

# PHYSICS & SOCIETY

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## From the Editor

A highlight of this issue is an article by Adam Frank, the latest winner of our Forum's Burton award "For multi-channel promotion of public understanding of physics, of science in general, and of the relationship between science and society, using methods and venues that effectively engage and provoke discussion among policy makers, scientists, and the public regarding important issues." This continues my policy of asking our prizewinners to write an article for the newsletter.

Over the past twenty years it has become the custom, for good or for bad to evaluate scientists using numerical indices. The most famous of these is the H-index. We have an article in this issue by the very inventor of this index, Jorge Hirsch, discussing some of the unintended and intended consequences of his invention. Many years ago, Jorge and I were co-authors in a couple of papers. Alas, these papers did not gather a number of citations large enough to contribute to my H-index, or to his own.

There are two more articles, one of which replies (in part) to an article that appeared in the October issue. My hopes to stir

more controversy are perhaps beginning to bear success.

More contributions from our general readership are always welcome. Articles and suggestions for articles should be sent to me, and also letters to the editor. Book reviews should go to the reviews editor directly ([ahobson@uark.edu](mailto:ahobson@uark.edu)). Content is **not peer reviewed and opinions given are the author's only, not necessarily mine, nor the Forum's or, a fortiori, not the APS's either.** I am very open as to what is appropriate.

Oriol



*Oriol T. Valls, the current P&S newsletter editor, is a Condensed Matter theorist.*

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Dear Editor,

The four worst greenhouse gases emitted from human activity that cause climate change are carbon dioxide ( $\text{CO}_2$ ), methane ( $\text{CH}_4$ ), nitrous oxide ( $\text{N}_2\text{O}$ ), and tropospheric ozone ( $\text{O}_3$ ). I propose four new annual days to bring awareness to each of these greenhouse gases and to cause people and organizations to reconsider their activities that are causing emission of these greenhouse gases.

The atomic number of a chemical element is the number of protons in the nucleus of each atom of that element. The atomic number uniquely identifies each element. In the periodic table of elements, elements are arranged from left to right and top to bottom in order of increasing atomic number.

A carbon dioxide molecule ( $\text{CO}_2$ ) consists of a carbon (C) atom and two oxygen atoms ( $\text{O}_2$ ). Carbon (C) has an atomic number of 6 and is the 6th element in the periodic table of elements. Oxygen (O) has an atomic number of 8 and is the 8th element in the periodic table of elements. To assign a date for  $\text{CO}_2$ , 8 for the position of oxygen in the periodic table is bonded to 6 for the position of carbon in the periodic table. The latter is bonded to 8 for the position of oxygen in the periodic table. The result is 868. The 868th date from January 1 at midnight not considering leap years is May 18. Therefore, May 18 each year is assigned as Carbon Dioxide Day or  $\text{CO}_2$  Day.

A methane molecule ( $\text{CH}_4$ ) consists of a carbon atom (C) and four hydrogen atoms ( $\text{H}_4$ ). Carbon (C) has an atomic number of 6 and is the 6th element in the periodic table of elements. Hydrogen (H) has an atomic number of 1 and is the 1st element in the periodic table of elements. To assign a date for  $\text{CH}_4$ , 6 for the position of carbon in the periodic table is bonded to 1 four times where 1 is the position of hydrogen in the periodic table. The result is 61111. The 61111th date

from January 1 at midnight not considering leap years is June 5. Therefore, June 5 annually is assigned as Methane Day or  $\text{CH}_4$  Day.

A nitrous oxide molecule ( $\text{N}_2\text{O}$ ) consists of two nitrogen atoms ( $\text{N}_2$ ) and an oxygen atom (O). Nitrogen (N) has an atomic number of 7 and is the 7th element in the periodic table of elements. Oxygen (O) has an atomic number of 8 and is the 8th element in the periodic table of elements. To assign a date for  $\text{N}_2\text{O}$ , 7 for the position of nitrogen in the periodic table is bonded to 7 for the position of nitrogen. The latter is bonded to 8 for the position of oxygen in the periodic table. The result is 778. The 778th date from January 1 at midnight not considering leap years is February 17. Therefore, February 17 each year is assigned as Nitrous Oxide Day or  $\text{N}_2\text{O}$  Day.

An ozone molecule ( $\text{O}_3$ ) consists of three oxygen atoms ( $\text{O}_3$ ). Oxygen (O) has an atomic number of 8 and is the 8th element in the periodic table of elements. To assign a date for  $\text{O}_3$ , 8 for the position of oxygen in the periodic table is bonded to 8 for the position of oxygen. The latter is bonded to 8 for the position of oxygen in the periodic table. The result is 888. The 888th date from January 1 at midnight not considering leap years is June 7. Therefore, June 7 annually is assigned as Tropospheric Ozone Day or  $\text{O}_3$  Day.

Each year, Nitrous Oxide Day on February 17, Carbon Dioxide Day on May 18, Methane Day on June 5, and Tropospheric Ozone Day on June 7 should cause countless people and organizations to reconsider their activities that cause emissions of these greenhouse gases and climate change.

Sincerely,

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## Physics, Outreach and the Crisis of Science Denial

Adam Frank, University of Rochester

It took me by surprise. I was an undergraduate physics major at the University of Colorado, Boulder and was attending office hours with one of my favorite professors. I was taking his Math Methods course and had stopped in to ask some questions when the conversation strayed to other topics. He told me of his time at Los Alamos and what life was like for young physicists in the 1950s. Then he asked me how I'd gotten interested in physics. I told him how much Carl Sagan's writing had influenced me as a teenager.

But the mention of Sagan did not go down well with my professor. "Sagan should be spending his time doing something more important" was his only comment and then the topic was changed.

That was the first time I'd encountered a dismissal of Sagan's outreach work and I was pretty shocked by it. By the time I was a post-doc though things had changed. After the Cold War, funding for basic science could no longer be assumed. Many researchers recognized that doing good physics and communicating its importance were both going to be essential to the health of our field.

But even that change in attitudes towards science outreach and science communication by researchers pales in comparison with the challenge our community faces today. With the rise of science denial, it's not just adequate resources for the maintenance of US excellence in science that we must worry about. Instead, it's the very idea of science's capacity for delivering independent truth that seems to be under attack.

Given that new reality it's a good time to think about how we in the science community approach outreach and communication.

Carl Sagan not only inspired me to do science, he also inspired me to write about science. His passion for research and the breadth of his curiosity taught me to think broadly about science and culture. I wanted others to see how extraordinary the ordinary became through the lens of scientific inquiry.

I got my first chance to publish something when a friend showed me a call for articles from the *The Exploratorium Quarterly* about the nature of language. I wrote a piece asking if mathematical physics could be considered a language. I was lucky that the guest editor for that edition was the renowned science writer KC Cole. When Cole moved to *DISCOVER* magazine, she gave me the chance to write for much larger audiences and schooled me in the best practices for good science journalism.

Through her and other great writers like Corey Powell, I learned that "narrative drive" in a science story meant just as much as cool new results. Along with facts about new Supernova discoveries, there also had to be a story about some-

one facing obstacles to get that discovery and then a story of obstacles overcome. I will always be grateful that I got these lessons from some of the nation's best science journalists. It changed my understanding of the gap between how scientists and non-scientists understand the meaning and importance of scientific inquiry. That understanding is, I believe, profoundly important now as we respond to the growing threat of science denial.

Most people do not interpret the world through data but through stories. When you meet a new person, you are unlikely to exchange vital stats about height, weight, blood type and blood pressure. Instead we tell each other stories about where we're from, what kind of family we grew up in or what kinds of day we just had. The emphasis in stories rather than data is essential in thinking about how we bring the results of research to the world. It also helps explain how science denial got its foothold.

Back in 2011 I co-founded NPR's *13.7 Cosmos and Culture* blog with physicist Marcelo Gleiser. Climate Change was a subject I covered a lot and through the comments page I watched the tide of climate denial rise. At first, I tried to answer a lot of these comments by showing how the writer was getting the science wrong. Soon I saw this didn't matter. They weren't interested in the science. They were interested in an alternative story about scientists, "elites" and hoaxes. There was no point in arguing because facts and truth didn't matter for those who adopted a mantle of denial.

But as physicists we know that nature's truth always has the last word. From climate to vaccines, you can only be in denial for so long before truth comes back to bite you.

That's why good science outreach and good science communication matter so much now. As crazy as it may seem, we can no longer expect people to just see the obvious benefits of living in a society that values science as arbiter of truth about the physical world. Nor can we expect people to understand, on their own, how we scientists parse the world into data, theories and their intersection. That is why we must all become Carl Sagan's to the degree we can. We must learn to tell stories, to anyone who will listen, about the beauty of the world science unveils and the beauty of the very human process that is science.

As scary as science denial is, I've seen time and again how my work as an astrophysics researcher can be an effective bridge for my work as a science communicator. The good news is most people are not deniers. Instead they are really interested in what science has to tell us. All they really need to light the spark is just a good story.

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# Superconductivity, What the H? The Emperor Has No Clothes

Jorge E. Hirsch, Department of Physics, University of California San Diego

A magnetic field  $H$  is expelled from the interior of a metal becoming superconducting [1]. Everybody thinks the phenomenon is perfectly well understood, particularly scientists with the highest  $H$ -index think that. I don't. I am convinced that without  $H$ oles, the little fiends that Werner  $H$ eisenberg conceptualized in 1931 [2], fifty years after Edwin  $H$ all had first detected them in some metals, you can't understand magnetic field expulsion nor anything else about superconductivity. Neither about the 'conventional superconductors' that are supposedly completely understood since 1957's BCS theory [3], nor about 'unconventional superconductors' like the high  $T_c$  cuprates discovered in 1986, about which there is no agreement on anything *except* that they must be described by a  $H$ ubbard model [4]. I believe that this whole mess that we are in started with  $H$ erbert Fröhlich's [5] original sin [6] and the isotope effect experiments on  $Hg$  [7] back in 1950, culminating in the current mania that metallic  $H$ ydrogen [8] or  $H$ ydrogen-rich alloys [9] will be (or already are! [10]) the first room temperature superconductors [11, 12]. I believe that the  $H$ ubbard model [13] has absolutely nothing to say about  $H$ igh temperature superconductivity nor any other superconductivity, despite the thousands of papers that have been written saying just that, and I believe that the theorem of  $H$ annes Alfvén [14] is the key to understand the Meissner effect despite the fact that nobody else believes that.

There. In the above paragraph I tried to explain the title of this essay, why I have been a  $H$ eretic in the field of superconductivity for over 30 years, and why I believe that  $H$ ans' little story about the emperor [15] perfectly captures the essence of the situation. You don't have to believe any of it of course, it is certainly true that madness of crowds is far less probable than madness of an individual. In any event, here is (a highly condensed version of) the  $wH$ ole story [16].

For better or for worse, I am most famous (or infamous) for the invention of the  $H$ -index. I designed the  $H$ -index [17] to measure individual scientific achievement. It attempts to summarize the large amount of information contained in the number of citations to each of the papers you have written in a single number. Just in case you haven't yet heard about it, it is the number of papers that you have written that have more than that number of citations. If your  $H$ -index is 25, you have written 25 papers that each have 25 or more citations, the rest of your papers have fewer than 25 citations each.

I thought about this in 2003, tried it out for a couple of years, and in early 2005 wrote a preprint that I sent around to some colleagues but otherwise didn't know what to do with. A couple of months later, at the urging of Manuel Cardona, that had heard about it by word of mouth, I posted it on arXiv in early August of that year [18]. Manuel was a great

physicist and a great human being, sadly deceased in 2014, that had a longstanding interest in bibliometrics, and had an extraordinarily high  $H$ -index.

The rest is history. The  $H$ -index has garnered wide attention, not only in physics but also in other natural sciences, social sciences, medicine, etc. Many papers have been written on its virtues, many more on its flaws, many variants of it have been proposed, yet so far none has been accepted as a better alternative.

In a nutshell, my observation is that about half the scientific community loves the  $H$ -index and half hates it, and the  $H$ -index of the scientist itself is a great predictor of whether s/he belongs to the first or the second group, in addition to its other virtues. I am not completely unhappy with the impact of my paper [19], which is by far my most highly cited one. As Oscar Wilde said, "There is only one thing in life worse than being talked about...".

I proposed the  $H$ -index hoping it would be an objective measure of scientific achievement. By and large, I think this is believed to be the case. But I have now come to believe that it can also fail spectacularly and have severe unintended negative consequences. I can understand how the sorcerer's apprentice must have felt.



Figure 1: Why there is no progress in understanding superconductivity.

For example, if you are a student learning from your professor about the physics of superconductivity, and your professor is an expert in the field as proven by his/her high  $H$ -index, are you going to doubt that s/he understands the most basic physics of superconductivity? And knows the answers to the most elementary questions? Probably not. So you will listen carefully to what your professor tells you is well known and understood about superconductivity, put aside any qualms you might have based on your physical intuition and gut feeling, and not ask questions that sound too simple and may make you look stupid in the eyes of the professor. If

those simple questions are not in the books, and the professor doesn't talk about them, they can't be valid questions. You will drink the Kool-Aid, learn how to work with the formalism, and later teach it to your students, who will be equally reluctant to question it as you were, since your  $H$ -index by then will be substantial.

The most highly recognized experts in the field of superconductivity have very high  $H$ -indices. They all agree unconditionally on some basic principles, namely: (1) *The BCS theory of superconductivity is one of the greatest, if not the greatest, achievement of modern condensed matter physics.* (2) *BCS is the correct theory to describe 'conventional superconductors', defined as materials described by BCS theory.* (3) *BCS is not the correct theory to describe 'unconventional superconductors', defined as materials that are not described by BCS theory.*

Wait, you will say—that's a tautology! True, so I should add: they also agree that the set of 'conventional superconductors' is not an empty set. And on that minor point I disagree. I am convinced that all superconductors are hole superconductors, and none is described by BCS theory.

Now my  $H$ -index is certainly astronomically smaller than the aggregate of the  $H$ -indices of all that are convinced that BCS theory is correct for conventional superconductors. It is also substantially smaller than that of many individuals that are highly recognized superconductivity experts in that group, e.g. Phil Anderson, Doug Scalapino, Marvin Cohen, Warren Pickett, Matthew Fisher, etc. Plus, the large majority of my papers that contribute to my  $H$ -index are not on the theory of hole superconductivity that I have been working on for the past 30 years. That work comprises about half of my total published work, and the aggregate citations to those 1,300 pages (which include a lot of self-citations) are less than 1/10 of my total citations, and less than 1/2 of the citations to my 4-page  $H$ -index paper [19].

So, if we believe citations and  $H$ -indices, by all counts my contributions to the understanding of superconductivity are insignificant.

Therefore, I have to conclude much to my regret that the  $H$ -index fails in this case. Because I know that the insights I have gained on hole superconductivity, in particular the real-

ization that electron-hole asymmetry is the key to superconductivity, are far more important than any other work I have done that has a lot of citations, e.g. Monte Carlo simulating the (electron-hole symmetric) Hubbard model [20].

Already in early 1989 I was convinced that I had discovered a fundamental truth about superconductivity that nobody suspected: that only holes can give rise to superconductivity. As I wrote back then [21], "*the essential ingredient of our theory is the realization that holes are different from electrons...electrons in bonding states lead to attractive interactions between ions and repulsive interactions between electrons; electrons in antibonding states (holes) lead to repulsive interactions between ions and attractive interactions between electrons. The bonding electrons give lattice stability and normal metals, the antibonding electrons give lattice instabilities and superconductors...We expect this mechanism to account for the superconductivity observed in all solids.*"

When I excitedly told this to my senior colleague Brian Maple back then, I thought I had caught his attention. In the 70's Brian had worked closely with Bernd Matthias [22], the superconducting materials guru that had always been skeptical of BCS theory [23] and had often observed that lattice instabilities and superconductivity compete [24]. I asked Brian, after explaining why I thought that electron-hole asymmetry was the key to superconductivity and why this explained the connection between lattice instabilities and superconductivity that Matthias had obsessed about: "are you convinced?" I vividly remember his reply: "I'm convinced you are convinced".

I expected back then that 'this mechanism' would be quickly accepted by the community to be a self-evident truth, others would go on to develop it much further, and I could move on to work on other interesting topics. Alternatively, that somebody would prove me wrong, so I could move on. So where are we 30 years later?

I have not moved on. I have since then published well over 100 papers on hole superconductivity [16], going over many humps and hurdles to get around hostile referees, the papers have been by and large ignored and the community is as unconvinced as it was 30 years ago (or even more) that this has anything to do with real world superconductivity. Despite all the additional evidence I have found since 1989

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that (in my view) strongly supports that my original conviction is right. Why is that?

One possible explanation is, of course, that I am wrong. The other more complicated explanation I believe is a combination of several factors: the opium of BCS theory [25], *H*-indices, paper-pushing grant managers and journal editors, lazy self-centered referees, and the emperor's new clothes [15].

Referees in particular. Did you ever have a hunch that referees are far more likely to view your paper favorably if it cites and/or talks favorably about their own papers? And that they are far less likely to give serious consideration to what your paper or grant proposal actually says and does or proposes to do if they get the impression that it undermines or potentially will undermine work that they have done? There is no remuneration for responsible refereeing nor is there a cost for irresponsible anonymous refereeing. Hence, given human nature and the refereeing system we have, it seems to me the guiding principle of refereeing in one sentence is: if publication of this paper or award of this grant will likely have a positive / negative effect on the *H*-index of the referee directly or indirectly in the future, s/he will recommend acceptance/rejection of the paper or grant proposal. Other criteria are second-order effects.

Ok, so what? Isn't that fair game, given that we are all both authors and referees? No, it is not to the extent that the game includes *others* that care that scientists that get paid by society to do work that supposedly ultimately benefits society actually do so.

Then there are the all important editors and grant managers. They decide who gets to referee your paper or grant proposal, typically go by rules of thumb that are the same for all papers and proposals, then do mindless vote-counting, oblivious to the difference between conforming papers or proposals and non-conforming ones. They have a natural tendency to pick referees that work on the same subject of your paper and don't take into account that if a paper questions the validity of a widely accepted theory such as BCS there is a conflict of interest with referees that have devoted their life and earned their reputation working with that theory.

BCS theory certainly made some valid points. Pairs undoubtedly play a role in superconductivity. Superconductors are macroscopically phase coherent. There is an energy gap in many superconductors.

But that can hardly justify the religious fervor with which the scientific community continues to cling to BCS theory today. One could understand it back in 1969, when Ron Parks compiled his famous treaty [26]. At that time, there was no reason to believe that more than one theory was needed to describe superconductivity in solids, and BCS was the only game in town.

But today? There are by a recent count [27] 32 different classes of superconducting materials, 12 of which are gener-

ally agreed to be 'conventional', i.e. described by BCS, 11 are generally agreed to be 'unconventional', i.e. not described by BCS, and 9 are 'undetermined', meaning there is no consensus whether they are BCS superconductors or not. So potentially 20 unconventional classes, where there is no agreement what is the mechanism governing them, versus 12 conventional, and we are still supposed to believe that BCS is the greatest achievement of modern condensed matter theory? Give me a break [28].

I believe that much of the explanation for this unconditional devotion to the conventional theory of superconductivity can be found in Andersen's little tale [15], that I will paraphrase here.

*'Many years ago there was an Emperor so exceedingly fond of new clothes that he spent all his money on being well dressed.'*

Many years ago there were physicists so enamored with their mathematical abilities to deal with complicated field theories that they forgot about physical reality.

*'clothes made of this cloth had a wonderful way of becoming invisible to anyone who was unfit for his office, or who was unusually stupid.'*



Figure 2: BCS: 'A theory of superconductivity is presented, based on the fact that the interaction between electrons resulting from virtual exchange of phonons is attractive when the energy difference between the electrons states involved is less than the phonon energy.' [3]

BCS-Eliashberg theory with the wonderful apparatus of field theory explains everything except to those that are unfit to be physicists or unusually stupid to comprehend it.

*'They set up two looms and pretended to weave, though there was nothing on the looms'*

They set out to predict the superconducting transition temperature of all the superconducting materials for which it had already been measured.

*'The whole town knew about the cloth's peculiar power, and all were impatient to find out how stupid their neighbors were.'*

All PRL referees knew about the peculiar power of BCS-Eliashberg-Bogoliubov-Ginsburg-Landau theory, and were impatient to reject the papers of stupid colleagues that would cast doubt on it.

*“Heaven help me” he thought as his eyes flew wide open, “I can’t see anything at all”. But he did not say so.’*

“Heaven help me”, thought smart students that couldn’t understand how BCS theory explains the Meissner effect. “I can’t possibly see how momentum conservation is accounted for and Faraday’s law is not violated”. But they did not say so.

*‘They pointed to the empty looms, and the poor old minister stared as hard as he dared. He couldn’t see anything, because there was nothing to see.’*

Theorists pointed to all the BCS calculations predicting new high temperature superconductors, and poor old experimentalists worked hard to make those superconductors and measure their  $T_c$ ’s. They couldn’t see anything, because there was nothing to see.

*‘“I know I’m not stupid,” the man thought, “so it must be that I’m unworthy of my good office. That’s strange. I mustn’t let anyone find it out, though”. So he praised the material he did not see.’*

“I know I’m not stupid,” experimentalists thought, “so it must be that I’m unworthy of my good office. That’s strange. I mustn’t let anyone find it out, though”. And they wrote their papers explaining why their nonsuperconducting samples had made a mistake, and why the superconducting samples that they had found serendipitously perfectly matched BCS calculations.

*‘The Emperor gave each of the swindlers a cross to wear in his buttonhole, and the title of “Sir Weaver.” ’*

The community awarded the theorists the Nobel prize, the Buckley prize, the Wolf prize, the John Bardeen prize, the APS medal, and membership in Academies and Royal Societies.

*‘So off went the Emperor in procession under his splendid canopy. Everyone in the streets and the windows said, “Oh, how fine are the Emperor’s new clothes! Don’t they fit him to perfection?” ’*

So off went the theorists to give talks, teach courses and write papers and books on their splendid theoretical framework. Everyone in the audiences, classrooms and reading rooms said, “Oh, how fine are these beautiful equations! Don’t they fit observations on superconducting materials in the real world to perfection?”

*‘“But he hasn’t got anything on,” a little child said... “But he hasn’t got anything on!” the whole town cried out at last” ... The Emperor shivered, for he suspected they were right. But he thought, “This procession has got to go on.” So he walked more proudly than ever, as his noblemen held high the train that wasn’t there at all.’*

“But these equations don’t predict anything”, Bernd Matthias said [29]... ““But they never have!”, the whole experimental physics community cried out at last” ... Senior theorists shivered, for they suspected they were right. But they thought, “This procession has got to go on.” So they walked more proudly than ever, as their students, postdocs and junior

collaborators held high the train that wasn’t there at all.

And that is where we are today. The train isn’t there at all. Let me explain why the emperor has no clothes.

Perhaps the simplest question you can ask about superconductivity is: how does a supercurrent stop? Even such a simple and fundamental question has never been asked, let alone answered, in the extensive literature on superconductivity. The answer is not trivial. When you heat a superconductor carrying a supercurrent across the superconducting transition, the current does not stop through onset of resistance. That would generate Joule heat, contradicting the fact that the transition is thermodynamically reversible.

Another fundamental question is: how does the Meissner effect work? Good conductors oppose changes in magnetic flux, and perfect conductors have magnetic flux lines frozen into them, because of Faraday’s law. How come superconductors expel magnetic fields? How do they overcome Faraday’s law, and satisfy momentum conservation? The final state carries a current that carries momentum, the initial state does not. How does all that happen in a reversible way, without Joule heat dissipation, as required by thermodynamics?

Another related question: how does a rotating normal metal generate a magnetic field when cooled into the superconducting state? How do electrons defy inertia, some electrons spontaneously slowing down, others spontaneously speeding up, to generate the observed magnetic fields? How is angular momentum conserved?

Another question never asked before: when a superconductor in a magnetic field below  $T_c$  is cooled further, how can the system reach a unique final state, independent of the rate of cooling, as BCS predicts, given that a variable amount of Joule heating is generated that depends on the speed of the process according to BCS theory?

These simple and fundamental questions have never been asked before in the BCS literature. There is nothing in BCS theory, the electron-phonon interaction, Cooper pairs, Bogoliubov quasiparticles, phase coherence, energy gap, spontaneous symmetry breaking, Higgs mechanism, Ginsburg-Landau theory, Eliashberg theory, that can say anything to answer the questions posed above.

I have asked these questions and showed that they can be answered within the theory of hole superconductivity, *if the normal state charge carriers are holes* [16].

Let me briefly explain the essential reason for it, it is simple and universal and can be explained in words. When you apply an external force to an electron near the bottom of the band, it acquires acceleration in the direction of the applied force, because its ‘effective mass’ is positive. We talk about holes rather than electrons when the Fermi level is near the top of the band. When you apply an external force to an electron near the top of the band, it acquires acceleration in direction opposite to that of the applied force, because its ef-

fective mass is negative. What that means is simply that there is another force acting on the electron in opposite direction, that is larger than the applied external force. That other force originates in the coherent interaction of the electron with the periodic ionic lattice. In this situation then, there is *transfer of momentum* between the electrons and the body, while in the first case, when the electrons are near the bottom of the band, there isn't. This transfer of momentum occurs without scattering off impurities or phonons, so it does not generate entropy, it is a *reversible process*.

In superconductors, it is necessary to have a mechanism to *transfer momentum* between electrons and the body in a reversible way, to answer the questions listed above, how is momentum conserved when a supercurrent starts and stops. Therefore, holes are needed. Electrons cannot do it. It is as simple as that. The theory of hole superconductivity explains in detail how it happens [16].

It is generally believed that BCS theory predicts and explains the Meissner effect, but that is just not so. The BCS 'proof' of the Meissner effect [3] is a simple linear response argument, starting with the system in the BCS state and applying a magnetic field to it. That is *not* the Meissner effect. The Meissner effect is the process that starts with the system *in the normal state* with a magnetic field and ends up in the superconducting state with the magnetic field expelled. BCS theory says nothing about the process, other than the fact that the energy is lower in the final than in the initial state.

When I argue this with colleagues they will say, 'well you are talking about time dependence, sure, that is complicated, BCS correctly describes the equilibrium state though.' I answer, Faraday's law only acts if there is time dependence, so refusing to consider time dependence means refusing to acknowledge that Faraday's law exists and governs natural processes. If BCS theory does not have the physics that is necessary to explain how the system can go from the normal to the superconducting state expelling magnetic field against Faraday's law, it cannot be the correct theory of the equilibrium state either. Period.

The physics that explains how to expel magnetic fields, is quite simply, explained by Alfvén's theorem [14]. A picture is worth a thousand words, the words are in my papers, the picture is at the right.

Alfvén's theorem, on which the entire field of magneto-hydrodynamics rests, is basically a restatement of Faraday's law. It states that in a perfectly conducting fluid magnetic field lines are frozen into the fluid and can only move together with the fluid. So why isn't it obvious that if magnetic field lines move out in the Meissner effect, it must be that fluid moves out, as in plasmas? Numquam ponenda est pluralitas sine necessitate. Of course there are several things to explain. What is the nature of the fluid that moves out, how can this happen without causing a charge and/or mass imbalance, what drives the motion, what does all this have to do with holes,

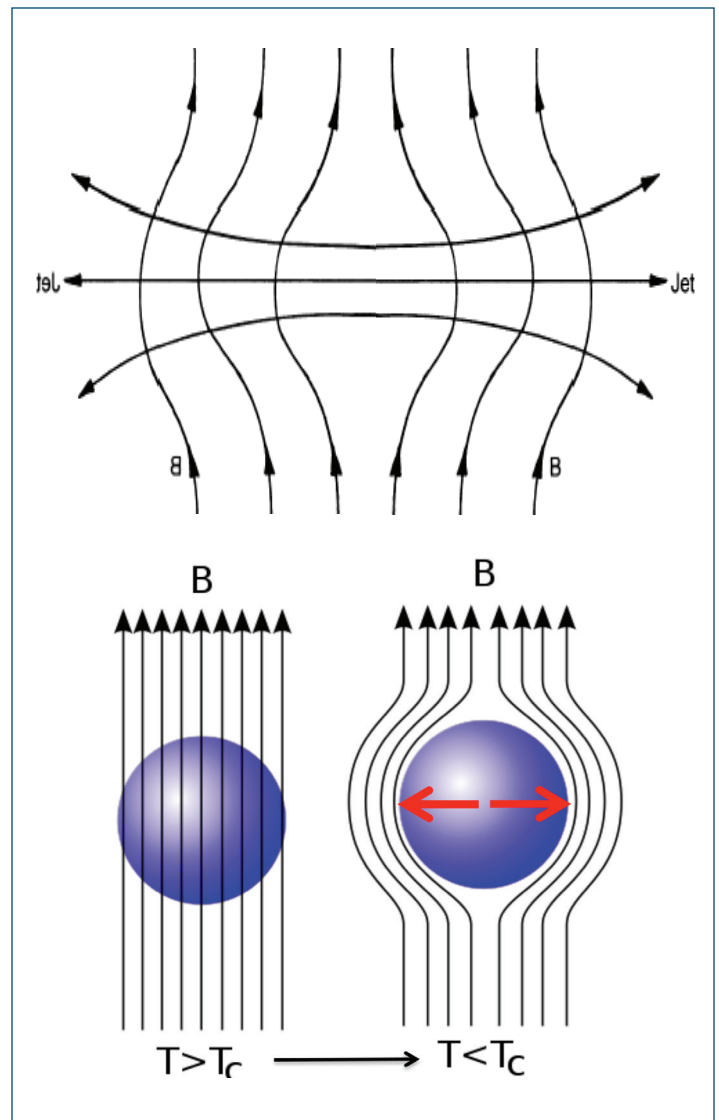


Figure 3: Top panel: the right half is from a picture in ref. [14], with caption: 'An example of Alfvén's theorem. Flow through a magnetic field causes the field lines to bow out.' I copied it, flipped the copy horizontally, and juxtaposed it to the left. On the bottom panel, a picture of the Meissner effect: as the temperature is lowered, it 'causes the field lines to bow out'. The red arrows show hypothesized 'Jets'

etc. For all that, see references in the last 5 years in Ref. [16].

BCS theory does not describe fluid moving out, so it cannot describe the Meissner effect.

Many other reasons for why holes are necessary for superconductivity are given in the papers we wrote through the last 30 years [16], many in collaboration with my colleague Frank Marsiglio. Simple arguments show why  $T_c$  is high in the cuprates and low in so-called 'conventional superconductors' [16], why there are 'electron-doped cuprates' [16], why the  $T_c$  of  $MgB_2$  is so high [16], why there is generically a positive isotope effect within this theory [16], even though the electron-phonon interaction has nothing to do with superconductivity, etc. Also, the periodic table shows a very significant correlation between sign of the Hall coefficient and



superconductivity. Superconducting elements such as *Pb*, *Al*, *Sn*, *Nb*, *V*, *Hg*, etc, have positive Hall coefficient. Nonsuperconducting elements such as *Cu*, *Ag*, *Au*, *Na*, *K* have negative Hall coefficient. In 1997 I calculated that the probability that this is accidental, i.e. unrelated to superconductivity, is less than 1/100,000 [30].

For an overview of my work on hole superconductivity please see my recent book [31].

To sum up: either BCS is right, and then there is necessarily at the very least one other or more likely several other mechanism and physics of superconductivity, to describe the myriad of ‘unconventional superconductors’. Or, BCS is wrong, and all superconductors are cut from the same cloth. If the latter can explain 140K superconductivity in the cuprates, it shouldn’t have too much difficulty in accounting for the 7K superconductivity of *Pb*, should it? Yet *Pb* is held up as the ‘posterchild’ of BCS theory, that supposedly proves beyond reasonable doubt that only BCS can account for its existence.

No matter how hard I have tried, it has proven extraordinarily difficult to ‘poke holes’ in the BCS theory of superconductivity. Journal referees, grant managers, conference organizers, are extraordinarily resistant to allow consideration of heretic views on this topic, particularly in the US. Even sympathetic colleagues that profess to be open to the possibility that BCS may not be completely right are reluctant to undertake any serious consideration of the issues raised here, correctly assuming that it would undermine their chances to get their grants renewed, their salary raised, their invitation to speak at the next conference, and the growth of their *H*-index.

Maybe they are right, maybe they are not. If the latter, at some point the tide will turn, but it could be many years from now, when we are all gone. Meanwhile, as far as I can see, the emperor will continue to have no clothes. Which makes me unfit for my office and unusually stupid.

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In the Fall 2019 issue of the *Forum on Physics and Society*, Dr Wallace Manheimer penned a [lengthy critique](#) of what he saw as flaws in the scientific consensus on anthropogenic climate change. Considering the long history of climate change discourse, earth scientists have by now become acutely familiar with the most common approaches used to question the evidence for global warming, and indeed Manheimer offers little intellectually new.

Manheimer's primary allegation is that the media regularly overstates the scientific basis for climate change and demonstrates bias by refusing to consider more skeptical viewpoints. Saying that media reporting occasionally overemphasizes aspects of climate change would be fair - [exaggerating the Amazon rainforest's role](#) in providing global oxygen and [misinterpreting the IPCC's Special Report on Global Warming of 1.5C to arrive at a 12-year "deadline"](#) for averting a global mean temperature increase of 1.5C, for instance. Pointing out these and other inaccuracies would represent useful critique and help rectify prevailing misperceptions on certain climate topics. However, Manheimer's accusation is actually directed at a different target, as in his view the media errs by even attributing climate change to rising greenhouse gas concentrations in the first place. His problem is fundamentally a problem with climate science, and he expends the majority of his efforts in attacking the overwhelming scientific evidence of anthropogenic climate change.

The media, while guilty of some misrepresentations of climate science, has generally represented the scientific literature on climate accurately. The vast body of research supporting ongoing climate change and its dominant anthropogenic drivers represents the sum of impressive scientific efforts spanning disciplines, continents, and generations of investigators. Manheimer's arguments in the face of such abundant evidence offers us as earth scientists an opportunity to demonstrate the robustness and rigor of the basis for climate change.

Here we respond to the multitude of disparate issues raised by Manheimer in his article, going through them one by one.

**Claim 1: Climate change pins all the blame on fossil fuel emissions of carbon dioxide even though the climate is a complex, poorly-understood system dependant on many factors**

**Response:** This view misrepresents climate science as attributing climate change solely to CO<sub>2</sub>, which is not a claim that the earth science community has ever made. To the contrary, anthropogenic climate change represents the product of multiple human influences in addition to fossil fuel emissions of carbon dioxide, including but not limited to deforestation,

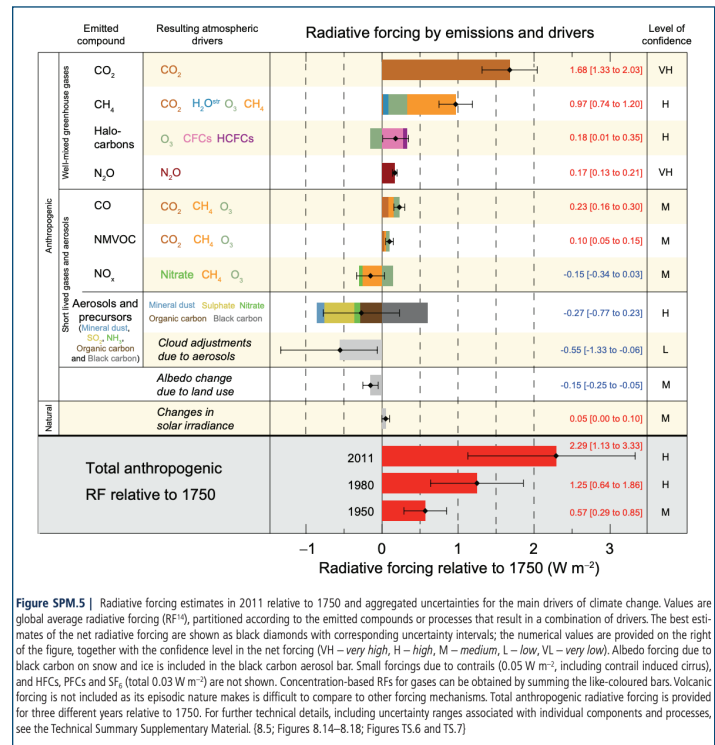


Figure 1: originally published in IPCC AR5, WG1, 2013.

release of chlorofluorocarbons, nitrous oxide emissions, tropospheric ozone, methane emissions from ruminant livestock and rice paddies, and reductions in ice and snow reflectivity from emissions of particulate black carbon.

**Claim 2: Earth scientists propose the single solution of stopping fossil fuel use, and do not even consider whether the climate effects of ceasing CO<sub>2</sub> emissions might be harmful.**

**Response:** The research community neither suggests total cessation of fossil fuel use, nor does reducing fossil fuel consumption represent the sole solution to climate change. Some sectors of the global economy such as steel manufacturing will likely prove very resistant to decarbonization, and so a degree of continued fossil fuel use over the 21st century is in fact virtually guaranteed. Rather, climate change mitigation relies upon achieving net zero emissions or better - a state where greenhouse gases are being added to the atmosphere at a lower rate than they are being removed through natural and/or industrial means. With world population projected to grow to 9-10 billion by mid-century (Connor and Mínguez, 2012), future changes to agriculture will also play a significant part in reducing humanity's climate impact. Finally, we point out that suggesting that burning fossil fuels produces minimal climate impact while in the next breath sowing fears

about the negative climate impacts of ceasing fossil fuel use is quite contradictory.

**Claim 3: Glaciers have been receding for 200 years, therefore predating industrial-era emissions of CO<sub>2</sub>. The Jakobshavn glacier in Greenland that everyone thought was receding is in fact growing, according to a recent study.**

**Response:** Manheimer’s claim that glaciers have been retreating for 200 years is uncited, making it difficult to ascertain where it originates from. Very few glaciers worldwide have been accurately monitored for at least two centuries. Manheimer may be referring to a recent study by Dickens et al., which used oxygen isotope data as a proxy for glacial discharge to identify an increasing trend in Antarctic ice shelf thinning over the past 300 years (Dickens et al., 2019). If anything, however, a longer-term trend of glacier retreat represents a cause for more worry, not less, as such glaciers may have already been predisposed to retreat prior to the onset of human-induced warming, suggesting that climate change could significantly accelerate this pre-existing trend (Dickens et al., 2019). Indeed, the World Glacier Monitoring Service has reported demonstrable recent acceleration in the rate of ice mass loss for the overwhelming majority of monitored glaciers in recent decades (WGMS, 2013).

Manheimer fails to mention that the Jakobshavn glacier study’s authors believe that its recent growth is only temporary and attribute it to natural cyclical variability in regional temperatures (Khazendar et al., 2019). Prior to this shift to recent ice mass accumulation, the Jakobshavn had retreated at an accelerating rate for two decades (Khazendar et al., 2019), single-handedly contributing to an estimated 0.9 mm of global mean sea level rise between 2000 and 2010 (Howat et al., 2011).

**Claim 4: Looking at surface temperature data, the increase in global mean temperature has plateaued over the past 20 years.**

**Response:** To the contrary, the reverse is true. Global surface temperatures have continued to increase over the past

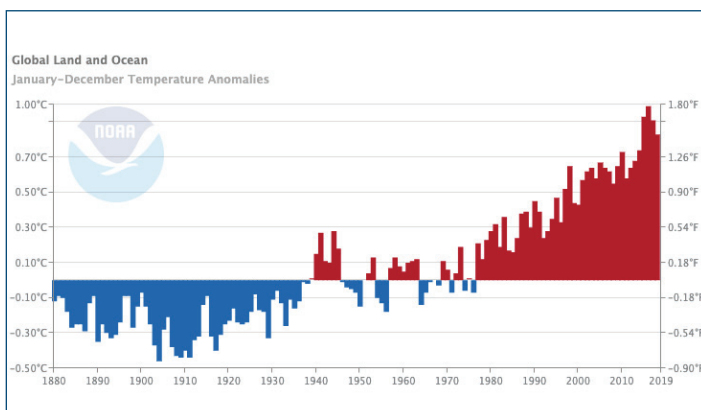


Figure 2: NOAA global surface temperature anomalies over time, 1880-present, plotted with respect to the 20th century average.

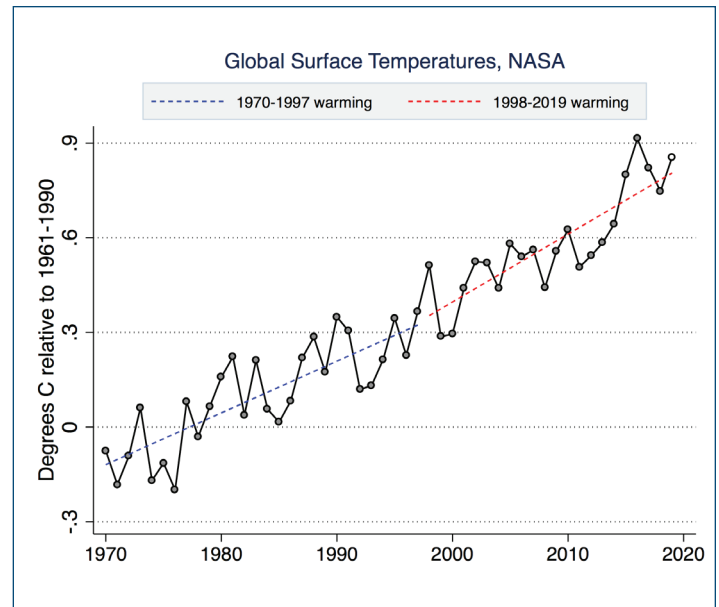


Figure 3: NASA global surface temperature anomalies over time, 1970-2019, with 1970-1997 and 1998-2019 trends highlighted.

20 years, and the rate of warming has in fact accelerated over the period from 1998-2019. The plot Manheimer displays is out-of-date, only including data up to ~2014. The same dataset extended to the current day shows that the warming trend has markedly continued. Interested readers can [access the same data](#) themselves.

The rate of warming over the past 20 years – the post-1998 period that was highlighted as a warming “hiatus” in the past, is now actually faster than the three decades pre-1998.

**Claim 5: The 1.5C warming target is less than the temperature difference between New York City and Boston, yet is identified with severe climate change consequences. If we have already warmed by 1C since the pre-industrial era, why will 1.5C cause such severe consequences?**

**Response:** Comparing 1.5C of global mean warming to the temperature difference between New York and Boston is nonsensical. The 1.5C figure represents a global spatial average as well as a temporal average - projected warming will not occur evenly across the entire world, nor will it apply evenly across the annual cycle of temperature. The poles, for instance, are warming at a much faster rate than the rest of the planet, with the Arctic Ocean currently experiencing a rate of warming of 0.5C per decade (IPCC SROCC Ch3). Land areas are expected to warm around 50% faster on average than the global mean. Even a modest degree of additional warming, evaluated over the course of a year, lengthens the warm period of the year and shortens the cold season, altering the seasonality of fires, rainfall, and ice melt, changes that can spark considerable ecosystem shifts.

The current pace of warming will see global mean temperatures well exceed 1.5C warming by 2100, likely in the range of 3-5C warming under no-policy scenarios (Haus-

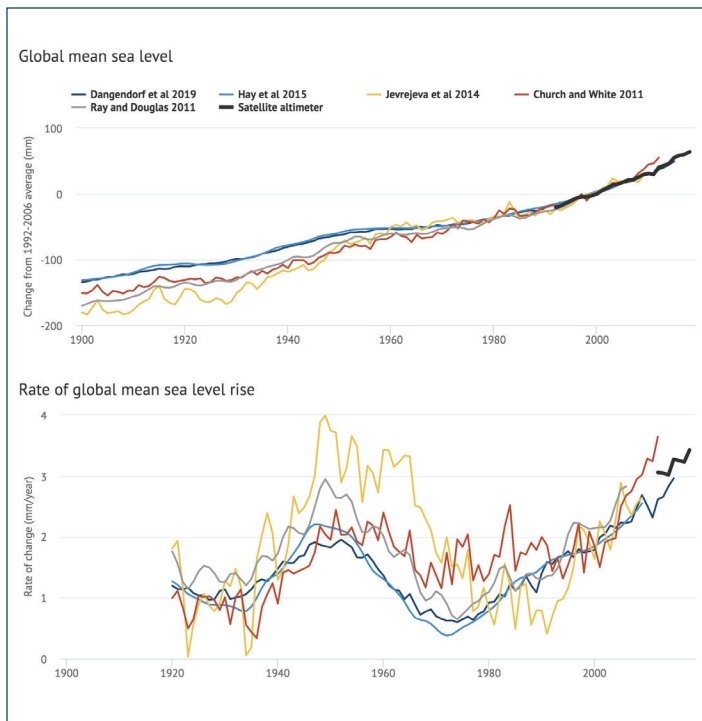


Figure 4: (Top) Global mean sea level over time, relative to the 1992-2006 average. (Bottom) Rate of global mean sea level rise (mm/yr) over time. Chart by Zeke Hausfather/[Carbon Brief](#).

father, 2019), so focusing on the consequences of a 1.5C warmer world alone is fallacious to begin with. The climate impacts of a 3-4C global mean temperature increase would be disproportionately more severe than 1.5C warming and reflect a simultaneously more threatening and more likely future that climate mitigation efforts today are seeking to avoid.

**Claim 6: Mainstream media claims that sea levels will rise by 10 feet by 2100, with some commentators claiming a 30-foot increase in this century. During the end of the last ice age, sea level rise took place at a rate of just 1 m per century [1 cm per year], yet you expect me to believe that we could get 3x to 10x that rate of sea level rise because of “a small increase of a trace gas in our atmosphere”?**

**Response:** There is no basis for any claims that sea levels will rise 30 feet by 2100. The IPCC estimates a sea level rise on the order of 0.6-1.1 m by 2100 (2-3.6 ft) for RCP8.5, which [arguably represents a worst-case emissions scenario](#) (IPCC SROCC Ch4).

The article referenced as estimating a potential for sea level rise of up to 10 ft by 2100 falls at the very high end of predictions made to date (DeConto and Pollard, 2016) and in particular adopted an aggressive approach to ice cliff instability (Edwards et al., 2019).

Contrary to Manheimer’s assertion, Chris Mooney’s article in the *Washington Post* does not claim that sea levels will rise by 30 feet by 2100. The scientific paper described in this article rather found past sea levels 125,000 years ago to have been 20-30 feet higher due to large-scale melt of the

East Antarctic ice sheet at that time (Wilson et al., 2018).

Regarding rates of sea level rise, it is fallacious to claim that just because sea level rates fell within a certain range during a specific period in the past, that it is impossible for the rate of sea level rise to exceed that range. Indeed, the IPCC predicts a high likelihood of sea level rise exceeding several cm per year by the 22nd century under a high-emissions RCP8.5 scenario (IPCC SROCC Ch4).

**Claim 7: The rate of sea level rise has decreased since 1960.**

**Response:** The opposite is in fact true. The rate of global mean sea level rise has significantly accelerated since 1960, climbing to a current day pace of 3.58 mm/yr (IPCC SROCC Ch 4). In comparison, the rate of sea level rise from 1901-1990 was approximately 1.4 mm/yr.

**Claim 8: Perhaps by 2100 ice caps will all melt based on models, “as many speculate now”.**

**Response:** This is an erroneous claim. No model projections anticipate full loss of all ice caps in 2100 or anything approaching it. Loss of major ice sheets in response to climate change is a long-term process taking place on a time frame of centuries if not millennia (IPCC SROCC Ch 3; IPCC SROCC Ch 4).

**Claim 9: James Hansen’s 1988 climate modeling paper overestimated global temperatures by 150% compared to real observations made in the decades that have followed its publication, with observed temperatures below even their lowest-emissions scenario in which CO<sub>2</sub> emissions stopped growing in the year 2000. CMIP5 models have continued to over-predict temperature increases.**

**Response:** An updated analysis with data extended to the present day indicates that contrary to Manheimer’s assertion, the middle-case model scenario utilized by (Hansen et al., 1988) has overall predicted the increase in global mean temperature quite well. Current temperatures are closely in line with the range of scenario predictions from what is now a rather dated model - a remarkable achievement. The figure cited by Manheimer only extends until 2012, the year in which the largest divergence between Hansen et al.’s model and observations occurred. Later generations of climate models with significantly-improved capabilities have continued to demonstrate a strong ability to predict global temperatures that we have observed since (Hausfather, 2017; Hausfather et al., 2019).

(Hansen et al., 1988) employed a climate sensitivity that would be considered on the high end of most models that are utilized today. The 150% overestimation figure Manheimer cites also misleads readers by comparing observed temperatures to the very worst-case emissions pathway modeled by Hansen’s team, which modeled emissions increased exponentially at rates well above those actually observed over the same period.

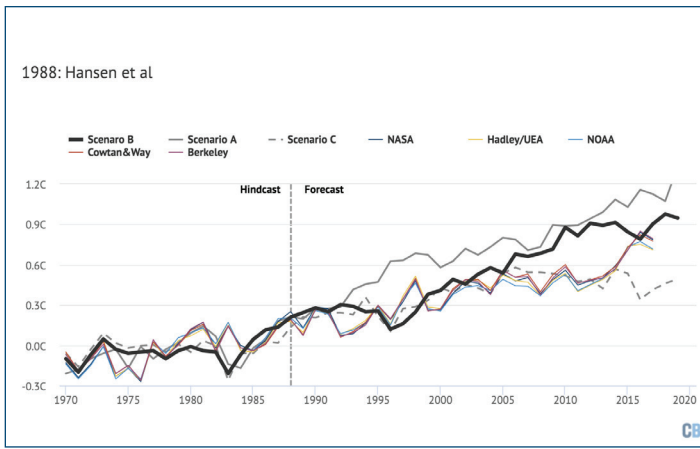


Figure 5: Projected warming from Hansen et al 1988 (scenario B—thick black line—and scenarios A and C—thin solid and dashed grey lines). Chart by Zeke Hausfather/Carbon Brief.

Here, we show a comparison of modeled (CMIP5) versus observed global mean surface temperatures. This analysis demonstrates an extremely strong agreement between observed and modeled temperatures, with observations falling entirely within the envelope of CMIP5 modeled temperatures (light dotted lines) and closely matching the blended multi-model mean.

**Claim 10: Damaging hurricanes are blamed on climate change, but the frequency of hurricanes has not increased, and may even have decreased since the 1930s!**

**Response:** Manheimer leverages a figure borrowed from a blog showing the number of Category 3+ hurricanes per year that have made landfall on the US mainland from 1851 to 2018. We first note that binning the number of Category 3+ hurricanes making landfall *over US soil* represents a flawed metric with which to assess overall changes in hurricane strength or frequency over time.

Ultimately, however, this claim regarding hurricanes represents a straw man, as the climate research community does

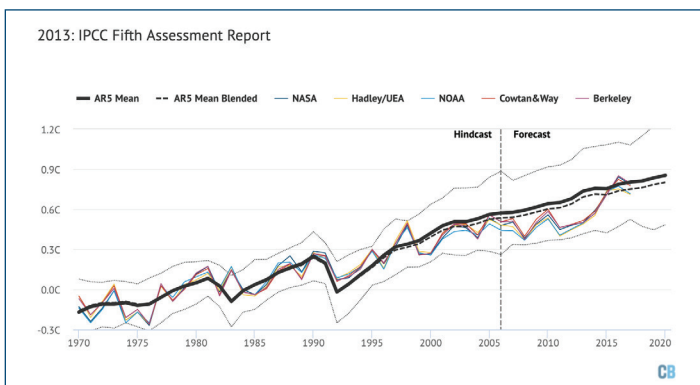


Figure 6: Projected warming from the IPCC Fifth Assessment Report (mean projection—thick black line, two-sigma upper and lower bounds shown by thin dotted black lines). Dashed black line shows blended model fields. Chart by Zeke Hausfather/Carbon Brief.

not currently claim that observed trends in cyclone frequency or intensity are attributable to climate change, and places low confidence on future projections of increased tropical cyclone strength (and *decreased* tropical cyclone frequency) in response to climate change (IPCC SROCC Ch 6).

That said, our ability to confidently attribute increased impacts from individual extreme events as a consequence of climate change has increased. For instance, researchers are able to conclusively state that the impact of Super typhoon Haiyan in November of 2013 was exacerbated as a result of sea level rise (Trenberth et al., 2015).

**Claim 11: The “most damaging” hurricane in US history occurred in 1900 in Galveston, Texas, so hurricanes cannot be getting more intense and destructive. People are also moving to the coasts, complicating interpretations of damages over time.**

**Response:** Changing coastal infrastructure and patterns of human habitation over history work both ways. The deadliness of the Galveston hurricane can be attributed not just to its strength but also to the absence of an early-warning weather system, differences in construction methods, and more primitive organization of disaster response.

As for economic damage, the scientific literature is currently inconclusive regarding whether or not US hurricanes are inflicting more economic losses today than they did in the past (e.g. Estrada et al., 2015; Weinkle et al., 2018).

**Claim 12: The media overstates the connection between climate change and tornadoes.**

**Response:** The article utilized to represent this viewpoint explicitly states: “The scientific evidence is not strong enough for a definitive link between global warming and the kinds of severe thunderstorms that produce tornadoes.” Manheimer misrepresents its true position, which emphasizes uncertainty is in quite in line with current research regarding the lack of conclusive evidence for a connection between climate change and tornadoes (Hausfather, 2019).

**Claim 13: California droughts are often held up as a symptom of climate change by TV news anchors. However, the overall drought severity index for the entire contiguous 48 states has not shown a trend since the pre-industrial era.**

**Response:** Any earth scientist would of course frown at using a country-wide metric to refute a claim that a particular region is experiencing changes over time. Examining the same Palmer drought index for the southwestern United States region only (PAGES Hydro2k Consortium, 2017), we observe that contrary to Manheimer’s claim, a sharp shift in conditions towards a progressively drier, more drought-prone state has taken place over the observational record

Manheimer’s plot showing an overall flat trend in the drought index for the contiguous United States is unsurprising, as climate shifts have strengthened rainfall for some locations while reducing precipitation in other areas. While

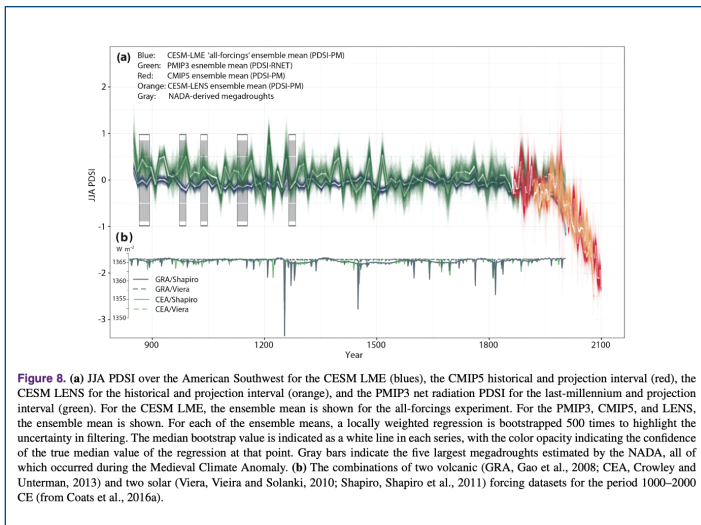


Figure 7: Original figure presented in (PAGES Hydro2k Consortium, 2017).

the southwestern United States, parts of the Mountain states, and portions of the southeastern US have experienced less rain over time, rainfall over the Midwest and Northeast has increased (USGCRP, 2018).

**Claim 14: Agriculture is portrayed to be under threat from climate change, despite the fact that agricultural yields have increased over the late 20th century.**

**Response:** To date, the planet has already warmed relative to the pre-industrial era by a global mean average temperature increase of 1C. Manheimer forgets that over the same period - indeed, during his own lifetime - a number of revolutionary technological changes have dramatically altered agriculture throughout much of the world. These included greatly expanded use of inorganic fertilizers, the breeding of vastly more productive staple crop variants, and the increasing mechanization and industrialization of agricultural production, collectively often referred to as the Green Revolution (Warren, 1998; Evenson and Gollin, 2003; Pingali, 2012). These innovations significantly increased crop yields across many world regions and are responsible for averting several famines and helping reduce world hunger. This transformative evolution of modern agriculture entirely explains the substantial increase in crop production worldwide.

That the impact of climate change was insufficient to negate the effects of such revolutionary technological change should not come as the slightest surprise. Pointing at increasing crop yields does nothing to disprove climate change - one might easily make the counterclaim that in the absence of climate change agricultural yields would have increased beyond the rate historically observed. Indeed, a sizable body of literature points towards negative impacts of climate change upon agricultural productivity (e.g. Chen et al., 2016; Moore et al., 2015).

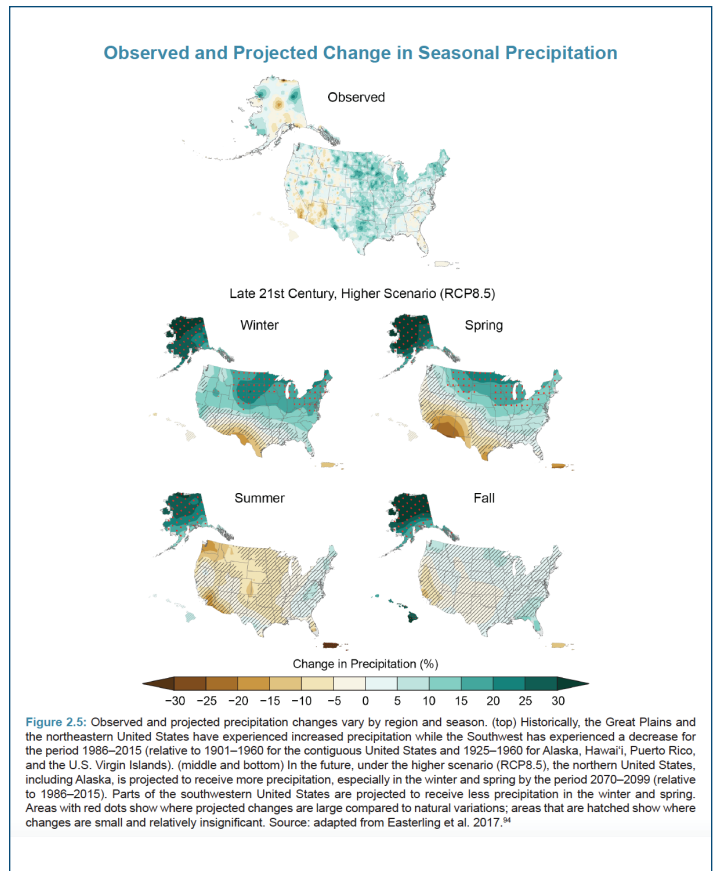


Figure 8: Original figure presented in (USGCRP, 2018).

**Claim 15: CO<sub>2</sub> may actually be beneficial, thanks to increasing agricultural productivity via CO<sub>2</sub> fertilization.**

**Response:** While increased CO<sub>2</sub> concentrations can provide a beneficial fertilizing effect for some plants when CO<sub>2</sub> levels adjusted in isolation, elevated atmospheric CO<sub>2</sub> levels are of course accompanied by changes to temperature and precipitation patterns. Furthermore, not all crops are anticipated to benefit from CO<sub>2</sub> fertilization. Agricultural plants utilizing the C4 photosynthetic pathway, such as corn and sugarcane, see few gains from increased CO<sub>2</sub> levels (Cure et al., 1986; Leakey et al., 2006). Furthermore, when considered in conjunction with climatic changes, plant biomass gains from CO<sub>2</sub> fertilization can be wiped out (Zhu et al., 2016). Ultimately, the impact of increased heat stress (e.g. Liu et al., 2016; Hawkins et al., 2013) and changes to precipitation patterns (Rosenzweig et al., 2002) is anticipated to outweigh any benefits provided by increased CO<sub>2</sub> availability.

Finally, increasing concern over the future global food supply is not limited to the substantial worry regarding climate impacts (Hanjra et al., 2010) but further involves challenges presented by population growth and by the potential of a future flattening of growth in agricultural yields (Connor and Mínguez, 2012). The question of future food security for the world should not be dismissed so lightly.

**Claim 16: Siberia is cooling very significantly. Look at this picture of Yakutsk, Siberia in winter, taken during an evening with temperatures of 60 degrees below zero!**

**Response:** The choice in particular of Yakutsk in the Russian Federation is conspicuous, as it happens to be one of the coldest locations on Earth outside of Antarctica, and is popularly known as [the world's coldest major city](#). The lowest temperature ever reliably recorded apart from Antarctic measurements was taken nearby in the city of Oymyakon ~425 miles to the northeast in the same province of Siberia (Stepanova, 2015).

Manheimer presents no other proof that Siberia is purportedly cooling apart from a link to [an EOS.org article](#) taken out of context. This article reports on a study assessing a trend in which Siberian *winter* temperatures have been lower over the past several decades. Manheimer neglects to mention that lower Siberian *winter* temperatures are assessed by the study to result from changes in atmospheric circulation caused by increased melt of sea ice in the Barents and Kara Seas during the fall (Zhang et al., 2018).

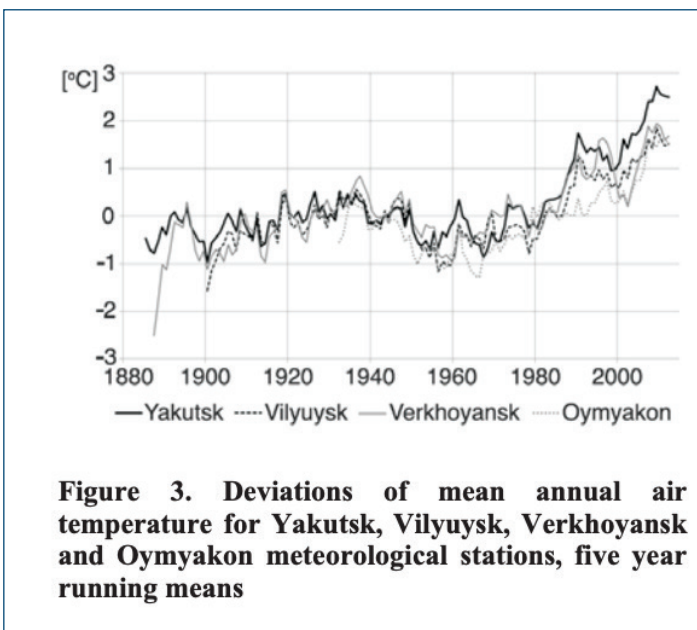


Figure 10: Originally presented in (Desyatkin et al., 2015).

With that aside, let us assess the trend in Siberian mean temperatures over the past century or more. Below, we present the long-term temperature data for four Russian meteorological stations in East Siberia (Desyatkin et al., 2015). All four time series show a clear increase in temperature since the 1950s.

**Claim 17: Temperature records taken at the poles show only slightly increasing temperature for North Pole region and no trend at the South Pole region.**

**Response:** The UAH MSU dataset Manheimer uses reports tropospheric temperatures, not surface temperatures, and furthermore possesses little coverage for latitudes between 80N-90N and 80S-90S. As the troposphere warms at a much slower rate than the Earth's surface over the poles, the North Pole region plot of tropospheric temperatures shown by Manheimer does not capture the dramatic rate of increase in Arctic surface temperatures over the observational record (Overland et al., 2019), with sea surface temperatures in the region climbing at a pace of up to 0.5C per decade (IPCC SROCC Ch 3)

Manheimer is correct that the South Pole exhibits no significant long-term trend in temperature, a finding supported by weather station measurements from the Amundsen-Scott outpost over 54 years (Lazzara et al., 2012). This comes as no surprise to the earth science community, for which this result - as well as its cause - has been known for decades (Thompson et al., 2002; Turner et al., 2005). Portions of Antarctica's interior are insulated from wider global temperature increases due to atmospheric and oceanic circulation patterns, and an increasing trend in the strength of circumpolar westerly winds caused by ozone depletion in the stratosphere of the Southern Hemisphere has been implicated as the cause of regional Antarctic cooling (Thompson et al., 2002).

**Claim 18: Cutting CO<sub>2</sub> threatens the lifestyles of billions.**

**Response:** Manheimer commits a false dichotomy in implying that reducing anthropogenic greenhouse gas emissions necessarily requires substantial reductions in quality of life for billions of people. To offer some obvious counterexamples, if cheap fusion-based generation of electricity to be commercially demonstrated tomorrow, or if dramatic technological advances substantially lower the cost of atmospheric carbon removal while increasing its efficiency, it stands to reason that significant reductions in net CO<sub>2</sub> emissions could be attained with no changes to standard of living. With ongoing improvements in the cost-competitiveness, efficiency, and scalability of clean energy, energy storage, clean vehicles, one has little reason to expect that the burning of fossil fuels is inextricably tied to human well-being. Rather, a spectrum of solutions and policy approaches may permit humankind to largely decouple modern society from carbon emissions even as it continues to improve standards of living for people globally.

Watching the media take new findings and draw the wrong conclusions in science reporting is an experience that scientists across all disciplines are likely intimately familiar with. Writers might tend towards exaggerating the risks of generating a black hole with a particle accelerator or overestimating the ease of obtaining weapons-grade material from nuclear waste. Similarly, journalists and reporters have been and should be criticized for misinterpreting climate science in some cases, but the most appropriate response to those lapses

merely requires scientists reaching out to correct the record on how some climate projections or impacts are framed or interpreted. The scientific basis behind anthropogenic climate change has grown far too robust for such minor misunderstandings to affect the larger pattern of a warming planet and evolving climate.

To focus overly on relatively insignificant popular misperceptions misses the bigger picture - namely, that the strong evidentiary basis for anthropogenic climate change warns us of serious ongoing and imminent consequences for human societies worldwide should our destabilizing perturbations of the earth system continue unabated.

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# A Buddy-system of Physicists and Political Scientists

Thomas Colignatus

The USA is only proto-democratic. More than a third of US voters have taxation without representation. A buddy system of physicists and political scientists may clear up confusions and would likely have a positive impact on society.

## SUMMARY AND INTRODUCTION

World society has a worrying trend of threats to notions and systems of democracy, see Wiesner et al. (2018) in the *European Journal of Physics*. It might be a fair enquiry whether physicists might play a role in enhancing democracy, also in their off-physics-research moments. Physicists have scientific training with a focus on empirics and a command of mathematics and modeling, and they would be ideally placed in providing sound reasoning and debunking confusion, potentially also in off-physics discussions about democracy. However, whatever this ideal position, when physicists don't study democracy then they are likely to be as uneducated as other people. One would expect that the true experts are political scientists, who might provide for such education also for physicists. This article will show however that political science still appears to be locked in the humanities on some crucial issues. Such political science rather creates confusion in the national educational system and the media, instead of providing the education that a physicist would need. The suggestion here is that the APS Forum on Physics and Society helps to set up a buddy system of physicists and political scientists so that the buddies – for all clarity consisting of a physicist and a political scientist per team – can educate and criticise each other in mutual respect, not only to each other's enjoyment, but likely with positive impact on society.

Democracy is a large subject, and the present article focuses on electoral systems. I will present some findings that are new to political science on electoral systems, and these will be indicated by the label *News*. They provide good points of departure when a physicist would begin a discussion with his or her political science buddy.

## WHY WOULD PHYSICISTS BE INTERESTED IN ELECTORAL SYSTEMS ?

Physicists meet with elections once in a while. Within faculties and professional organisations sometimes formal voting procedures are used. In such cases, often the actual decision has already been made in (delegated) negotiations so that the formal voting procedure only serves for ratification and expression of consent by the plenum. Physicists may also vote in local, state or national elections, in which, one would hope, the outcome has not been predetermined. The often implicit suggestion is that such electoral systems have been well-designed so that they no longer need scrutiny. However,

the highly worrying and disturbing diagnosis provided in this article is that countries like the USA, UK and France appear to be only proto-democratic. They are not the grand democracies as they are portrayed by political science in their books, the media and government classes in highschool. Physicists might be as gullible as anyone else who hasn't properly studied the subject. Physicists might consider to rely upon mathematicians who write about electoral systems but mathematicians tend to lack the training on empirical research and create their own confusions, see Colignatus (2001, 2014). Physicists might however be amongst the first scientists who would be able to perceive that proper re-education would be required, and that the creation of said buddy system would be an effective approach, and perhaps even a necessary approach given the perplexities in the issue.

The US midterms of November 6 2018 allow for an illustration of a new finding from August 2017. This new insight is a game changer, compare the news that the Earth is not flat but a globe. Policy makers might need more time to adapt US electoral laws but the new information can be passed on quickly. It appears that more than a third of US voters have taxation without representation. It presents a problem that buddies of physicists and political scientists can delve into, to each other's perplexion.

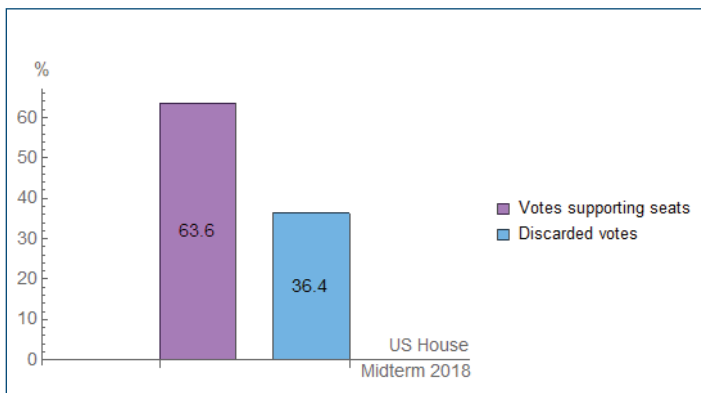
## DISCOVERY IN AUGUST 2017

Some readers will be familiar with the distinction between “district representation” (DR) versus “equal proportional representation” (EPR). In DR the votes in a district determine its winner(s) regardless of national outcomes. In EPR parties are assigned seats in equal proportion to the vote share, with particular rules to handle integer numbers. Before August 2017 I thought that the properties of DR and EPR were well-known, and that the main reason why the USA, UK or France did not change from DR to EPR was that a party in power would not easily change the system that put it into power. Then however I discovered that the literature in the particular branch of “political science on electoral systems” (including referenda) did not discuss the properties with sufficient scientific clarity. Many statements by “political science on electoral systems” are still locked in the humanities and tradition, and they aren't scientific when you look at them closely. For its relevance for empirical reality this branch of political science can only be compared to astrology, alchemy or homeopathy. The 2018 proof is in paper 84482 in the Munich archive MPRA, Colignatus (2018a). Thus the academia have been disinforming the world for the greater part of the last century. Americans express a preference for their own political system – an excellent book in this respect is Taylor et

al. (2014) – but they are also indoctrinated in their obligatory highschool Government classes, which in their turn again are disinformed by the academia, like indeed Taylor et al. too. Rein Taagepera (born 1933) started as a physicist and continued in political science with the objective to apply methods of physics. Shugart & Taagepera (2017) present marvels of results, yet run aground by overlooking the key distinction between DR and EPR, as discussed here. Let us now look at the US midterm of 2018, and apply clarity.

## US HOUSE OF REPRESENTATIVES 2018

In the 2018 Midterms for the US House of Representatives, 63.6% of the votes were for winning candidates and 36.4% were for losing candidates, see the barchart. This chart is novel and is conventionally not shown even though it is crucial to understand what is happening. The US system of district representation (DR) has “winner take all”. The traditional view is that the losing votes are “wasted”. Part of the new insight is that the latter terminology is distractive, too soft, and falsely puts the blame on the voter (who should be wiser than to waste his or her vote). In truth we must look at the system that actually *discards* these votes. These votes no longer count. These voters essentially have taxation without representation.



## LEGAL TRADITION IN THE HUMANITIES VERSUS EMPIRICAL SCIENCE

Economic theory has the Principal – Agent Theory (PAT). Supposedly the voter is the principal and the district representative would be the agent. However, a losing voter as principal will hardly regard a winning candidate as his or her agent. The legal storyline is that winning candidates are supposed to represent their district and thus also those who did not vote for them. Empirical science and hardnosed political analysts know that this is make-believe with fairy tales in cloud cuckoo land. In practice, losing voters in a district deliberately did not vote for the winning candidate and most losing voters commonly will not regard this winner as their proper representative but perhaps even as an adversary (surely

this cannot be *News*? But textbooks in political science do work the point). The textbook by Taylor et al. (2014) refers to PAT but applies it wrongly as if legal formality suffices. Under the legal framing of “representation” these Housewinners actually *appropriate* the votes of those who did not vote for them. Rather than a US House of Representatives we have a US House of District Winners, but we might also call it the US House of Vote Thieves.

These voting outcomes are also highly contaminated by the political dynamics of district representation (DR). The USA concentrates on bickering between two parties, with internal strife and hostile takeovers in the primaries (Maskin & Sen (2016)). Many voters only voted strategically in an effort to block what they considered a worse alternative, and originally had another first preference. In a system of equal proportional representation (EPR) like in Holland, there is “electoral justice”. Holland has 13 parties in the House and allows for the dynamic competition by new parties. Voters are at ease in choosing their first preference and thus proper representatives. They might also employ some strategy but this would be in luxury by free will. In the USA voters often fear that their vote is lost, and the outcome is also distorted by their gambling about the odds. Thus we can safely conclude that even *more* than a third of US voters in 2018 are robbed from their democratic right of electing their representative.

## LEGAL TRADITION VERSUS THE UNIVERSAL DECLARATION OF HUMAN RIGHTS

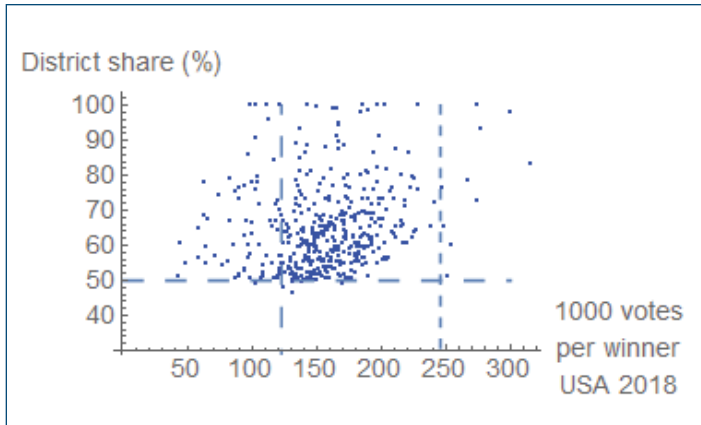
Article 21 of the *Universal Declaration of Human Rights* (UDHR) of 1948 states: “Everyone has the right to take part in the government of his country, directly or through freely chosen representatives.” When votes are not translated into representation of choice, then they are essentially discarded, in violation of this human right. The USA helped drafting and then ratified the UDHR but apparently did not realise that its own electoral system violates it. The USA has been saved somewhat by the workings of the Median Voter Theorem and by *parties* defending their voters in losing districts (which runs against the principle of representing your own district). The loss of economic well-being must be great, e.g. compare Sweden and Holland, that switched from DR to EPR in 1907 resp. 1917, that are among the happiest countries.<sup>1</sup>

## CONFIRMATION BY A SCATTER PLOT

We see this diagnosis confirmed by the district results of

<sup>1</sup> Caveat: these countries must thank the USA and UK for saving them from the Nazis. A common line of argument is that DR protected the USA and UK from dictatorship, and that EPR allowed the Nazis to seize power. Instead, EPR made it more difficult for the Nazis, and they only got in control by the fire of the Reichstag and arresting communists in the Weimar parliament, see Boissoneault (2017). (This is not *News* since some specialists know this, but it still is not common knowledge amongst political scientists.)

the US Midterms, see the scatter chart with horizontally the number of votes per winner and vertically the share of that winning vote in the district. Some districts are uncontested with 100% of the share. The key parameter is the *electoral quota*, defined as the total number of votes divided by the 435 seats in the US House. This is about 246 thousand votes, given by a vertical dashed line.



In EPR a seat in the House would be fully covered by this electoral quota, and practically all dots would lie on this line except for some remainder seats. In DR in the USA in 2018 only some 11 dots manage to reach this quota, helped by having large districts. Gerrymandering can help to create such districts. There can be more districts with fewer voters in which the gerrymandering party hopes to have an easier win, remarkably often with even less than half the electoral quota at 123 thousand. While some people speak out against gerrymandering, it is the very point of having districts itself that disenfranchises voters.

In the USA the winners tend to gain more than 50% of the votes in their districts, which plays into the storyline that they gain a majority in their district, but this still is a make-believe fairy tale because they fall brutally short of the electoral quota for proper representation. That winners tend to get more than 50% merely reflects the competition between only two parties, at the detriment of other views.

## ORDINARY LANGUAGE INSTEAD OF SCIENTIFIC PRECISION

Above observation on taxation without representation could be an eye-opener for many. Perhaps two eyes may be opened. This unscientific branch of political science relies upon ordinary language instead of definitions with scientific precision. Physics also borrowed common words like “force” and “mass”, yet it provided precise definitions, and gravity in Holland has the same meaning as gravity in the USA. The “political science on electoral systems” uses the same words “election” and “representative” but their meaning in Holland

with EPR is entirely different from the USA with DR. We find that the USA, UK and France are locked into confusion by their vocabulary. The discussion above translates into the following deconstruction of terminology .

- In EPR, we have proper elections and proper representatives. Votes are bundled to go to their representative of choice (commonly of first preference), except for a small fraction (in Holland 2%) for tiny parties that fail to get the electoral quota. Those votes are wasted in the proper sense that the technique of equal proportionality on integer seats cannot handle such tiny fractions. A solution approach to such waste is to allow alliances (“apparentement”) or empty seats or at least to require qualified majority voting in the House .
- In DR, what is called an “election” is actually a contest. A compromise term is “election contest”. What is called a “representative” is rather a local winner, often not the first preference. (This is often recognised in the PS literature and thus no *News*, but remarkably political scientists then switch to the legality of representation and continue as if a winner is a representative indeed.) The legal terminology doesn’t fit political reality and Principal – Agent Theory .

An analogy is the following. Consider the medieval “trial by combat” or the “judgement of God”, that persisted into the phenomenon of dueling to settle conflicts. A duel was once seriously seen as befitting of the words “trial” and “judgement”. Eventually civilisation gave the application of law with procedures in court. Using the same words “judgement” and “trial” for both a duel and a court decision confuses what is really involved, though the outward appearance may look the same, i.e. that only one party passes the gate. It is better to use words that enhance clarity. The system of DR is proto-democratic while proper democracy uses EPR.

Shaun Lawson (2015) in the UK laments how elementary democratic rights are taken away but still doesn’t understand how. Now we know. The problem lies first of all with the academia.

## BLAME ALSO THE UNSCIENTIFIC COWARDICE OF R.A. DAHL AND C.E. LINDBLOM

Both eyes might be opened even further by a glance at the US presidency, that currently occupies the USA so much, and that creates such needless national division. Arthur Schlesinger, “*The Imperial Presidency*”, 1973, was concerned that the US presidency exceeded its constitutional boundaries and was getting uncontrollable. Robert Dahl & Charles Lindblom, “*Politics, Economics, and Welfare*”, 1976, page 349, take this into account and provide their answer:

“Given the consequences of bargaining just described, what are the prerequisites of increasing the capacity of Americans for rational social action through their national government? (...) Certainly the adoption of a parliamentary system along British lines, or some version of it, may be ruled out, not

only because no one knows enough to predict how it would work in the United States, but also because support for the idea is nonexistent. Although incremental change provides better opportunity for rational calculation than comprehensive alternations like substitution of the British system, there is little evidence even of a desire for incremental change, at least in a direction that would increase opportunities for rational calculation and yet maintain or strengthen polyarchal controls.”

This is a statement of unscientific cowardice. A scientist who observes climate change provides model, data and conclusion, and responds to criticism. Dahl & Lindblom show themselves as being afraid of stepping out of the line of tradition in the humanities. They fear the reactions by their colleagues. They want to keep saying that the US is a democracy rather than conclude that it is only proto-democratic. They resort to word-magic and present a new label “polyarchy” as a great insight while it is a cover-up for the failure on democracy (p276). The phrase about predicting how a parliamentary system would perform in the USA is silly when the *empirical experience* elsewhere is that it would be an improvement (this cannot be *News* since the evidence exists but it might be *News* to political scientists that D&L close their eyes for the evidence). Nowadays, the US House of Vote Thieves can still appoint a prime minister. For this governance structure, it is only required that the US president decides to adopt a ceremonial role, which is quite possible within the US constitution, and quite logical from a democratic point of view. For the checks and balances it would also be better that the (ceremonial) president doesn’t interfere with the election of the legislature, but we saw such meddling in 2018. See also Juan Linz, “*The perils of presidentialism*”, 1990. The reference by Dahl & Lindblom to Britain partly fails because it also has DR, while the step towards proper democracy includes the switch to EPR, also for Britain. See Colignatus (2018e) for an explanation how Brexit can be explained by the pernicious logic of DR and referenda, and for a solution approach for Britain to first study electoral systems, switch to EPR, have new elections, and then let the UK parliament reconsider the issue.

In his obituary of Dahl, Ian Shapiro stated in 2014: “He might well have been the most important political scientist of the last century, and he was certainly one of its preeminent social scientists”. Also the informative and critical Blokland (2011) does not deconstruct this image. The truth rather is, obviously with all respect, that Dahl was still locked in the humanities and tradition. He lacked the mathematical competence to debunk Kenneth Arrow’s interpretation of his “Impossibility Theorem”, see Colignatus (2001, 2014). Dahl’s unscientific cowardice has led “political science on electoral systems” astray, though political scientists remain responsible themselves even today. Scandinavia has EPR but its political scientists can still revere Dahl. Teorell et al. (2016) follow Dahl’s misguided analysis, and their “polyarchy index” puts the USA, UK and France above Holland, even while at least

a third of US voters are being robbed from representation because of the US House of Vote Thieves. Hopefully also the Scandinavians set up a buddy system for their political scientists.

## INCOMPETENCE MAY BECOME A CRIME

If the world of political science would not answer to this criticism and burke it, then this would constitute a white collar crime. The US has a high degree of litigation that might turn this into a paradise for lawyers (not really news). Yet in science as in econometrics we follow Leibniz and Jan Tinbergen (trained by Ehrenfest), and we sit down and look at the formulas and data. Empirical scientists tend to be interested in other things than democracy, and when they haven’t studied the topic then they may have been indoctrinated in highschool like any other voter (not really *News*). Scholars who are interested in democracy apparently have inadequate training in empirics (this is *News*). Those scholars have started since 1903 (foundation of APSA) with studying statistics and the distinction between causation and correlation, but a key feature of empirics is also observation. When it still is tradition that determines your frame of mind and dictates what you see and understand, then you are still locked in the humanities, without the ability to actually observe what you intend to study. It is crucial to observe in DR that votes are discarded and are not used for representation of first preferences, unhinging the principal-agent relationship that you claim would exist. Also FairVote USA is part of the problem, who do not clearly present the analysis given here and who misrepresent equal proportionality by trying to make it fit with DR, while the true problem is DR itself. The USA is locked in stagnation.

## A BUDDY-SYSTEM OF SCIENTISTS AND SCHOLARS FROM THE HUMANITIES

The obvious first step is that real scientists check the evidence (at MPRA 84482), which would require that scientists in their spare time develop an interest in democracy, and that scholars in “political science on electoral systems” overcome their potential incomprehension about this criticism on their performance. The suggested solution approach is to set up a buddy-system, so that pairs of (non-political) scientists (physicists) and (political science) scholars can assist each other in clearing up confusions.

Some may fear what they might discover, and fear what they might have to explain to (fellow) US voters, but like FDR stated in 1933: There is nothing to fear but fear itself.

PM 1. The evidence for this article is provided in Colignatus (2018a) at MPRA 84482. **Appendix A** summarizes supplementary evidence by Colignatus (2018b). **Appendix B** discusses seeming inconsistencies in this article. For consequences for UK and Brexit, see Colignatus (2018d) in the

October 2018 *Newsletter of the Royal Economic Society*. See Colignatus (2018e) for a suggestion of a moratorium.

PM 2. The data in the charts are from the *Cook Political Report* of November 12 2018, with still 7 seats too close to call but presumed called here.

PM 3. I thank Stephen Wolfram for the programme *Mathematica* used here. For the creation of *Mathematica*, Wolfram was partly inspired by the program *Schoonschip* by Martinus Veltman.

## APPENDIX A. SUPPLEMENTARY EVIDENCE ON INEQUALITY / DISPROPORTIONALITY OF VOTES AND SEATS

The following is from Colignatus (2018b). Political science on electoral systems uses measures of inequality or disproportionality (ID) of votes and seats, to provide a summary overview of the situation. Relevant measures are (i) the sum of the absolute differences, corrected for double counting, as proposed by Loosemore & Hanby (ALHID), (ii) the Euclidean distance proposed by Gallagher (EGID), and (iii) the sine as the opposite of R-squared in regression through the origin, as proposed by me (SDID). For two parties, or when only one party gets a seat so that the others can be collected under the zero seat, then Euclid reduces to the absolute difference.

The following table at the bottom gives the US data for 2016 and preliminary 2018. Conveniently we use data and indices in the  $[0, 10]$  range, like an inverted report card (Bart Simpson: the lower the better). The ALHID of 2016 gives a low value of 0.63 in a range of 10, but SDID provides a magnifying glass and finds 3.24 on a scale of 10. In 2018 the inequality / disproportionality seems much reduced. Observe that the votes are not for first preferences due to strategic voting, and outcomes thus cannot be compared to those of countries with EPR.

Taylor et al. (2014:145) table 5.6 give electoral disproportionalities in houses of representatives in 31 democracies over 1990-2010, using EGID. Proportional Holland has 0.1 on a scale of 10 (there is little need to measure something that has been defined as equal proportional), and disproportional France has 1.95 on a scale of 10. The USA has 0.39 on a scale

of 10. Taylor et al. p147 explain the much better performance of the USA compared to France by referring to the US two-party-system, including the impact of the US primaries. This statement is curious because it doesn't mention strategic voting and thus the basic invalidity of the measure. In 2018 more than a third of the votes in the USA are discarded, so their table 5.6 does some number crunching as if it were science but misses the key distinction between EPR and DR.

Taylor et al. may be thanked for their mentioning of the primaries, because this highlights that the USA labels of "Republican" and "Democrat" are only loosely defined. District candidates have different origins and flavours. A Southern Republican in 2018 may rather derive from the Southern parties who supported slavery and thus be less rooted in the original Republicans of Lincoln who abolished slavery in 1863. Condoleezza Rice may wonder which Republican Party she joined. Thus, above aggregate measures are dubious on the use of these labels too. In the aggregate we see that district winners are supposed to defend losers of the same party in other districts, but this runs against the notion that a representative ought to represent the own district. This objection is stronger when the party labels over districts are only defined loosely.

Thus, as an innovation for the literature, it is better to use the ALHID = EGID and SDID measures per district, and then use the (weighted) average for the aggregate. In each district there is only one winner, which means that the disproportionality is large, and we see more impact from the phenomenon that losing votes are not translated into seats. When we weigh by seats, or the value 1 per district, then we get the plain average. Alternatively we can weigh by the votes per district. We find that the 2018 aggregate ALHID of 0.18 rises

All in the $[0, 10]$ range	ALHID	SDID
Using aggregate data only	0.18	1.61
Districts, weighted by seats	3.5	6.4
Districts, weighted by votes	3.64	6.57

	Parties	Votes	Seats	Differences	
USA[2016] → {Table →	Rep	4.91	5.54	0.63	, ID → AbsLoosemoreHanbyID → 0.63 SineDiagonalID → 3.24
	Dem	4.8	4.46	-0.34	
	Other	0.29	0.	-0.29	
	Parties	Votes	Seats	Differences	
USA[2018] → {Table →	Rep	4.58	4.67	0.09	, ID → AbsLoosemoreHanbyID → 0.18 SineDiagonalID → 1.61
	Dem	5.24	5.33	0.09	
	Other	0.18	0.	-0.18	

to the average 3.50 (weighted by seats) or 3.64 (weighted by votes) on a scale of 10. SDID uses a magnifying glass. These outcomes are still distorted by strategic voting, of course, but the outcomes show the dismal situation for representation in the USA much better. In the best measure (SDID) on a scale of 0 (best) to 10 (worst), the USA is 6.57 off-target.

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## APPENDIX B. SEEMING INCONSISTENCIES

This article runs the risk of an inconsistency (A): (i) The information was known around 1900 so that Sweden and Holland could make the switch from DR to EPR, (ii) There is *News* for the political science community so that now the USA, UK and France can make the switch too. Formulated as such, this is a plain inconsistency. However, political scientists in the USA, UK and France invented apologies to neglect the information under (i). The *News* under (ii) debunks such apologies. Thus there is no inconsistency. There is a distinction between full information (with arguments pro and con) and an apology to neglect information. Sweden and Holland did not invent such apologies and thus were informed back then, and are not in need of debunking now. One might consider that Sweden and Holland were too rash in their switch from DR to EPR, since they overlooked such apologies to neglect information. This however would be like arguing that a proper decision also requires putting one's head under the sand, at least for some 100 years, in order to see the full spectrum of possible choices.

This article runs the risk of inconsistency (B): (i) It is a strong claim that something is *News*, and this would require knowledge of all political science literature, (ii) The author is no political scientist. Formulated as such, this is a plain inconsistency. However, Colignatus (2018a) selects a political science paper that is "top of the line" and then debunks it. For all practical matters this is sufficient.

Colignatus (2001, 2014) discusses single seat elections. My intention was to write a sequel volume in 2019 on multiple seat elections, combining (2018a) and (2018b) and related papers. This present article is a meagre abstract of this intended sequel. I got sidetracked in 2018-2019 on the environment and climate change by assisting Hueting & De Boer (2019) and drafting Colignatus (2019).

The *News* in this article has not been submitted to political science journals, so that the underlying diagnosis maintains its validity for a longer while, i.e. that political science on electoral systems still is locked in the humanities. This *News*

has been indicated to the board of the Political Science association in Holland, but they are likely unaware about the econometric approach to Hume's divide between Is and Ought, see Colignatus (2018c), p6-7.

The *News* in this article has not been submitted to political science journals because the community of political science has had ample opportunity since 1900 to listen and we can observe as an empirical fact that they do not listen but invent apologies not to listen, and thus don't do science properly. While Sweden and Holland switched from DR to EPR so early in the 1900s, the USA ("American exceptionalism") and UK ("the world's first democracy") had the same discussion but kept DR, and the very manner of reasoning does not show rationality but traditionalism verging on mystic glorification of national history. France had a phase of EPR but then some political parties tried to stop the popular Charles de Gaulle by switching to DR, and they in fact created a stronger power base for the Gaullists. Instead of disseminating the *News* via a submission to a political science journal where it will be handled by methods of astrology, alchemy and homeopathy, it is better to call in the cavalry. Let the world observe the dismal situation of political science on electoral systems, and let the scientific community put a stop to it.

An example of a physicist looking at democracy is Karoline Wiesner. The paper Wiesner et al. (2018) is not presented as the final truth here. There is no guarantee that such study will be useful without the *News* provided here as points of departure. For example, their article uses the *The Economist* Intelligence Unit (EIU) *Index of Democracy*, that does not catalog the proto-democratic electoral systems in the USA, UK and France as major threats to democracy.

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## REVIEWS

### A Bright Future: How Some Countries Have Solved Climate Change and the Rest Can Follow

Joshua Goldstein and Staffan Qvist (Public Affairs, New York, 2019). 276 pp. ISBN 978-1-5417-2410-5.

Because of my concern about climate change, a friend thought I would want to read this book, co-authored by an Emeritus Professor of International Relations at American University and a Swedish engineer, scientist, and consultant to clean energy projects. Because the subtitle suggested that other countries had found a magic bullet to solve this problem, I readily accepted and dug in.

In the foreword I read Steven Pinker's claim that this is the "first book on dealing with climate change that is grounded in reality," recognizing the massive changes that need to be made as shown by the nations that have made them. In the first chapter, titled "Climate Won't Wait," I read the authors' argument that carbon dioxide emissions need to be reduced to nearly zero in a few decades to keep climate change from getting out of hand. The Paris Agreement would not achieve this, they point out; and "little progress has been made on" the "climate stabilization wedges" proposed 15 years ago. What is needed, they claim, is an effort comparable to dealing with an asteroid on course to strike Earth in the same time frame.

The second chapter, titled "What Sweden Did," cuts right to the chase. I learned that from 1970 to 1990 Sweden halved its carbon emissions while doubling its electricity generation and expanding its economy 50% by using *kärnkraft*, that its

*kärnkraft* plants generate 40% of its electricity and hydro another 40%. So the "magic bullet" for "solving climate change" is *kärnkraft*! But it didn't take me long to piece together from my knowledge of German that this is *nuclear power*.

Already in chapter two the cat is out of the bag! The rest of the book presents the reasons Goldstein and Qvist feel that nuclear energy is the best antidote to climate change. Their first talking point comes in chapter three, titled "What Germany Did." In contrast to Sweden, Germany has embarked on phasing out nuclear energy. While Sweden is adding renewable energy to supplement nuclear energy, Germany is adding renewable energy to *replace* nuclear energy. That solar and wind are diffuse and intermittent, while nuclear is concentrated and constant, makes this difficult and leaves fossil fuels to make up the difference, thus increasing carbon dioxide emissions.

The next three chapters of the book focus on what Goldstein and Qvist call "half measures." The first of these is energy conservation and efficiency, both of which are acknowledged to reduce energy use, but the authors point out that the trend worldwide is *greater* energy use, as developing countries *increase* their need for energy with improved living standards, and the need for worldwide decarbonization must be viewed in this context. The only energy source thus far that can scale up to decarbonize amidst increased energy use, they assert, is nuclear.

The second "half measure" that Goldstein and Qvist consider is renewable energy. "The *story* of using only re-



newables seems compelling, but the *scale* does not work to rapidly decarbonize the world,” they observe. Historically most renewable energy has come from hydroelectricity, whose constancy makes it suitable for baseload energy, but most sites for it have already been tapped. They add that the problem posed by the intermittency of solar and wind could be avoided if the electrical energy they produce could be stored until needed, but the resulting added cost makes these sources uncompetitive.

The third and last “half measure” is burning methane in the form of natural gas instead of coal to generate electricity. While natural gas is the cheapest energy source to generate electricity and emits half as much carbon dioxide per unit of energy as coal, Goldstein and Qvist caution that it is not free of greenhouse gases. Moreover, methane leakage from natural gas wells adds another greenhouse gas to the atmosphere, producing 25 times the effect of carbon dioxide, although methane lingers there only decades compared to centuries for carbon dioxide.

In addressing the safety of nuclear energy, Goldstein and Qvist feel that the biggest downside from the nuclear accidents at Fukushima Daichi, Chernobyl, and Three Mile Island has been the pollution from the fossil fuels burned to generate the electricity no longer generated by these nuclear plants and which would have been generated by nuclear plants never completed due to public opposition. They compare 30 deaths from generating a terawatt-hour of electricity from coal to less than a tenth for the same amount of nuclear-generated energy.

Because people are likely to perceive accidents at nuclear plants as highly memorable, Goldstein and Qvist recognize that they are perceived as disproportionately risky, and riskier than medical radiation, which is planned and controlled. But they counter that nothing is completely risk-free, and argue that government controls to make nuclear energy as risk free as possible makes nuclear energy less economically competitive than energy from fossil fuels, which is not similarly regulated.

On the subject of nuclear wastes, which I find to be the most critical problem posed by nuclear energy, I find Goldstein and Qvist to be almost cavalier. While the chemical waste from a coal-fired power plant is permanent, nuclear waste decays, they point out. They give the impression that the few years that spent fuel is kept in temporary storage are sufficient for most radioactive isotopes to decay to a level of minimal concern—but if that were so, why would this waste need to be encased at a more permanent storage site? When they do cite longer-lived isotopes, with radioactivity to linger “tens of thousands of years,” they seem to have in mind plutonium without naming it and note that it can fuel future reactor

designs. One of these is the breeder reactor, which they say is operating in Russia (but say nothing about the difficulties attending breeder reactor development around the world). They leave long-lived waste storage of beyond a century to new technologies what will have evolved by then. For those concerned that nuclear energy leads to nuclear weapons, Goldstein and Qvist correctly point out the difference between the two, but they avoid discussing the nuclear rogue states for which both nuclear energy and weapons are important.

Goldstein and Qvist begin the final section of their book, titled “The Way Forward,” with a plea not to close American nuclear power plants prematurely while they tout the advantages of what are considered third and fourth “generation” nuclear power plant designs which are able to shut down automatically in case of accident. But since climate change must be addressed globally, they also focus on three other critical players on the world scene: China, Russia, and India. Although China now leads the world in carbon dioxide emissions and is a leader in building coal-burning power plants, it is also credited for its investment in nuclear and renewable antiaggression earns more from its natural gas by exporting it than burning it, and exporting it to Germany to replace the coal they burn would reduce Germany’s carbon dioxide emissions. Furthermore, Russia is the world’s leading exporter of nuclear reactors. It is developing a fourth-generation “Breakthrough” reactor design, and hopes to increase its percentage of nuclear electricity to 50%.

India’s coal consumption is second only to China’s and growing, and its nuclear energy program is in its infancy. Goldstein and Qvist would like to see China and India join Russia in accelerating their nuclear energy programs. Their “poster child” is Ontario, which has emulated Sweden to reduce carbon dioxide emissions from its electric sector by 90% by building 16 reactors in seventeen years. However, like Sweden, Ontario needed nuclear power for only 60% of its energy because it was able to depend on plentiful hydro. Goldstein and Qvist acknowledge that attempts in the European Union, USA, and Canada to reduce carbon dioxide emissions with a cap-and-trade-based tax have had mixed results. However, they argue that it is more effective than persuasion or regulation.

Because the three main end uses of energy are electricity, heat, and transportation, the book concludes that the procedure for total decarbonization is “(1) generate electricity cleanly and (2) electrify everything.”

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