A STREAMLINED EXPLANATION OF ANTHROPOGENIC GLOBAL WARMING

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SUMMARY

This report will discuss *evidence for anthropogenic global warming* in the broad sense. It will evaluate the claims of climate scientists, while also examining the kinds of methodologies utilized by these experts to reach their conclusions. In doing so, this report will not only make the case for the claims of climate scientists, but also address dissenting arguments and the very nature of evidence itself to deliver a thorough yet very layman-accessible case for the existence of human-oriented climate change.

The purpose of the first section is to lay out, in frank and unambiguous language, just what the phrase *global warming* really means (including a look at the semantic differences between "climate change" and "global warming"). This will include detailing the history of the subject from the Irish physicist's John Tyndall's first model of the greenhouse effect to the overt politicization of the subject around the late twentieth century.

After firmly establishing the often-confused definition of *global warming* as a scientific theory, this report will delve deeper into the foundations of scientific thought and standards of evidence. Why is this necessary? Because basic elements of empirical thought are very easy to take for granted, and more importantly are not always intuitive.

The third section will discuss the methods used for measuring the planet's warming phenomenon, from the increasing trends in heat that has been trapped in the atmosphere to other direct effects such as the acidification of oceans and the detrimental effects on the polar ice caps. In doing so, the section will use what has already been established about standards of evidence to demonstrate the efficacy of these methods.

This report will then examine the effects of climate change on Washington state, from the impacts on the state's environment to the potential repercussions on the social and economic fronts. The final of this report's sections will be devoted to addressing common objections to the claims of climate scientists.

INTRODUCTION

Climate change is, despite the rhetoric surrounding the subject in our current political atmosphere, not a matter of belief. It matters not whether or not one or many 'believe' in climate change, because what can be observed about the planet's warming in the time period since the Industrial Revolution is not a matter of opinion. This report will not only show how we can know this for a fact, but will also devote a section to addressing potential counterarguments and common objections to the theory of global warming.

This report will not only examine the scientific consensus regarding the reality of climate change that has been determined to be caused by human action, but the key methodologies employed by experts to reach these conclusions and how they can be tested, repeated and observed.

Anthropogenic global warming is a very real phenomenon, and its effects can be easily demonstrated with the help of corroborating data and a rather basic sense of scientific literacy. This report is designed to be helpful to both newcomers to the topic and/or those looking to “brush up” on the rudimentary facts of the topic.

BACKGROUND

In the current political atmosphere of the United States, one or two words are all that it takes to elicit a certain Pavlovian response from voters of either side of the political spectrum. “Abortion”, “socialism”, “global warming”; it has come to sound like any other “buzzword” that is bandied about in the current political climate. It is a highly politicized phenomenon, but what are the facts? Despite the near-ubiquitous presence of this topic in political discourse, just how well understood is this phenomenon? Although this is not the case in the scientific community (or even the case in many other countries), the American public is still largely divided on and seemingly confused about this subject.

THE ASSERTIONS OF CLIMATE SCIENTISTS

Nearly everyone in the modern age has been exposed to one of two terms, each of them variations on the same idea (and the semantic differences between which will be elucidated shortly): the two phrases are *climate change*, and *global warming*. Though understood in shorthand to refer to more or less the same concept, the former is a bit less specific than the latter; *climate change* is a useful phrase to use when discussing the fluctuations in global temperature in any direction (human-caused or otherwise), whereas the former describes a more clear upward trend.

It might be worth nothing that *climate change* is a somewhat older phrase than *global warming*, as the former's usage dates back to at least 1956.

First, it is necessary to review the concept of climate change and consider the history of the idea among scientists, and how that has informed the current consensus. To do that, it is a good idea to go through a brief history of the warming concepts and some of the other discoveries that have paved the way for our current understanding.

GENESIS OF THE UNDERLYING THEORY (c. 19th century)

The broader suggestion that human beings (and more importantly, the large-scale civilizations of which they are a part) are capable of inflicting dramatic changes on the planet's climate is not necessarily a new idea. In the nineteenth century, the agricultural boom in the new world raised some concerns about the negative repercussions of deforestation. When the removal of trees seemed to alter the rainfall, suspicions arose that the actions of mankind could be capable of rather dramatic effects on the planet's climate; the time's lack of comprehensive information/methodologies, of course, meant that this amounted largely to conjecture.

One of the most important milestones that ultimately set up the framework for our current understanding of the global warming crisis (and the methodologies used for its measuring, as further discussed in Section 3) arrived in 1859, when Irish physicist John Tyndall discovered that there was a group of natural gases capable of trapping heat rays from the sun. Water vapor (H20) proved to be a particularly potent example, as did carbon dioxide (CO^2) and methane ($CH_{4).}$

RECENT HISTORY AND EARLY CAUSES FOR ALARM (c. 1950s – 1970s)

The 1950s marked the first minor wave of serious scientific attention being paid to the possibility of the planet warming due to human action. In 1955, the head of the U.S. Weather Bureau stated during a press conference that there has been a two degree (Celsius) rise in the global temperature over the last half-century. Later on that very decade, a similar concern was raised over the observed melting of the polar ice caps to down well below the level they had been at through the previous century. However, it must be noted that when climatologist Helmut Landsberg raised this latter concern in 1959, the problem was still not treated as a particularly drastic one and, moreover, the link to human action was still somewhat ambiguous.

The discourse on climate change remained this way for quite some time: a “fringe” issue that could be somewhat readily dismissed with the (admittedly, then-valid) argument that all the facts were not in. In 1962, marine biologist Rachel Carson published *Silent Spring*. This book, examining the negative effects on the environment by use of pesticides, arguably acted as a catalyst for the bigger dialogue to come about modern industry’s relationship with the natural world.

“GLOBAL WARMING” TAKES ROOT IN THE PUBLIC CONSCIOUSNESS (1980s – present)

In 1981, climate scientists predicted that by the effects of carbon dioxide rises in the atmosphere might not be detectable until roughly the turn of the century, and that appropriate action had to be taken as early as possible to curb these lingering effects.

In 1990, the Intergovernmental Panel on Climate Change (IPCC) – founded just two years earlier under the auspices of the United Nations – released their first report, in which they concluded that while the planet had indeed been warming, it would take something in the order of another decade before it could be definitively said that the greenhouse effect was the primary cause. Nonetheless, the panel reported with confidence that a “business as usual” outcome – that is to say, a future where industrial practices and their effects on the climate continued as usual – would almost certainly mean higher temperatures in the future.

By the turn of the century, the effects had become far more conspicuous and, as a result, awareness of the problem began to take hold in the public mind.

By the mid-2000s, a consensus had definitively been reached by scientists: the global temperature had indeed been rising, and the reason for this owed chiefly to human activity such as the excessive output of greenhouse gasses. Around this same time, former vice president Al Gore's book and corresponding documentary *An Inconvenient Truth* helped to raise international public awareness about global warming. Currently, however, the public in the United States is considerably more conflicted on this issue than is the scientific community; a recent Pew Research study suggests that over half of the American population agrees with the scientific consensus (that global warming is not only very real but is being caused and intensified by human action), which stills leaves a significant portion who either don't accept the consensus or altogether reject the theory of global warming.

CURRENT SCIENTIFIC CONSENSUS ON CLIMATE CHANGE (2016)

Currently, the overall judgment among scientists is that the planet is “unequivocally” warming and that human action is the direct cause. Specifically, mass industrial greenhouse gas output coupled with deforestation and depletion of the ozone layer has led to an increase in global temperature over the last two hundred years.

However, in order to appreciate the gravity of the consensus that exists in the scientific community regarding global warming, it’s necessary to consider carefully what we're talking about when we talk about evidence – it seems like this would all be a first grasp on the obvious, However, it needs to be stated clearly for posterity, and to establish the lens through which this report is to engage with the evidence.

THE STANDARD OF EVIDENCE

For those who don’t necessarily deal regularly in scientific research and therefore are not under pressure to think in scientific terms, it is very easy to take certain truths for granted. One such example is the fact that not all evidence is equal, and that certain forms of evidence warrant far greater credence than others.

WHAT *IS* EVIDENCE?

Though there might be very little distinction in the common parlance sense of words, it may prove monumentally helpful to differentiate between the fairly distinct meanings of the word **proof** and the word **evidence**.

- **Evidence** is the grounds for granting a certain hypothesis legitimacy/or credence. Scientific evidence is the building block on which a hypothesis or theory can be said to be supported or unsupported.
- **Proof** is the conclusive end to the means of evidence; proof is the establishment of a certain thing as true when a sufficient standard of evidence is met. Proof, though the word is often used colloquially in reference to something’s scientific validity, is something of a tricky idea in the scientific community.

WHAT IS *NOT* EVIDENCE?

While a subsection listing off every type of logical fallacy might provide some useful knowledge, for

brevity's sake it will do to focus primarily on the fallacies that are most relevant to this subject matter, and which will manifest in this report's penultimate section addressing objections. These would include:

- *Anecdotal evidence* – The notion that anecdotal evidence is a weak form of evidence or may in some cases hardly be deemed worthy of being called evidence at all may seem, at first glance, counterintuitive. The problem with statements like "I heard that Bill is a lumberjack" or "I personally saw Bill adorn lumberjack's wear and saw down a tree" is that the reasons for believing this story about Bill begins and ends with the accuser's word. Without objective evidence for the assertion, there is far less grounds to give the claim any credence.

  While anecdotal evidence does not constitute evidence in and of itself, this doesn't necessarily mean that it should be written off entirely. The value, or lack thereof, of anecdotal evidence depends to a large degree on how it is corroborated with harder forms of evidence.

- *Appeal to authority* – This form of argument is not necessarily inherently fallacious, depending largely on the context of how it is used. This argument becomes functionally fallacious when a person attempts to substantiate their position not with evidence but with the claim that something is true because someone, allegedly an expert, said so. For example, "I know that global warming is a hoax because of the founders of Weather Channel said so, and he knows much more about climate than I do". Such a fallacious form of this appeal assumes: 1) that all authority is equal, and that if indeed a person is an expert in one field, they must be an authority in the field relevant to the discussion; and 2) that this person's authority has any bearings on the facts themselves.

- *Reverse empiricism* (also known as *confirmation bias*) – This fallacy describes when a person posing an argument performs the scientific method backwards; instead of making an observation and exploring the possible answers through experimentation, they arrive at their conclusion before engaging with evidence and therefore found only what they were actively looking for.

- *Appeal to consequences* – This fallacy will prove particularly relevant with further exploration of the global warming discussion. Consider a hypothetical argument like "If we put forth any effort to mitigate the effects of climate change, that might require taxation that might in turn lead to firms having to downsize and loss of jobs, therefore no mitigation action should be

taken". Such an argument ignores the fact that not all mitigation efforts would have such an undesirable consequence(s), if indeed they would have such consequences at all.

A BRIEF WORD ON SCIENTIFIC LINGO

"It's just a theory**!**"; before these four words were used to derail and misdirect conversations about global warming, they were used to muddy the waters around another scientific topic that continues to elicit controversy among ordinary Americans (though certainly not those affiliated with the scientific community). That topic, of course, is Darwin's theory of evolution by natural selection. Both red herring arguments, when used to ridicule both theories, rely on a misunderstanding of what actual biologists, anthropologists, ecologists and other natural scientists are talking about when they use the word *theory.*

In the common parlance, the word *theory* refers to something that is suggested, a conjecture that is more roughly equivalent to the scientific definition of a *hypothesis*. In the everyday sentence "Bill has a theory that it will rain through the weekend," the common usage would imply that Bill is making a guess based loosely on – perhaps it has rained several days in a row, or Bill has noted that the clouds have gotten darker. If the strict scientific sense of the word were applied, it would mean that Bill is using a predictive model of some kind to make a substantiated forecast of how the weather will behave.

THE METHODOLOGIES

With not only an abstract of what it is that climate scientists have determined to be the case but also a solid groundwork for what *is* and is *not* scientifically viable evidence, it is also useful to examine how exactly the experts arrived at these conclusions.

GLOBAL TEMPERATURE INCREASE AND THE GREENHOUSE EFFECT

As John Tyndall discovered, there are certain gases that trap heat from the Sun in Earth's atmosphere. In this process, naturally occurring greenhouse gases allow direct sunlight to reach Earth's surface. As short-wave energy is absorbed by the planet's surface, the longer-wave energy is re-radiated back into the atmosphere. In the natural carbon cycle, this other remainder of deflected energy escapes back in to outer space. However, this process is impeded when there is an excess amount of carbon dioxide in the atmosphere. Because carbon dioxide is a greenhouse gas that traps heat in the atmosphere, this means that the heat's natural route of escape from the planet is disturbed by the excess amounts of the gases being emitted since the Industrial Revolution.

The connection between the Industrial Revolution – which, in this case, broadly refers to the large-scale industrial shift in the Western world from the mid-to-late 18th century to the mid-19th century – and the increase in total carbon emissions is a very important one to recognize. Major advances in technology resulted in higher combustion of fossil fuels, of which CO^2 is a natural byproduct. As an inescapable result, CO^2 emissions have increased dramatically over the last two centuries to levels that are largely unprecedented in the history of human civilization. Consider the staggering increase in the last few decades alone; in the year 1970, the global carbon emission from fossil fuel was at 4,000 million metric tons. By 2011, this number had almost doubled.

The Mauna Lao Observatory has been a very pivotal part of climatologist's understanding of the warming trends that have persisted for the last century. Ever since 1956, the observatory has been continuously keeping track of the carbon dioxide present in the planet's atmosphere. The resulting trend line is called the *Keeling curve*, named for the geo-chemist who first supervised the measurements at the project's inception, Charles David Keeling.

The Keeling curve has been instrumental in our understanding of the increase in global temperatures over the last century. What has been observed is that there has been a clear upward trend of carbon fraction in dry air since the 1960s.

While measurements of global temperature and carbon output is perhaps one of (if not definitively *the*) most factors measured by scientists to draw conclusions about the global warming phenomenon, there are others that bear mentioning as well.

OTHER CONSEQUENCES/EVIDENCE OF WARMING

- *Ocean acidification* – The planet's oceans are an example of what is known as a carbon sink. This means that it, much like forests, absorbs carbon that is already in the atmosphere.
- *Acid rain* – This is closely tied with ocean acidification and perhaps fall under the same auspices, but one that carries with it its own set of negative repercussions that warrant discussion. Acid rain is defined as rain – or, really any form of precipitation – with abnormally low pH levels. As is the case for ocean acidification and increased global temperature, one of the most significant man-made contributions to the occurrence of acid rain is the combustion of

fossil fuels through commercial, industrial and private use. If unchallenged, acid rain can pose very serious health risks for humans/other animals, plant life and other ecology. Rivers, lakes and other bodies of water are vulnerable to the presence of acid rain. This in turn can be deadly to aquatic life and can further negatively impact the ecosystem's food web and biodiversity. In other species, such as humans, the presence of acid rain can

A BRIEF SYNOPSIS OF WHAT THIS MEANS FOR WASHINGTON STATE

While the effects of climate change on the world at large have been established, how vulnerable is our very own state to the effects of this phenomenon? What will the consequences be for this state's unique climate? Experts estimate that the average temperature of the Pacific Northwest as a whole will rise two degrees (by 1970 - 1999 standards) by the 2020s and three degrees by the 2040s. This increase will result in a myriad of problems for Washington state, for humans, wildlife and the ecology of the region.

A "warm winter" – a phrase that may show up through this section – is defined by the Washington Department of Ecology as "*[a winter] during which average monthly temperatures for at least one month of the December-February period exceeds a rain-versus-snow threshold temperature of 32°F (0°C)*".

ECOLOGICAL CONSEQUENCES

With rising temperatures, Washington state may see some of its wetlands disappear, either through drying up or being flooded out. As they are natural carbon sinks, the loss of wetlands is very problematic in our attempt to curb CO^2 output.

Then, there is the matter of wildlife. Salmon, which are of course an important element to Washington state's ecosystem, live in delicate cycles of hatching, spawning and migration which are negatively impacted by climate change. For example, salmon (like many other fish) need cold water to spawn and rear eggs. As water warms, it holds less oxygen for fish to remain healthy. Warmer water also reduces the food available for fish and in some cases can cause salmon die-offs, as was seen on the Fraser River in 2004.

SOCIAL AND ECONOMIC CONSEQUENCES

One of the most significant repercussions of increased warming in the state of Washington is the danger

of rising sea level. When warming occurs, precipitation comes down in the form of rain instead of snow. As this happens, it puts coastal communities at hazard for flooding as the sea level rises. This poses not only a threat of physical danger, but also could have serious financial costs in the form of lost or damaged infrastructure, property or business.

Hydroelectricity, which is a critical source of energy consumption for Washington, could suffer loss of energy production if the water temperature continues to rise. Similarly, reduced snow on account of warmer precipitation could also hurt the tourism market in Washington; snow sports and other recreational activities offered at ski areas may lose commerce with an increasing frequency of "warm winters". Skiing areas situated at lower elevations are especially vulnerable to loss of snow cover.

Climate change in Washington affects agriculture (a complex sector that we will paint with a somewhat broad brush for the sake of convenience) in a number of ways, not all of them necessarily for the worse. For example, longer growing seasons may yield a larger quantity of crops, but farmlands that rely strongly on irrigation could be seriously at risk as drought and water availability continue to be concerns, most especially in the summer.

ADDRESSING SKEPTICAL ARGUMENTS REGARDING CLIMATE CHANGE

The idea of human-caused global warming, as a generalized concept, has met with a great deal of resistance ever since its very inception, but more especially since it has gained popularity in the mid-2000s to present.

Let it be first restated that skepticism is perhaps one of the healthiest and most productive tools with which to approach evidence-based thinking. Positive claims necessarily incur the burden of proof on their makers, and without an appropriate standard of evidence, However, there comes a point – in the -life cycle of a given hypothesis – when it has survived the test of scrutiny and becomes something that can be tested, repeated and observed. When a hypothesis makes it to this point and effectively becomes theory, the context changes somewhat: to challenge the hypothesis, a doubter now has to bring more to the discussion than just their doubt. In the face of overwhelming evidence,

This is the troublesome territory where skepticism flirts dangerously with becoming denialism. Outlined below are responses to common criticisms of the theory, delineated into the two broad camps

into which they often fall.

“DENIALIST” TIER

Objection: “There is no warming, and the supposed climate change is just the result of natural processes.”

Response: This argument is climate denialism in its most generic and streamlined form, but because outright denial is still in vogue, it does still need to be addressed. The counterargument to it, simply enough, is the abundance of evidence that has already been described in the previous sections. The data from the Keeling curve, the depletion of the ice caps and the upward trend in global temperature all point very sufficiently to a certain conclusion.

Objection: “Action should not be taken as there is still no consensus scientific on global warming.”

Response: Even if it were the case that the vast majority of credible scientific experts did not agree that global warming was a very real phenomenon that was being exacerbated greatly by human activity, simply making the appeal to an imaginary authority has no bearing on the facts themselves. This argument would fail on that basis regardless of what the actual situation was, but the fact that there is *indeed* a very clear consensus on the matter sinks this argument quite efficiently.

Objection: “Global warming is the fraudulent contrivance of a global conspiracy.”

Response: Though it may not properly represent the mainstream face of climate change skepticism, it is worth addressing this fringe school of thought which suggests that global warming is a deliberate hoax orchestrated by powerful wrongdoers. Unsurprisingly, these accusations vary in terms of who is behind the plot and for what reasons; some of these hypotheses indict the United Nations as the force behind the supposed deception, some indict vague anti-industrial interests (e.g., Communist sympathies, hard-green environmentalists, etc).

In addition to the irrationally paranoid nature of conspiracy “theories” surrounding global warming, the entire hypothesis suffers from being wholly illogical. For global warming to be nothing but a political fabrication, the reach of this deception would have to extend back to the mid-nineteenth century when John Tyndall first began to develop and substantiate his theory about the interactions between greenhouse gases and solar heat. It would also require that 97% of credible scientists be in on such a scheme without one whistleblower. Such notions, of course, stretches credulity.

Objection: “Not only is there no global warming, but the planet has in fact been cooling.”
Response: When putting forward evidence put this argument, it's not uncommon for the claimant to cite a short-term episode of temperature cooling. There are two major problems with this line of reasoning. The first is that it assumes that global warming is defined by climate scientists to be some sort of perfect, linear upward pattern in which the global temperature ubiquitously rises without fluctuation. There is naturally going be fluctuation; to assume otherwise is misrepresent the climate scientists' side of the argument.

However, this leads directly into the second problem with this claim: the evidence for supposed 'global cooling' trend is typically drawn from focusing on short-term data. For example, 1998 was an unusually intense El Nino year and as a result the global surface temperature was well above average. If one focuses on the net surface temperatures from the next years, it may give the impression of a significant cooling effect. While such a conclusion would not even be technically wrong, it ignores the greater context of what has been happening.

“DOWNPLAYING” TIER
Objection: “Yes, climate change is a real phenomenon, but it isn’t linked to human action.”
Response: If one factors in how the greenhouse effect works and doesn’t disavow the workings of Earth’s entire ecosystem, there is very little room to argue that human activity doesn’t contribute significantly to the warming of the planet through the entrapment of heat caused by excess greenhouse gases. Couple this with what has already been established about the effects of deforestation and this line of reasoning is practically an argument from ignorance.

A variation on this argument is the claim that the planet has indeed experienced “climate change” before, independently of human action. On the face of it, this claim is not entirely wrong. Furthermore, this doesn't detract from the seriousness of our current situation; the climate change events of the past were consequential enough to create uninhabitable conditions for life on the planet and drive many species to extinction.

Objection: “Yes, climate change is a real phenomenon, but there’s nothing we can do about it.”
Response…: This defeatist point of view is illogical because, firstly, it assumes that there is no middle ground between total surrender and total mitigation. Although this may be a broad normative statement, it would behoove all human beings with any sense of self-interest to act in any way they can, from the smaller steps in everyday activities (e.g., recycling, energy conservation, other forms of pollution

abatement on a personal level) to decisions that affect a much larger scale (e.g., informed voting, environmental activism, public policy decisions).

Because mitigation of the suffering caused by climate change (and indeed efforts to curb climate change itself) are perfectly feasible, inaction is a vastly inferior option to action in terms of net results.

*Objection: "*There is a global warming hiatus!"
Response…: This point of view acknowledges the occurrence of a warming phenomenon, but insists that there has been some "pause" or even a drop-off in the upward trend since the exceptionally warm El Nino year of 1998. This assertion is, however, a falsehood. Credible institutes have come to a consensus that there has, in fact, been no such standstill.

Once again, this reasoning ties into the "escalator" fallacy previously mentioned, in that it focuses on a comparatively small piece of the available data while casting aside the more important conclusions that can be drawn from observing the greater mosaic.

CONCLUSION (WITH A WORD OF CAUTION TO THE LIKE-MINDED)

Everything that has been laid out in this report should be sufficient ammunition for anyone interested in arguing the case for the reality of man-made climate change. However, here is a final word of warning for even those of us most strident in this cause: while the facts seem to bear out the case very well, take caution not to fall into the pratfalls of personal biases and putting politics before reason. Personal values always have a place in anyone's pursuit of the truth, but beware of adopting pet theories. The nature of science dictates that one must remain diligent, always ready to part with ideas that one may personally favor when information is updated and always likewise ready to accept undesirable facts when the evidence is overwhelming.

This seemingly trite piece of advice bears mentioning because this topic is a very easy one to put emotional investment into. It's not difficult to see why global warming is such an inherently politicized topic, compared to any geologic fact such as the existence of landslides or oceanic dead zones. How one approaches this specific issue is highly symptomatic of their fundamental attitude about the role and/or significance of humankind on this planet. To accept that human beings may have already done irreparable harm to the planet's environment that will have far-reaching consequences for generations

to come – be they future generations of human beings, or future generations of other creatures – is not a proposition taken lightly. The idea, and its implications, can be upsetting for many. Our responsibility as communicators of climate science must be to understand this emotional dimension of the bigger argument. With this knowledge, effective communication will necessarily rely on logic over fear-mongering and emphasis on climate solutions as well as informed, collective action over emphasis on only the catastrophic consequences of climate change.

There is a pertinent quote that applies to this situation, sometimes attributed to American philosopher Daniel Dennett and sometimes attributed to philanthropist Rose Kennedy. Regardless of who uttered the words, the quote conveys a powerful truism: “There is nothing worse than a poor argument for a position that I hold dear.”

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