

Energy, climate, science and sense

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Abstract

Science is a way of understanding nature. Human beings affect and measure the natural world, and the fruits of science have made our twenty-first century lives more comfortable and easier in many ways than those of our ancestors. Much of has been enabled by exploitation of cheap, concentrated sources of energy. There are, inevitably, consequences of our choices. Modern life produces concentrated sources of pollution that overwhelm nature's ability to clean it up. What sensible alternatives are available to us to enable our lives to continue without destroying our environment? We shall attempt to begin to answer this question in light of the knowledge and limitations of science.

Keywords: Climate change, Science and society, Philosophy of science.

Resumen

La ciencia es un camino para entender la naturaleza. Los seres humanos afectan y miden el mundo natural, y los frutos de la ciencia han hecho de nuestro siglo 21 vidas más cómodas y más fáciles en muchos aspectos que las de nuestros antepasados. Gran parte de esto ha sido posible gracias a la explotación de fuentes económicas, concentradas en fuentes de energía. Estas son, inevitablemente, consecuencias de nuestras decisiones. La vida moderna genera fuentes concentradas de contaminación que superan la capacidad de la naturaleza para limpiar. ¿Qué alternativas razonables están a nuestro alcance para nuestra vida y seguir sin destruir nuestro medio ambiente? Vamos a tratar de comenzar a responder esta pregunta a la luz de los conocimientos y las limitaciones de la ciencia.

Palabras clave: El cambio climático, la ciencia y la sociedad, la filosofía de la ciencia.

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I. INTRODUCTION

This much is obvious to any technical person: Any course of action has costs and benefits. To obtain the benefit, we need to pay the cost. No power plant pollution means no power plants. No power plants means no electricity. No electricity means no modern surgical procedures, no medical diagnostics, no comfortably lighted and cooled homes, etc., all things most people want to have or at least have available to them. As I emphasize in my textbook *Energy* [1], there can never be a simple solution because there are gains and losses, and these are often unequally distributed and those in power make the rules. Also, there are invisible, stealth costs, characterized by Hardin as “tragedy of the commons” [2]—in the example of a coal-fired power plant, people downwind can be exposed to pollutants such as small particulates, nitrogen oxides, sulfur dioxide, mercury, thorium, and so on. Abundant research has shown deleterious effects on people's health when exposed to such pollutants [1]. The downwinders bear the costs, but may not reap the benefits.

The twentieth and early twenty-first centuries have seen rising emissions of greenhouse gases (hereafter, GG), particularly carbon dioxide (over 30 gigatonnes per year) and

methane. These are both consequence of rising global fossil fuel use [3]. As the economies of various “underdeveloped” countries continue to grow, the current model of development seems to require concomitantly that fossil fuel use inexorably fated to increase.

This paper attempts to examine the global effects of emissions of GG, the underpinning of the reasoning laying the responsibility at humanity's doorstep, and a sensible approach to assuring the human race survives on a livable planet.

II. EFFECTS OF UNRESTRAINED GREENHOUSE GAS EMISSIONS

This is the central conundrum of our times—how to take meaningful action to prevent a possible catastrophic change in the livability of Earth for everyone while creating conditions for or maintaining sufficient energy resources for our global population to live in dignity at reasonable levels of comfort (what the Religious Society of Friends calls “right sharing”). To see why action is necessary, we must address the effects of emissions as supported in the scientific data that has been gathered.

It is beyond doubt that Earth's temperature is increasing. I have examined the temperature record of the National Oceanic and Atmospheric Administration (NOAA) [4] from 1880 through 2010, looking for the 25 warmest January years, February years, etc., in the record, giving 300 data points (12x25) each for highest and lowest record temperatures. Fig. 1 shows the result. The year 1899 was the first year to have any (one) record warm month; 1992 is the last year having any (two) record cold months. As discussed in Sec. III, this increase is due to us.

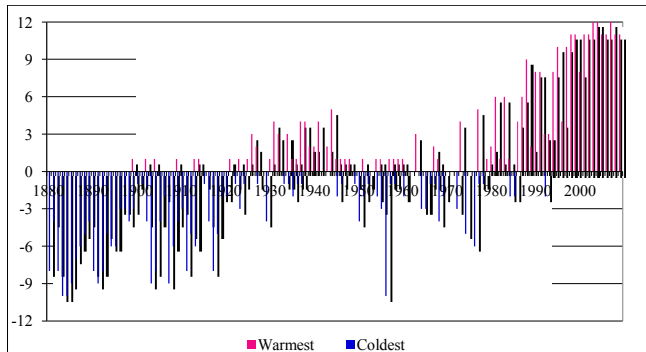


FIGURE 1. The 300 warmest and coldest months in the 1880-2010 NOAA record (above, warm; below, cold).

A study of European temperatures spanning 2500 years by Büntgen *et al.* [5] shows clearly the unique nature of the current warming over that period. Hegerl *et al.* [6] claim that human forcing can be detected prior to 1900, and they are able to see effects of volcanic eruptions on their record. Other research shows that L. Tanganyika has warmed appreciably since AD 500 [7]. Heatwaves are expected to increase in frequency and severity [8]; Stott *et al.* saw the 2003 European heatwave as presaging the future [9].

Efforts to enforce the Kyoto Protocol, an international effort to reduce GG, have been mired in rancor and foot-dragging, particularly by the United States and China. China and India, though not responsible for the majority of the current inventory of GG in the air (the U.S. and Eurasia are), are experiencing faster-growing emissions than the biggest past emitters [3].

The world public appears to believe that waiting for certainty is acceptable before a decision must be made, and even educated people share that belief [10]. However, there is inertia in the climate system and the effects of current emissions are delayed, contributing to a false sense of security. Many of the decision-makers as well as the public appear to believe that the problem, if at last it is acknowledged to be serious, can be addressed by immediate action leading to immediate reduction in the GG impacts on life. But the emissions constitute a problem requiring a millennial solution unless radical proposals for geoengineering are adopted. In the latter case, there are security implications that could even lead nations to go to war [11].

Recent research [12] suggests that carbon emissions must be cut enough by 2050 for levels to begin decreasing

to avert disaster. Science acts by asking questions that can be answered but policy has to deal with imponderables. Scientists should back all sorts of energy alternatives and hope that half or more will fail -- because if we don't explore options that could fail, we're not looking hard enough.

If we were to stop emitting carbon dioxide tomorrow, the effects would continue to grow for several centuries despite that cessation of emissions [13]. The effects will last over a thousand years, continuing to affect climate [13] and be amplified [14]. Meinshausen *et al.* [15] predict that even halving greenhouse gas "emissions by 2050, ... we estimate a 12–45% probability of exceeding 2°C—assuming 1990 as emission base year and a range of published climate sensitivity distributions". They go on to say that "the probability of exceeding 2°C rises to 75%" with probability range "53–87% if global [greenhouse gas] emissions are still more than 25% above 2000 levels in 2020". Similarly, in a different paper, the same group of researchers write [16]: "Total anthropogenic emissions of one trillion tonnes of carbon (3.67 trillion tonnes of CO₂), about half of which has already been emitted since industrialization began, results in a most likely peak carbon-dioxide-induced warming of 2°C above pre-industrial temperatures, with a 5–95% confidence interval of 1.3–3.9°C". They recommend that policymakers should "limit emission rates of shorter-lived agents to avoid dangerous rates of warming and to use the concept of [cumulative warming commitment] to limit cumulative emissions of CO₂ (and other very-long-lived agents) to avoid a dangerous total warming commitment".

It is equally important to communicate to the public that this search for failure is necessitated by the threat of a millennium-length consequences of the greenhouse gases we have already released. Part of that communication needs to be by teachers who can help students (and the wider public) explore how science informs policy [17].

III. THE EVIDENCE FOR ANTHROPOGENIC CLIMATE CHANGE

While the stakes for the energy future of the planet are tied up with citizen and legislator perceptions of nuclear activity, contamination, and lifetime in the democratic countries and those of political leaders elsewhere, arguably the stakes are even higher for citizens and legislators who must address human response to climate change's effects on life on Earth [18, 19]. This review is perforce sketchy.

The Intergovernmental Panel on Climate Change (IPCC) should serve as the natural conduit of scientific advice to policymakers. The reports of IPCC have reviewed and examined more and more clear evidence that humans are causing climate change. The first three reports, summarized, said: 1990, First Assessment Report: "The unequivocal detection of the enhanced greenhouse effect from observations is not likely for a decade or more"; 1995, Second Assessment Report: "The balance of evidence suggests a discernable human influence on global climate"; and 2001,

Third Assessment Report “There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities”.

As some have pointed out [17], their clear and unequivocal statement that humans are almost certainly contributing to climate change in the 2007 (latest) IPCC report reads, “Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations”. [20] was not received with the meaning it was meant to have. The IPCC *means* a 90 to 99% probability by “very likely”; many people will interpret this as a lesser result [17]. If they were to read the report carefully, they would not be confused on this point at all. A great deal of evidence is evinced that shows the human fingerprint. For example, the graph of model calculations with error bars assuming no human effect from release of greenhouse gases diverge from from temperature data after 1960. When the human emissions are factored in to the models, agreement results within errors. Ackerley *et al.* [21] see that human aerosol emissions contributed to the Sahel drought, presumably through affecting the seasonal movement of the Inter-Tropical Convergence Zone.

Data can be replicated. The so-called hockey stick graph was generated in the late 1990’s [22] using several different proxy temperature data sources, and was promptly attacked by skeptics and denialists [23]. However, despite some slight errors in analysis, different groups using different datasets have replicated the graph in gross detail (error estimates do differ, but the warming of Earth experienced since the 1990s is unprecedented in all reconstructions) [5].

As Ref. 24 states, “A global-mean warming of roughly 7°C would create small zones where metabolic heat dissipation would for the first time become impossible, calling into question their suitability for human habitation. A warming of 11–12°C would ... encompass most of today’s human population. ... If warmings of 10°C were really to occur in next three centuries, the area of land likely rendered uninhabitable by heat stress would dwarf that affected by rising sea level”.

Parmesan’s review [19] states, “The direct impacts of anthropogenic climate change have been documented on every continent, in every ocean, and in most major taxonomic groups. ... One study estimated that more than half (59%) of 1598 species exhibited measurable changes in their phenologies and/or distributions over the past 20 to 140 years. ... A meta-analysis of range boundary changes in the Northern Hemisphere estimated that northern and upper elevational boundaries had moved, on average, 6.1km per decade northward or 6.1m per decade upward ($P < 0.02$)”.

The European heatwave of 2003 shows, according to Stott *et al.* [9] that “past human influence has more than doubled the risk of European mean summer temperatures as hot as 2003, and with the likelihood of such events projected to increase 100-fold over the next four decades, it is difficult to avoid the conclusion that potentially dangerous anthropogenic interference in the climate system is already underway”. Schär and Jendritzky [25] characterize Ref. 9 as

the “first successful attempt to detect man-made influence on a specific extreme climatic event”. While it deals with effects on Europe, readers will understand that the conclusions reached in this research are more universal than local.

Every scientist will recognize that these cited data constitute the evidence for a tentative acceptance of the effect of human beings on climate. That is because all scientific understanding is tentative. Scientists are aware that science cannot ever *prove* anything, only *disprove* things.

The evidence of the data emphatically do not disprove the human effect on climate. Not many of our fellow citizens (or students) will appreciate that, as a result, *all understanding* in all science is subject to change should disproof occur. People need to understand why there is the need to do something in the absence of “proof”. I hope that has been answered by the considerations detailed in Sec. II.

The acceptance of human-caused climate change is the simplest hypothesis not ruled out by data (and data are consistent with the hypothesis). As noted in Ref. 17, this is part of the job for physics (science) teachers; the media do not necessarily explain climate change clearly, even when the attempt is made to be clear and unbiased.

IV. SENSE

As pointed out in Ref. 17, mental models are formed prior to contact with science. As Sterman notes [26], these pre-existing models lead to “pervasive errors and biases in judgment and decision making ... about the structure and behavior of complex dynamic systems”. As far back as 1991, inappropriate notions of climate change among the public have been documented [27]. Optimistically, Kempton believed that more information would remedy the problem, especially if educators and journalists explicated “the gaps and misleading prior models ... identified here” [27].

However, as Pidgeon and Fischhoff point out [28], information is insufficient. As they say, many avenues of research “believe the simple behavioural theory underlying the ‘deficit model’ of the public understanding of science, which assumes that simply teaching more science will bring lay behaviour into line with scientists’ expectations”. The background and facts are essential, but more is required of us in support of science and its processes.

Physics teachers can help with public understanding of climate change by educating people to whom they speak about the scientific worldview. But basic information is science processes is just the beginning, not the ultimate goal.

As teachers, we have produced generations of citizens who, in the main, do not understand the processes of science, people educated out of their native curiosity, leaving college without exposure to the sorts of inquiry we scientists engage in every day. Wishful thinking and denial become the order of the day (it may be emblematic that in a certain former U.S. administration, one of the high officials was quoted as saying that “we make our own facts”), a decidedly unscientific (not to say antiscientific) view that may partly have been responsible for inaction on climate

issues. Teachers should be aware that these lurk in the background of students' (and citizens') minds.

People ignore the effects if they appear distant in space or time. Lake Tanganyika's warming may be compelling to a scientist, but so far away as to be dismissed by a nonscientist. Americans may dismiss the experience of Europe. The IPCC focus on 2050 and 2100 as the expression of effects may undermine the message. There are many fine references that explain the effects on the U.S. For example, Fig. 2 [29] shows the effect of future climate change on the state of Michigan; it is a sobering picture, although it requires acquaintance with rational explanation.

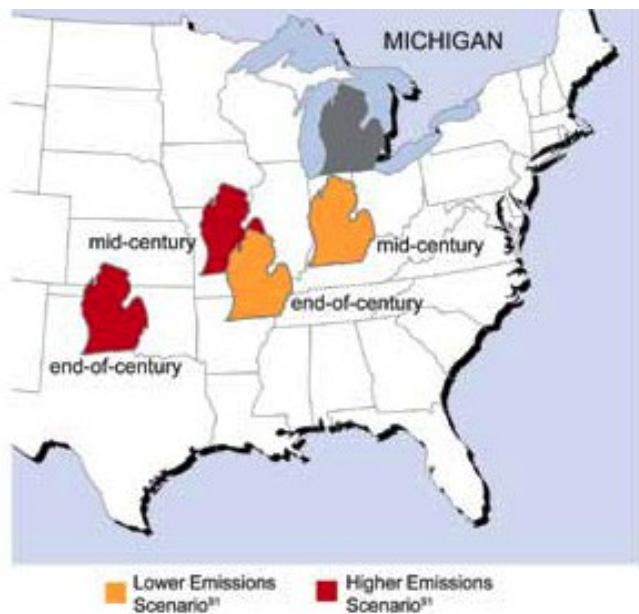


FIGURE 2. How the climate of Michigan is expected to change by 2050. From Ref. 29, pp. 117.

Science teachers believe in rationality, but despite blandishments from the National Academies in the 1990s to McKinsey and Associates in 2009 that there is a great deal of low-hanging fruit in reducing carbon emissions at negative costs, few of the recommended measures have been implemented. Indeed, as Weber notes [30], “most people living in western countries fail to install energy-saving technologies, even if doing so would save them money in the long run”. One of the few such measures that was implemented in the U.S., a phaseout of inefficient incandescent lightbulbs in a law passed in 2007 is being revisited as a political issue in the American House of Representatives in July, 2011 with a view to undoing the legislation [31].

Another difficulty teachers and explicators face is denial. Norgaard [32] has found that educated Norwegians continued to ignore the possible devastating effects of climate change because its effects were too painful and people are fearful of their own guilt for their parts; she characterizes this as a form of “social organization of denial”: “community members had sufficient information about the issue

but avoided thinking about global warming at least in part because doing so raised fears of ontological insecurity, emotions of helplessness and guilt, and was a threat to individual and collective senses of identity”. That can hold as true for the general public and possibly even for our students.

Finally, we mention the difficulty of the students and the public in dealing with risk, with uncertainty, and with a lack of understanding of probabilistics. There is some instinctual grasp of high-probability low-consequence risks (walking outside without an umbrella in threatening weather), but many of the risks of climate change are low-probability, high-consequence risks (nuclear war) for which intuition fails as a guide. Scientific uncertainty is seldom taught; most people fail to understand that the reported value from every measuring instrument is inherently uncertain and what that means. Teachers can help the information deficit to some extent.

V. CONCLUSIONS

This paper addresses the idea that physics teachers have a role to play in explicating climate change to students and the public. Teachers should be aware of preconceived mental models and be prepared to deal with them. This is, of course, harder to effect than to write.

I have argued from research that “information deficit” is not the sole problem science faces. Teacher knowledge of bias and general misunderstanding allows the beginning of effective information exchange. But there is a need to address the issues of complex systems, apparent spatial distance and temporal disjunction, of lack of understanding of timescales, of lack of comprehension of how science works, of the limits of technology to deal with the problems of climate change, of dealing with set mental models. Having science teachers cognizant of these conceptual issues can help them deal more effectively with student and public understanding.

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