To: Senator James M. Inhofe

From: Drs. J. Scott Armstrong and Kesten C. Green

Re: **Your Request for an Analysis of the U.S. Environmental Protection Agency's Advanced Notice of Proposed Rulemaking for Greenhouse Gases**

Statement

Scientific understanding about the Earth's climate is tentative at best. As a result of uncertainties over what causes climate to change and how and when, there are rival theories and arguments among scientists about how to interpret the evidence.

Rather than join these arguments, we have examined the processes that have been used to analyze the available data in order to derive forecasts of climate over the 21st Century. We have concluded that the forecasting process reported on by the Intergovernmental Panel on Climate Change (IPCC) lacks a scientific basis.

1. *No scientific forecasts of the changes in the Earth's climate*. Currently, the only forecasts are those based on the opinions of some scientists. Computer modeling was used to create scenarios (i.e., stories) to represent the scientists' opinions about what might happen. The models were not intended as forecasting models (Trenberth 2007) and they have not been validated for that purpose. Since the publication of our paper, no one has provided evidence to refute our claim that there are no scientific forecasts to support global warming.

   We conducted an audit of the procedures described in the IPCC report and found that they clearly violated 72 scientific principles of forecasting (Green and Armstrong 2008). (No justification was provided for any of these violations.) For important forecasts, we can see no reason why any principle should be violated. We draw analogies to flying an aircraft or building a bridge or performing heart surgery—given the potential cost of errors, it is not permissible to violate principles.

2. *Improper peer review process*. To our knowledge, papers claiming to forecast global warming have not been subject to peer review by experts in scientific forecasting.

3. *Complexity and uncertainty of climate render expert opinions invalid for forecasting.* Expert opinions are an inappropriate forecasting method in situations that involve high complexity and high uncertainty. This conclusion is based on over eight decades of research. Armstrong (1978) provided a review of the evidence and this was supported by Tetlock's (2005) study that involved 82,361 forecasts by 284 experts over two decades.

   Long-term climate changes are highly complex due to the many factors that affect climate and to their interactions. Uncertainty about long-term climate changes is high due to a lack of good knowledge about such things as:
   a) causes of climate change,
   b) direction, lag time, and effect size of causal factors related to climate change,
   c) effects of changing temperatures, and

d) costs and benefits of alternative actions to deal with climate changes (e.g., CO_2 markets).

Given these conditions, expert opinions are not appropriate for long-term climate predictions.

4. *Forecasts are needed for the effects of climate change*. Even if it were possible to forecast climate changes, it would still be necessary to forecast the *effects* of climate changes. In other words, in what ways might the effects be beneficial or harmful? Here again, we have been unable to find any scientific forecasts—as opposed to speculation—despite our appeals for such studies.

   We addressed this issue with respect to studies involving the possible classification of polar bears as threatened or endangered (Armstrong, Green, and Soon 2008). In our audits of two key papers to support the polar bear listing, 41 principles were clearly violated by the authors of one paper and 61 by the authors of the other. It is not proper from a scientific or from a practical viewpoint to violate any principles. Again, there was no sign that the forecasters realized that they were making mistakes.

5. *Forecasts are needed of the costs and benefits of alternative actions that might be taken to combat climate change*. Assuming that climate change could be accurately forecast, it would be necessary to forecast the costs and benefits of actions taken to reduce harmful effects, and to compare the net benefit with other feasible policies including taking no action. Here again we have been unable to find any scientific forecasts despite our appeals for such studies.

6. *To justify using a climate forecasting model, one would need to test it against a relevant naïve model.* We used the Forecasting Method Selection Tree to help determine which method is most appropriate for forecasting long-term climate change. A copy of the Tree is attached as Appendix 1. It is drawn from comparative empirical studies from all areas of forecasting. It suggests that extrapolation is appropriate, and we chose a naïve (no change) model as an appropriate benchmark. A forecasting model should not be used unless it can be shown to provide forecasts that are more accurate than those from this naïve model, as it would otherwise increase error. In Green, Armstrong and Soon (2008), we show that the mean absolute error of 108 naïve forecasts for 50 years in the future was 0.24°C.

7. *The climate system is stable*. To assess stability, we examined the errors from naïve forecasts for up to 100 years into the future. Using the U.K. Met Office Hadley Centre's data, we started with 1850 and used that year's average temperature as our forecast for the next 100 years. We then calculated the errors for each forecast horizon from 1 to 100. We repeated the process using the average temperature in 1851 as our naïve forecast for the next 100 years, and so on. This "successive updating" continued until year 2006, when we forecasted a single year ahead. This provided 157 one-year-ahead forecasts, 156 two-year-ahead and so on to 58 100-year-ahead forecasts.

   We then examined how many forecasts were further than 0.5°C from the observed value. Fewer than 13% of forecasts of up to 65-years-ahead had absolute errors larger than 0.5°C. For longer horizons, fewer than 33% had absolute errors larger than 0.5°C. Given the remarkable stability of global mean temperature, it is unlikely that there would be any practical benefits from a forecasting method that provided more accurate forecasts.

8. *Be conservative and avoid the precautionary principle.* One of the primary scientific principles in forecasting is to be conservative in the darkness of uncertainty. This principle also argues for the use of the naive no-change extrapolation. Some have argued for the

precautionary principle as a way to be conservative. It is a political, not a scientific principle. As we explain in our essay in Appendix 2, it is actually an anti-scientific principle in that it attempts to make decisions without using rational analyses. Instead, cost/benefit analyses are appropriate given the available evidence which suggests that temperature is just as likely to go up as down. However, these analyses should be supported by scientific forecasts.

References

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Information on the authors

We are experts in scientific forecasting methods. Dr. Armstrong has been working in the field for 48 years. He is a founder of the *International Journal of Forecasting*, *Journal of Forecasting*, International Institute of Forecasters, and International Symposium on Forecasting, and the author of *Long-range Forecasting* (1978, 1985), the *Principles of Forecasting Handbook*, and over 70 papers on forecasting. Dr. Green has developed two important new forecasting methods and has published seven articles on forecasting. His first article was accompanied by six commentaries and was awarded Best Paper of 2002-2003 by the *International Journal of Forecasting*. Dr Green established publicpolicyforecasting.com to promote the use of scientific forecasting methods to help improve public policy decision making. Along with Dr. Armstrong, he is a director of forecastingprinciples.com.

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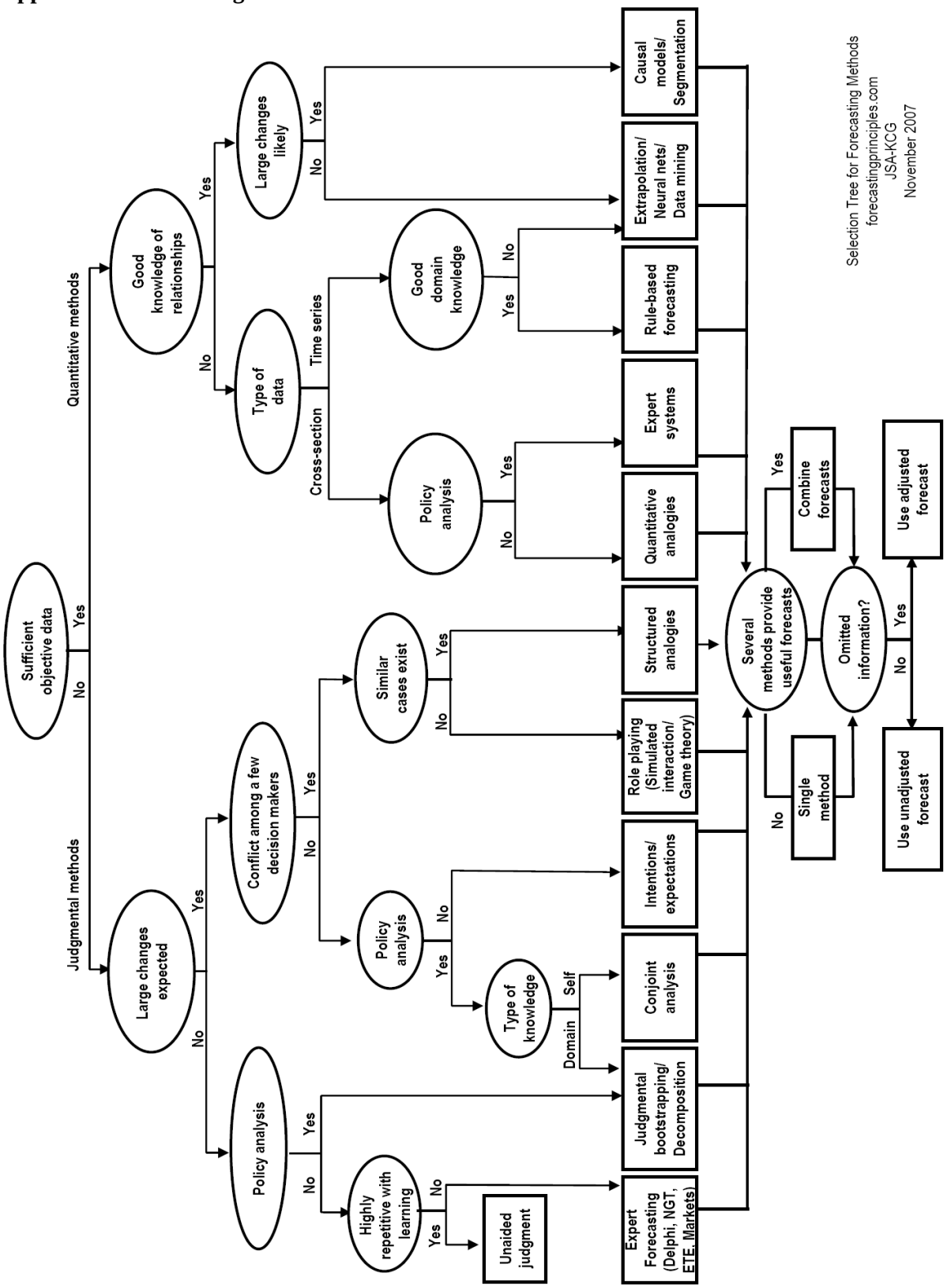
Appendix 1: Forecasting methods selection Tree



Appendix 2
Uncertainty, the Precautionary Principle, and Climate Change

Kesten C. Green & J. Scott Armstrong
August 9, 2008

The precautionary principle is a political principle, not a scientific one. The principle is used to urge the cessation or avoidance of a human activity in situations of uncertainty, just in case that activity might cause harm to human health or the natural environment. There is an interesting discussion of the history of the term in Wikipedia.

In practice, the precautionary principle is invoked when an interest group identifies an issue that can help it to achieve its objectives. If the interest group is successful in its efforts to raise fears about the issue, the application of the scientific method is rejected and a new orthodoxy is imposed. Government dictates follow. People who dissent from the orthodox view are vilified, ostracized, and may have their livelihoods taken away from them.

Consider the case of "climate change". Warnings of dangerous manmade global warming from scientists, politicians, and celebrities have received much publicity. They admonish us to dramatically reduce emissions of CO_2 in order to prevent disaster over the course of the 21st Century. Efforts have been made to stifle a scientific approach to the issue. In an article titled "Veteran climate scientist says 'lock up the oil men'", James Hanson, who heads the NASA Goddard Institute for Space Studies, was quoted as suggesting that those who promote the ideas of global warming skeptics should be "put on trial for high crimes against humanity." The skeptics themselves have been ejected from, for example, State Climatologist positions and prevented from publishing research in mainstream journals, and they and their views are routinely attacked.
Much complexity and uncertainty surround climate change. The cumulative empirical evidence on proper forecasting procedures suggests that the most appropriate method in this case is naïve extrapolation. In simple terms, this means to forecast no change. Of course there will be change, but with current knowledge there is no more reason to expect warming than to expect cooling.
As we describe in our paper, we have been unable to find any forecast derived from evidence-based (scientific) forecasting methods that supports the contention that the world faces dangerous manmade global warming.

Appeals for urgent curtailment of human activity "just in case" are often couched in ways that imply that industrial societies are inherently sinful, rather than that there might be a problem to be dealt with. Indeed, interpretation of the precautionary principle is subjective and it is arguable that it is being misapplied to the issue of climate change.

Firstly, even if forecasts of increasing temperatures turned out to be accurate, predicted temperatures and other conditions are within the range of variations that have been experienced in the past. There is no evidence that the natural environment "prefers" relatively cool to relatively warm average temperatures. In fact, life in general prefers warmth.
Secondly, curtailing human activity would harm people's health by making them poorer than they would otherwise have been. This is likely to be the case even if curtailing human activity happened to reduce global average temperatures. When the situation is framed in this way, the precautionary principle dictates that it is policies to curtail economically efficient human activity that should themselves be curtailed.
The outlook for the climate over the 21st Century is highly uncertain. There is a word in the English language to express high uncertainty. That word is "ignorance". And ignorance is not a basis for responsible government action. We should expect our politicians to have the courage to resist interest groups' calls for action in the face of ignorance.

The precautionary principle brings to mind the slogan on the Ministry of Truth building in George Orwell's *1984*: "Ignorance is Strength." Instead of this political principle, we hope that politicians will turn to scientific principles for making public policy.