THE FALLACY OF CLIMATE SKEPTICISM

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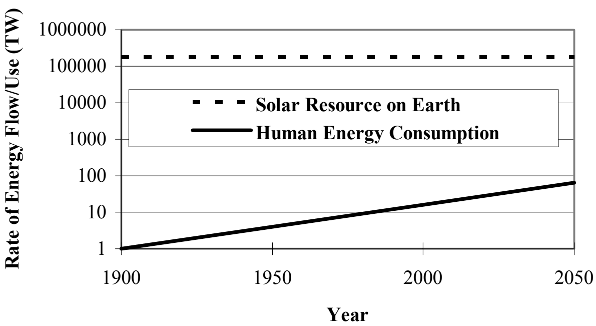
Abstract
The world's weather over the past few years has become much warmer and more erratic with many climatic extremes. This is consistent with climate change scenarios proposed for many years. The atmospheric system, with more energy trapped near the surface by the "greenhouse gases", acts more vigorously to disperse this energy and thus becomes more erratic and more extreme. However climate skeptics argue that uncertainty about climate modelling justifies international inaction on reversing emission trends. This paper argues that climate skepticism is not a respectable position. Uncertainty over climate sensitivity to greenhouse forcing is an argument for action, not inaction. This paper presents some simple illustrative scenarios about the outcomes in the 21st century. The fallacy of climate skepticism is that it addresses only one of these scenarios. At the same time philosophical questions about the nature of economic success are raised using a vector metaphor. Using this metaphor, the need for a change of direction becomes apparent.

Introduction

"Creating the Right Climate" is the theme of this conference, a theme with many layers of meaning. The phrase has an optimistic tone - after all this is a conference of technologists who know that solar energy is an abundant resource (Figure 1) which can be harnessed in a multitude of increasingly cost-effective ways. We know, and can therefore be optimistic, that solar energy can displace fossil fuels, thus minimising global climate change and literally "creating the right climate". At the same time our theme acknowledges the challenge at the political level, to create the right economic climate and to create a climate of awareness.

Figure 1 - Abundant Solar Energy, 10,000 x Human Use
(Note: sustainable fossil fuel use ~ $5x10^{-6}$ TW,
3 million times too little for humanity's requirements!)



But underlying all these layers of meaning is the implicit assumption that climate change is a problem which needs to be addressed. Is this merely an assumption? More frequent, more extreme and more long lasting El Niños are bringing massive destruction, loss of life and economic costs around the world. Climate data in our own region also provides evidence for concern for actual costs and risks to human life. Aside from the drought and flood costs of El Niño and La Niña in Australia and New Zealand, the trend for increasing numbers of tropical cyclones in the Southwest Pacific (Table 1) is strong evidence of increased risk of damage to property and lost lives.

Table 1: Recorded numbers of tropical cyclones in the Southwest Pacific.
Early decades could have one or two missing cyclones but the post World War II data has little chance of a missed cyclone, Kerr (1976) and NIWA (pers. comm.)

Decade	Number of Tropical Cyclones
1940-49	58
1950-59	64
1960-69	72
1970-79	91
1980-89	130

And this is happening when atmospheric CO2 has only increased 25% from pre-industrial levels - it is expected to more than double in the next century! Simple common-sense tells us that such a prospect is very likely to be costly, if not

down-right nasty. This is also what the Second Assessment Report (SAR) of the Intergovernmental Panel on Climate Change (IPCC) is telling us, albeit couched in careful scientific prose:

> "Potentially serious [projected] changes have been identified, including an increase in some regions in the incidence of extreme high-temperature events, floods and droughts, with resultant consequences for fires, pest outbreaks, and ecosystem composition, structure and functioning, including primary productivity...... future climate changes may also involve 'surprises'....... the risk of aggregate net damage due to climate change, consideration of risk aversion and the precautionary approach, provide rationales for actions beyond 'no regrets'."
>
> Bolin et al (1995)

Strange as it may seem to any observer of the increasingly frequent climate-related disasters and record weather extremes, the assumption that climate change presents a threat in the 21st century is not self-evident to some people. In spite of the wealth of evidence and scientists like Kevin Trenberth (1998) telling us that there is a real problem, and in spite of our awareness that there are solar solutions, too often the politicians are persuaded to inaction by lobbyists claiming there is either no problem, no solution, or neither problem nor solution.

Why is this so? Why for example has the Kyoto Protocol resulted in a delay of ten years in steps to stabilise developed nation emissions, when it is clear that about a 60% reduction in present global emissions is required to meet the ultimate objective of the Framework Convention on Climate Change (FCCC)? And meanwhile developing nations, for want of any leadership from developed nations, continue to increase their emissions exponentially. And why are New Zealand and Australia, with high standards of living and particularly abundant solar resources, behaving like developing nations in this regard?

The only answer which makes sense is that business-as-usual interests have successfully used what we will call the "climate skeptic" argument to delay action. This argument nibbles away at the science of climate change by highlighting its inherent uncertainties. Because climate change - to date or to come - can not be proven (runs the argument), we should not act to avert it until it can be proven. Otherwise (it is argued) the costs of action could prove to be higher than the costs being avoided.

The climate skeptics could be right about that last sentence (of which "could" is the key word). But Bolin et al (1995) are warning that they are **probably wrong** - that the costs of climate change are more likely than not to be higher than the costs of action. **And whatever the probable outcome of the climate experiment, they are certainly wrong to draw the conclusion that inaction is justified and the experiment should be continued!** The uncertainty argument works both ways. This paper will illustrate why the argument for action is more powerful than the argument for inaction.

A Question of Risk Analysis

The only rigorous way to view the climate change issue is in terms of risk-benefit analysis. Climate change is above all a question of risk analysis. Inaction is the base-case which can be analysed in principle as indicated in Figure 2, where it is assumed that "inaction" leads to an atmospheric carbon dioxide concentration of 600 ppm by the year 2100.

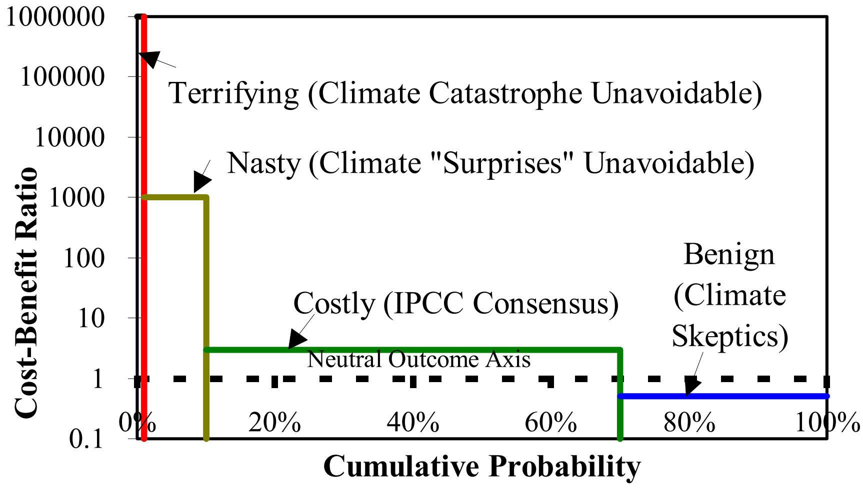
The x-axis of Figure 2 is labelled cumulative probability. In spanning 0-100% it takes in all possibilities, which I have arbitrarily broken up into four scenarios. In reality such graphs, familiar to engineers and scientists as exceedance curves, are smooth curves. The "true" picture for Figure 2 would also be a smooth curve, representing the infinity of scenarios before us, and asymptotically approaching the logarithmic y-axis at each end (0% and 100% cumulative probabilities). But for simplicity I have chosen four scenarios which cover the span of possibilities.

The y-axis of Figure 2 is labelled cost-benefit ratio. This parameter is chosen because it is inherently dimensionless and thus appropriate for the illustrative purposes of this paper. Neutral outcomes equate to a value of 1, which is indicated by the dotted line. Anything above the dotted line represents a net cost, anything below the dotted line, a net benefit. Because of the range of possibilities the y-axis is necessarily logarithmic.

Figure 2 is the sort of mental construct useful for dealing with the question which climate skeptics are effectively raising: "does it matter if we do nothing to avert or minimise climate change". The answer, as illustrated by Figure 2, is possibly not, but probably yes, indeed possibly it matters enormously, and in fact possibly it is a life-and-death issue for our species and for all species. Any of these last three responses provides sufficient grounds for action:

- the first because there is a high probability of a significantly costly outcome
- the latter two because, while the probabilities are low, the outcomes would be extraordinarily costly.

Figure 2 - Atmospheric Carbon Dioxide 600 ppm by 2100:
Possible Outcomes from Inaction



But what does the y-axis really represent? As will become clear from the discussion of scenarios, this question is tied up with the question of how economic success is measured. From an environmental or ecological point of view it is well-known that GNP (as the main example) is woefully inadequate as a measure of success. When it comes to considering the implications for global population dynamics in the scenarios, this issue also raises disturbing philosophical questions.

To make use of Figure 2 in principle one would need to consider some "action" case (where the action is expected to result in a lower), and do the following steps:

- convert the y-axis of Figure 2 from a cost-benefit ratio to a net cost value (say Figure 2A)
- calculate the expected net cost of inaction (ENCI), being the sum of the probability-weighted net costs for each scenario
- produce a similar graph of net cost (say Figure 2B) for the action case with the lower carbon dioxide concentration
- calculate similarly the expected net costs in the action scenarios (ENCA)
- subtract the two expected net costs to arrive at the expected benefit of action (EBA = ENCI - ENCA)
- compare the expected benefit of action with the costs of taking action (CTA) (is EBA > CTA?)

While this process would theoretically be valid, one does not need to be a trained economist to realise that such a calculation would be fraught with uncertainties. Therefore for formal decision-making, one can not expect to be able to make a provable case that a particular set of actions, aimed at achieving a particular stabilisation value of atmospheric CO_2, would be cost-effective. Even to attempt to do so would require an acceptance of social economic theory applied internationally and inter-generationally. The y-axis in Figure 2 can only be interpreted in terms of global societal costs over a time-scale of about 100 years. But how can nation-states be motivated to act for the greater international good of future generations? Not by an attempt to rigorously analyse cost-benefit ratios as indicated by Figure 2. One can appreciate the real difficulties in achieving international agreement on an action plan!

While Figure 2 is not a practical tool for rigorous-decision making on any proposed action plan (is there such a tool?), it does offer useful insights into the nature of the problem, and a rationale for refuting the climate skeptic position. This will become clear from a more detailed consideration of the scenarios, which are considered from right to left as they appear on Figure 2.

Scenarios for Possible Outcomes if 600 ppm by 2100

The following sections take us through the scenarios from an imagined perspective in the year 2100.

Scenario 1: Benign

In this scenario the costs associated with climate change prove to be smaller than the benefits associated with economic growth on a business-as-usual basis. This is essentially what the climate skeptics are saying, so in this scenario they have been proven right - it would have been a mistake to take action to achieve a lower CO_2 concentration than 600 ppm.

One would imagine that in this scenario:

- the effects of climate change have proved minor, in some cases beneficial
- strong economic growth has been achieved in the developing and developed world
- the global population is levelling off at 12 billion well-fed souls.

How likely is this scenario? In the light of the IPCC reports, e.g. Bolin et al (1995), and the growing evidence of significant climate-related costs at present-day 360 ppm, one must rate this as a less-than-even bet. Scenario 2 has to be more likely, so if we give the climate skeptic case the highest possible rating (commensurate with the tenacity and noisiness of its proponents), Scenario 1 would be rated at about a 30% chance. (Note: these numbers do not really matter to the final argument, and essentially represent the authors' judgement.)

Scenario 2: Costly

In this scenario climate change has proved to be significant and costly. This is the outcome that the IPCC consensus is pointing to.

One would imagine that in this scenario:

- economic growth has been disrupted by floods, droughts and sea-level rise
- the global population is levelling off at 10 billion. It would have been higher but for a number of regional conflicts which broke out due to stresses due to relocating the inhabitants of various low-lying islands along with (for example) 70 million Bangladeshis and 70 million Chinese.[1] The 21st century has proved to be little better than the 20th in this respect, just different causes for war.
- standards of living have improved in the developing world, and the climate system has not thrown up any nasty surprises relative to computer predictions from the mid-1990's. But quality of life has improved little in the developed world and the global economy is still overly dependent on fossil fuels.

Scenario 2 is rated as about a 60% chance.

Scenario 3: Nasty

In this scenario climate “surprises”[2] have been triggered in an irreversible way. One of the most likely "surprises" is that a sudden shift towards an ice age climate could be precipitated. If the global climate is bistable (i.e. having two relatively stable states, ice age and warm interglacial) additional greenhouse forcing could cause an over-compensating swing back to the ice age phase. The exact mechanism of this is not fully proven, but the major ocean currents (including the Gulf Stream) would play an important role - see for example Broecker and Denton (1990).

One would imagine in this scenario:

- the Gulf Stream has been disrupted, due to sudden influxes of fresh water into the North Atlantic "conveyor" from ice melt from Greenland. As a result the Gulf Stream shuts down and temperatures fall rapidly in Europe.

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[1] "A number of studies have evaluated sensitivity to a 1 m sea-level rise. ... Large numbers of people also are affected, for example, about 70 million each in China and Bangladesh. ... One of the potentially unique and destructive effects on human settlements is forced internal or international migration of populations." Watson et al (1995)

[2] "There are many uncertainties and many factors currently limit our ability to project and detect future climate change. Future unexpected, large and rapid climate system changes (as have occurred in the past) are, by their nature difficult to predict. This implies that future climate changes may also involve “surprises”. In particular, these arise from the non-linear nature of the climate system. When rapidly forced, non-linear systems are especially subject to unexpected behaviour. Progress can be made by investigating non-linear processes and sub-components of the climatic system. Examples of such non-linear behaviour include rapid circulation changes in the North Atlantic and feedbacks associated with terrestrial ecosystem changes." Bolin et al (1995).

- economic growth, already disrupted by floods, drought and sea-level rise, is now threatened by a sudden ice age
- the global population of 10 billion now faces prospect of massive emigrations from Europe and the threat of a Third World War.

While one would hope that this is not a highly probable scenario, it is consistent with a considerable amount of theory, and geological records of the last million years. And although it is "nasty" it would not cause extinction of the human or most other species. This scenario is rated as a 9% chance.

Scenario 4: Terrifying
In this scenario a climate catastrophe has been triggered in an irreversible way because the positive feedbacks in the climate system outweigh the negative feedbacks. Examples of these known or potential positive feedbacks (tending to increase greenhouse forcing in a warmer world) are:

- plant respiration rates increasing more than photosynthesis rates
- increased carbon dioxide emission by forest fires
- increased carbon dioxide and methane emission by plant decay
- increased water vapour content in atmosphere
- decreased albedo as ice melts
- sea-surface degassing of carbon dioxide
- continental-shelf sediment and permafrost releasing methane.

See Houghton and Woodwell (1989) and Schneider (1989).

One would imagine in this scenario:

- forest fires would be one of several positive feedbacks which have overwhelmed the global climate system's self-regulating, negative feedbacks in an unpredictable way
- avoiding the Venus effect (runaway greenhouse), not economic growth, becomes the main preoccupation
- the global village now faces extinction of all life although the Sun (bathing the Earth in several thousand times humanity's energy requirements) still has 4 billion years to live.

While it may be unlikely, this scenario or ones similarly devastating for the human species could have a 1% chance of occurring if we push the CO2 concentration to twice the level it has been for the last several hundred thousand years.

A climate skeptic might argue that this scenario is much less likely than a 1% chance, that the probability is vanishingly small or of the same order as a major meteor impact which could also wipe out life on the planet. But this is where the uncertainty argument rebuts the climate skeptic position. **The onus falls on the climate skeptics to prove that this probability is vanishingly small! The non-linearities in the system and the inherent uncertainty in the models (which the climate skeptics cite as a reason for inaction) become compelling reasons for action.**

And until the climate skeptics can prove that this probability is vanishingly small, we would hope that all engineers in particular would join in the call for significant action to minimise the risks associated with climate change. The engineering profession routinely deals with events of low probability on a design basis. Engineers can not build a nuclear power station or an airliner with anything approaching a 1% chance of catastrophic failure. Why then do so many engineers and other technologists stand silent as we experiment with the entirely planetary eco-system?

The True Meaning of the Y-axis in Figure 2
As mentioned earlier, interpreting the y-axis raises disturbing questions about the meaning of economic success. Consideration of the above four scenarios illustrates that the basic measure of global economic success can only be in terms of the **total number of well-fed souls that the planet will carry**. But do conventional economic measures lead us to that insight? Should we be aiming for maximum GNP (which could be consistent with this) or maximum per-capita GNP (which puts the emphasis on the "well-fed" part of the definition)? In the first case, population could continue to explode, but the average standard of living could actually fall. In the second case, the average standard of living would increase, but population could fall (perhaps even catastrophically). Do we want a "survivalist" fantasy future, where a few thousand well-armed survivors enjoy a high personal standard of living (high per-capita GNP), or a science fiction nightmare where huge numbers of human beings struggle for existence in a bleak, polluted world (high total GNP)?

There are other well-known problems with GNP as a measure of success:

- it does not discriminate between goods and bads - money spent on crime-fighting or cleaning up environmental disasters ends up being counted in GNP
- it does not measure capital assets, in particular environmental resources or the carrying capacity of environmental sinks
- it is purely a material measure, and even if it measures material well-being (which arguably it does not do very well for reasons given above), it ignores the spiritual dimension in life - "money does not buy happiness" may be hackneyed but it is still a truism for most people.

But even leaving aside such questions, the uncontroversial assertion above that "the basic measure of global economic success can only be in terms of the **total number of well-fed souls**" leads us to realise that GNP (total or per-capita) is an inadequate (or at least confusing) measure of success. So even thinking in simple material terms, GNP is inadequate!

The point is that GNP should not be seen as an end in itself. Society needs to decide what its ends are at a political level and strive for those ends. In the process GNP will normally grow, especially if the society is united and striving for a common purpose. The simple example of "total number of well-fed souls" is a case in point. It is an end in itself which most people would deem worthy. Aiming for this end would undoubtedly increase GNP. But, as explained above, the converse does not apply - aiming to increase GNP (total or per-capita) does not necessarily increase the total number of well-fed souls.

GNP's Vector Properties

There are many who would argue that GNP, imperfect as it is, is still a useful measure. While accepting this, the insight which we would offer is the recognition that GNP has **vector properties**. GNP is a scalar product of two vectors:

- a production vector, being all the goods and services expressed in physical units (tonnes etc)
- a price vector, being the unit price of each good and service.

The price vector effectively represents society's material values - for example how much we value a microwave oven versus a refrigerator, or a tonne of coal versus a tonne of firewood. Therefore GNP embodies society's material values, as much as it reflects the physical units of production. This is what we mean by GNP's vector properties: it has a sense of "direction" (a set of material values) as well as being a quantity.

To illustrate this point one can envisage a sequence of years where GNP grows each year. The production vector changes each year, as does the price vector. In theory, after (say) ten years the production vector could be back where it started, i.e. the same number of microwave ovens, refrigerators etc. But GNP would have increased significantly. This would reflect the changing values which society has apportioned to the different goods and services, not the change in physical production.

It also follows from this vector aspect, that GNP can continue to increase while:

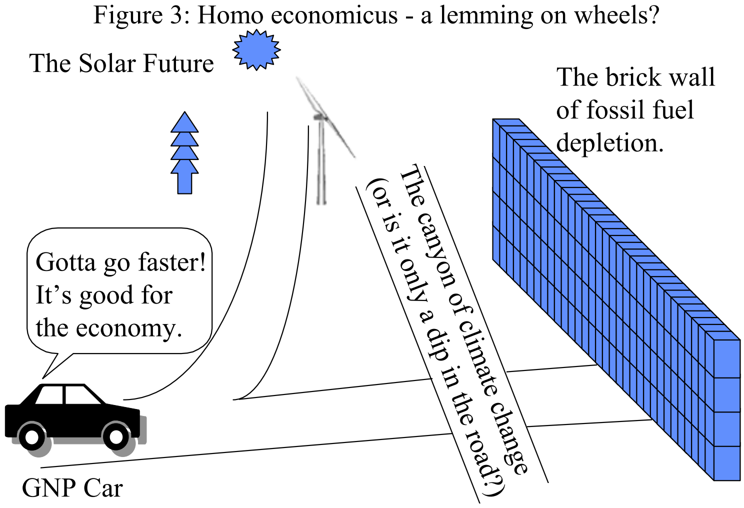
- the production vector remains constant or even reduces each year, or
- the elements of the production vector change due to product substitution, or
- the elements of the price vector change, reflecting a change in society's material values.

In other words, to use the metaphor of velocity, a change of direction does not necessarily mean a slowing-down.

How about a change of direction?

Using this metaphor of velocity, the following cartoon illustrates how nonsensical the climate skeptic, business-as-usual approach is.

Figure 3: Homo economicus - a lemming on wheels?



The idiot in the car has forgotten he has a steering wheel and can change direction, or rejects a change of direction because he wrongly thinks this means slowing down.

He knows the road he is on leads to a brick wall, because the fossil fuels will run out one day. And he is blasé about the dip in the road ahead, the depth of which he is quick to point out can not accurately be foreseen.

But, like a drunken hoon on a Saturday night, all he wants to do is go faster. He can not even see the road to the solar future, because he is so intoxicated with the sensation of fast driving in a straight line.

Truly, this man is a lemming on wheels.

Logic cries out that we need a change of direction. Many of the papers at this conference are pointing the way to the solar future (for example a paper by one of us ambitiously titled "Creating the Right Climate: the Economic Solution"). Therefore we will not dwell on the elements of the solar future. The purpose of this paper is simply to point out the folly and the fallacy of the climate skeptic approach.

Conclusion

Climate skepticism is not a respectable position. Uncertainty over climate sensitivity is an argument for action to minimise or avoid climate change, not inaction. Doubling atmospheric carbon dioxide will be a frightening extension of the experiment already under way. It increases the likelihood, not only of the most likely scenario (which we have called "costly"), but also of two much more extreme, albeit unlikely, scenarios ("nasty" and "terrifying") which involve major irreversible disruption to the climate system. While the numbers and scenarios may be debatable, the potential risks (costly, nasty and terrifying) are not. The onus falls therefore on climate skeptics to prove that the probability of the "terrifying" scenario is vanishingly small. As this is impossible the precautionary principle must apply.

In principle this issue can be addressed in terms of risk-benefit analysis, as indicated by the discussion around Figure 2. But in practice, the quantification of the economic risks is even more uncertain than that of the changes to climate parameters. Thus again the precautionary principle must apply.

Furthermore the risk-benefit analysis inevitably leads one into the analysis of global societal costs over a time scale of 100 years, and from there into fundamental questions about the nature of economic success. We offer no new insights into these questions except to note that:

- GNP should not be seen as an end in itself. Society needs to set its goals at a political level
- GNP has vector properties - therefore the sense of direction needs to be taken into account as well as the raw speed.

In summary our society is behaving like a drunken hoon behind the wheel of the economy. This is unacceptable. We must be prepared to change direction and we need to learn that this does not necessarily mean slowing down.

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