THE SMALL PRINT

What the Royal Society Left Out

The Global Warming Policy Foundation

GWPF Briefing 15

GWPF REPORTS

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About this briefing

In December 2014 the Royal Society published *A Short Guide to Climate Science*, a layman's introduction to the key issues in the subject. The guide was accompanied by a video and was widely reported in the media.

The authors who wrote the guide were not identified. Nor were the members of the Royal Society asked whether they endorsed it or not. So in referring to it herein as the 'Royal Society' guide we only mean to indicate who published it. We have no way of knowing how many Royal Society Fellows actually agree with it.

Many commentators were concerned that the guide was profoundly misleading, misrepresenting major points while overlooking some of the key issues and question marks over the science, glossing over them as if they were of little consequence. As an example, when the Royal Society addresses the long-term rise in Antarctic sea ice it says that 'changes in winds and in the ocean seem to be dominating the patterns of sea ice change in the Southern Ocean around Antarctica'. In reality, what is being described in these words is a recently proposed hypothesis, so while a reader of the *Short Guide* might come away with the impression that science had a broad understanding of what was happening in the Southern Ocean, what they should have been told was that the changes in Antarctic sea ice are not understood. In a time of universal overconfidence, to be willing to state what is not known is an essential, albeit controversial, duty of scientists.

This report attempts to give a more accurate picture of climate science and to add in the caveats and to explain the gaps in our knowledge over which the Royal Society guide drew a veil.

The Royal Society, quite properly, does not draw policy conclusions from the meager science they present (and misrepresent), but they, most assuredly, know that others will.

Caveat

This report was prepared by, and endorsed by, the undersigned authors, all of whom are members of the Academic Advisory Council of the GWPF. It does not represent a corporate position of the GWPF itself.

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1 Is the climate warming?

Royal Society: Yes. Earth's average surface air temperature has increased by about 0.8°C (1.4°F) since 1900, with much of this increase taking place since the mid-1970s. A wide range of other observations such as sea-level rise, reduced Arctic sea ice extent and increased ocean heat content provide incontrovertible evidence of a warming Earth.

A fuller picture: This is hardly an important question. The Earth's surface is always warming or cooling, or on some occasions barely changing. What is important is that the change referred to is small and imperfectly measured. It should also be stressed that the Royal Society guide does not mention the role of the time window they are using for comparison. The climate has cooled since the mid-Holocene climatic optimum 8,000 years ago, and the warming of the past few decades is relatively small in comparison.

Surface temperatures have increased on average by about 0.8°C since 1900. There was a rise of around 0.5°C at the start of the twentieth century, followed by a small fall from 1940 to 1970. From then until the late 1990s temperatures rose by around 0.5°C. Differences of a tenth of a degree are insignificant. The temperature is virtually unchanged from that at the beginning of the century. The two periods of increase are indistinguishable, although the earlier increase cannot be attributed to increased carbon dioxide.

The relation of other observations such as sea-level rise, Arctic sea ice extent and ocean heat content all depend on more factors than global mean temperature, and are hardly incontrovertible evidence of warming. That said, the possible acceleration of ocean heat content accumulation and sea level rise are close to the limits of our ability to detect and the values involved cannot be reconciled to each other. Depending on the time scale, other observational datasets are still more equivocal: global sea ice levels declined for several decades but are now above their long-term mean.

2 How do scientists know that recent climate change is largely caused by human activities?

Royal Society: Human activity leads to emissions of greenhouse gases (causing warming), and of other pollutants that produce small particles in the atmosphere (which can have both cooling and warming effects). The dominant influence of human activities on recent climate change is clear from an understanding of the basic physics of the greenhouse effect and from comparing the detailed patterns of recent climate change with those expected from different human and natural influences. Only when human influences on the composition of the atmosphere are incorporated can models reproduce observed changes in climate.

A fuller picture: The warming effect of greenhouse gases is widely recognised. However, the direct effect is known to be relatively small: about 1 °C for a doubling of carbon dioxide levels. Most of the warming predicted in climate models arises from knock-on effects ('feedbacks') associated with changes to cloud cover, atmospheric humidity and so forth. Feedback processes are mostly hypothetical and are therefore much more uncertain, and some may even have cooling effects.

The Royal Society guide claims that models fail to explain recent warming unless they incorporate anthropogenic forcing. This assertion depends on the readily falsifiable claim that models correctly replicate natural variability. Models fail on natural variability, therefore the Royal Society's claim fails in the real world. However, even if the conclusion were correct, it would still be consistent with the view that the climate is not very sensitive to greenhouse gases since the observed changes have been small (to the point of being indiscernible for the past 15 years).

3 Carbon dioxide is already in the atmosphere naturally, so why are emissions from human activity significant?

Royal Society: Human activities have significantly disturbed the natural carbon cycle by extracting long-buried fossil fuels and burning them for energy, thus releasing CO_2 to the atmosphere. The concentration of CO_2 has increased by 40% since the Industrial Revolution.

A fuller picture: Carbon dioxide levels have been increasing steadily. A body of evidence points to this being due to human effects – emissions from burning of fossil fuels and land-use changes – although the Earth's carbon dioxide budget is not sufficiently understood to accurately quantify the human and natural contributions. Natural fluxes in the carbon cycle are an order of magnitude higher than manmade emissions, so any natural imbalances, perhaps as a result of temperature changes, can swamp human contributions. Regardless, given the aforementioned evidence that the sensitivity to carbon dioxide is low, anthropogenic GHGs cannot by themselves explain 20th century warming.

4 What role has the Sun played in climate change in recent decades?

Royal Society: The Sun has not played a major role in recent climate change. The Sun provides the primary source of energy driving Earth's climate system and variations in the energy emitted by the Sun affect Earth's climate. However, satellite measurements since the late 1970s show no overall increase in the energy emitted by the Sun, while the climate system has warmed.

A fuller picture: It is frequently claimed that the Sun has not played a major role in recent climate change because the overall energy emitted by the sun has changed little. This is simplistic. There is significant evidence that the Sun has played an important role in climate change, and over the 20th century in particular. Quantifications of these changes suggest forcing comparable to anthropogenic forcing. While variability of total solar irradiance may be small, variability of specific components of solar output can be large, and some of these are believed to affect the climate through mechanisms other than direct heating, for example by influencing cloud formation. These effects are a matter of current inquiry.

5 What do changes in the vertical structure of atmospheric temperature – from the surface up to the stratosphere – tell us about the causes of recent temperature change?

Royal Society: The observed warming in the lower atmosphere and cooling higher up in the stratosphere is the result expected from increases in CO_2 and decreases in stratospheric ozone. Natural factors alone cannot explain the observed changes.

A fuller picture: Not so: basic physics implies that increasing levels of carbon dioxide will lead to increased cooling in the stratosphere. This is quite separate from the greenhouse impact in the troposphere of increased carbon dioxide. However, measurements in the stratosphere indicate that although the overall trend is down, any cooling is only seen in the immediate aftermath of volcanic eruptions. Between such eruptions, stratospheric temperatures have been rising. This merely indicates that carbon dioxide levels here as elsewhere are not the only factor determining temperature.

Similarly, temperatures in the troposphere over the tropics are predicted to rise faster than anywhere else, including at the surface. This too is a matter of basic physics, where the temperature profile follows what is known as the moist adiabat. Models are, indeed, consistent with this. However, observed warming in the tropical troposphere is very weak compared to warming at the surface, suggesting problems with observations at the surface or in the troposphere or both. Given the small changes that are being studied, neither possibility is implausible.

6 Climate is always changing. Why is climate change of concern now?

Royal Society: All major climate changes, including natural ones, are disruptive. Past climate changes led to extinction of many species, population migrations, and pronounced changes in the land surface and in ocean circulation. The speed of the current climate change makes it more difficult for human societies and the natural world to adapt.

A fuller picture: The Earth has many and hugely varied climates. The climate also changes naturally on every timescale. Mankind is remarkably adaptable, living in almost all of these climates. It is impossible to know how rapidly climate changed in the distant past since the time resolution of the data we have is mostly inadequate for resolving the timescales that we are currently concerned about. However, there is ample evidence of rapid climate change associated with cold periods during the most recent glaciation (more than 12,000 years ago).

Climate change is only one concern among many at the present time, and a disproportionate focus on it and its possible impacts detracts from our ability to address many other more pressing matters.

7 Is the current level of atmospheric CO_2 concentration unprecedented in Earth's history?

Royal Society: The present level of atmospheric CO_2 concentration is almost certainly unprecedented in the past million years, during which time modern humans evolved and societies developed. The atmospheric CO_2 concentration was however higher many millions of years ago, at which time temperatures and sea levels were also higher than they are today.

A fuller picture: While carbon dioxide levels appear to be higher than they have been for hundreds of thousands of years, they are relatively low compared to most of the last 600 million years (when most lifeforms evolved), during which time levels were often from 2–20 times greater than today. Counter to the Royal Society, there were periods during which the carbon dioxide level was as much as 10 times higher than today but the climate was colder, for example the Silurian Period (about 443–420 million years ago). The fact that most plant life evolved during these periods is because plants thrive when carbon dioxide is increased. Moreover, our present estimates of carbon dioxide variations over the past 700,000 years are based on the analysis of ice cores, and these analyses may have inadequately dealt with diffusion, which could cause major adjustments to our estimates of early carbon dioxide levels.

8 Is there a point at which adding more carbon dioxide will not cause further warming?

Royal Society: No. Adding more CO_2 to the atmosphere will cause surface temperatures to continue to increase. The addition of extra CO_2 becomes progressively less effective at trapping Earth's energy, but surface temperature will still rise.

A fuller picture: Each additional increase of carbon dioxide levels is expected to produce less and less greenhouse warming, so it takes far more emissions to produce the second degree of warming than the first. Thus unless carbon dioxide emissions rise exponentially in the long term, warming should slow down. In theory temperatures will always keep rising, but eventually at a rate indistinguishable from zero. As usual, the question is not about warming per se but about how much warming there will be compared to natural variability. The available evidence is entirely consistent with the answer 'not much.'

9 Does the rate of warming vary from one decade to another?

Royal Society: Yes. The observed warming rate has varied from year to year, decade to decade, and place to place. These shorter-term variations are mostly due to natural causes, and do not contradict our fundamental understanding that the long-term warming trend since the mid-20th century is primarily due to human-induced changes in the atmospheric levels of CO_2 and other greenhouse gases.

A fuller picture: Temperature and many other climatic measurements vary naturally on all timescales, from decades to centuries and longer. Long periods in which the climate warms or cools naturally are therefore to be expected. Because climate models do not incorporate all of the different factors that might affect the climate, many of which are as yet unquantified, unequivocal attribution of recent warming is not possible, although at least part of it may be due to human emissions of greenhouse gases. A major error in modelling is the failure to account for natural variability. For the Royal Society to use this variation as an excuse for the obvious mismatches in models is strange indeed. Rationally, the fact that current models have greatly overestimated observed warming would suggest that models are too sensitive – a possibility that the Royal Society should have pointed out.

10 Does the recent slowdown of warming mean that climate change is no longer happening?

Royal Society: No. Since the very warm surface temperatures of 1998 which followed the strong 1997–98 El Niño, the increase in average surface temperature has slowed relative to the previous decade of rapid temperature increases, with more of the excess heat being stored in the oceans. Despite the slower rate of warming, the surface temperatures in the 2000s were on average warmer than the 1990s.

A fuller picture: Surface temperatures have exhibited no warming since the start of the century. Weather satellite records suggest the pause has been going on even longer. The reasons for the pause are unknown. Numerous explanations have been proposed, the most high profile being a suggestion that the missing heat has found its way to the deep ocean. However, this is simply an obscure way of blaming natural internal variability, for which the ocean circulations (which are always exchanging heat between surface and deep water) are a major cause. There is no known way to distinguish these natural exchanges from the notion that 'heat is hiding in the ocean'. What we do know is that these major ocean circulations are not correctly captured in the current climate models.

11 If the world is warming, why are some winters and summers still very cold?

Royal Society: Global warming is a long-term trend, but that does not mean that every year will be warmer than the previous one. Day to day and year to year changes in weather patterns will continue to produce some unusually cold days and nights, and winters and summers, even as the climate warms.

A fuller picture: Global warming refers to a long-term trend – spanning periods of decades to centuries – which has been very small compared to the weather, which varies a great deal from year to year. Cold weather is therefore not unexpected in a warm climate. By the same token, one should expect warmer episodes from time to time even if there were no global warming.

12 Why is Arctic sea ice reducing while Antarctic sea ice is not?

Royal Society: Sea ice extent is affected by winds and ocean currents as well as temperature. Sea ice in the partly-enclosed Arctic Ocean seems to be responding directly to warming, while changes in winds and in the ocean seem to be dominating the patterns of sea ice change in the Southern Ocean around Antarctica.

A fuller picture: There is no basis for the assertion that winds are less important in the Arctic, and evidence exists that summer sea ice has often been low. Most climate models predict fast reductions in both Arctic and Antarctic sea ice, although the two are very different systems. The steady record rise in Antarctic sea ice is therefore not predicted by models, although there has been some speculation as to the reasons for the failure. In any case, Arctic ice remains fully with us in winter despite summer lows. Even in the height of summer substantial ice remains (many millions of square kilometres).

13 How does climate change affect the strength and frequency of floods, droughts, hurricanes and tornadoes?

Royal Society: Earth's lower atmosphere is becoming warmer and moister as a result of human-emitted greenhouse gases. This means that more water is likely to be drawn into major rain storms, which could lead to more flooding events. There is considerable uncertainty over changes in hurricanes and tornadoes, but the extra energy available may make the strongest hurricanes stronger. Dry areas of the subtropics are expected to become drier in the future.

A fuller picture: Climate models can have little to say about what happens below their level of resolution, which remains coarser than most storminess. There is no evidence of any increase in either intensity or frequency during the recent period of global temperature average rises. In fact, there has been a remarkable lack of landfalling hurricanes in the Atlantic. Tornadoes are unlikely to be affected by any global warming.

Extra energy does not cause storms. Nor does it necessarily increase their strength. Energy differences and gradients cause storminess. Changes in internal energy and moisture that do not affect gradients and differences can have little effect. Speculation that wet areas become wetter and dry areas become drier are claims about increases in gradients and differences, which the global warming hypothesis does not contain. In fact models call for a decrease in gradients between equator and poles, which would imply a reduction in storminess. Drought levels have, if anything, fallen worldwide in recent decades and there is little evidence of global changes in floods.

14 How fast is sea level rising?

Royal Society: Best estimates of the global-average rise over the last two decades suggest 3.2 mm per year (0.12 inches per year). The overall observed rise since 1901 is about 20 cm (8 inches). If CO_2 and other greenhouse gases continue to increase on their current trajectories, it is projected that sea level may rise by a further 0.5 to 1 m (1.5 to 3 feet) by 2100.

A fuller picture: In a warming planet sea levels would necessarily rise due to thermal expansion of the oceans and melting of glaciers and ice sheets. But sea level has been rising for thousands of years – since long before GHG emissions became significant. Claims of an acceleration in sea level rise from 2 to 3 mm per year and its attribution to mankind must be treated with caution. In particular, it is not currently possible to reconcile estimates of sea level rise with estimates of the factors that are thought to contribute to it. The picture is even more unclear at the local scale where, depending on the location, many contributions have nothing to do with climate, such as tectonics, vegetation cover, hydrology, etc.

15 What is ocean acidification and why does it matter?

Royal Society: About a quarter of the emissions of carbon dioxide from human activities are soaked up by oceans each year. The extra CO_2 causes the chemical balance of seawater to shift to a more acidic state (lower pH) and some corals and shellfish have shells composed of calcium carbonate which dissolves more readily in acid. Acidification is likely to shift the competitive advantage among species, with as-yet-to-be determined impacts on marine ecosystems and the food web.

A fuller picture: The oceans absorb some of the extra carbon dioxide released into the atmosphere. It would form a weak acid if it were not already mostly alkaline. Human emissions of carbon dioxide will tend to make sea water less alkaline and more chemically neutral. The projected change over the next century is between 0.1 and 0.5 pH units. However, seawater pH naturally varies from 7.5 to 8.5 between regions of the ocean, between habitats, between days, and even between times of day. It is therefore misleading to talk of 'ocean acidification'. Shallow-water coral reefs are already subjected to hourly, daily and seasonal changes in pH that encompass the full range of ocean variability, hence the effects of changes in pH can be studied. Claims that corals and shellfish will find it harder to grow in acidic water are overly simplistic, not only because the water is not expected to be acidic but because the dissolved carbon dioxide forms bicarbonate and carbonate ions, the raw material for shellfish shells. Most studies find mixed effects, with some groups of organisms thriving as a result of increased dissolved carbon dioxide and some doing less well.

16 How confident are scientists that Earth will warm further over the coming century?

Royal Society: Very confident. If emissions continue on their present trajectory, then warming of 2.6 to 4.8°C (4.7 to 8.6°F), in addition to that which has already occurred, would be expected by the end of the 21st century. The range of values accounts for the fact that there are open questions as to how exactly some natural processes such as cloud formation amplify or reduce the direct warming effect of increasing levels of CO_2.

A fuller picture: Increasing carbon dioxide levels are likely to bring some warming. Climate models predict 0.6–1.8°C by mid-century, but observational evidence indicates that they substantially overestimate how sensitive the climate system is to increasing carbon dioxide levels, and may well also overestimate how much of the emitted greenhouse gases will remain in the atmosphere. The failure of models to make correct predictions over the recent period diminishes our confidence in their ability to make correct predictions of the far distant future.

17 Are climate changes of a few degrees a cause for concern?

Royal Society: Yes. Even though an increase of a few degrees in global average temperature does not sound like much, global average temperature during the last ice age was only about 4 to 5°C (7 to 9°F) colder than now. Global warming of just a few degrees will be associated with widespread changes in regional and local temperature and rainfall as well as with increases in some types of extreme weather events. These and other changes (such as sea level rise and storm surges) will have serious impacts on human societies and the natural world.

A fuller picture: There is little indication of serious problems in the short-term. Links to extreme weather are not supported by observational, theoretical or even model evidence, and suggestions that rainfall patterns would vary are no more than hypotheses (and counterfactual hypotheses at that). A warmer climate would also bring substantial benefits, for example longer growing seasons and fewer cold-related deaths. Higher carbon dioxide levels will fertilise plants, including many important crops. Estimates of the economic impact of temperature changes suggest little net impact until the temperature is several degrees above pre-industrial levels.

As concerns the ice age comparison, the Royal Society guide is patently absurd. Changes in temperature averages represent effects, not causes. They cannot discriminate between very different processes of change. It is even possible for there to be climate change where the global mean temperature doesn't change at all. It is well known that the ice ages were driven by huge changes in Arctic insolation in summer (changes that are of the order of 50 times larger than changes in the mean radiative budget), and that changes in mean temperature are simply the small residue of the larger high-latitude changes. Any familiarity with fluid dynamics would show that the Royal Society has things backwards in asserting that the small changes in the mean drive the much larger regional changes.

18 What are scientists doing to address key uncertainties in our understanding of the climate system?

Royal Society: Science is a continual process of observation, understanding, modelling, and testing. The prediction of a long-term trend in global warming from increasing greenhouse gases is robust and has been confirmed by a growing body of evidence. Nevertheless, understanding (for example, of cloud dynamics) remains incomplete. All of these are areas of active research.

A fuller picture: Scientists continue to address some of the unknowns regarding the climate system. Some are concerned that funding continues to be focused on characterizing human influences on the climate rather than investigating natural variability, and on developing complex computer models rather than improving observational data-gathering systems or fundamental theory. One would be hard-pressed to identify the 'growing body of evidence' that the Royal Society guide refers to. Certainly, the evidence of the past 40 years points clearly to exaggeration by existing models. Moreover, the 'incomplete understanding' that the Royal Society guide so glibly acknowledges happens to be fundamental to the crucial question of climate sensitivity. 'Nullius in Verba', the society's motto, means we do not even take the word of the Royal Society guide on these things. We don't.

19 Are disaster scenarios about tipping points like 'turning off the Gulf Stream' and release of methane from the Arctic a cause for concern?

Royal Society: Results from the best available climate models do not indicate any abrupt changes or 'tipping points' in the climate in the near future. However as warming increases, the possibilities of major abrupt change cannot be ruled out.

A fuller picture: While these disaster scenarios are raised from time to time and have been discussed in previous IPCC reports, they are largely discounted in the current IPCC report, as is appropriate.

20 If emissions of greenhouse gases were stopped, would the climate return to the conditions of 200 years ago?

Royal Society: No. Even if human emissions of greenhouse gases were to suddenly stop, Earth's surface temperature would not cool and return to the level it was at before the Industrial Revolution for thousands of years because CO_2 is only removed from the atmosphere over these very long time scales.

A fuller picture: This question insinuates that there was some sort of 'steady state' of the climate before industrialisation. Indeed, before industrialisation, the Earth was in the Little Ice Age, and few would want to return to such a period. However, because the Earth's climate varies naturally on all known timescales, it is not possible to make definitive statements about what the climate would be like today had there been no manmade greenhouse gas emissions. Similarly, it is not possible to say what will happen in the future, regardless of the levels of future GHG emissions. Moreover, the statement that carbon dioxide is only removed from the atmosphere over timescales of thousands of years is highly misleading. The majority of the excess carbon dioxide over preindustrial levels should be removed from the atmosphere within a century after a sudden halt to emissions, assuming that there are no long-term changes in the natural carbon cycle, which would swamp human contributions even for small changes. It is only a modest proportion that would take thousands of years to be removed.

GWPF BRIEFINGS

The Global Warming Policy Foundation is an all-party and non-party think tank and a registered educational charity which, while openminded on the contested science of global warming, is deeply concerned about the costs and other implications of many of the policies currently being advocated.

Our main focus is to analyse global warming policies and their economic and other implications. Our aim is to provide the most robust and reliable economic analysis and advice. Above all we seek to inform the media, politicians and the public, in a newsworthy way, on the subject in general and on the misinformation to which they are all too frequently being subjected at the present time.

The key to the success of the GWPF is the trust and credibility that we have earned in the eyes of a growing number of policy makers, journalists and the interested public. The GWPF is funded overwhelmingly by voluntary donations from a number of private individuals and charitable trusts. In order to make clear its complete independence, it does not accept gifts from either energy companies or anyone with a significant interest in an energy company.

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