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environment /ən'vaɪrə(n)m(ə)nt/

noun

- the area surrounding a place or thing; the environs, surroundings, or physical context: *Bairuth, with its kind picturesque environment.*
- the physical surroundings or conditions in which a person or other organism lives, develops, etc., or in which a thing exists; the external conditions in general affecting the life, existence, or properties of an organism or object: *the organism is continually adapted to its environment.*
- the natural world or physical surroundings in general, either as a whole or within a particular geographical area, esp. as affected by human activity: *the situation is clouded by a widespread confidence that this impact of man upon environment can continue indefinitely.*

Oxford English Dictionary, 3rd Edition

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Michael Oppenheimer is the Albert G. Milbank Professor of Geosciences and International Affairs and director of the Center for Policy Research on Energy and Environment at the Princeton School of Public and International Affairs. Educated as a chemist and physicist and working at the interface between public policy and science, Oppenheimer has long been a leader in calling for governmental action on climate change. His efforts to bring together scientists and policymakers to elaborate the implications of climate change played a significant role in initiating the negotiations that led to the UN Framework Convention on Climate Change, the parent document of the Kyoto Protocol and the Paris Agreement. **Karen M'Closkey** spoke with Oppenheimer about scientific assessments, uncertainty, and how he has remained optimistic after 40 years of advocacy.

+ References to human-induced climate change from CO2 emissions appeared as early as 1896. However, one of the first to warn about its deleterious effects is a 1965 report on the environment by the US President's Science Advisory Committee. Later, a 1969 memo to President Nixon said we should consider stopping fossil fuel use. When did you become aware of the problem?

I became aware of the issue when I read an article by Gordon McDonald in the alumni magazine *MIT Technology Review* in 1969. His article was about the multiple ways that humans influence, and could influence, the climate globally and otherwise. I am a very calm person. I don't get frightened by big threats. This scared me. At the time, I was in a transition from thinking about science as a career to thinking about science as a tool for public betterment. I received a Ph.D. in chemical physics in 1970 and went to work at the Harvard-Smithsonian Observatory, applying atomic and molecular chemistry and physics to astrophysics. It was intellectually stimulating, but I decided that astrophysics research was costly to governments and secondary in importance to me compared to solving problems burdening people and societies. Thus, by the late 1970s, I had decided that academia wasn't a good fit for me, so after 10 years at Harvard, I left for a job as an activist scientist doing policy-relevant work on acid rain, ozone depletion, and climate change for the next 21 years with the Environmental Defense Fund (EDF).

+ You were one of the earliest and most outspoken scientists warning about climate change. In your congressional testimony in 1986, you said, "If left unchecked [it] will come to dominate all others in its effect on our environment. ...We do not need a comprehensive understanding to undertake action." In 1990, you followed up with *Dead Heat: The Race Against the Greenhouse Effect*, coauthored with Robert H. Boyle. Did you imagine that efforts to reduce greenhouse gases would be so slow given the evidence at that time?

One way that I've managed to work on this problem for more than 40 years is that I didn't give much thought to how long it would take. There was no way to have a good frame of reference for how long it would take the world to recognize a problem like this, to make the institutional arrangements to negotiate with other countries, and to educate people about it. With the encouragement of the foundations that supported my work at EDF, I joined up with several other scientists in 1985 to develop a five-year plan to move the issue from the scientific community to the policy arena. We thought the time for action was ripe because a consensus on the inevitability of climate change and the need for governments to consider action had been reached among scientists. Our objective was called a framework convention, a type of treaty.

It took seven years, but the convention was signed at the Rio Earth Summit in 1992. So, we had the treaty, but very little work had been done politically in the US to get people interested in the proposition. This was the big lacuna that the environmental movement let lie there. People came to me in the mid-'80s and said, "You're trying to generate a treaty on an issue that nobody has heard of, and that would involve tearing apart the fossil fuel industry: you've got to be joking." I guess there was no clear strategy; maybe there couldn't have been one that early. People didn't start waking up to it until we started seeing consequences in the climate that scientists could point to and say, *This is climate change*. So, my timeframe in the early days was probably a decade or two for getting some serious action. Now, almost 40 years later, we have some serious action by governments - though not serious enough.

+ In 1983, the Academy of Natural Sciences report on climate change stated that 3°C to 4°C of warming could have deleterious and inequitable effects globally but did not believe that the evidence supported steps to move away from fossil fuel dependency. The report concludes, "In our calm assessment, we may be overlooking things that should alarm us." Why was the report so tepid in its recommendations?

The thing you have to realize about scientific assessments is that experts' individual biases sometimes influence them, especially when there are only a few experts involved. In that report, which was a mixture of science and policy and economics, there was little understanding or focus on how climate change would affect the average person. Some, like George Woodwell, were pushing to get firmer statements about the aspects of climate change we were certain about scientifically. Certainly, Woodwell believed it was time to start thinking about policy, while others on the panel had more influence over the final wording, particularly scientist Bill Nierenberg, the chair, who was rather politically conservative. And there were two economists, Thomas Schelling and Bill Nordhaus, who were also a little too cautious in their approach. They basically said we need 10 more years of research, which I thought was ridiculous. You don't deal with an earth-shaking problem by waiting: at the very least, you start making plans and laying out policy options while at the same time learning more from vigorous research.

Oddly, but not coincidentally, an EPA report came out either the day before or the day after that Academy report. It was written by a core of experts within the EPA, some of whom were working quietly on both the ozone depletion problem and the climate problem. This was during the Reagan administration, you have to remember. The EPA report had a message that was completely opposite to the Academy report. It said it is too late to avoid significant warming. That was the entry point for me to address the issue in a public way. I used it as an opportunity to write an op-ed for the *New York Times* about these two reports, arguing that there is no point in waiting to take action.

+ The First Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), which provided a strong scientific background for negotiations of the United Nations Framework Convention on Climate Change (UNFCCC), was issued in 1990. In 2023, the IPCC 6th Assessment Report was published. Have the reports changed in terms of how they approach policy recommendations?

The big difference is in the rhetoric. IPCC has become more willing to express statements of fact in language that isn't overly cautious. Its language is not out of proportion to the problem on the various points on which it makes statements, but the statements are clearer and more readily understandable than in the early reports. It is better to do that than to write in a neutral tone or, in some cases, complex and uninterpretable language that the average person, and many experts, disdain.

The part of IPCC that deals with policy is Working Group III. It has expanded significantly. Its authors do a variety of things, like modeling the energy system, projecting future emissions, discussing the positives and negatives of international agreements on climate change, and discussing ways to reach an international agreement. They have gotten more and more detailed, but they are careful to avoid pronouncements about national policy because the IPCC is a collaborative effort between governments and scientists. In other words, the scientists found a client that was interested in receiving the reports. IPCC was put together by the clients: governments. The IPCC reports are the jumping-off point for things like the US national assessment, which provides more detailed, nationally relevant information about climate change. In this way, IPCC has been extremely influential in shaping the body of knowledge that governments look to, and they have taken argumentation about science out of the hands of the negotiators at the conferences of the parties to the framework convention, which is a good thing. Otherwise, a few contrarians in the room would argue about what the science is. Now, the delegates don't have to argue about the science. They take it as a given.

+ You said in your co-authored book *Discerning Experts: The Practices of Scientific Assessment for Environmental Policy* (2019) that consensus is not necessarily the most important feature of assessments. How do you deal with information that does not have much certainty or consensus?

A lot about the climate change problem is very well known within a very narrow range of uncertainty, such as the Earth is warming and it has warmed about 1.2°C in the last 100 years, plus or minus a tenth of a degree; however, you can't reach that kind of consensus with everything. Millions of micro-facts make up the climate problem. For many of these, there is a high degree of uncertainty. We don't have enough observations and governments aren't willing, or can't afford, to pay for dense observation networks. For example, we still can't definitively say whether Southern California will get more or less rainfall because the models can't project with geographic precision, for two reasons. One, the computers are not fast enough, and two, we don't know a lot about the basic science of things you would think we would know a lot about, such as what goes on inside a rain cloud and how a rain cloud forms. So, there is going to be a lot of uncertainty on many specifics. The important thing is not reaching a consensus on every possible statement of fact but reaching a consensus on how big the uncertainties are. IPCC has been doing that rather well. However, even when there is disagreement about the range of uncertainty on a particular factual statement, that disagreement is made public and underscored.

+ Dealing with uncertainty is challenging for designers, particularly when critical factors such as the elevation and datums for building new infrastructure need to be defined.

The issue of how policymakers can grapple with decision-making about climate change is a field that is expanding. There are different models for doing so—mental models as well as computer models—but there is no agreement yet on the best way forward. We're going to learn. We're going to learn by doing in the midst of a growing problem, unfortunately. Our biggest challenge is deciding what actions to take – actions that affect particular people in particular places. For example, our ability to forecast some things, like the height of the surge in Hurricane Francine at a particular place, so you know what the future risk is from other tropical cyclones everywhere along the global coast that are affected by tropical cyclones. In some cases, you need rather detailed knowledge because you don't want to pull people out of where they live unless you have to. Nor do you want to spend trillions of dollars on defensive infrastructure if it turns out that it is unnecessary or should have been put somewhere else. That is where the real battle is today. It's not about whether we should get off fossil fuels: of course we should. It's about how we are going to protect people in this long transition period—both before and after we get off fossil fuels—when the climate will still be warming for decades.

+ We often hear about keeping the global temperature increase below 1.5°C. Where did that number come from?

No scientific law says it must be 1.5°C. There is no threshold to danger – things get continuously worse and the effects catenate. However, the damage increases rapidly when you get somewhere around 1.5°C or 2°C. Some ecosystems, like coral reefs, are already facing severe damage at this temperature. We don't know if significant sections of the ice sheets in Antarctica and Greenland will remain more or less stable at 1.5°C; if they don't, it will lead to continuous acceleration of sea level rise in the coming decades and centuries. In the 1990s, a benchmark of 2°C for the onset of climate "danger" began to percolate among some scientists and policymakers who were looking at things like the potential collapse of the West Antarctic ice sheet. Other changes in the climate system were considered as benchmarks – those that would happen at somewhat higher temperatures and some that could happen at lower temperatures, namely the widespread loss of coral reefs. These impacts would



MEMORANDUM

September 17, 1969

FOR JOHN EHRLICHMAN

As with so many of the more interesting environmental questions, we really don't have very satisfactory measurements of the carbon dioxide problem. On the other hand, this very clearly is a problem, and, perhaps most particularly, is one that can seize the imagination of persons normally indifferent to projects of apocalyptic change.

The process is a simple one. Carbon dioxide in the atmosphere has the effect of a pane of glass in a greenhouse. The CO₂ content is normally in a stable cycle, but recently man has begun to introduce instability through the burning of fossil fuels. At the turn of the century several persons raised the question whether this would change the temperature of the atmosphere. Over the years the hypothesis has been refined, and more evidence has come along to support it. It is now pretty clearly agreed that the CO₂ content will rise 25% by 2000. This could increase the average temperature near the earth's surface by 7 degrees Fahrenheit. This in turn could raise the level of the sea by 10 feet. Goodbye New York. Goodbye Washington, for that matter. We have no data on Seattle.

It is entirely possible that there will be countervailing effects. For example, an increase of dust in the atmosphere would tend to lower temperatures, and might offset the CO₂ effect. Similarly, it is possible to conceive fairly mammoth man-made efforts to countervail the CO₂ rise. (E.g., stop burning fossil fuels.)

In any event, I would think this is a subject that the Administration ought to get involved with. It is a natural for NATO. Perhaps the first order of business is to begin a worldwide monitoring system. At present, I believe only the United States is doing any serious monitoring, and we have only one or two stations.

+ The 1965 report that I referenced earlier suggests that geoengineering—stratospheric aerosol injection (SAI) specifically—might be necessary to counter global warming. You are a chemist and physicist. Should we be studying these technologies?

+ Climate scientist James Hansen argues that we have reached a point where SAI has become necessary. He states that if governments don't take the research seriously, it will not be understood and, therefore, cannot be regulated, leaving tech companies to pave the way.

have global reverberations. Then, there was a related discussion of what it would cost to limit warming to 2°C. And a third discussion: Is it feasible to limit warming to this threshold, and to do it quickly? All these considerations went into defining the two-degree target in the Paris Agreement.

But developing countries were annoyed that it wasn't enough, that even at 2°C some of the small island states will lose a lot of territory. If you let it warm 2°C above pre-industrial levels, large areas of Africa will become drier and hotter and won't produce enough food. So, a bargain was struck in the Paris Agreement. The developed countries agreed to set the long-term objective at 1.5°C if the developing countries gave up the idea of deserving financial compensation for the damages that climate change was starting to do. The political reality is that negotiations would likely have collapsed if we hadn't made a significant concession to developing countries – in other words, adopting the 1.5°C target. Many of the rich nations accepted the 1.5°C target pretty much knowing that they would not achieve their fair share of the emissions reductions that were needed to achieve it. Currently, we are on track to exceed 1.5°C, and we are likely to surpass 2°C. With luck and diligent policy implementation, we might end up in the range of 2°C to 2.5°C. But higher temperatures cannot be ruled out; it's possible we could wind up at 3°C of warming, which would portend worldwide disaster.

It's a high bar for me to say we shouldn't be doing research on certain things. The only time I felt strongly we should outlaw research on certain things was, number one, the GMO controversy in the 1970s, when scientists were just starting to think about genetically modifying organisms. I thought the stuff should be banned, at least for the time being. In retrospect, I was wrong in that case because the scientists behaved well and developed a system for monitoring and conducting experiments. I think the world is better off, so far, that genetic modification for medical purposes is now feasible. We might not be having this conversation if the COVID-19 vaccines hadn't gotten out so quickly. Nevertheless, I think a few things are, from many points of view, too dangerous for scientists to research without restrictions, and stratospheric aerosol modification is one of them. At this time, I am utterly opposed to outdoor research experiments because they are a slippery slope from a small-scale experiment that doesn't affect anybody to something that changes climate in a detectable way. I don't trust all the potential players to avoid that slippery slope. Until there can be agreement among scientists, social scientists, policymakers, ethicists, and public health experts—a broad group—over what is safe to do in the open environment, no experiments involving SAI should be done outside.

I'm not sure how much of his view is based on the idea that somebody will do it anyway and it is ungovernable, which I disagree with, or his desperation about how severe the climate problem has gotten. I think he expected people to listen. He expected it to be a rational world, but it turns out not to be a totally rational world. I think he's willing to countenance things on this score that I personally wouldn't. I also believe that barriers to actions by individual bad actors can be constructed. If countries got together and one or two countries wanted to deploy this technology, but all the other countries did not, there is enough power in the group to prevent it. Somebody might do something at a small scale and get away with it, but doing

something big enough that it would be possible to detect its effect on the climate, either locally or globally, is very unlikely because, at this point, nobody knows what the pluses and minuses are for specific places, and most countries would not want to bet that they will be among the winners rather than steep losers. Uncertainty is our friend in this case.

+ The UN Environment Programme 2023 report on SAI doesn't rule out small-scale outdoor experiments, but it does say that, once it scales up a little bit, an experiment cannot be differentiated from a deployment. Do you agree?

It is an important point that I and others have made many times. The climate system is so noisy that you could be affecting the climate in ways that are not detectable. By the time you go on for decades, suddenly, you could have pushed the climate into a state you don't want it to be in. I'm basically supportive of more resources to do more and better computer simulations of what a stratospheric aerosol modification, or stratospheric aerosol release, would do. Computer research should push us in the direction of enlightenment about what the effect of a large-scale release is. If, in the process of doing that research, we find that we cannot answer all the key questions we need to know, then we could start discussing what are safe experiments. I firmly believe that something like the Belmont Principles need to be followed if scientists are going to play with the global climate. A few people seem to be willing to put quite a lot of money into geoengineering, some after careful thought and others merely swayed by a belief that silver bullet solutions can save us – which is delusional as far as I'm concerned. It does not apply to the climate problem. Life is more complicated; monolithic, large-scale solutions also tend to entail new and large-scale problems.

+ You mentioned the Paris Agreement. What do you think has been the most important policy or action on climate globally?

The most important thing didn't happen because of the Paris Agreement. It happened sort of inadvertently because China and Germany informally collaborated to decrease the price of solar energy. Germany decided to aggressively subsidize renewable energy, but it became affordable because the Chinese wanted to dominate the international market for mass-producing solar panels and wind turbines. That, to me, is the most important thing that happened to advance the solution to the problem.

With regard to the Paris Agreement itself, the most important thing was that China and the US made a bilateral agreement with specific targets and timetables a year earlier, in 2014. That made countries think that if they went to Paris and negotiated, something good would come of it. Furthermore, at the time, the US finally had an administration in place that was in a position to do something strong due to a 2007 Supreme Court ruling, *Massachusetts v. EPA*. That freed the Obama administration to put a lot of strong greenhouse gas regulations in place using its Clean Air Act authority. The fact that Congress—and later a Supreme Court with a different crew of justices—has become so obstructive to action on climate and environment has limited the amount that can be done using regulation, particularly in the power sector. So, it was very important that the Biden administration, realizing this, decided to throw a huge amount of money after the climate problem under the Inflation Reduction Act. Tax breaks and subsidies without strong regulations accompanying them is a second-best way to solve environmental problems. However, with a second Trump administration looming, it's the most promising alternative we have.

+ Do you mean throwing money at it to change industry?

I mean throwing money and only throwing money isn't enough. What works best is incentivizing research, development, demonstration, and deploying producer and consumer tax breaks and subsidies. However, regulations on what products can be marketed are also needed so industry can anticipate that, as it commercializes climate-friendly technologies like solar panels, heat pumps, or electric cars, consumers won't have the choice to continue buying older, high-emissions products. Getting the timing so that research and development and marketization are synchronized around the exigencies of climate change didn't happen until recently. Now that a second Trump administration is about to take over the government, it will likely proceed to destroy the regulatory structure put in place by Biden.

We don't need to negotiate tougher emissions limits internationally for a while because most countries haven't even put effective and sufficiently comprehensive policies in place based on the commitments they made a few years ago. So, I think it would be a complete waste of time. Instead, the negotiations should be about resolving the loss and damage issue, which is the question of what developed countries will pay the developing countries to help them deal with the problem, even if the developed countries do not explicitly acknowledge that it can be viewed as "compensation," because that word is off the table.

+ As you said, the Supreme Court has ruled on several cases that have significantly limited the regulatory powers of federal agencies for environmental protection, and we are about to have a president who is a climate-change denier. What gives you hope that we can achieve our climate goals?

If we focus on the US, change is well underway. US emissions have been going down for 15 years. Part of that is fortuitous. It was not dictated for climate reasons. It was because of hydrofracking, which replaced a lot of coal with natural gas at a cheaper price. It may, in fact, make the greenhouse situation worse because there are too many natural gas leaks throughout the system, and the leaking gas is primarily methane, a potent greenhouse gas. But that is at least something you can fix. Now the big change underway is stimulated partly by the Inflation Reduction Act (2022) and partly by a deal in the Obama administration, which got the auto companies to agree to clean up their emissions in exchange for the government bailing them out during the financial crisis. Because of that, auto companies have not made a lot of noise about the demand for progressively cleaner cars, which has pushed the industry toward being serious about electrification. Now that China is producing electric vehicles, the auto industry can't go back. There is momentum. There will be stops and starts, like the problem with wind energy and its high capital costs, but overall, renewable energy continues to get cheaper. I think the US is well on its way toward a renewable energy economy in a way that can be slowed but not reversed.

In other countries, there are still issues. India has made a commitment to net zero emissions by 2070, which is fairly aggressive for them, even though it's 45 years in the future. China's emissions may peak in this decade. So, the question is, what is the next country coming over the emissions horizon? We've got to be ready with a better working framework at the international level than what the Paris Agreement offers. There is reason for optimism, if optimism means we'll eventually get the problem under control before it warms 3°C, 4°C, or 5°C. There is no reason to be optimistic about avoiding 1.5°C warming. I can countenance minimal optimism for avoiding 2°C.

IMAGE CREDITS

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p. 15: Walter Reuther leads Farm Workers, Delano Rally, CA circa 1965–66. George Ballis / Take Stock / TopFoto.

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p. 34: Herbert Bayer, ARCO Refinery, Philadelphia, 1972, Red Pyramid, Photocollage, and Yellow Undulating Wall, Photocollage. Images © 2025 Artists Rights Society [ARS], New York / VG Bild-Kunst, Bonn.

p. 38: Herbert Bayer, ARCO Refinery, Philadelphia, 1973 sculptural screens [proposal]. Photocollage. Denver Art Museum: Gift of BP Corporation, 2001.565. Image courtesy Denver Art Museum. © 2025 Artists Rights Society [ARS], New York / VG Bild-Kunst, Bonn; Herbert Bayer, Highway Gate in Three Parts, 1971 acrylic, collage, and graphite. Images © 2025 Artists Rights Society [ARS], New York / VG Bild-Kunst, Bonn.

p. 39: Clockwise from top left: Herbert Bayer, ARCO Refinery, Philadelphia, 1972 fence and building [proposal]. Colored pencil drawing. Denver Art Museum: Gift of BP Corporation, 2001.569. Image courtesy Denver Art Museum; Herbert Bayer, Road in deep embankments, 1972 acrylic and charcoal; Herbert Bayer, Positive negative highway, 1971, wood, mat board, paint, toy automobile; Herbert Bayer, Highway landscape with four hills, 1972 pastel and collage. All images © 2025 Artists Rights Society [ARS], New York / VG Bild-Kunst, Bonn.

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