A Realistic Path to a Bright Future

20 December 2021

James Hansen

Why is nobody telling young people the truth? "We preserved the chance at COP26 to keep global warming below 1.5°C." What bullshit! "Solar panels are now cheaper than fossil fuels, so all we are missing is political will." What horse manure! "If we would just agree to consume less, the climate problem could be solved." More nonsense!

Young people, I am sorry to say that – although the path to a bright future exists and is straightforward – it will not happen without your understanding and involvement in the political process. Ever since 2008 I have been amazed by your acumen and your ability to affect national elections and appreciate global issues. With appropriate focus, you can alter the course of our world in a good way. I hope that you find something in my experiences that helps you in your pursuit of a bright future.

Do not feel sorry for yourself or get discouraged. Yours is not the first generation to be dealt a bad hand. Some were born into great depressions. Some were sent to fight in world wars or senseless conflagrations in far away places such as Viet Nam or Iraq. Your battle will cover more years. Nature has a long timescale in its response to human-caused forces, and it takes time to alter human-made energy systems. But your cause is noble – your challenge is nothing short of guiding humanity and other life on our planet to a bright future.

The long timescales should not dishearten you. The slow response of nature provides the time needed to alter the infrastructure of our energy systems and improve land use practices. However, your task is now urgent. The next 10 years – the fourth decade since the adoption of the Framework Convention on Climate Change in 1992 – must be the decade in which young people take charge of their own destiny.

On the scientific front, several colleagues and I assert that IPCC (Intergovernmental Panel on Climate Change) has underestimated the sensitivity of climate to growing freshwater injection from melting ice. One potential consequence – if we continue with business-as-usual emissions – is shutdown of the overturning North Atlantic and Southern Ocean overturning ocean circulations by midcentury, each of which will contribute to acceleration of mass loss from the Antarctic ice sheet, with the likelihood of sea level rise of several meters within the lifetime of children born today.

Existential climate threat arises from the combination of sea level rise, the increasing difficulty of life in the tropics and the subtropics in the summer as temperatures rise, and the increase of climate extremes as higher temperatures drive droughts, heat waves and fires, on one hand, but also heavier rains, greater floods and stronger storms on the other hand. These effects will increase emigration pressures from low latitudes and coastal cities, thus potentially creating a planet that is practically ungovernable.

Climate science reveals that we have overshot sensible targets not only for atmospheric carbon dioxide, but also for global temperature. We will need to return to a global climate no warmer than the middle of the 20th century, and likely somewhat cooler, for the sake of maintaining global shorelines. That task is made more difficult by our Faustian bargain with particulate air pollution, which has tended to diminish global warming by reflecting sunlight to space. Our Faustian payment is coming due as health-damaging particulate pollution is being reduced, Earth's energy imbalance is increasing, and the rate of global warming is accelerating.

The good news is that the aerosol and climate research reveal a pathway by which the present extreme human-made interference with Earth's energy balance can be diminished as fossil fuel emissions decline and greenhouse gas levels diminish. Don't worry – it does not require Frankenstein geoengineering of our home planet. Instead, we should reduce our present human interference with nature as promptly as practicable. An essential early requirement is that global greenhouse gas emissions begin to decline during this 4th decade of the Framework Convention. That does not imply that we must reduce global energy use – on the contrary, more energy will be needed to reduce poverty and raise global living standards – rather it implies that we need a realistic clean-energy plan and that we carry out the R&D to support it.

China and the United States – as the largest current and historical sources of emissions – should cooperate to achieve the most rapid transition to clean energies. De facto cooperation of the West and China helped drive down the cost of renewable energies, but more extensive cooperation will be needed to apply the brakes to accelerating climate change. As the largest economies in the world, the two nations have the ability to alter the global energy pathway via agreement on simple, honest carbon pricing, but adequate pricing becomes practicable only in concert with advances in carbon-free energy technologies including modern nuclear power. To achieve the cooperation that will speed these advances, scientists in the West and East can help lay the groundwork by continuing and expanding their mutual research to promote common understanding.

Young people in the United States have the most urgent and crucial task: to fix the broken two-party political system. You have the power and the means to achieve the political transformation that is required to break the grip that special interests have on Washington, our energy systems, and your future, but the transformation requires that you understand the underlying problem and organize accordingly. The urgency has more to do with the boiling frustrations of the public as they witness the endemic graft and incompetence of our elitist government. Young people must learn not to follow the siren of old orators from the broken system. You must take charge of your future. You have the incentives and the abilities to achieve the changes that are needed for the sake of both your nation and the world.

As for climate science, we have our own challenges. The forces that humanity is exerting on the climate system are unprecedented. The great inertias of the massive ocean and ice sheets are the cause of the greatest threat – because future change builds up without the warnings that public response requires – but these inertias also provide us opportunity to achieve a soft landing for humanity and nature, provided that we have adequate understanding of the system. As with your politics, our science must advance this decade so as to be in position to provide the guidance required to achieve that soft landing. Global climate models are a useful tool for that purpose, but they must be matched by comparable focus on paleoclimate – especially the Eemian period, which appears to have been as warm as today – and on ongoing physical processes, especially in the ocean and the periphery of Antarctic ice.

I am sorry that we are leaving you – young people – with such a burden, but I know that you will accept it as a challenge. You have a magnificent opportunity to change the course of history this decade, to move the world onto a realistic path to a bright future for your own sake and for that of your children, grandchildren and future generations.

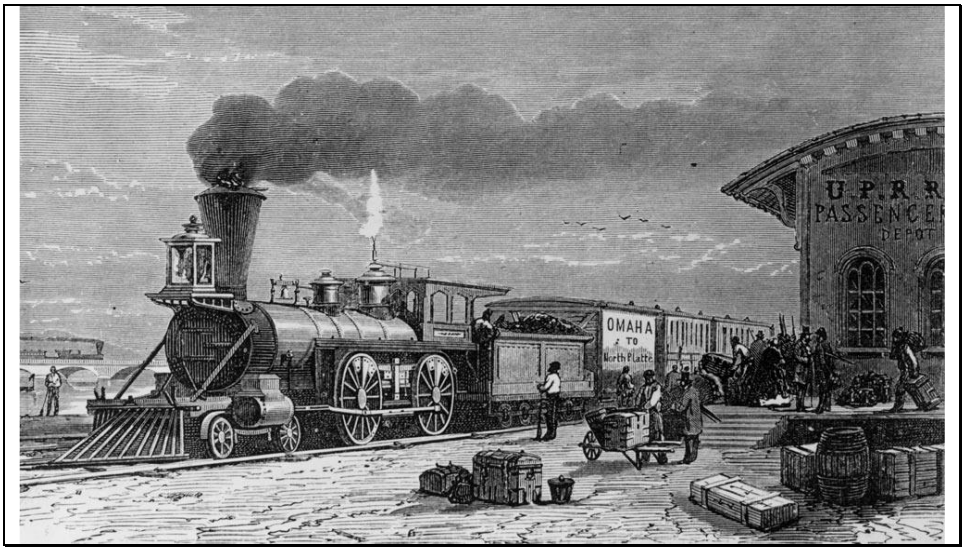
Conclusion of COP21 in Paris in 2015

I prepared this presentation in the wake of COP26, the Conference of the Parties of the United Nations Framework Convention on Climate Change, held at Glasgow, Scotland, in November 2021. COP meetings are actually Conferences of the Pretenders. Political leaders make statements that they know – or should know – are blatant nonsense. COPs can produce numerous minor accomplishments, which is sufficient reason to continue with the meetings. However, they ignore the two elephants in the room that will determine the future.

I will also criticize three other groups. The fossil fuel industry, for disinformation campaigns and for bribery of "big green" organizations that preserves fossil fuel emissions and locks in consequences for young people; the media for often reporting what they think the public wants to hear, rather than what the public needs to know; and we scientists for letting the politicians, fossil fuel industry, and media get away with doing a poor job of describing reality.

One more introductory comment: the climate story does not need to be gloom and doom. There is a straightforward path to a bright future, but we must be honest about what is needed and follow the science.

To achieve the bright future, young people must understand what is needed and affect the political process accordingly.



The industrial revolution first raised living standards in Western civilization.

The energy source fueling the industrial revolution in the 19th century was coal.

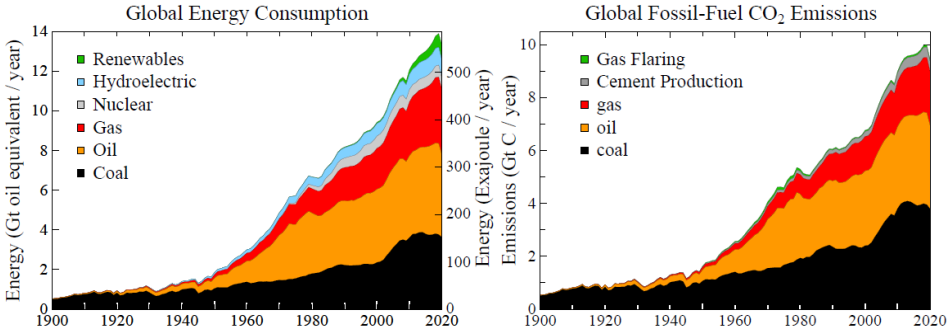
In the 20th century oil and gas joined the party.

Their condensed energy was comparable to that of coal, and more convenient.

One gallon of gasoline contains the work equivalent of 400 hours labor by a healthy adult.

Fossil fuels raised living standards in half of the world.

The other half wants to follow that path, and they have the right to raise their living standard.



BP energy consumption data are used from 1965; earlier CDIAC data (Gilfillan et al.)are adjusted by factors near unity to match BP in 1965. CO_2 data are from CDIAC through 2017, followed by BP data as adjusted to match BP in 2017.

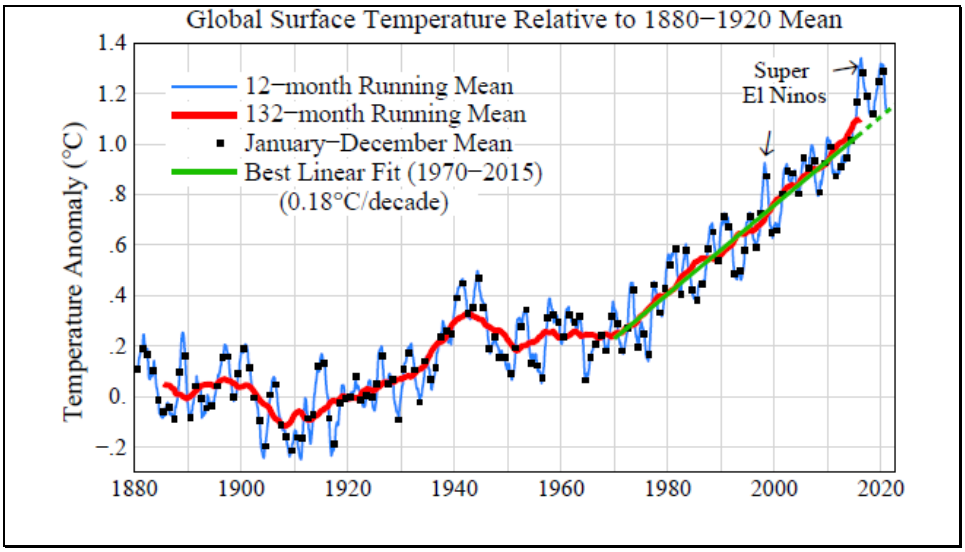
(*Gilfillan D; Marland G; Boden T; Andres R (2021): Global, Regional, and National Fossil-Fuel CO_2 Emissions: 1751-2018 CDIAC-FF, Research Institute for Environment, Energy, and Economics, Appalachian State University.*)

They are doing that, and thus global energy consumption is rising.

About 80 percent of the energy is from fossil fuels, so the CO2 emissions from fossil fuel burning are rising.

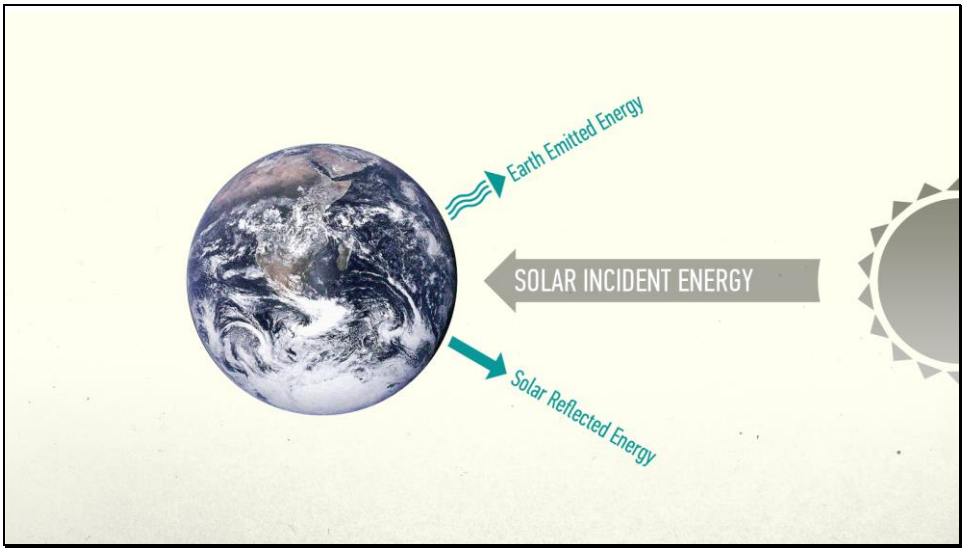
Note that growth of fossil fuel use was not stopped by even the landmark COP meetings – the Kyoto Protocol in 1997, the Paris Agreement in 2015.

Energy use and emissions dropped 5-6 percent in the past 2 years due to covid, but growth seems to be resuming now.



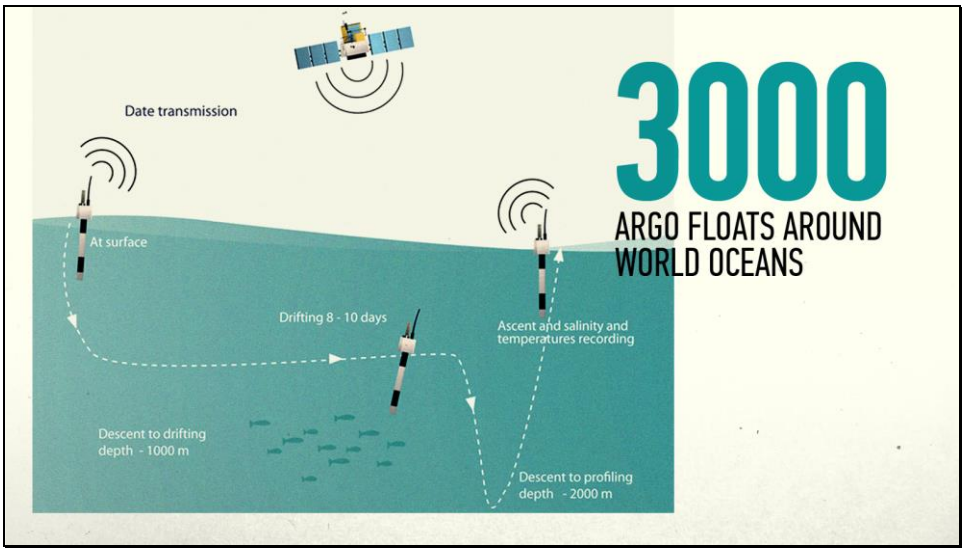
So the world is getting warmer because of the greenhouse effect of increasing CO2, with help from a few other gases, especially methane and nitrous oxide.
Earth has warmed by 1.2°C – that's 2.2°F – since the beginning of the 20th century.
Global leaders, at the conclusion of the COP, asserted that we can still keep global warming below 1.5°C.
That assertion is pure, unadulterated, bullshit – I mean blatant nonsense – because of the 3-decade-long failure of the COPs to address the two basic requirements to stabilize climate.

Before discussing those two requirements, let's explain why it is certain that 1.5°C warming will be exceeded. We can prove that in two ways.
The first way is from the physics. Earth is now far out of energy balance, and that imbalance almost doubled in the past decade.
Earth's energy imbalance is the proximate cause of global warming – not the 2-3 ppm annual CO_2 increase, which is a small forcing – but rather the portion of the historical forcing that Earth has not yet responded to because of the ocean's large thermal inertia.



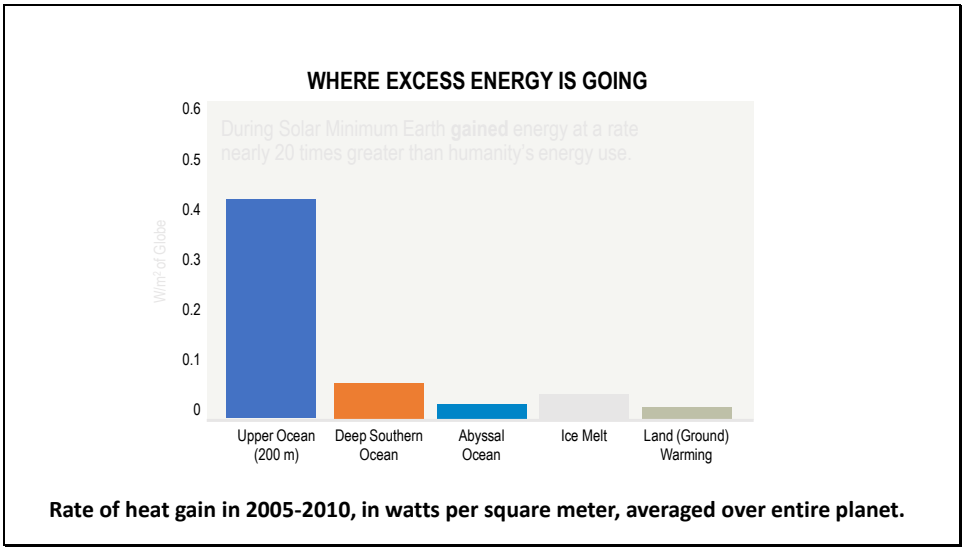
The physics is simple. Normally, Earth sends back to space as much energy as it receives from the Sun and global temperature is stable. However, added CO_2 blocks heat radiation from Earth to space; thus, with more energy coming in than going out, Earth warms.

However, it takes centuries for the ocean to fully warm up and restore energy balance. That delay is both bad and good.
It's bad because it means that people don't notice much climate change until a lot more is in the pipeline.
But the delay is good because it gives us time to fix the problem – <u>if</u> we have our wits about us.



We can now measure Earth's energy imbalance by measuring the rate at which the heat content is changing in Earth's heat reservoirs.

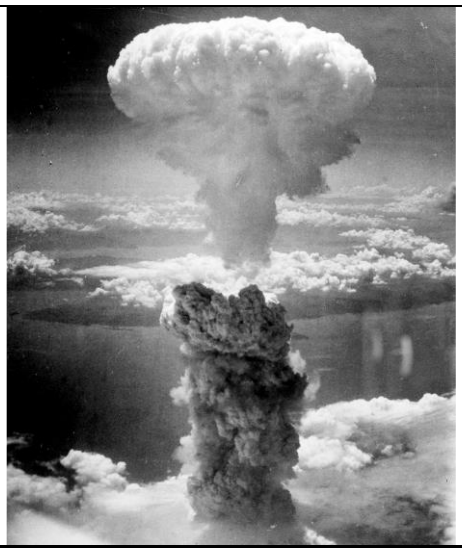
The biggest reservoir, the ocean, is now sampled by about 4000 Argo floats.



These floats reveal that the upper ocean is gaining a lot of heat. The deep ocean is gaining heat at a smaller rate.

Energy also goes into melting ice and warming the continents to depths of tens of meters.

The total energy imbalance during the past half century averaged about half a watt per square meter a decade ago, but in the past decade it has increased to almost 1 W/m^2.



That's a lot of energy – more than 20 times greater than the rate of energy use by all of humanity.

It's equivalent to exploding about 600 thousand Hiroshima atomic bombs per day, every day.

That's how much extra energy Earth is gaining each day, most of it going into the ocean.

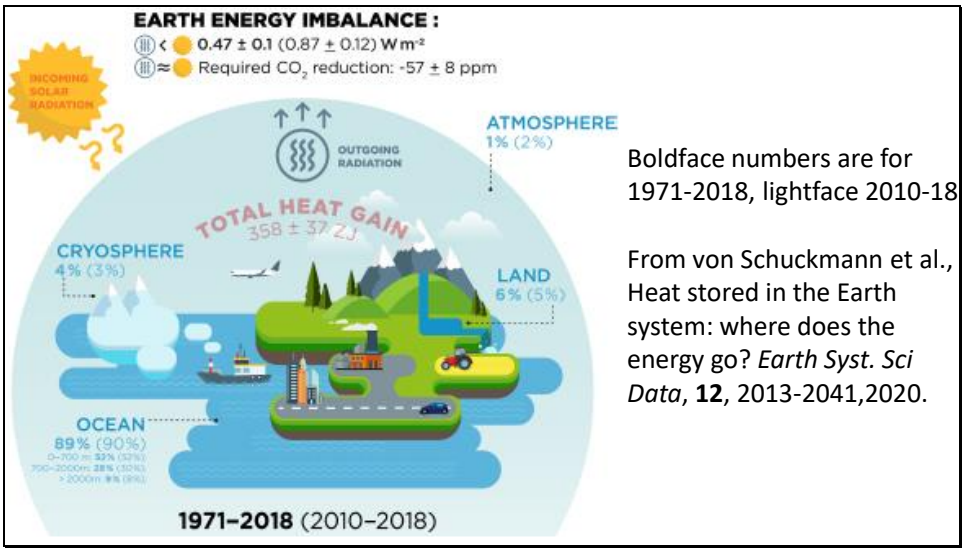
Karina von Schuckmann photo: Teresa Bellina

From "Sentinel for the Home Planet" www.Columbia.edu/~jeh1 07 September 2020 communication

Karina von Schuckmann was a post-doc when she first published the ocean data more than a decade ago. She's now the leading expert in the world in analyzing Argo float data at Mercator Ocean International in France.

I describe her as the sentinel for the home planet, because Earth's energy imbalance is the crucial number telling us how much additional global warming is already in the pipeline.

The energy imbalance also implies how much we must reduce atmospheric greenhouse gases to restore global energy balance and stabilize climate.



Boldface numbers are for 1971-2018, lightface 2010-18

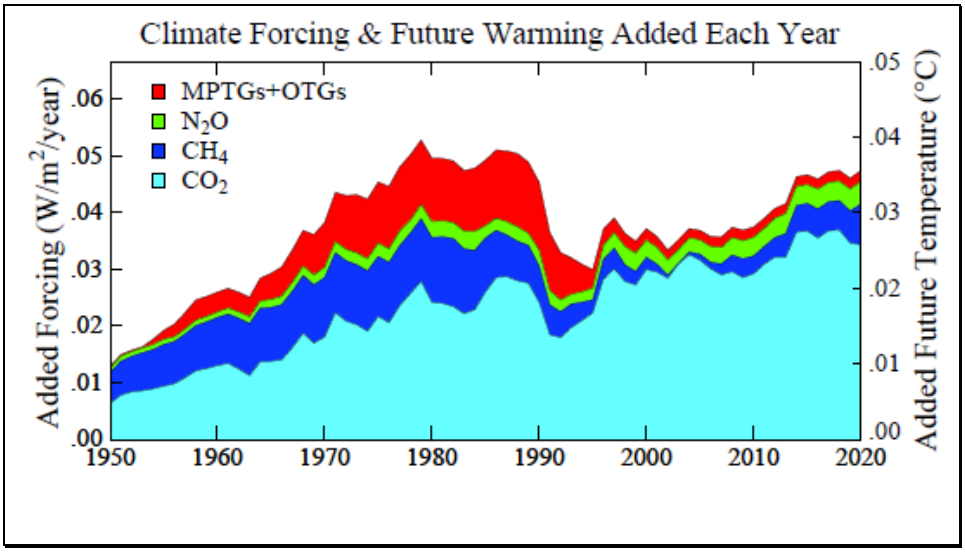
From von Schuckmann et al., Heat stored in the Earth system: where does the energy go? *Earth Syst. Sci Data*, **12**, 2013-2041,2020.

Last year Karina and other experts[1] concluded that Earth's energy imbalance had increased during the past decade to about 0.9 W/m^2.

That energy imbalance, by itself, will drive global temperature above 1.5°C, even if greenhouse gases (GHGs) suddenly stop increasing.

But is it plausible that GHGs will stop increasing in the near future? Are growth rates of GHGs plummeting toward zero? That's essential, if we want to keep global warming anywhere near 1.5°C. Let's check.

[1]von Schuckmann, K., et al.: Heat stored in the Earth system: where does the energy go?, *Earth Syst. Sci. Data* 12, 2013-2041, 2020.

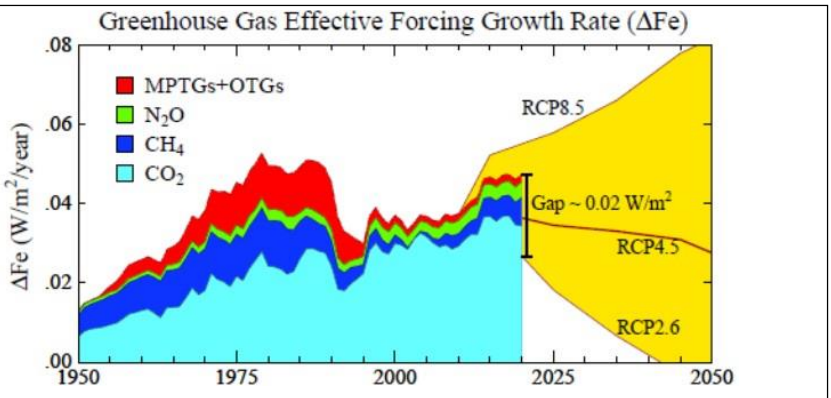


Greenhouse gas amounts are not stabilizing; on the contrary, they are still increasing rapidly, adding more climate forcing every year.

The climate forcing is increasing by about four one-hundredths of a W/m^2 per year, as shown by the scale on the left.

The annual addition to eventual temperature rise is a few hundredths of a degree, which is a few tenths of a degree Celsius per decade.

The temperature scale is based on an assumed climate sensitivity of 3°C global warming for doubled CO_2 forcing of 4 W/m^2., in other words, ¾ of a degree Celsius for each watt per square meter of added forcing.



Annual growth of greenhouse gas climate forcing (red is trace gases, mainly CFCs). RCP2.6 is a greenhouse gas scenario designed to keep global warming below 2°C.

Hansen, et al., Young people's burden: requirement of negative CO_2 emissions, *Earth Syst.Dyn.* **8**, 1-40, 2017.

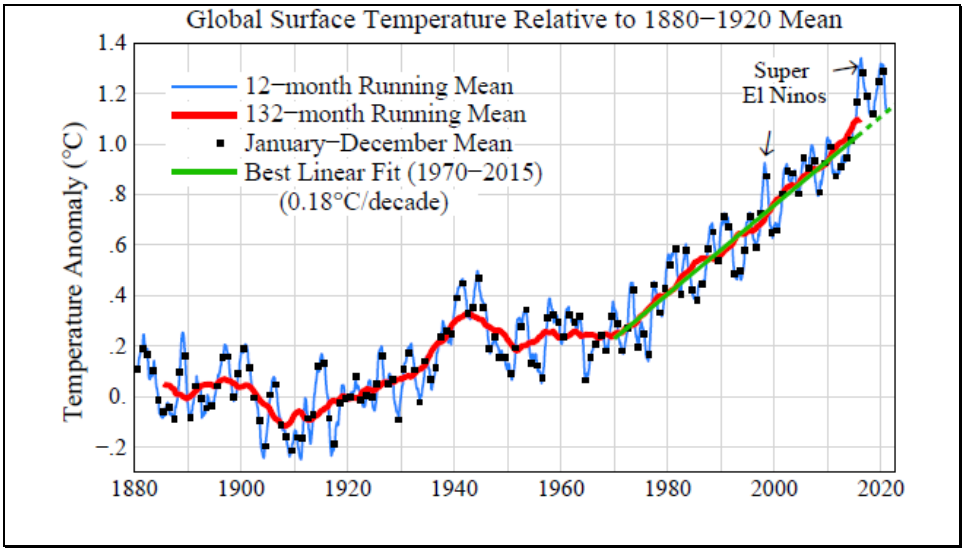
In principle, we could keep global warming to 2°C by following the IPCC greenhouse gas scenario RCP2.6, which was in vogue at the time (2015) of the Paris Agreement. RCP2.6 is the lower edge of the yellow area. Reality is the upper edge of the red area. There's already a huge gap between RCP2.6 and reality. [note: target of RCP2.6 is 2°C, not 1.5°C; this chart was corrected on 20 Dec. 2021]

We could close that gap by sucking CO_2 from the air, but the estimated annual carbon capture cost in 2021 is about $2 trillion, or $900 billion with the most optimistic cost estimate. This annual cost is growing each year. Obviously, it's not happening. We do not even have technology ready to capture CO_2 on such enormous scale.

This cost range is based on the (optimistic) cost range in *Young People's Burden*[1] ($150-350 per tC). Based on the costs derived from the pilot plant of David Keith's company[2] ($450-920 per tC) the cost for extraction in the single year 2021 is $2.6-5.4 trillion.

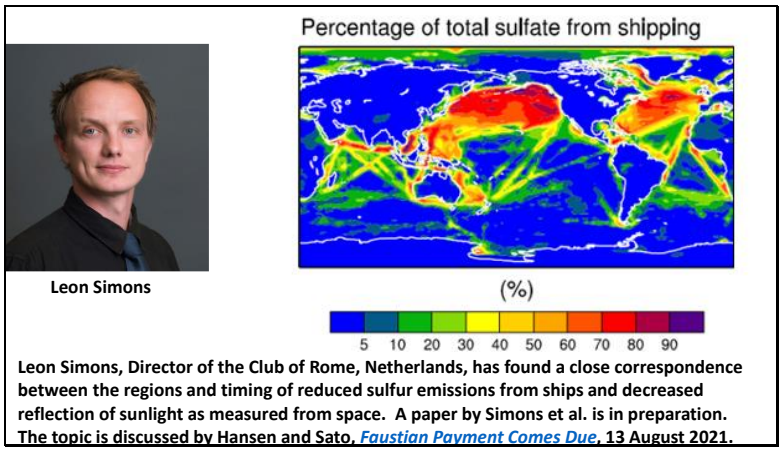
Therefore, it's certain that global warming will exceed 1.5°C and almost certain that it will exceed 2°C. That's what real data from the physical sciences tells us.

[1]Hansen, J. and 14 coauthors, Young people's burden: requirement of negative CO2 emissions, *Earth Syst. Dynam.* 8, 1-40, 2017.
[2]Hansen, J., P. Kharecha: Cost of carbon capture: Can young people bear the burden?, *Joule*, **2**, 1405-1407, 2018.



There's another nail in the coffin of the unrealistic dream that global warming might be kept below +1.5°C: the first payment in humanity's Faustian aerosol bargain[1] has come due.
The proximate cause of global warming acceleration in the last several years is the recent increase of Earth's energy imbalance. But the underlying cause, almost surely, is reduction of maritime anthropogenic aerosols as a result of tightened regulations on bunker fuels burned by ships.

[1]Hansen, J., Storms of My Grandchildren, Bloomsbury, 319 pp., 2009.



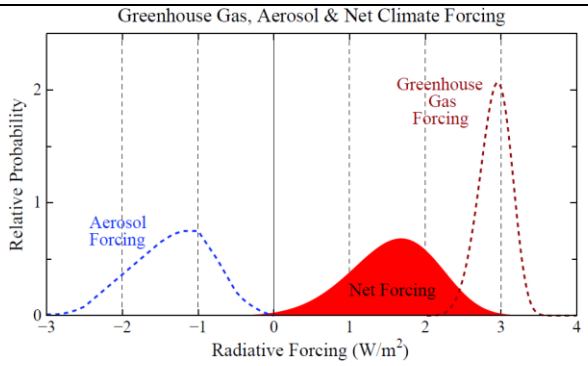
Leon Simons, Director of the Club of Rome, Netherlands, has found a close correspondence between the regions and timing of reduced sulfur emissions from ships and decreased reflection of sunlight as measured from space. A paper by Simons et al. is in preparation. The topic is discussed by Hansen and Sato, *Faustian Payment Comes Due*, 13 August 2021.

Leon Simons has shown that the temporal and spatial distributions of the perturbation to Earth's energy balance coincide with the timing of tightened controls on the sulfur content of maritime fuels and with a satellite-measured decrease of solar radiation reflected from the heavily-trafficked regions of the North Pacific and North Atlantic Oceans.

The chief mechanism is the effect of aerosols on cloud cover and cloud albedo. Sulfuric acid aerosols (the same stuff that the Venus clouds are made of) are formed from the emissions of ship traffic. The aerosols serve as condensation nuclei for cloud drops, so an increase of aerosol number leads to more and smaller cloud drops, thus brighter longer-lived clouds.

Sulfate aerosols have decreased in the past several years in regions of heavy ship traffic, and thus Earth's albedo (reflectivity) has decreased. Increased absorption of sunlight increased Earth's energy imbalance and the rate of global warming.

Simons' finding has profound implications, as described in the following charts.

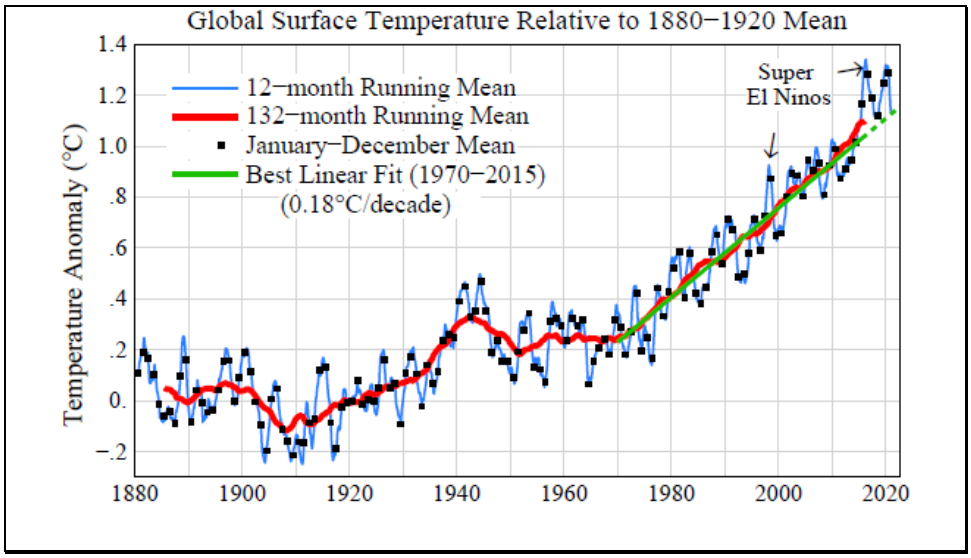


Climate forcings in 2000-2005[1] relative to 1850, the GHG forcing being about +3 W/m².
Most climate models used a (negative) aerosol forcing of magnitude ~1 W/m² or less.
Aerosol scientists suggested that the aerosol forcing may be closer to –2 W/m².
[1]GHG forcing reached +3 W/m² in 2000 with forcing efficacies included (Hansen, J. et al., *J. Geophys. Res.* **110**, D18104, 2005).

Simons' finding confirms a suspicion that climate models employed by IPCC – as a whole – understate the aerosol cooling effect.
In 2008 Reto Knutti wrote an article[1] "Why are climate models reproducing the observed global surface warming so well?"
Knutti wondered why the models could match observed warming while including only a small negative aerosol forcing.
In fact, most models didn't include the aerosol indirect effect on clouds, which aerosol scientists thought was the main aerosol forcing.
Knutti speculated that models compensated for a too-large net forcing by mixing heat too efficiently into the ocean.

In 2011 we used Karina von Schuckmann's accurate data on ocean heat uptake to confirm Knutti's suspicion.
With the assumption that climate sensitivity is 3°C for doubled CO_2 we inferred the aerosol forcing as -1.6 ± 0.3 W/m^2.
If climate sensitivity Is greater than 3°C – the likely range is 2.5-4°C for doubled CO_2 – the magnitude of the inferred (negative) aerosol forcing would be even greater.

[1]Knutti, R., Why are climate models reproducing the observed global surface warming so well? *Geophys. Res. Lett.*, 35, L18704, 2008.
[2]Hansen, J., M. Sato, P. Kharecha and K. von Schuckmann, Ice melt, sea level rise and superstorms: evidence from paleoclimate data, climate modeling, and modern observations that 2 ◦C global warming could be dangerous, *Atmos. Chem. Phys.*, 11, 13421-13449, 2011.



Simon's finding also implies that the acceleration of global warming in the past several years is not a chance fluctuation. Indeed, accelerated warming will continue; the relatively cool year 2021 is due to a moderately strong La Nina.

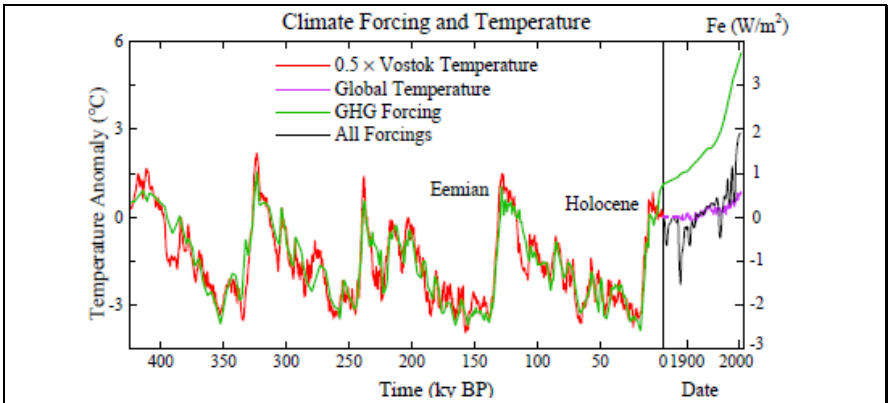
The present large planetary energy imbalance should cause a new global temperature record to be reached by 2023 or 2024. Barring the unlikely event of a Pinatubo-scale volcanic eruption, the+1.5°C level should be breached within a decade.

One point to emphasize here is that there's nothing magic about transient passage through temperature level +1.5°C. Global temperature surely will rise well above +1.5°C, but that is no reason to panic or to frighten young people. Also, there is nothing magic about year 2030; we are not doomed if do not do such-and-such by 2030 or any other arbitrary date.

We have already pushed beyond several planetary boundaries. We will need to pull back, but we can do that. The inertia of the climate system allows us the opportunity to ameliorate consequences, if we understand the climate system and take sensible actions.

Most amplifying feedbacks do not, per se, imply a "tipping point" or "point of no return." For example, GHG release from melting tundra and methane clathrates on continental shelves are sufficiently slow that the consequences can be obviated by the global cooling that will be necessary on the long run to preserve our coastal cities and shorelines.

There is legitimate cause for concern about practically irreversible effects from the potential shutdown of the Atlantic Meridional Overturning Circulation (AMOC) and from runaway mass loss of a substantial mass of certain ice sheets. Yet here, too, the most dangerous consequences can still be avoided, if we have sufficient understanding and take timely actions that are still practical to achieve.



Target Atmospheric CO_2: The World Is Already Well Into Overshoot of Atmospheric Greenhouse Gases*

*Hansen, J., M. Sato, P. Kharecha, D. Beerling, R. Berner, V. Masson-Delmotte, M. Pagan, M. Raymo, D.L. Royer and J. Zachos: Target Atmospheric CO2: Where should humanity aim?, *Open Atmos. Sci.* 2, 217-231, 2008.

IPCC climate analyses rely heavily on global climate models (GCMs), which are now ubiquitous. However, our understanding benefits from a comparable emphasis on information from paleoclimate and from modern observations of ongoing climate processes. IPCC has begun to pay more attention to paleoclimate data, but modern observations remain shockingly deficient in areas such as monitoring of aerosol climate forcing and observations of ocean and ice processes on the Antarctic periphery.

Overshoot of atmospheric GHG levels was already clear in 2008, when a group of scientists concluded that it was necessary to reduce atmospheric CO_2 to a level less than 350 ppm. Greater specificity was not needed, because the 350 ppm target already implied the need to phase down fossil fuel CO_2 emissions as rapidly as practical. By the time a CO_2 amount of 350 ppm is approached from above the long-term target will be clearer.

The figure above from the "Target CO_2" paper is particularly informative. Global temperature change during the past 400,000 years is well accounted for by the GHG and surface albedo climate forcings, albeit most of the GHG and surface albedo changes (ice sheet size changes inferred from sea level change) were actually slow feedbacks, with the instigator of those changes being changes of Earth's orbit and the inclination of the spin axis.[1]

The Holocene is particularly interesting, as significant increase of CO_2 and CH_4 beginning several thousand years ago was not matched with rising temperature. We suggest elsewhere[2] that Bill Ruddiman's suggestion[3] that humanity began affecting those greenhouse gas amounts several thousand years ago – via deforestation and agriculture – may be at least partly correct, but GHG warming by increasing GHGs is offset by aerosol cooling. Even small aerosol emissions could cause a significant aerosol indirect effect in the pristine atmosphere when human aerosol emissions were just beginning.[2]

GHG climate forcing, which is known accurately, had already reached about 3.5 W/m^2 by 2000 relative to the early Holocene. Global warming since 1900 was about 0.7°C in 2000, but perhaps barely above the prior maximum Holocene temperature.[4] The net (GHG + aerosol) forcing became substantial by about 1970 and global warming has been rapid since then.

Net forcing today (2021) is probably about 2.5 W/m^2, but the exact value is uncertain because of the absence of measurement of the aerosol climate forcing. The eventual response to this forcing – if it is left in place – will be global warming of about 4°C (left scale of figure above). The time required to achieve that full warming could be as long as a few millennia, as long as needed for the size of the ice sheets to reach equilibrium with the forcing.

Equilibrium global warming in response to 2.5 W/m^2 forcing with fixed ice sheet size – the Charney problem – for climate sensitivity 0.75°C per W/m^2 is about 1.9°C. That response (which includes fast climate feedbacks) would itself require centuries to be fully achieved because of the ocean's thermal inertia – if the forcing remained fixed at 2.5 W/m^2.

Unfortunately, the forcing is not going to remained fixed at 2.5 W/m^2 – instead, it will continue to rise for some time, even in the best scenario (Chart 14).
Fortunately, the slow response time of the climate system allows us time to reduce the forcing before equilibrium response occurs. However, we need a broad understanding of the climate and energy systems to help us to achieve the reduced forcing fast enough to avoid the most threatening climate consequences.

[1]Hansen, J., draft Chapter 25 (Paleoclimate & "Slow" Feedbacks) of *Sophie's Planet,* Bloomsbury, 2022.
[2]Hansen, J., M. Sato, P. Kharecha, G. Russell, D.W. Lea and M. Siddall, Climate change and trace gases, *Phil. Trans. Roy. Soc*. A 365, 1925-1954, 2007.
[3]Ruddiman, W.F., The anthropogenic greenhouse gas era began thousands of years ago, *Clim. Change* 61, 261-293, 2003.
[4]Hansen, J. and 14 coauthors, Young people's burden: requirement of negative CO2 emissions, *Earth Syst. Dynam*. 8, 1-40, 2017

Climate, Energy, Economic, Social Sciences

2000: Alternative scenario (PNAS paper)
Air Pollution & CO_2, half-century problem

2002/5: Workshops @ East-West Center
China, India, U.S., Europe

2005-8: Post-censorship opportunities
Environmentalists, Utility CEOs & their staff

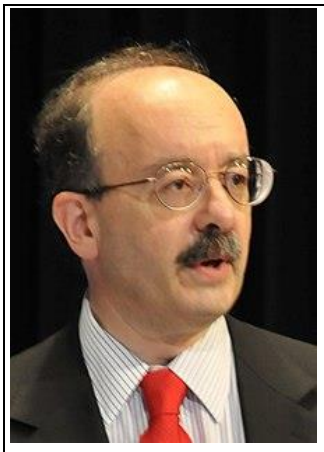
2008: Workshop in DC, Letter to Obama

By good fortune, I received an intense education in the relevant sciences – climate, energy, economic and social sciences – over the past 20 years, but especially in the period 2000-2008.
In 2000 I wrote a paper An Alternative Scenario[1] because IPCC (the Intergovernmental Panel on Climate Change) did not have any scenario that kept global warming to 2°C or less.
That seemed strange. Did humanity not have any free will? Must we walk straight into climate disasters?
So, in that paper we gave equal emphasis to air pollution and CO_2. We focused on methane, black carbon, and tropospheric ozone, as well as CO_2.
We thought it would take at least half a century to phase off fossil fuel CO_2 emissions, but by focusing on other air pollutants as well as CO_2, it would be possible to keep global warming from exceeding 2°C.

This paper irritated the relevant scientific community – most of whom contributed to IPCC reports – and I found it hard to defend and publish our perspective.
Nature magazine reported as "News" only criticisms of our paper and would not publish my defense of the paper.[2]
But one of the great things about the U.S. is that it is possible to promulgate an alternative perspective, if you work at it.
I was able to get support from a wonderful man, philanthropist Gerry Lenfest, who provided funding for workshops that I organized at the East-West Center in Hawaii.
Our idea was that most future emissions would come from developing countries such as China and India. And they had tremendous air pollution.
So there was strong incentive for us to work together to find a science and technology pathway to a bright future for the planet and future generations.

Well, I ***thought*** that I could pursue ideas freely. But in 2005 the White House told NASA to prevent me from giving talks or speaking to the media without prior approval.
Prior restraint is unconstitutional. When I told Andy Revkin of the NY Times about it, the shit hit the fan. Publicity about this censorship – on the front page of the Times, on Sixty Minutes television news, and in a book by Mark Bowen[3] – led to the opportunity for interactions across the spectrum – students, environmentalists, Big Green organizations, utility CEOs such as Jim Rogers of Duke Energy and Ralph Izzo of PSE&G and their expert technical staffs – people charged with keeping the lights on.
Interaction with the utility CEOs led to planning a workshop in Washington to discuss energy policies, and then to a letter to President-elect Obama describing the two essential actions needed to phase out carbon emissions.
Those two essential actions can be clarified with the help of just two graphs, which are each pregnant with information.

[1]Hansen, J., M. Sato, R. Ruedy, A. Lacis, and V. Oinas: Global warming in the twenty-first century: An alternative scenario. *Proc. Natl. Acad. Sci.*, 97, 9875-9880, 2000.
[2]Hansen, J., draft Chapter 35 (Dangerous Interference) of *Sophie's Planet,* Bloomsbury, 2022.
[3]Bowen, Mark, *Censoring Science: Inside the Political Attack on Dr. James Hansen and the Truth of Global Warming*. New York: Dutton, 2008.



Amory Lovins

I'm an advisor to major firms and governments in 65+ countries for 40+ years; a practitioner of integrative design for advanced energy efficiency in buildings, vehicles, and industry; a member of the National Petroleum Council 2011–18; author of 31 books and over 600 papers; recipient of the Blue Planet, Volvo, Zayed, Onassis, Nissan, Shingo, and Mitchell Prizes, MacArthur and Ashoka Fellowships, 12 honorary doctorates, the "Alternative Nobel," Heinz, Lindbergh, National Design, and World Technology Awards. In 2009, Time named me one of the world's 100 most influential people, and Foreign Policy, one of the 100 top global thinkers. In 2016, the President of Germany awarded me the Officer's Cross of the Order of Merit.

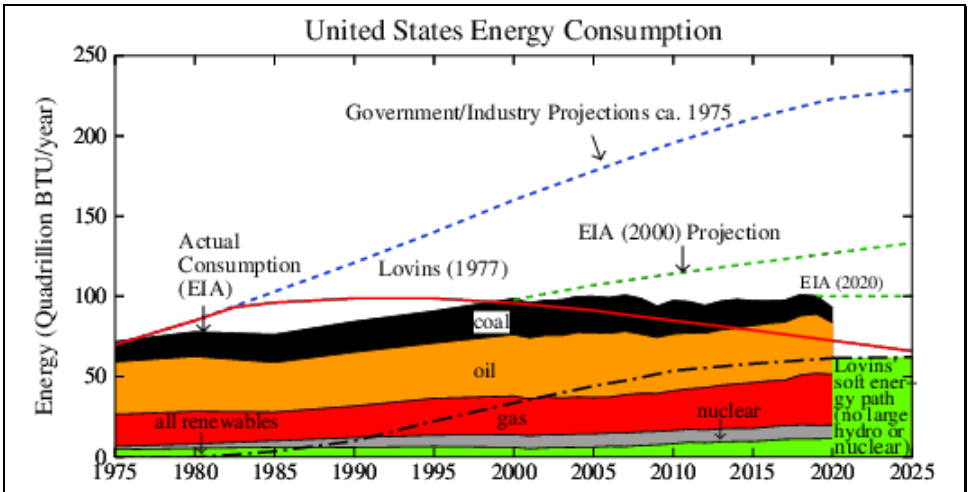
Fig. 39.1 From Forbes Magazine Contributor Profile

But before I show those two graphs, let me show a photograph – of Amory Lovins.
Amory is a recognized leading thinker on energy. He advises governments and industry all around the world. He has received every prize imaginable.

Amory visited our Institute in the late 1970s. He had impressive knowledge of energy efficiency – of the potential to reduce energy demands, if we remove the barriers to efficiency.
Amory is a persuasive salesman. He was adviser to Arkansas Governor Bill Clinton, and he continued as energy guru to President Clinton and Al Gore.

The most amazing thing that Amory concludes is that there is so much potential in energy efficiency that we can get all of our energy from soft renewables.
Soft renewables exclude large hydro, which many environmentalists do not like.

Amory says we do not need any fossil fuel – oil, gas or coal – we do not need large hydro, nuclear power, or a carbon tax.
It's no wonder that Amory is worshipped by liberals. By the way, I am a political Independent and I am so registered.



Update of Figure 2 in Hansen, J.: *Storms of My Grandchildren*, Bloomsbury, 320 pp., 2009.

In 2001 I was invited to speak to the first meeting of President Bush's Climate Task Force, which consisted of six Cabinet members, EPA Administrator, National Security Adviser, and Vice President Dick Cheney as chairman.
I brought copies of our Alternative Scenario paper. The Vice President read (out loud) a few sentences of the paper focused on the non-CO2 (air pollution) climate forcers and invited me to speak to the second meeting.

That second meeting did not go well, from my perspective. As discussed in Storms of My Grandchildren, I did not do a good job of countering Richard Lindzen's disinformation about climate change.

The only good thing was that when I got home I changed the name of my student research team – high school and college students participating in our summer program, the Institute on Climate and Planets.
We changed the name of our team to "The A-Team," for Alternative Scenario, and we changed our research focus from climate modeling to energy and climate.

I dug out a graph on U.S. energy consumption that Amory had left with me in the late 1970s, and we updated the graph to see how the real world compared with Amory's projections.
Lovins' energy projection – the red line – was good. Energy use increased from about 70 to 100 quadrillion BTUs per year. It would have been greater, but much of our industrial production moved overseas.

However, the soft renewable projection – the dash-dot line – was way off. The green area is much too small, even though about half of it is large hydro.
Growth of renewables was due to Renewable Portfolio Standards, which force utilities in most states to get a fraction of their energy from renewables.
It's an almost unlimited subsidy, with costs passed on to the customers, but it does raise the use of renewable energies.
However, it is also raising the use of gas to complement intermittent renewable energies, which means fracking, water pollution, pipelines, methane emissions, and CO2 emissions. It's almost as bad as coal.

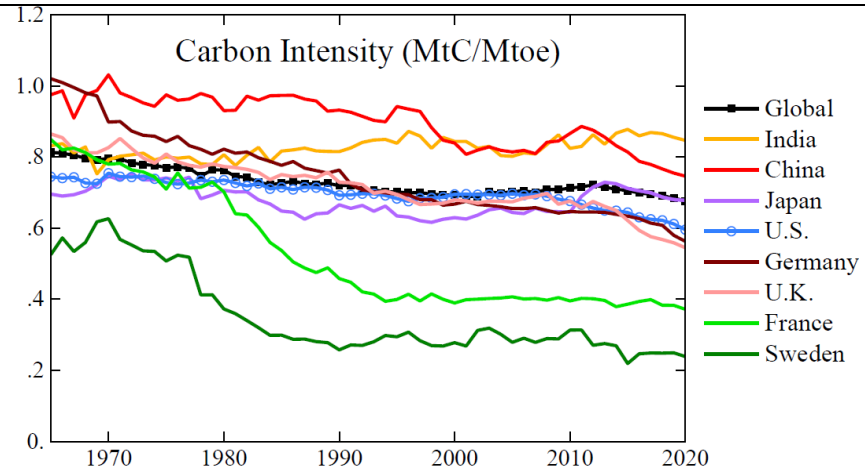
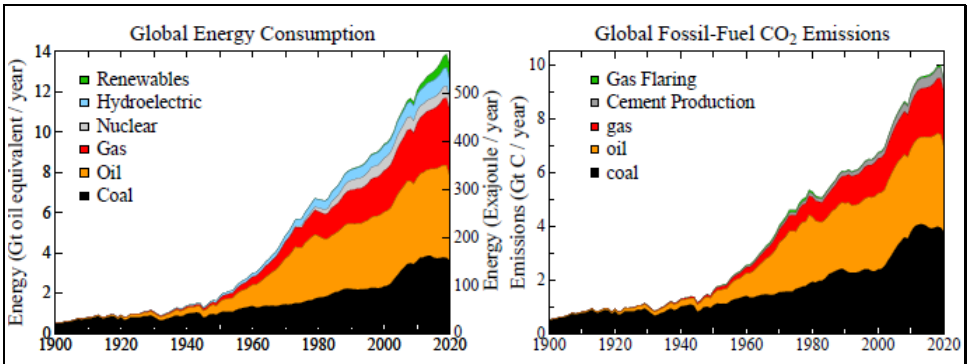


Fig. 47.5. Carbon intensity (carbon per unit energy) of global and national energies. MtC: megatons carbon. Mtoe: megatons oil equivalent. *[Sophie's Planet, Chapter 47]*

This is the most important graph – carbon intensity – the amount of carbon per unit energy. Carbon intensity must go to near zero to solve the climate problem.
In 55 years, global carbon intensity has gone from 80% to a bit less than 70%. It's a very big job to approach zero carbon intensity! It will take at least several decades longer for the world to achieve that.
The U.K. is doing a bit better than Germany. They are both doing better than the U.S.

Most important, notice that Sweden and France cut carbon intensity in half quickly – in about 15 years. How? They built nuclear power plants to almost completely decarbonize their electricity.
Sweden started with a lower carbon intensity, about 60%, because half of their electricity was from hydropower. They chose a design for nuclear plants and built 10 of them, which took about a decade.
Sweden even uses electricity to heat homes. They need one more big step: to make liquid fuels from electricity, which we know how to do.

Now, remembering that global carbon intensity since 1965 decreased only from 80% to 70%, let's look at the world's total energy use.

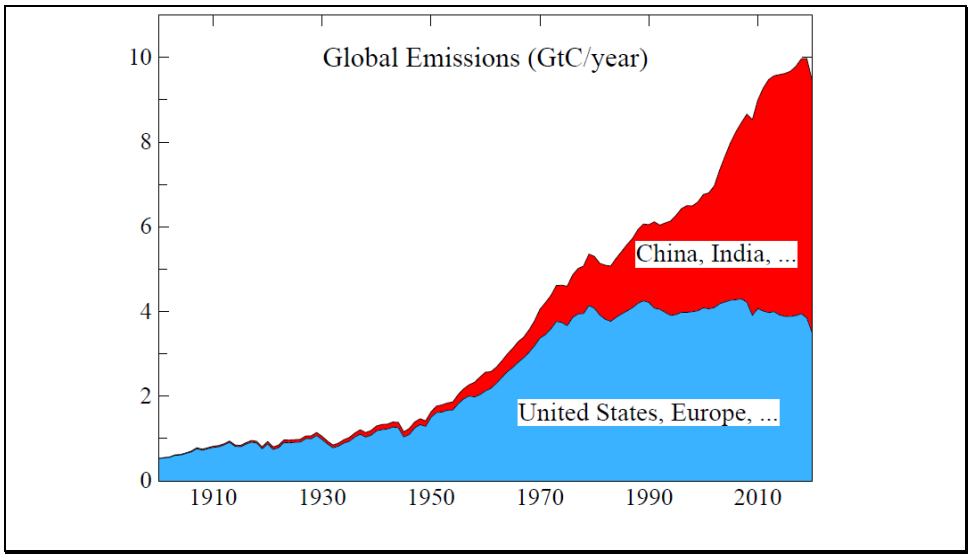


Global energy consumption and fossil fuel emissions. BP data are used from 1965. Gilfellan et al. earlier data are adjusted by factors near unity to match BP in 1965.

see Chapter 43: Energy for the World, *Sophie's Planet*, available www.columbia.edu/~jeh1

Global energy consumption since 1965 increased by more than a factor of three.
Renewables – the green area – are increasing, but not enough to replace other energies.

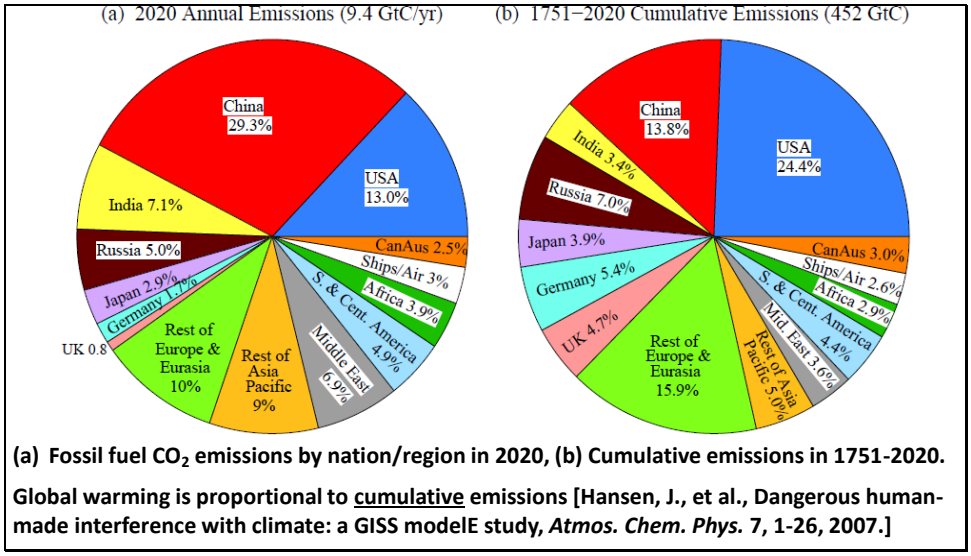
Because the carbon intensity of the energy decreased only from 80% to 70%, global CO_2 emissions – the graph on the right – increased by a factor of three.



Emerging economies will be the source of most future emissions.

So we should work together with China, India, Indonesia, Viet Nam…and other economies that are growing rapidly.

In fact we in the West have an obligation to do that, as we used much more than our fair share of the carbon budget.



(a) Fossil fuel CO_2 emissions by nation/region in 2020, (b) Cumulative emissions in 1751-2020.

Global warming is proportional to cumulative emissions [Hansen, J., et al., Dangerous human-made interference with climate: a GISS modelE study, *Atmos. Chem. Phys.* 7, 1-26, 2007.]

Today, China has the greatest emissions. China, the U.S. and India produce half of global emissions, as shown by the pie chart on the left.

However, global warming is accurately proportional to cumulative emissions – total historical emissions – the pie chart on the right.

The West – especially the United States – is responsible for more than half of historical emissions, despite the relatively small population of the West.

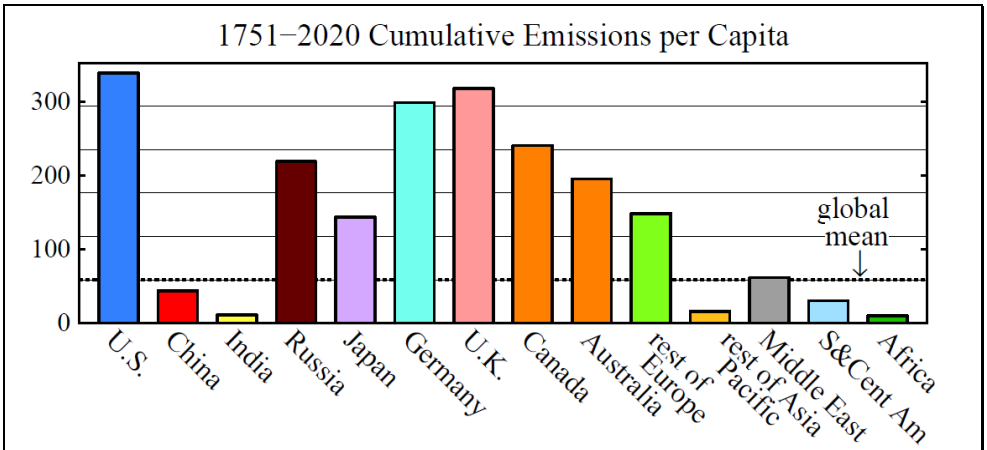


Fig. 47.6. Cumulative 1751-2020 carbon emissions (tons C/person; 2020 populations). Horizontal lines are multiples of the global mean. [from *Sophie's Planet,* Chapter 47]

So, on a per capita basis – using today's populations – the U.S., the U.K., and Germany are the three major nations most responsible for global warming. Per capita responsibilities of China and India are much smaller.

O.K., now we can make clear why it is impossible to keep global warming from exceeding 1.5°C, and why it will be exceedingly difficult – and unlikely – to keep warming below 2°C.

Limitations on Emission Reduction Rate

Realpolitik (practical matters)

- Need to "keep the lights on"
- Need to raise living standards

Real Politics (bad governance)

- Bribery by special interests (corruption)
- Political opportunism: climate change is a "hoax"
- Bad ideas (subsidies v. competition, cap v. fee)

Why can't we reduce global emissions rapidly? I define realpolitik as legitimate practical constraints on how fast energy systems can be changed.
First, all governments give priority to keeping the lights on. And it's more than the lights. When the price of gasoline jumped in the U.S., the public demanded "turn on the oil spigot!" and President Biden had to respond. When Chinese industry was running out of coal, the Chinese government worked hard to increase coal production. All governments work to keep their public and industry supplied with energy.

Second, all nations want to raise living standards. That's the priority of governments. So, given the energy options readily available today, emissions will rise.
Good energy planning and international cooperation can minimize Realpolitik emissions. We will see examples of good energy planning, such as Sweden, but, unfortunately, many examples of awful planning.

In addition, we have real politics, which results in bad governance and much higher emissions than necessary for the services that we need
Special interests wade in the Washington swamp and bribe politicians. Politicians lie to the public to try to gain favor, for example, by declaring that climate change is a hoax.
Politicians devise complex cap-and-trade-with-offsets schemes that allow them to reward special interests. So emissions will decline only slowly.

How can we overcome these obstacles? It is possible, but we need a laser focus on the two essential actions.

Essential Elements of Solution

1. **Fossil Fuel Price Must Include Costs to Society**
   - **Human Health & Climate Change Costs**
   - **Practical Solution: Rising Carbon Fee & Dividend**
   - **Some regulations still needed (e.g. on refrigerator efficiency, no power use by idle electronics, etc.)**

In December 2008 I wrote to President-elect Barack Obama describing these two actions. I could not get Obama's Science Adviser to deliver the letter, so I put it as an open letter on my website.
These proposed actions were the product of 8 years of interactions with environmentalists, economists, utility experts, health professionals, two East-West workshops with China and India, and one Washington workshop.

First, we must make the fossil fuel price include their costs to humanity – the human health costs of air pollution and water pollution and the costs imposed by climate change.

A rising carbon price is the basic requirement to solve the climate problem; it will make all other actions to reduce emissions work better and faster.

Carbon Fee & 100% Dividend

Fee: Collected at Domestic Mine/Port of Entry
Covers all Oil, Gas, Coal → No Leakage

Dividend: Equal Shares to All Legal Residents
Effect is "progressive"; Low-income people gain

Merits:
Transparent; Public can understand & support it
Market-based; Stimulates Economy & Innovation

In my letter to Obama I called it carbon tax and 100% dividend, but soon changed the name to carbon fee and dividend, to emphasize that no money goes to the government.

The fee is across the board, on oil, gas and coal, collected at the source – domestic mines and ports of entry.

Carbon fee & dividend is the most fundamental requirement to solve the climate problem. With a rising fee, business people and entrepreneurs will reduce carbon emissions faster than governments can.

The dividend should be 100%, so that most people come out ahead. Fee & dividend is a progressive approach that helps to reduce the widespread problem of growing wealth disparity.

Carbon Fee & Dividend Addresses

1. **Economy: Stimulated**
   - Fee Growth Provides Certainty to Businesses & Entrepreneurs
   - Dividend Will Be Popular & Address Growing Wealth Disparity
2. **Energy: Rapid Fossil Fuel Phasedown**
   - Stimulates Innovation – Fastest Route to Clean Energy
   - Complements Energy RD&D and Efficiency Regulations
3. **Climate: Viable International Approach**
   - Border Duties on Products from Nations w/o Carbon Fee
   - Rebates to Industry on Exports to Nations w/o Carbon Fee

Carbon fee & dividend stimulates the economy. Economic studies show that fee & dividend is the fastest way to phase off fossil fuels onto alternative energies.

It's also the most viable international approach, which can be enforced near-globally via border duties.

When China and the United States agree on a rising carbon fee, the climate problem will be on the way to solution, and we will have a much cleaner, healthier, world.

Essential Elements of Solution

1. **Fossil Fuel Price Must Include Costs to Society**
   - Human Health & Climate Change Costs
   - Practical Solution: Rising Carbon Fee & Dividend
   - Some regulations still needed (e.g. on refrigerator efficiency, no power use by idle electronics, etc.)
2. **Nuclear and Related Technology Development**
   - Nuclear Power Requires Support
   - Government Should Facilitate Long-Lead RD&D
   - Rising Carbon Fee Will Spur Tech Development

The other essential requirement is government support of modern nuclear power. The choice is between gas and nuclear power for dispatchable electricity available 24/7 to complement intermittent renewables. If we choose gas, we choose fracking, we choose pipelines, we choose groundwater pollution, we choose methane, we choose climate change that will exceed 2°C.

Germany has chosen gas. And they are attempting to force their preference on other nations by demanding that the European Union treat gas as clean energy and nuclear power as dirty energy to be phased out.
If Germany "succeeds," gas will not be phased down – global gas use will grow and gas will be a major energy source throughout most of this century. The goal of net zero CO_2 emissions by mid-century will be unachievable.

In the U.S., the Democratic Partly has chosen gas. In the Build Back Better legislation and 2022 budget before Congress, the Democrats zero-out funding for the Department of Energy's Versatile Test Reactor (VTR) and include support for nuclear generation of electricity for only 4 years while subsidies for renewables are extended 8 years. Their budget remains consistent with the Democrat's long-term goal to phase out nuclear power. The VTR is needed for nuclear research and development on advanced reactors to make more efficient use of nuclear fuel and keep the U.S. as a global leader in nuclear technology.

Because of the absence of government support for the nuclear industry, private sector investment in nuclear power continues to be nil. There is more investment if still-futuristic nuclear fusion than in modern nuclear fission reactors that are needed now and in the next several decades.

A cost-free alternative energy policy – alternative to deficit spending and heavy subsidies aimed at forcing an all-renewables future -- would be: (1) carbon fee & dividend, (2) clean energy portfolio standards instead of renewable portfolio standards. These policies allow energy efficiency, renewables and nuclear to compete on a level playing field, as the rising carbon fee phases down fossil fuel emissions at the most rapid possible pace.

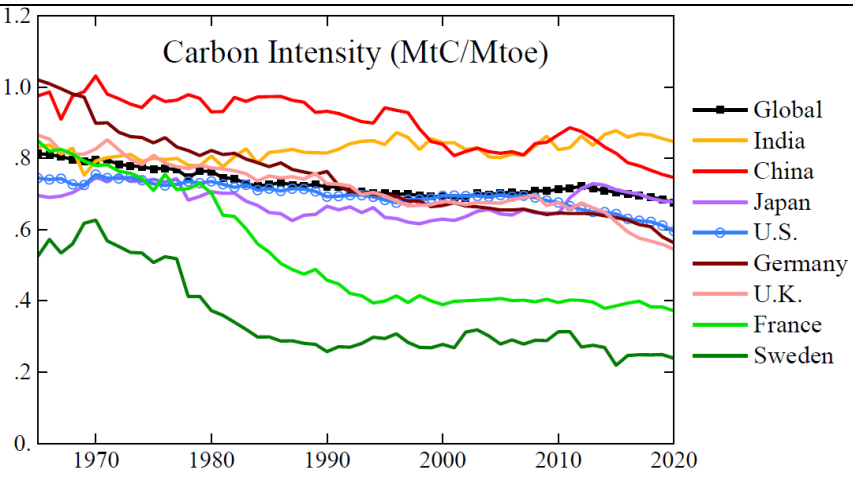


Fig. 47.5. Carbon intensity (carbon per unit energy) of global and national energies. MtC: megatons carbon. Mtoe: megatons oil equivalent. *[Sophie's Planet, Chapter 47]*

U.S. national energy policy makes sense only if it makes sense globally. Let's recall the global need to drive down carbon intensity to near zero.

When President Xi of China and Prime Minister Modi of India say that they will aim for net zero emissions by 2060 and 2070, they recognize the difficulty of the task and the fact that the world is not taking actions to make carbon intensity dive rapidly toward zero. The required actions are a rising carbon fee – to make the price of fossil fuels include their costs to society – and modern nuclear power as cheap as fossil fuels.

Based on mutual interests, the West should work with China and India to achieve those results. Indeed, we have a responsibility to work together because we burned more than our fair share of the global carbon budget.

But, instead, we preach to those nations, telling them to build solar panels and windmills. Those are good things to do, but grossly inadequate.

East-West Cooperation is Vital

1. Rising Carbon Fee

It would then quickly become near global

2. Nuclear Power Development & Deployment

To enhance safety, minimize cost

Incentives & Benefits:

One planet: we will share the same fate

Mutual interests in emission reductions & safety

East-West cooperation is needed for the world to move faster. Of course, there is economic and ideological competition among nations, but we must recognize the existential threat to all of us.

We should promote cooperation and refrain from actions that tend to provoke a cold war.

In early 2014 the think tank of China's State Council and the Kissinger Institute on China and the United States held a symposium in Beijing titled *New Type of Major Power Relationship*.[1]

I was invited to speak about climate. My talk[2] was blunt, about the threat of climate change and the need for both a carbon fee and the development of modern, ultrasafe nuclear power.

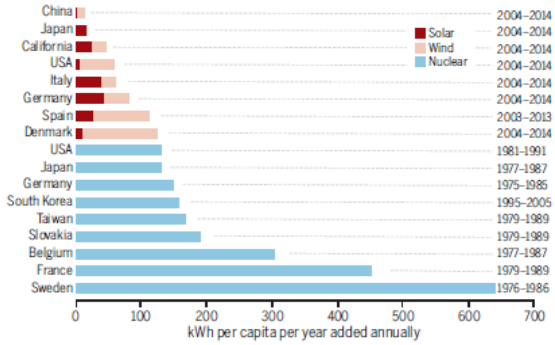
[1]Hansen, J., Chapter 47: China and the Global Solution, in *Sophie's Planet*, Bloomsbury, 2022.
[2]Hansen, J., Beijing Charts: presentation at Symposium on a New Type of Major Power Relationship, 24 February 2014.

NUCLEAR ENERGY

China-U.S. cooperation to advance nuclear power

Mass-manufacturing and coordinated approvals are key

Science magazine
5 August 2016 Vol 353
By Junji Cao, Armond Cohen, James Hansen, Richard Lester, Per Peterson, Hongjie Xu

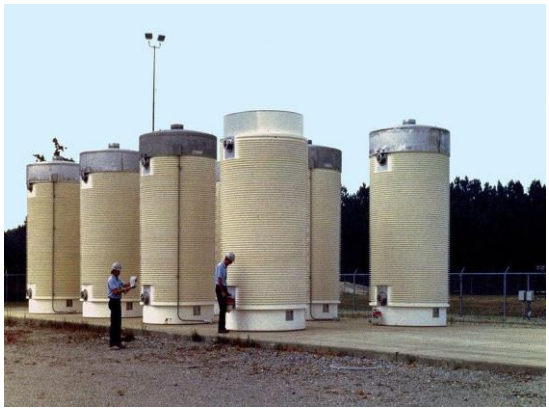


Following the symposium, I initiated correspondence with American and Chinese colleagues to organize a workshop on China-U.S. cooperation to advance nuclear power, which we held in 2015 in Hainan, China.

History shows that once a good design for a nuclear power plant is approved, nuclear power provides the fastest way to decarbonize because of the massive amount of energy provided by each power plant.

De facto cooperation between China and the U.S. drove down the cost of solar and wind energy. We can do the same for nuclear power. One suggestion is product-type licensing to minimize delays in power plant approval.

However, cooperation with China was terminated by the Trump administration and under the Biden administration cooperation has not yet returned to even the level under the Obama administration.

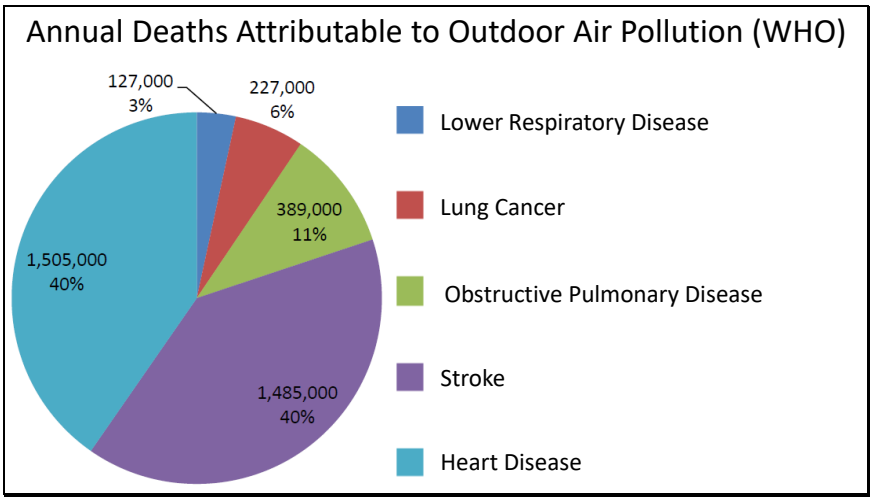


Dry cask storage of nuclear "waste," which still contains about 99% of the energy in the nuclear fuel.

If we want global CO_2 emissions to approach net zero, we should cooperate with China and other emerging economies, because that's where most future emissions will arise.
In preparation for that, we must improve our understanding of the potential of nuclear power and the barriers that nuclear power faces.

I gained insight after censorship by the White House in 2006, which led to interactions with people across the environment and energy spectrum. One of those people was Jim Warren, a gentle man, but fierce in determination to move Duke Energy to renewable energies and energy efficiency. Jim told me that I likely would be asked about nuclear power – which he opposed – and I should express my opinion freely. I probably made him happy when I said that nuclear power was carbon-free energy, but it had issues with nuclear waste, dangers of nuclear radiation, and high cost.

As I became more informed about energy issues, I learned that disinformation is the biggest problem faced by nuclear power. Nuclear waste, for example, harms nobody as it sits in dry cask storage. It can be stored in caverns, where it is available for advanced nuclear reactors to utilize more of the fuel that remains in the "waste." The safety of nuclear waste compares favorably with the waste from all other major energy sources.



For example, compare contained nuclear waste with fossil fuel waste. Fossil fuel waste is spewed into the air, treating the atmosphere as if it's a free open sewer.
Outdoor air pollution kills 3.7 million people per year, that's about 10,000 deaths per day.

And that's just the half of it. The World Health Organization has determined that indoor air pollution from the burning of wood, other biofuels, and fossil fuels kills about 3.5 million people per year, almost 10,000 per day.

Compare that with nuclear power. The worst nuclear accident in the United States occurred in 1979 with the meltdown of a reactor core at the Three Mile Island nuclear power plant in Pennsylvania. This meltdown released radiation into the atmosphere and caused the governor of Pennsylvania to order evacuation of surrounding area, but it was determined that the radiation had not caused discernable harm to anybody.

Yet there was soon a concert in New York City in which 200,000 people were swinging and swaying to a song that includes "give me the warm glow of a wood fire, but take your poison atomic power away." The wood fires have caused many orders of magnitude more deaths than nuclear radiation.

After 10 years advising survivors of the Fukushima disaster about radiation, Masaharu Tsubokura thinks the evacuations posed a far bigger health risk

Normile, D., Nuclear Medicine, *Science* **371**, 978-982, 2021.

Disinformation about nuclear radiation abounds. We live on a planet bathed in natural radiation. Some places have much greater radiation than others, with no apparent effect on health.

Even the major nuclear accident at Fukushima, with meltdowns at three reactors, the radiation release did not kill members of the public. Ill-advised large-scale evacuation killed more than a thousand people because of the stress, especially on older people. Even with those stress-caused deaths included, statistics show nuclear power has been the safest of all major energy sources on a deaths per kilowatt hour basis.[1]

Besides, modern nuclear reactors can shut down in the case of an anomaly such as an earthquake and not require external power to keep the nuclear fuel cool, making nuclear power even much safer than in the past.

[1]Markandya, A. and P. Wilkinson, Electricity generation and health, *The Lancet*, 370, 979-990, 2007.

Humpback whale frolicking at Diablo Canyon nuclear power plant

The most important point may be the fact that nuclear power has the smallest environmental footprint of all major energy sources. Because of the huge power output from a single power plant, we can leave more room on the planet for other species.

Another important fact is that there is enough nuclear fuel in the ocean to last the lifetime of the sun. The technology to extract that fuel has been demonstrated by Japan and the United States. So nuclear fuel is inexhaustible. It is just as inexhaustible as sunlight.

However, we are not taking advantage of this potential. Instead, the world is basically following the German model, which could cause hundreds of thousands of deaths in the near term.[1]
Germany used its position as host nation for COP6 in Bonn in 2001 to declare that nuclear power is not eligible as a clean development mechanism. Now Germany is trying to force that position on the rest of the EU. And, worse, Germany is trying to get the EU to declare that gas is a clean energy.
That would be a disastrous course for the world. It works for German internal politics and monetary benefit, but not for the planet or the future of young people.

However, there is plenty more blame to go around. After Ken Caldeira, Kerry Emanuel, Tom Wigley and I wrote an open letter[2] to environmental leaders on 3 November 2013, explaining that "…there is no credible path to climate stabilization that does not include a substantial role for nuclear power" and asking for their support, private discussion with the head of NRDC (Natural Resources Defense Council) revealed that they could not change their anti-nuclear position without losing a substantial fraction of their funding. Such deception – amounting to pretense that fossil fuels are better than nuclear power for animals and nature – is widespread. Michael Shellenberger has documented the extensive fossil fuel funding of NRDC, Friends of the Earth, and other Big Green "environmental" organizations.[3]

What about the media? Are they incapable of ferreting out the connection of fossil fuels with Big Green? Instead, they delight in sensationalist, inaccurate stories about nuclear accidents, failing to compare this with orders of magnitude greater harm from other energy sources, especially fossil fuels.

[1]Kharecha, P.A. and M. Sato, 2019: Implications of energy and CO_2 emission changes in Japan and Germany after the Fukushima accident. *Energy Policy*, 132, 647-653.
[2]http://www.columbia.edu/~jeh1/Documents/LetterToEnvironmentalLeaders.CNN+AP.2013.pdf
[3]Shellenberger, M., Chapter 10: All About the Green, in *Apocalypse Never*, HarperCollins, 2020.

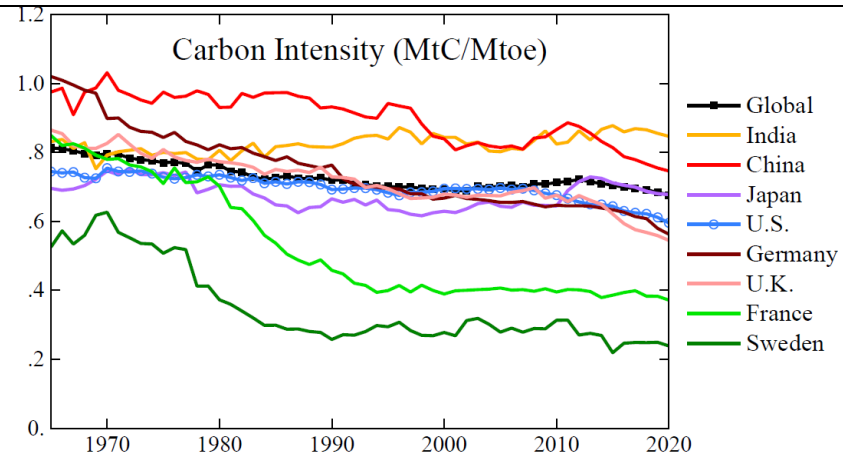


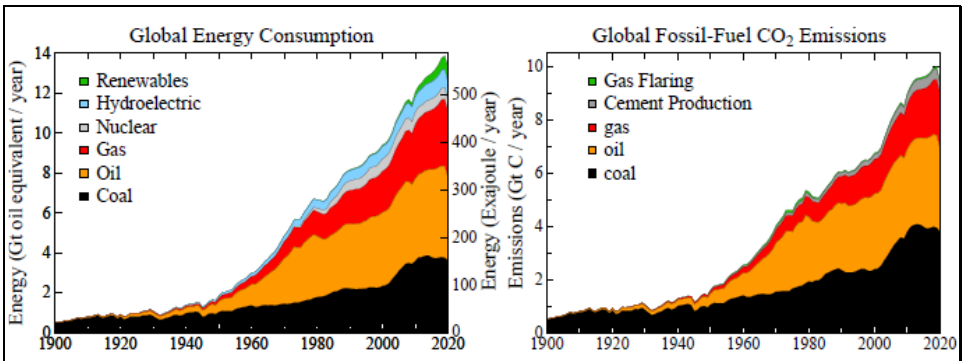
Fig. 47.5. Carbon intensity (carbon per unit energy) of global and national energies. MtC: megatons carbon. Mtoe: megatons oil equivalent. *[Sophie's Planet, Chapter 47]*

We must look at real data to assess the global situation. We cannot rely on soothing words heard at the COPs, words about goals for 2050.

The data[1] are damning. The data reveal minimal progress toward the zero carbon intensity goal.

The data should make us suspect that carbon-free plans for 2050 are in part a hoax, a "scheme," as opposed to true carbon-free energy. Beware of any reference to "net zero" or "offsets."

The crucial requirement is that electricity generation be truly carbon-free. In most countries carbon-free electricity is unlikely to be achieved without a significant contribution from nuclear power.

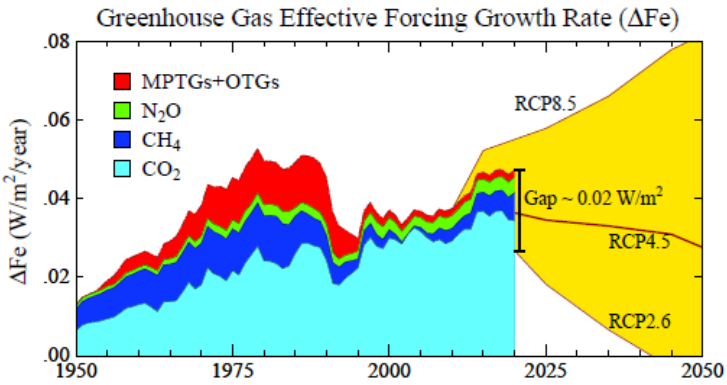


Global energy consumption and fossil fuel emissions. BP data are used from 1965. Gilfellan et al. earlier data are adjusted by factors near unity to match BP in 1965.

see Chapter 43: Energy for the World, *Sophie's Planet*, available www.columbia.edu/~jeh1

Carbon intensity must be multiplied by energy consumption, which is rising – so global emissions are rising.

There is no evidence of a rapid emissions downturn, only a probably brief covid dip.



Annual growth of greenhouse gas climate forcing (red is trace gases, mainly CFCs). RCP2.6 is a greenhouse gas scenario designed to keep global warming below 1.5°C.

Hansen, et al., Young people's burden: requirement of negative CO_2 emissions, *Earth Syst. Dyn.* **8**, 1-40, 2017.

Absolute proof of the pudding is the greenhouse gases. Look at what happened since the Paris Agreement of 2015. Gases are growing as fast as ever.
A pathway to keep warming to 1.5°C was defined, but already a gap has opened up that would cost about $1 trillion dollars per year to close.
Boris Johnson claimed that COP26 was a success – the goal to keep global warming below 1.5°C was still achievable.

That assessment is pure, unadulterated bullshit. There is now no chance whatever of keeping global warming below 1.5°C.

Young people, you cannot count on today's politicians to solve the problem – you must get involved – don't be discouraged – look at it as an invigorating challenge.

Existential Threat

1. Sea Level Rise
Tipping point, Exponential, Loss of coastal cities

2. Low Latitude Overheating
Outdoor work and recreation become impossible

3. Regional Climate Extremes Increase
Becoming noticeable, more in pipeline

4. Emigration Pressures → Ungovernable

Let's first summarize the existential climate threat, and then we can talk about how you can solve the problem.

Large sea level rise is the irreversible climate impact that we must avoid. We are warming the ocean and it is beginning to melt the ice shelves around Antarctica.
We may be close to the tipping point at which the West Antarctic ice sheet collapses and sea level goes up several meters.
Contrary to the impression left by models that IPCC relies on, we know from Earth's history that ice sheet collapse is exponential.
Sea level rises slowly until a point where it goes whoosh; I will come back to this topic because it is crucial for the targets that we must aim for.

Low latitudes are on the verge of becoming too hot for outdoor work and recreation. I refer to the tropics in much of the year, and the subtropics in summer.
These regions could become unlivable, if we continue down a business-as-usual fossil fuel emissions.

Regional climate extremes are beginning to noticeably increase. Because of global warming at the times and places when it is dry, it is hotter, droughts can be more extreme and fires burn hotter.
The atmosphere holds more water vapor, so when rainfall occurs it is often in more intense events, with greater floods, and stronger storms.

One consequence of sea level rise, low latitude overheating, and climate disasters will be increased emigration pressure that could make the planet almost ungovernable.

So Why Am I Optimistic?!

Democracies Threatened, Including U.S.
Role of money, Instability of 2-party extremism

Climate & Governance Exigencies Coincide
Next 10 years will determine outcomes

Young People Understand the Situation
Capable and ready to lead, and they must

How can I be optimistic when a long-standing problem with our democracy has remained untreated and grown to threaten our American democracy and democracies almost worldwide?
Symptoms are obvious. Politicians launch into the next campaign the day after an election. They are more concerned with retaining their office than with serving the public.

The underlying cause has long been recognized: the role that money is allowed to play in our democracy. When President Eisenhower was preparing his farewell address, in which he warned the nation of the threat of a growing military-industrial complex, an early draft of the speech referred to the military-industrial-congressional complex. But Ike backed off. When his brother, Milton, asked about the deletion he replied "It was more than enough to take on the military and private industry. I couldn't take on the Congress as well."[1]

I do not discount the validity of Ike's warning about militarism, though his warning had little impact. Investments in defense contractors outperform the overall stock market.[2] More important, the reign of the military-industrial complex leads to "wars of choice"[3] that the public does not want. Our Constitution grants decision-making over war and peace to Congress, but Congress has allowed the President to usurp that role and even employ the CIA as an unaccountable secret army.

Eisenhower's omission – the role of Congress in this distortion of the democratic process – is the fundamental problem: Congress is permitted to accept bribes under the rubric of "campaign" funds. This problem grew to a monstrous scale when the Supreme Court – supposedly the guardian of our democracy – ruled in *Citizens United* that corporations – with their vast resources – are free to participate in this vulgar, legalized corruption.

Public frustration with the Washington swamp of special interests has led to the rise of the extremes in both of the two American political parties. As power oscillates from one party to the other and neither party delivers, frustrations grow higher. This two-party oscillation is unstable and could result in the collapse of our democracy, if we do not solve the underlying problem.

Solution must come from idealistic young people, who are not yet weighed down or captured by the system. It is possible. When I gave climate talks on campuses in 2008, there was a wave of excitement and enthusiasm for the upstart candidate, Barack Obama. He swept past Hilary Clinton on that wave without the benefit of the establishment or big donors. Young people were the force behind that wave. Little money was needed. Skill with social media helped. I have great confidence that young people today are even better able to take on the task of saving our democracy and their future.

[1]Goodman, M.A., National Insecurity: The Cost of American Militarism, City Light Publishers, 464 pp., ISBN-10 0-87286-589-4, 2013.
[2]Schwarz, J., $10,000 invested in defense stocks when Afghanistan war began now worth almost $100,000, New York Times, 16 August 2021.
[3]Sachs, J., Our misguided 'wars of choice,' Boston Globe, 16 April 2017.

THE LARGEST STATEMENT *of*
STUDENT GOVERNMENT LEADERS IN U.S. HISTORY

More than 350 college student government presidents – representing more than 4 million students in all 50 states – issued a bipartisan statement in support of carbon fee and dividend.

They are following the science – climate, energy and economic sciences.

Young people understand the fundamental requirements for solving the climate problem. Old people in Congress do not. Once elected to Congress, members of both parties join the elite, the privileged class. They lose touch with the common people. Of course, they rant about the needs of commoners – rich people are especially good at that spiel – but their first priority becomes their own reelection.

Young people get it. They understand what will work to solve the climate problem. They want to follow the science. If 100 percent of the fee collected from fossil fuel companies is distributed to the public, most people come out ahead. The economy grows. Entrepreneurs and innovations help modernize infrastructure at no cost to the public.

Elite Congress does not get it. When 200,000 members of Citizens Climate Lobby begged Congress to pass fee & dividend, that gave Barbara Boxer and Bernie Sanders an idea. They introduced a fee & dividend bill, the Boxer-Sanders bill, in which they immediately stole 40 percent of the public's money for the government, which they would dole out according to Congress (and their lobbyists) wishes.

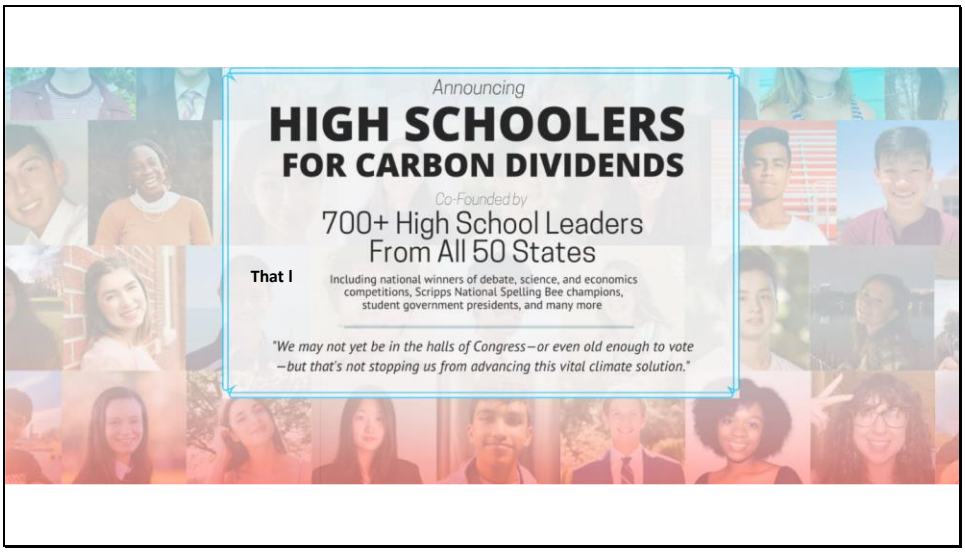
There is zero chance that such a scheme would fly in the Midwest. The public would get a meager dividend that does not make up for the rising price of fossil fuels.

It becomes easy for the other party to make fools of left-wingers.

The electoral strategy of the left is to throw goodies to the proletariat. That's their strategy to get reelected.
In order to have enough goodies they borrow the money – they borrow it from young people and future generations.
There is a good chance that this electoral strategy will not fly in most of the country.

Leaders of the other party (my father called them "the rich man's party") are also elitists and on the take – well-funded by the fossil fuel, pharmaceutical and other industries.
So they have plenty of money to fund winning campaigns – negative campaigning that focuses on foolish ideas of the left-wingers, such as "defund the police."

That leaves young people with the task of saving our democracy and creating a government capable of good governance.



What! You expect young people to save our democracy and the planet?

Well, yea, why not? They have the most at stake. They are smart. They understand the issues. They know how to use social media without money. They are not carrying the baggage that many oldsters lug about.

High schoolers can understand the most fundamental requirement to phase down carbon emissions. Yes, I know, the students who have looked at these issues and can discern policy needs are the cream of the crop, but our future leaders should come from the cream of the crop.

Politicians today are not necessarily from the cream of the crop. Incentives to be a politician have not usually attracted the best people. Everyone is aware that we have a special-interest, money-driven political system. Who is inspired to take part in a system where you take money from special interests and start campaigning for the next election the day after the last one? Not the cream of the crop.

Today the incentives are changing for young people. They have great incentive to become involved in government for the sake of saving their own future. And that's feasible. But they need to seize control of their future soon, before geopolitics goes haywire, before the course of future climate is set in stone (or ice). Let's come back to this topic after I note that young people also understand the need for nuclear power.

good energy collective

Our Progressive Policy Agenda for Advanced Nuclear Energy

Recommendations for advanced nuclear technologies as part of the U.S. climate change response

by Suzanne Baker, Jessica Lovering and Rachel Slaybaugh

In students, I find wide support for nuclear power as a key part of a clean energy future, especially because of its small environmental footprint.

Young people emphasize the need for social and environmental justice, with leadership diversity and equitable access to clean energy and high-quality jobs for all communities. Here's a link to a progressive nuclear energy agenda of a nonprofit organization "good energy collective."

However, young people face formidable opposition. In Chapters 43[1] and 45 of Sophie's Planet I describe deceptive actions of the Democratic Party in appointing anti-nuclear people to the Nuclear Regulatory Commission NRC). It is difficult to quantify the effect of long delays (several years) and extreme costs of NRC approvals for nuclear reactors, but I know from "environmentalist" acquaintances that those were desired outcomes. I also learned – when I spoke out in favor of nuclear power – that the anti-nuke former NRC members are on stand-by, ready to go on the media to counter any pro-nuclear information. They seemed to be analogous to the handful of scientists repeatedly called on as climate change deniers – they have detailed technical knowledge, so they sound impressive to the public.

Despite all this and despite an anti-nuclear bias in liberal media, a majority of the public favors nuclear power! It increases my faith that it is possible to make democracy work even in the face of well-healed special interests (the fossil fuel industry strongly opposes nuclear power). Perhaps the public realizes that nuclear power has the smallest environmental footprint of all energies, it's very safe, and nuclear power plants provide a lot of high-paying jobs.

Nevertheless, the Democratic Party remains staunchly, if deceptively, anti-nuclear. The single action on energy of most effect by the present government – in which Democrats control the House, the Senate and the Presidency – is the quiet removal of all funding for the Versatile Test Reactor (VTR) from the FY2022 budget. It's as if the Democratic Party prefers that Russia, China and other nations assume the leadership role in nuclear technology. Suzanne Baker and three coauthors describe the crucial need for the Versatile Test Reactor, if the U.S. wishes to maintain a leadership role in nuclear technology.[3]

[1]Hansen, J., Chapter 43: Energy for the World, draft chapter for *Sophie's Planet*, Bloomsbury, 2022.
[2]Hansen, J., Chapter 45: Energy and World Peace, draft chapter for *Sophie's Planet*, Bloomsbury, 2022.
[3]Baker, S., J.T. Gordon, J. Greenwald and J. Toth, The VTR will play a key role in the nuclear energy innovation ecosystem, *Energy Source*, 28 September 2021.

Equal Rights and Opportunity: The Platform

1. No funding from special interests
Individual donations only, max = $100?/year

2. Party control of who/whether to run
Avoid being spoiler if ranked voting not available

3. Advocate ranked voting
Begin pushing for this immediately

4. Carbon fee & 100% dividend
Eventually supplemented by energy fee

5. Renew civilian control over war-making
Congress should uphold its Constitutional duty

Marshall Saunders, who died 27 December 2019, was a visionary, and a wonderful, generous person who believed in our democratic system. Marshall formed Citizens Climate Lobby (CCL) in 2007 with the objective to advocate for the cap & trade system to drive down U.S. carbon emissions.[1] In 2008 he realized that carbon fee & dividend would be more effective and accordingly changed the objective of CCL. Within a few years, as we realized the difficulty of getting either political party to be fully supportive of fee and dividend,[2] I argued that we needed a third political party, a centrist party that would take no money from special interests and would focus on equal rights and opportunity for all people, including young people, which we believed to be guaranteed by the Constitution. Marshall agreed to advocate for such a third party when I finished *Sophie's Planet*, which would include the rationale for the third party in one of its final chapters.

I was too slow. It's hard to carry out scientific research, find support for my research team, and also write a book. But I believe more than ever that such a third party is needed to help right our democracy and make it functional again, as required to address not only climate change but many needs that have languished as the political system has become polarized and dysfunctional. I will finish the final three chapters of Sophie's Planet as soon as it is a bit clearer what the Biden administration is doing and not doing about climate change. Here I note a few of the ideas to be discussed in Chapter 49: Equal Rights and Opportunity.

For a decade, beginning in the 1990s, Carolyn Harris and I ran a program – the Institute on Climate and Planets – at the NASA Goddard Institute for Space Studies in New York City. At any given time it involved as many as about 50 students, teachers and researchers from New York City high schools (one junior high) and colleges who worked with us on NASA research projects. All of the students were underrepresented minorities, because one of my objectives was to get (white, male) NASA to look more like America. We changed the name of the research team that I headed as our research topic changed. The last name before funding for the program terminated was "The A-Team," for Alternative Scenario, as described in Storms of My Grandchildren. If I could reassemble the A-Team now, the task that I would propose would be definition of a proposed platform and modus operandi of a new political party, perhaps titled Equal Rights and Opportunity. A few of the ideas that I would proffer are listed above.

I believe that it is necessary for the party to control whether it will run a candidate in any given election because it is important to avoid a situation in which the party's candidate functions as a spoiler and results in the worst of multiple candidates being elected. For the same reason, the party should advocate and fight for ranked voting[3] in as many states and locales as possible.

Carbon fee and dividend, I argue, should be a fundamental plank in the party platform as it is not only the foundation needed to achieve a stable climate, it is progressive, helping to address wealth disparity. In time, as carbon emissions decline to a small amount, it can usefully be supplemented and replaced by energy fee and dividend for the sake of limiting wasteful over-consumption.

Surely the problem that Eisenhower pulled back from – the military-industrial-congressional complex – must be addressed via a central plank of the party platform. As a party that takes no money from special interests, it will be easier to lay the truth before the American public. I would ask all members of the A-Team to view an 8-minute description of American military adventures overseas and discuss the degree to which these actions are making America safer or placing us – and our democracy – in greater danger. It is important to take the long view. America did not enter World War II until we were attacked. We emerged from the war as a most admired nation, and we were magnanimous to the vanquished as well as to allies who were worn down by the proximity and length of the fighting. Since then, our military-industrial-congressional complex has encouraged war-making worldwide, ostensibly to make us safer. A majority of the wars have been small and hidden from the American public, but the public in nations where fighting takes place are generally aware of American involvement. These secret wars, as well as the public ones in which we have intervened to remove a despotic leader or install a nominally democratic government, overall may have done more to create ill-will toward America and make us less safe, rather than safer. The founders of our democracy expected Congress to exercise control over war-making –

with wisdom expected especially from the Senate. We cannot expect wisdom from Congress as long as money rules, which is why plank #1 is crucial.

You may be growing skeptical about whether such mountains can be scaled. I remind you that a majority of the public has more than an inkling about how things have deteriorated in Washington. That's why voters oscillate from one extreme to another, willing to support anyone who is an outsider – but that won't work as long as the government is composed of the two parties that are both beholden to special interests. A third party can achieve significant power with a small number of representatives in Congress because of the frequent near-balance between the major parties. Moreover, once a third party is recognized as honest and not beholden to special interests, there could be a major influx of support from the public. The public thirsts for a new birth of freedom – they do not want government of the people, by the people, for the people, to perish from Earth.

There are many other planks that you should consider and prioritize. Equal rights and opportunity, in my opinion, requires universal pre-K education and affordable college.

I'm in a rush to finish this, and I have not yet written the Equal Rights and Opportunity chapter of Sophie's Planet, so I am probably missing some of the most important planks. Suggestions are welcome.

Ah, let me mention one more, because, in the early chapters I mention the need to set aside more land for nature, a contiguous north-south corridor, incorporating some national parks, expanding as land is added by donations and philanthropy. I think that you can figure out a way that Native Americans could be given a special role in maintaining that land, which should be open to all for non-destructive recreation.

[1]Hansen, J., Chapter 42: Old King Coal Lives, draft chapter for *Sophie's Planet*, Bloomsbury, 2022.
[2]Hansen, J., Chapter 44: Tell the President the Whole Truth, draft chapter for *Sophie's Planet*, Bloomsbury, 2022.
[3]A voter ranks all candidates in order of preference. If no candidate receives 50% of the vote, the candidate with fewest votes is eliminated. Voters listing that candidate first are instead granted their second choice and votes are retabulated. If necessary, the candidate receiving next fewest votes is dropped, until a candidate receives over 50%. These re-tabulations can be done almost instantly by a computer; there is no need for a runoff election.

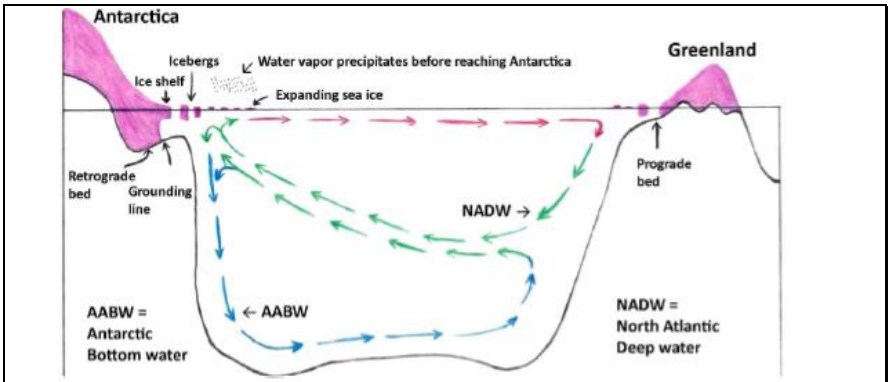


Fig. 35.1. Schematic of stratification and precipitation amplifying feedbacks. Stratification: increased freshwater flux reduces surface water density, thus reducing AABW formation, trapping NADW heat, and increasing ice shelf melt. Precipitation: increased freshwater flux cools ocean mixed layer, increases sea ice area, causing precipitation to fall before it reaches Antarctica, reducing ice sheet growth and increasing ocean surface freshening. Ice in West Antarctica and the Wilkes Basin, East Antarctica, is most vulnerable because of the instability of retrograde beds.

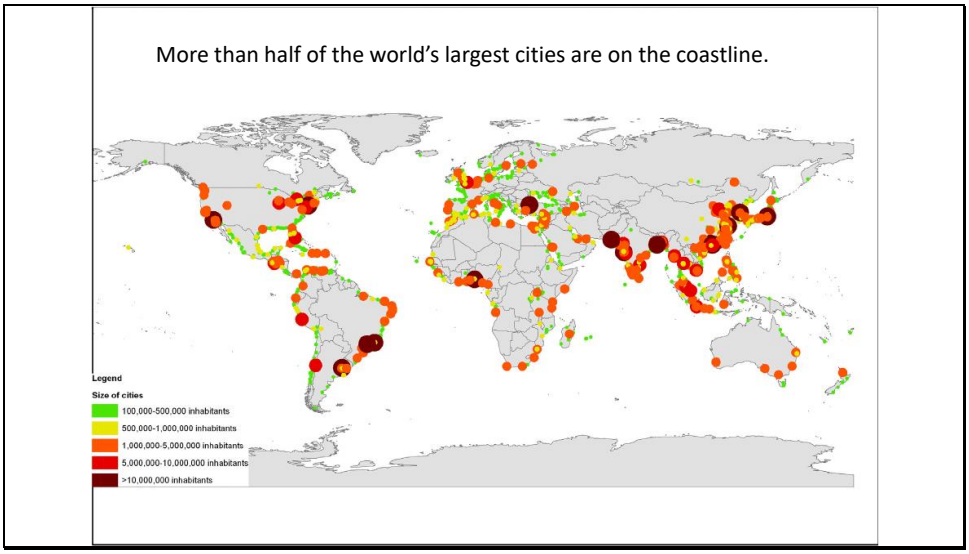
As for me, I will focus on climate science, once I finish *Sophie's Planet*. During the next 10 years, while the American democracy is being rescued, and while the world begins to recognize with increased clarity the threat that climate change poses to global governance and to the prospects for young people and future generations, I want to focus on the climate science that must be well understood if and when the climate crisis becomes so obvious that governments will be ready to take actions.

Specifically, we must investigate further and understand better the threat of large, rapid sea level rise. I believe – I am confident – that the IPCC (Intergovernmental Panel on Climate Change) badly understated the threat of large, rapid sea level rise. How could that be, given the many thousands of scientists involved in the extensive IPCC reports? The issues that I raise do not involve the many thousands of scientists, who have done exceptional work overall. The problems arise from the subset of IPCC concerned with model projections of the future. Indeed, IPCC analyses have succumbed to overemphasis on models. Better insight is obtained via comparable emphasis on paleoclimate data on how Earth responded to changing forces in the past, precise observations of ongoing climate processes today, and interpretation of these paleo and modern data with the help of models. If I were a lone scientist with these concerns, you may be justified in ignoring the matter. But I know these concerns are shared by Eelco Rohling and Eric Rignot – top world experts in the relevant paleoclimate, sea level, and ice sciences – and many other scientists.

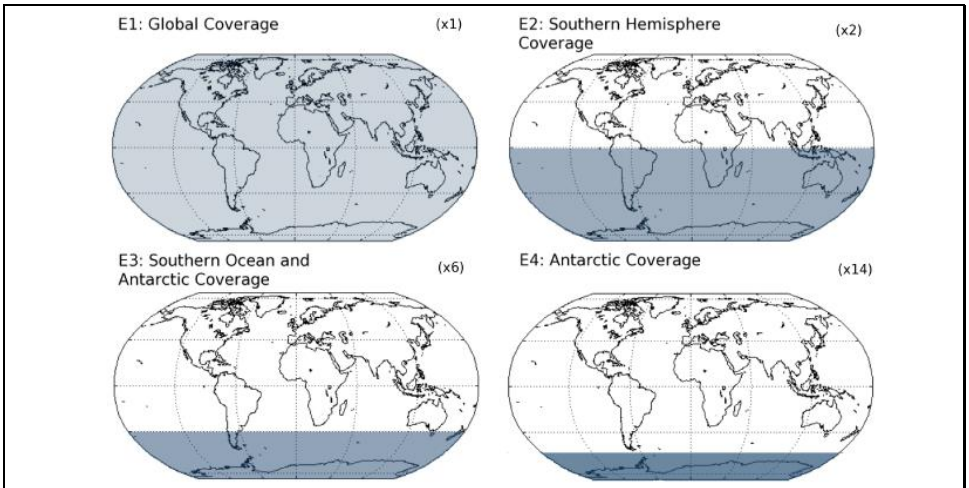
I recently described[1] a 10-year research path that led to deduction that continued high greenhouse gas emissions will cause shutdown of both the Atlantic Meridional Overturning Circulation (AMOC) and the Southern Ocean Meridional Overturning Circulation (SMOC) by midcentury. Also – if greenhouse gas emissions remain high – feedbacks associated with these ocean changes[2] will cause exponential sea level rise of several meters by the end of the century – consistent with the nonlinear way that ice sheet disintegration has almost always occurred in the past. My colleagues and I concluded[3] that most ocean models are unrealistically insensitive to the increasing injection of freshwater from melting ice and that ice sheet models fail to capture realistic ice sheet collapse. We believe that there has been inadequate focus on identification of crucial uncertainties in the most basic "physics" of the climate system and on required observations, especially of the Antarctic ice shelves and adjacent ocean.

This research deficiency leads the Intergovernmental Panel on Climate Change (IPCC) to stand the world on its head. IPCC reports conclude that even high greenhouse gas emission scenarios have only a low probability of causing disastrous, multimeter sea level rise this century. We come to the opposite conclusion: ice sheet disintegration is an exponential process and large sea level rise this century is the expected outcome, if high emissions continue. Distinction between these conclusions makes all the difference for policy. IPCC reports lead to an emphasis on adaptation to climate and sea level change, as well as mitigation of emissions. Adaptation is needed, but it will be ineffectual for most coastal cities in the event of exponential sea level rise by several meters. With high emissions, coastal fortification would prolong the lifetime of such cities by only several years. A majority of the world's largest cities are coastal. If ice sheet disintegration is allowed to pass a point of no return, today's young people thus could inherit a situation that's out of their control.

[1]DellaSala, D.A. (ed), *Conservation Science and Policy for a Planet in Peril: Speaking Truth to Power,* Elsevier: Boston. ISBN-10: 0128129883 https://www.amazon.com/Conservation-Science-Advocacy-Planet-Peril/dp/0128129883, 2021.
[2]The principal effect of growing freshwater injection into the upper ocean is to reduce the volume of relatively warm deep water reaching the ocean surface around Antarctica, thus shutting down that escape valve for deep ocean heat. Instead the ocean heat melts the marine ice shelves that buttress the ice sheet above sea level. As the ice shelves melt, mass loss from the ice sheet can increase exponentially. Fig. 35.1 is from Hansen, J., Chapter 35: Dangerous Interference, draft chapter for *Sophie's Planet*, Bloomsbury, 2022.
[3]Hansen, J., M. Sato, P. Hearty, R. Ruedy, M. Kelley, V. Masson-Delmotte, G. Russell, G. Tselioudis, J. Cao, E. Rignot, I. Velicogna, B. Tormey, B. Donovan, E. Kandiano, K. von Schuckmann, P. Kharecha, A.N. Legrande, M. Bauer, and K.-W. Lo: Ice melt, sea level rise and superstorms: evidence from paleoclimate data, climate modeling, and modern observations that 2 C global warming could be dangerous *Atmos. Chem. Phys.*, 16, 3761-3812, 2016.



These are all of the world's largest cities. More than half are on coastlines. Cities would become dysfunctional long before they were totally under water, so we cannot allow a sea level rise of several meters. Effects would be irreversible on any time scale that we care about.

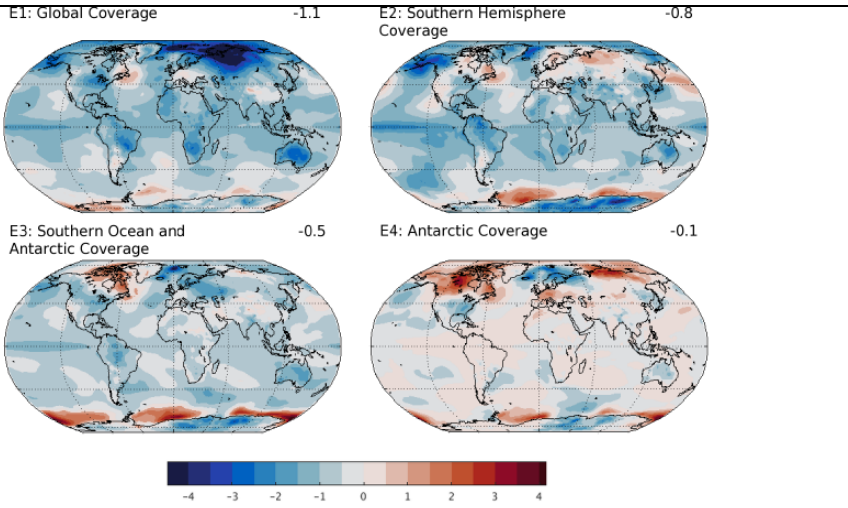


Four Experiments: Pinatubo-like aerosol amount distributed over different regions.

Our expectation of multi-meter sea level rise on the time scale of a century refers to the case of continued high greenhouse gas emissions. The time scale for ice sheet collapse and large sea level rise might be longer if greenhouse gas emissions are much reduced and global warming is more limited. Despite uncertainty in the time scale of the ice sheet response, paleoclimate data imply that we will need to aim to return to a global climate no warmer than the mid-20th century, and perhaps cooler, if we wish to maintain reasonably stable sea level.

Global loss of coastal cities would be a disaster of such enormity, that we must develop knowledge of potential actions in case we find that the time scale for ice sheet collapse is shorter than the time scale over which we can bring down global temperature by reducing greenhouse gas amounts. The easiest way to reduce global temperature rapidly is reflect some of the incident sunlight to space. To study the effect of such "solar radiation management," I asked Craig Rye to carry out global climate model simulations for four alternative geographical distributions of stratospheric aerosols of a continuing aerosol amount equal to that from the 1991 Mount Pinatubo volcanic eruption. I reported the results of these experiments at the first joint meeting of the American Geophysical Union and the Chinese Academy of Sciences held at Xi'an, China in 2018.

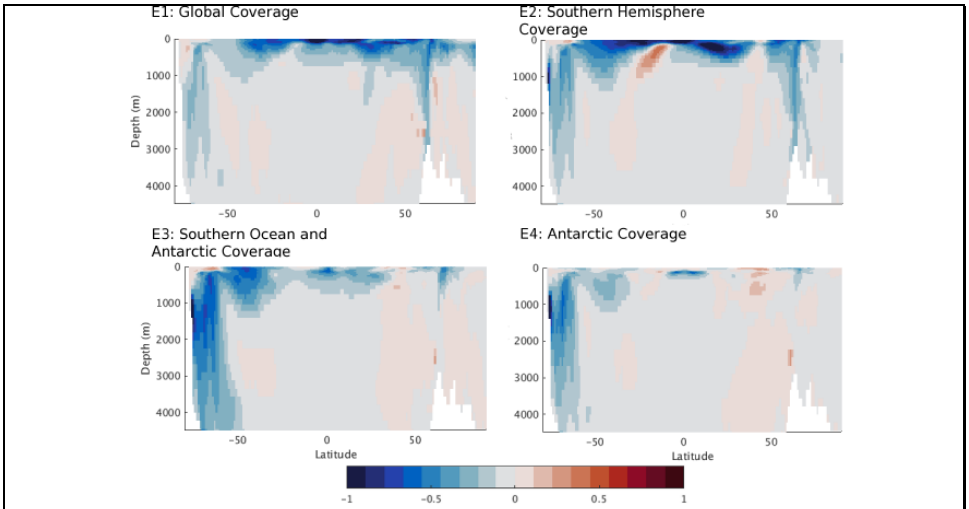
[1]Hansen, J., Aerosol effects on climate & human health: urgent research needs, American Geophysical Union – Chinese Academy of Sciences Meeting on Atmospheric PM2.5, Xi'an, China, 17 October 2018.



Change of surface temperature after 40 years. Number in upper right is global cooling (°C).

As expected, the stratospheric aerosols produced global cooling in all cases, although of negligible amount when the aerosols are only over Antarctica. Global cooling is 1.1°C after 40 years when the aerosols are spread uniformly over the globe.

The most interesting case is when the aerosols are located over the Southern Ocean (plus Antarctica). Global cooling is 0.5°C, but there is warming of the ocean surface around the Antarctic coast.



Change of internal ocean temperature after 40 years (mean for years 35-45).

The reason for the surface warming is apparent from the temperature change versus depth in the ocean. The effect is the opposite of the case of increasing greenhouse gases and increasing ice melt, as described in our *Ice Melt* paper.[1] Instead of SMOC shutting down, SMOC speeds up. Heat is, in effect, pumped from the near-coast deep ocean into the ocean mixed layer Increase of ocean polynyas melts sea ice, opening up the escape valve for heat from the deep ocean to the atmosphere and space. This is thus a logical result, but needs to be investigated further.

I doubt that it will ever make sense to employ human-made stratospheric aerosol cooling in an attempt to minimize adverse effects of human-made greenhouse gases. It is not only the idea that trying to offset one pollutant by adding another pollutant is repugnant. There are recognized dangers in the stratospheric aerosol approach, including possible effects on stratospheric ozone. These matters have been discussed in hundreds of papers in the literature, which I do not attempt to review.

On the other hand, condemnation of investigation of ways to alleviate global warming impacts – and demonize them all with the "geoengineering" label – is unhelpful. We already are geoengineering the dickens out of the planet, pumping energy into the ocean at a rate that's much greater than any time in Earth's history that we know about. There may be options to reduce this geoengineering while we take the necessarily time-consuming actions to reduce atmospheric greenhouse gases. For example, scientists are investigating the possibility of autonomous floats that spray salt particles into the air over ocean areas to increase cloud cover. By choosing optimum areas in the Southern Ocean, it may be possible to achieve significant cooling of the ocean near Antarctic at the depths that would be effective in slowing or even reversing mass loss from ice shelves. It would make sense to carry out modeling studies this decade.

Perhaps more important is to investigate what happened during the last interglacial when sea level seemed to have increased several meters in less than a century while global temperature was not much warmer than today. We need to understand the relation between events in the North Atlantic and the Southern Ocean. There is evidence of shutdown of the overturning circulation in the North Atlantic, which potentially added to warming in the Southern Hemisphere that was associated with Earth orbital parameters. It may be possible to learn something from that period relevant to the present situation, in which we may simultaneously warm the Southern Ocean from an increasing greenhouse effect and shut down the North Atlantic overturning circulation.

[1]Hansen, J., M. Sato, P. Hearty, R. Ruedy, M. Kelley, V. Masson-Delmotte, G. Russell, G. Tselioudis, J. Cao, E. Rignot, I. Velicogna, B. Tormey, B. Donovan, E. Kandiano, K. von Schuckmann, P. Kharecha, A.N. Legrande, M. Bauer, and K.-W. Lo: Ice melt, sea level rise and superstorms: evidence from paleoclimate data, climate modeling, and modern observations that 2 C global warming could be dangerous *Atmos. Chem. Phys.*, 16, 3761-3812, 2016.