emission. USA -- 14%. EU -- 10%. India -- 7%. Russia -- 5% (https://en.wikipedia.org/wiki/List_of_countries_by_carbon_dioxide_emissions#Fossil_CO2_Emissions_by_country/region). US greenhouse ga emission has been steadily ***declining*** since 2007 (https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks).

(9) China owns the largest and the most powerful photovoltaic power plant (1.5 GW, 43 sq. km). Two next largest ones are owned by India. Th follow United Arab Emirates, India and China again, Mexico, UAE again, and then the US with its largest plant of 0.579 GW (https://en.wikipedia.org/wiki/List_of_photovoltaic_power_stations#World's_largest_photovoltaic_power_stations). Size does matter, to a degree: China generates nearly 3x solar energy compared to the US (https://en.wikipedia.org/wiki/Solar_power_by_country).

(10) Do you know that ***the whole*** CO_2 in the atmosphere (not only man-made, but all of it) could be eaten by Earth's plants in some 10-20 years, provided there are no new sources? That's an 8th grade calculation to show. Yet the CO_2 keeps climbing. Why? Because while alive plan grow and "eat" CO_2, the dead ones decompose in the soil and return it back. These two processes are at a nearly perfect equilibrium. Simply planting more trees isn't a solution. Again, climate change is a more complex phenomena than what popular articles often try to tell us.

(11) Even ***scientific*** publications, where people make great efforts to attain the truth, show 20-40% of irreproducible results (https://en.wikipedia.org/wiki/Replication_crisis#In_medicine). Think about that. After spending ***years*** to verify the details, and to check all data sources, and to double-check formulas and logic, and reviewing it with smart peers, one third of (depending on the area though) scientifi papers are not true. You need to read at least 2-3 of them on a given subject to triangulate a reliable picture. Now what would you expect of common media, where people must publish ***daily***?

(12) If you introduce the unit Q = 10^{21} Joules (also 1 ZJ) of energy, then the world energy production in all forms amounts to about 0.6 Q/y. (https://en.wikipedia.org/wiki/World_energy_consumption#Energy_supply,_consumption_and_electricity). It doubles every 30 years or so (https://en.wikipedia.org/wiki/World_energy_consumption#/media/File:World_primary_energy_consumption_in_quadrillion_Btu_by_region

(13) Using Q as a unit, one can make the following statements regarding various energy sources:

> Hydro: current production is 0.1 Q/y. The theoretical limit is around 0.5 Q/y, but that would require building dams on every damn sprin and river on Earth which is hardly imaginable.
> Wind power alone can easily generate 0.5 - 1.0 Q/y. Renewably.
> To produce 0.6 Q/y of solar, you'd need to cover land area the size of Germany or Japan with solar panels. Engineering improvements c reduce that by a factor of ~2.5x, but that'd be the theoretical limit. Building in deserts and closer to the equator can squeeze another 2x so.
> Total nuclear energy reserves are over 1000 Q (https://en.wikipedia.org/wiki/Peak_uranium), but we still have no good plan on handlin spent nuclear fuel. Today, more than 100,000 tons of it is accumulated from 60 years of operating nuclear reactors at modest ~0.03 Q/y (https://www-pub.iaea.org/MTCD/Publications/PDF/te_1591_web.pdf). No, breeders won't be completely waste-free.
> Theoretical limit for geothermal energy is around 0.1 Q/y.
> Land-based biofuel/biodiesel is limited by ~0.1-0.3 Q/y depending on how much food crop production one is willing to sacrifice.
> Thermonuclear (fusion) reserves could be roughly estimated at one billion (1,000,000,000) Q. If only we learn how to use it.
> Tidal electricity really consumes the energy of Earth's rotation. In theory, there is 200 million Q in there. But to harvest it effectively, yo need planetary-size machinery.
> Current oil reserves are estimated at 9 Q, natural gas at 36 Q, coal at 20 Q (https://en.wikipedia.org/wiki/World_energy_resources#Fossil_fuel).
> Burning all oxygen in the Earth's atmosphere with coal will make 2500 Q of thermal energy.
> A typical fossil fuel power plant converts 30-40% of fuel thermal energy to electricity.

Why am I providing so few references with point #13 figures? Because (except for reserves data) those figures could be calculated on a back of napkin, starting off well-known fundamental figures measured long ago. If you meet an energy "expert" who does not know most of these figures, or cannot estimate them, or drastically disagrees to most of them, just tell them to bug off.

That's it. Thank you all and have a wonderful 21st century!

=== 5. An Afterword ===

It took me two days to write a draft of this rather lousy article. And then a week to calm down, remove @#$%s and &*%$@s, and make it generally more balanced. So great was the disturbing effect of dangerous, deadly misconceptions expressed in Waves 1 & 2! Waves stared by Greta the Saint, Greta the Possessed... I'm still thankful to her for initiating this media mess, even though most of it is of little help to saving th climate.

To me, it seemed like dealing with Titanic heading in the wrong way, and I felt the responsibility -- an utter, hopeless, dire responsibility -- to tr to push it off the deadly course with my bare hands.

I probably did not succeed much, but I did what I had to do. My apologies to everyone I possibly offended. It's just because I care. Really care. There must be something broken in this world if a former Plasma Physicist has a much better work as a Data Scientist yet feels obligated to wri on climate change at his spare time.

Despite sounding very confident, I am only a human. I do not possess the complete understanding of a problem, neither I think that I know a 100% solution to it. I'm pretty sure I made my share of errors here. I am only hoping that some of the points expressed would help us to solve this complex and dangerous problem we are facing today.

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