Approaches to Quantifying Carbon Emissions with Human Deaths

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When attempting to quantify future harms caused by carbon emissions and to set appropriate energy policies, it has been argued that the most important metric is the number of human deaths caused by climate change. Several studies have attempted to overcome the uncertainties associated with such forecasting.

Keywords: carbon emissions ; greenhouse gas emissions ; global catastrophic risk ; climate change ; energy policy ; human mortality

1. Introduction

Despite repeated and ever more serious warnings [1] from the scientific community, global greenhouse gas (GHG) emissions and carbon dioxide (CO_2) concentrations in the atmosphere continue to increase as fossil fuel combustion increases [2]. It is now established with 95% confidence that anthropogenic global climate destabilization is occurring [3][4] and has potentially irreversible negative repercussions for global environment and the social and economic welfare of humanity [5][6]. Yet, despite these well-known facts, there has been a reluctance to apply aggressive energy policies to eliminate fossil fuel combustion. The reasons are both political (involving conflicting interests) and psychological (involving abstractions that may not be directly perceptible).

Climate change causes human deaths in diverse ways, which can be divided into direct, intermediate, indirect, and their interactions. Direct mortal effects of climate change include heat waves, which have already caused thousands of human deaths [7][8][9] by a combination of heat and humidity (wet-bulb temperature > 35 °C, such that the human body is physically unable to cool itself with perspiration). Intermediate causes of death (between direct and indirect) involve crop failures, droughts, flooding, extreme weather, wildfires, and rising seas. Crop failures [10][11] can exacerbate existing socially-constructed global hunger and starvation resulting in tens of thousands of human deaths [12][13][14]. More frequent or severe droughts [15][16][17] can lead to more frequent or severe wildfires [18][19][20] that also cause human deaths. Droughts lead to contaminated water, diseases, and deaths from dehydration [21][22]. The 2022 IPCC Report (6th Assessment Report) predicted that drought would displace 700 million people in Africa by 2030 [23]. Climate change can cause flooding and consequent destruction of property and crops, which also drives hunger and disease [24]. Climate change drives sea level rise and the resultant submersion of low-lying coastal areas and shoreline erosion [25][26], saltwater intrusion [26][27], storm damage to coastlines, and exacerbated flood risks [18][28][29][30]. These dangers are life-threatening for billions of people in coastal cities who face the prospect of forced migration [31]. Climate change increases extreme weather events (e.g., hurricanes), which indirectly kill and cause damage worth billions of dollars [32][33][34]. Extreme weather events kill in many ways including, for example, electric grid failures and power outages [35][36] that reduce access to electric-powered medical care. Indirectly, climate change increases the probability of conflict [37][38][39][40][41]. As the number of climate refugees increases [42][43][44], countries further from the equator might increasingly refuse to offer asylum. In a worst-case scenario, social collapse is possible [45][46].

For humanity, the most important consequence of climate change will be human deaths. The value of human life may be considered the foundation of all human values, as reflected by the universal legal importance of crimes such as murder, manslaughter, and genocide [47]. Therefore, when attempting to quantify the future harms caused by carbon emissions, the number of human deaths caused by climate change may be the most important metric.

“Casualties” can be deaths, injuries, or illness. In the medical literature these complexities are normally dealt with using the disability-adjusted life year (DALY), which is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death [48][49]. DALYs have been found to be a useful tool for quantifying human damage from environmental pollution [50]. Since the World Bank first published the DALY concept in 1993, the use of life expectancy estimates, disability weights, age weighting, and discounting has evolved [51]. Unfortunately, as researchers in

many fields have adjusted the equations used for estimating the DALY and have increasingly challenged assumptions underlying these calculations, comparing DALY estimates across different studies has become difficult. More concerning are studies that argue that the conceptual and technical basis for DALYs is flawed, its assumptions and value judgments are questionable as well as implications of age-weighting and discounting [52][53][54]. The stakes are high for the assumptions that underly a DALY because it is often used for cost-effectiveness analysis, which is used for funding allocations [55].

2. Approaches to Quantifying Carbon Emissions with Human Deaths

2.1. The 1000-ton Rule

The 1000-ton rule says that a future person is killed every time humanity burns 1000 tons of fossil carbon. It is derived from a simple calculation: burning a trillion tons of fossil carbon will cause 2 °C of anthropogenic global warming (AGW) [56][57], which in turn will cause roughly a billion future premature deaths spread over a period of very roughly one century [58]. On the assumption that 2 °C of warming is either already inevitable (given the enormous political and economic difficulties of achieving a lower limit) or intended (given that the business plans of big fossil fuel industries make it inevitable), it can be concluded that burning 1000 tons of fossil carbon causes one future premature death.

The numbers “one billion” (for the total death toll at 2 °C) and “one thousand” (for the amount of carbon that needs to be burned to cause one death) are both very approximate (both are hardly more than order-of-magnitude estimates), but also consistent with diverse evidence and arguments:

- Before 2022, humans burned roughly 0.6 trillion tons of fossil carbon, causing a global temperature increase of roughly 1.2 °C. Incidentally, about the same amount of carbon is currently part of living things on this planet (550 billion T) [59].
- The carbon budget for 2 °C of AGW is about one trillion tons [60]. Thus, if humanity burns that amount altogether, the global mean surface temperature will rise by 2 °C. A more exact estimate is not necessary, because predicted death tolls will inevitably be even more approximate.
- About five trillion tons of fossil carbon are available in the Earth’s crust. If humanity collectively burned all of that, global mean surface temperature would increase by up to 10 °C relative to the pre-industrial era [56][57] and could threaten human extinction [61]
- Dividing one trillion by one billion, one thousand tons is the amount of carbon that needs to be burned today to cause a future premature death in the future: 1000 tons.

It has been clear for a decade or more [62] that the final death toll due to AGW will be much greater than 100 million, or one million per year for a century—an extreme best case if current death rates from AGW miraculously remained constant at about one million per year (a level that may have already have reached). Conversely, the final death toll in a 2 °C warming scenario will certainly be much less than 10 billion, which is the predicted global human population in 2100 in the absence of AGW [63]. Although climate change clearly represents a global catastrophic risk to food supplies [64], only a small minority are suggesting that 2 °C of warming could cause human extinction [65]. Warming of well over 2 °C, however, could indeed cause natural climate feedbacks to get out of control, leading eventually to human extinction [65]. Between these extreme boundaries, it is likely more than 300 million (“likely best case”) and less than 3 billion (“likely worst case”) will die as a result of AGW of 2 °C. That prediction is consistent with detailed predictions of climate science summarized by the World Health Organization and their probable consequences for human mortality [66].

2.2. Convergent Evidence for the 1000-ton Rule

Although AGW is a global concern, some studies have looked specifically at a single country’s emissions (USA) to illustrate the methods used. The 1000-ton rule is roughly consistent with two such independent studies from different academic disciplines—philosophy and economics. The authors of those studies arrived at their estimates of future death tolls by different methods but came to similar conclusions. First, an American philosopher John Nolt [67] concluded that the carbon emissions of the average American are causing the death or suffering of one or two future people. That is because the average American, in the course of a lifetime, causes (by her or his personal choices or participation in regular social structures) 1840 metric tons of CO_2 equivalent to be emitted. This corresponds to about 500 tons of carbon, so according to the 1000-tonne rule, those emissions are enough to kill half of a future person.

2.3. The Temperature Niche

Xu and colleagues [68] have argued that “accounting for population growth projected in the SSP3 scenario, each degree of temperature rise above the current baseline roughly corresponds to one billion humans left outside the temperature niche, absent migration”. That is consistent with the 1000-ton rule if it is assumed that long-term survival outside the ecological niche is unlikely. Specifically, for every additional degree of warming beyond 2 °C, roughly an additional billion deaths will be caused, leading to human extinction at very roughly 10 °C of warming [58]. At 2 °C of warming, roughly 2 billion people would find themselves outside the climate niche as defined by Lenton et al. [69]. If it is assumed that global warming will be the ultimate cause of death for half of those people (e.g., due to the inability to migrate), then 2 °C of warming will cause a billion deaths.

2.4. Marginal Carbon Emissions-Related Deaths

The 1000-ton rule makes it clear that there is a marginal human death cost to every amount of warming, no matter how small. Thus, every 0.1 °C degree of warming can be expected to cause 100 million deaths. Similarly, every 0.001 °C of warming will cause a million deaths. If humanity misses the 2 °C target or any of the more granular goals to stop ‘dangerous climate change’ [70], which appears likely according to AI models [71], rather than relax and accept it, all efforts to reduce carbon emissions can be viewed as lifesaving.

3. Carbon-Related Deaths to Guide Energy Policy

3.1. Large Numbers and the Millilife

Understanding the large variability in the number of human deaths from climate change requires an accessible unit of measure for carbon footprints that is easy to understand and may be used to set energy policy to help accelerate carbon emissions reductions. Using the “1000-tonne rule” as a basis it is possible to convert any carbon footprint to human lives. A *millilife* is defined as a measure of intrinsic value that is equivalent to one thousandth of the value of human life. A millilife is roughly the same as a month in the richest countries, assuming a lifespan of about 80 years, but it is closer to half a month in the poorest countries, in which the lifespan is closer to 40 years.

The 1000-ton rule says that a millilife is destroyed when a ton of fossil carbon is burned. For example in Canada, which has some of the highest yearly carbon emissions per capita in the world at around 19 tons of CO_2 or 5 tons of carbon per person [72], roughly 5 millilives are sacrificed by an average person each year. As the average Canadian lives to be about 80, he/she sacrifices about 400 millilives (0.4 human lives) in the course of his/her lifetime, in exchange for a carbon-intensive lifestyle. Canada is one of the world’s largest economies, currently ranked 9th [73]. Whereas the average gross domestic product globally is US$12,183/person, Canada generates US$51,988/person, more than 4 times the global average [73]. Canadians are thus not only wealthy by global standards but many already live outside of the human temperature niche. Climate change will likely benefit the Canadian economy in some sectors (e.g., agriculture and tourism), causing GDP to increase by up to 0.3% ($9 billion/year) [74].

Parncutt assumed [58] for the purpose of the 1000-ton rule that an average future AGW-victim in a developing country will lose half of a lifetime or 30–40 life-years, as most victims will be either very young or very old. If the average climate victim loses 35 life-years (or 13,000 life-days), a millilife corresponds to 13 days. Stated in another way: if a person is responsible for burning a ton of fossil carbon by flying to another continent and back, they effectively steal 13 days from the life of a future poor person living in the developing world. If the traveler takes 1000 such trips, they are responsible for the death of a future person.

This concept can also be applied to large-scale energy decisions. For example, the Adani Carmichael coalmine in Queensland, Australia, is currently under construction and producing coal since 2021. Despite massive protests over several years, it will be the biggest coalmine ever. Its reserves are up to 4 billion tons of coal, or 3 billion tons of carbon. If all of that was burned, the 1000-tonne rule says it would cause the premature deaths of 3 million future people. Given that the 1000-tonne rule is only an order-of-magnitude estimate, the number of caused deaths will lie between one million and 10 million.

3.2. Quantifiable Metrics Warranting Industry-Wide ‘Corporate Death Penalties’

Many authors have considered the benefits of a “corporate death penalty” (judicial dissolution of a corporation by the government) for reigning in companies that do harm [75][76][77][78][79][80]. Pearce considered quantitative criteria for industry-wide penalties of that kind in the case of non-carbon air pollution deaths from the U.S. coal mining industry [81]. The USA

consumed about 546 million tons of coal in 2021 [82], corresponding to about 400,000 future deaths according to the 1000-tonne rule (as the worst lignite is only 65% carbon whereas the best anthracite is 92% and these are short tons, which are about 900 kg, but the 1000-ton rule originally applies to metric tons (tonnes) which are 1000 kg).

Under what circumstances might a government ban or outlaw an entire corporation or industry, considered a legal entity or person—for example, the entire global coal industry? The Universal Declaration of Human Rights [83] suggests how this question might be answered:

- Everyone has the right to life (Article 3) [83]. The right to life is the primary right, as it is necessary to be alive to enjoy any other right such as the right to work.
- Everyone has the right to work (Article 23) [83]. Corporations promote this right if they offer employment.
- Corporations are human inventions, created by law to benefit humanity. The law should only give corporations the right to exist if they are beneficial to humanity. In the simplest case, a corporation can be viewed as 'good' if it creates profit and jobs (benefiting humans), but not if the operation of the business infringes the universal human right to life.

Ideally, a company should not cause any human deaths at all. If it does, those deaths should be justifiable in terms of improvements to the quality of life of others. For example, a company that builds a bridge might reasonably risk a future collapse that would kill 100 people with a probability of 1%. In that case, the company accepts that on average one future person will be killed as a result of the construction of the bridge. It may be reasonable to claim that the improved quality of life for thousands or millions of people who cross the bridge justifies the human cost.

Fossil fuel industries are causing far more future deaths than that, raising the question of the point at which the law should intervene. As a first step to solving this problem, it has been proposed a rather high threshold (generous toward the corporations) is appropriate. A company does not have the right to exist if its net impact on human life (e.g., a company/industry might make products that save lives like medicine but do kill a small fraction of users) is such that it kills more people than it employs. This requirement for a company's existence is thus:

Number of future premature deaths/year < Number of full-time employees (1)

This criterion can be applied to an entire industry. If the industry kills more people than it employs, then primary rights (life) are being sacrificed for secondary rights (jobs or profits) and the net benefit to humankind is negative. If an industry is not able to satisfy Equation (1), it should be closed down by the government.

Coal is primarily burned for electrical generation. Coal-fired power plants pollute the air with a combination of greenhouse gases (carbon dioxide and methane) [84], particulate matter, nitrogen and sulfur oxides, and heavy metals such as mercury [85][86][87]. The resultant poor air quality causes mortality and morbidity effects on respiratory, cardiovascular, urinary, nervous, and digestive systems [88][89][90][91]. In this way, the coal industry kills people by polluting the air that they breathe [92][93]. Fossil fuel-related air pollution was responsible for 10.2 million excess deaths globally in 2012 (due to PM2.5 from this source) with 62% of deaths in China (3.9 million) and India (2.5 million) [94]. In the U.S., about 52,000 human lives are sacrificed per year to provide coal-fired electricity [95]. Such death rates can be estimated from meteorological models that analyze emissions and pollutant concentrations. Concentration-response functions allow researchers to estimate the number of deaths that could be avoided if combustion emissions from coal were eliminated [95].

In the U.S., coal employed 51,795 people in 2016. Since the number of people killed is greater than the number employed, the U.S. coal industry does not satisfy Equation (1) and should be closed down [81]. This conservative conclusion does not include future deaths caused by climate change due to burning coal [96][97][98].

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