Climate Change Predictions:
Bad Economics, Bad Science

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About the Author

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About this paper

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The IPCC emissions scenarios

The climate models calculate the consequences of increasing atmospheric GHG concentrations – typically at a level equivalent of a doubling of atmospheric carbon dioxide compared to the pre-industrial level. However, in order to predict expected warming, modellers need estimates of the rate of increase of CO_2 in order to forecast how long it will take for concentration to double. In other words they need forecasts of human emissions of CO_2 through the 21^{st} century.

The IPCC has made such long range forecasting exercises for all of their three assessment reports since 1992. The latest results were published in 2000 in the Special Report on Emissions Scenarios (SRES)[1]. The SRES working group produced 40 scenarios out of which six were chosen as "marker scenarios" and fed into the climate models. In other words the emissions scenario exercise is a crucial step in creating the above mentioned temperature growth range for 2100 of 1.3 to 5.8 degrees Celsius. In fact, most of the span in this temperature range is produced by the huge difference in emissions across the marker scenarios.

The scenarios are based on parameters influencing emissions such as:

- GDP per capita growth on a country, regional and global level
- Population growth
- Energy efficiency (how much GDP does one unit of energy produce)
- Composition of fossil fuel consumption (coal, oil, gas)
- Non-carbon fuel share of total energy production (nuclear, wind, solar etc.)

Evaluation of the emissions scenarios

Obviously the quality of the emissions forecasts depends completely on the way these parameters are treated and the values given to them in the different scenarios. Over a time span of a century the degree of uncertainty for each parameter is enormous and as explained below, some of these uncertainties compound. However, this does not mean that anything should be considered plausible. Unfortunately the SRES scenario group does a very poor job of creating plausible scenarios.

Allow me to include a personal comment at this point. I am an economist and economic historian by training and have used scenario methods professionally for a number of years. Based on this experience I have to conclude that the SRES scenario effort is problematic. There are three basic reasons for concern:

- Sloppiness
- Bad methods
- Scenarios being used as forecasts

For the purpose of this paper, the most important thing is the criticism of scenarios being used as forecasts which I'll deal with below. First, let me just briefly mention some of the criticism that has been advanced concerning sloppiness and methods.

The criticism concerning sloppiness includes treating the period 1990 – 2000 as part of the forecast period without taking into consideration that we now have data for that period. Apparently the SRES has been reusing data from previous scenario exercises. The problem is that time and real world observations have proven these projections wrong. For instance the scenario figures used for the increase in world GDP between 1990 and 2000 vary between 20.6 percent and 35.4 percent. However, IMF data for most of that period was available in 1999 and showed growth of 36.5 percent[2]. Probably this error doesn't have a substantial impact on model results by 2100. Nevertheless, it's amazing that such sloppy practices are allowed as part of an input to a modelling exercise that involves the use of supercomputers and costs millions of Euros.

The IPCC also suffers from poor methodology. One leading economic modeller, John Reilly of the MIT Joint Program on the Science and Policy of Global Change calls the SRES approach to scenario building an "insult to science."[3] According to Reilly, the scenario teams have worked backward from a desired end result in terms of emissions and temperature increases. In other words, the IPCC has allegedly started with an emission projection then made an estimate of the relationship between emissions and growth and finally calculated the growth rate needed to achieve the desired emissions projection.[4]

Another criticism of methods has been advanced by Ian Castles, former President of the International Association of Official Statistics, and David Henderson, former Chief Economist of the OECD. They accuse the SRES team of using inappropriate exchange rates which exaggerate current global economic inequality. Since the scenarios assume that income equality will improve over the course of the century, models overestimate growth rates in low income countries[5].

While the SRES methods concerning growth projections are technically unsound, the scenario models will have to be modified before we can conclude if the exchange rate error should lead to substantial reductions in total global growth rate projections. However, the "end result" in terms of world GNP/GDP does seem very high. Many of the scenarios give us a world economy which by 2100 is up to approx. 25 times larger than it is today[6].

In order to achieve that multiplication the world economy would have to grow 3 percent a year. This does not seem to be a realistic assumption, even for a high end scenario, given the historical performance of the world economy. But then, the SRES does not seem to take historic trends much into consideration. As David Henderson points out:

> "It is a surprising feature of the SRES that in a document surveying the long term future, which contains over 300 pages of main text and presents 40 different scenarios prepared by six different modelling groups, there is no chapter which systematically reviews the evidence of the past. The starting point for any such quantitative future-oriented inquiry should be a clear and careful survey of earlier developments and trends, going right up to the present"[7]

What such a survey could have considered is the fact that since 1975 world GDP per capita has grown at an average 1.2 percent per annum[8]. Extending this growth rate for 110 years would give us a world per capita income which was 3.7 times larger than the present. If we assume that population doubles over the same period (and that would be a high estimate) we get a global economy which is 7.4 times bigger than the present. That's quite far from a 25 time increase.

The only economy which has produced average annual growth rates comparable to the IPCC assumption over a sustained period is Japan. Between 1913 and 1996 Japan grew at an annual rate of 3.36 percent[9]. But it seems doubtful that the entire world economy would be able to do the same for as long as a century.

The use and abuse of scenarios

Let me turn to the most serious of my objections to the way in which the IPCC uses scenarios. The scenarios are presented as an exercise in "free thinking" about the future. The SRES states that they are "images of the future or alternative futures" and should not be seen as predictions or forecasts. They are in fact "computer aided storylines". But at the end of the day the scenarios end up presenting a very concrete result in terms of numbers (emissions). These numbers are fed into a computer, which in turn produces a temperature. The SRES tries to have it both ways: a non-committal scenario process and a clear result in terms of a number.

The SRES claims that the scenarios "are not assigned probabilities of occurrence, neither must they be interpreted as policy recommendations"[10]. But since each scenario gives a result which translates into a number there is in fact an implicit bias in favour of extreme scenarios. An extreme scenario extends the temperature range. A less extreme scenario doesn't. Therefore, an extreme scenario is implicitly given more importance. In the real world we would normally treat an extreme outcome as less likely and therefore assign less importance to it.

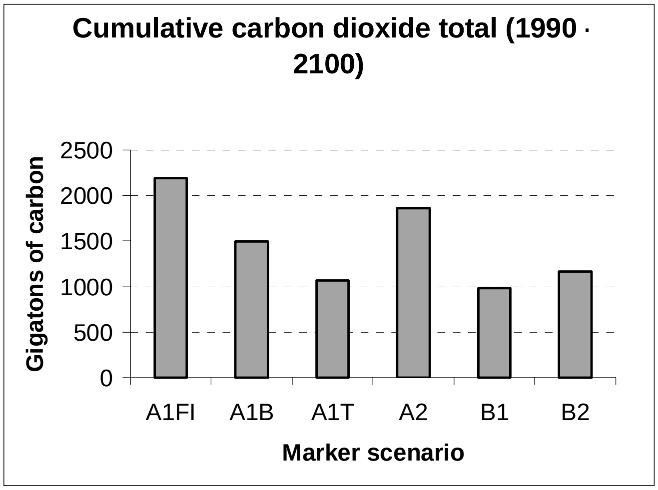
But the SRES scenarios are not assigned probabilities. That's normal when working with scenarios. The whole point of a scenario exercise is to cover the full range of possible futures. But this also implies that scenarios should not be used as forecasts, because a forecast doesn't make sense without a discussion of probability. Meteorologists only make weather forecasts extending 3-5 days into the future. The reason why they don't make longer forecasts is that the probability of being right becomes too small. The SRES scenarios are used to make forecasts. In other words, the SRES team abuses the scenario method.

Improbable high end scenarios

The following section will show that the high end temperature projection (which is being used as a forecast) is based on two scenarios which again are based on assumptions that have a very low probability, especially combined.

The six marker scenarios were based on very different assumptions about the parameters listed above. It is therefore not surprising that they produce very different results in terms of carbon emissions as shown in figure one.[11]

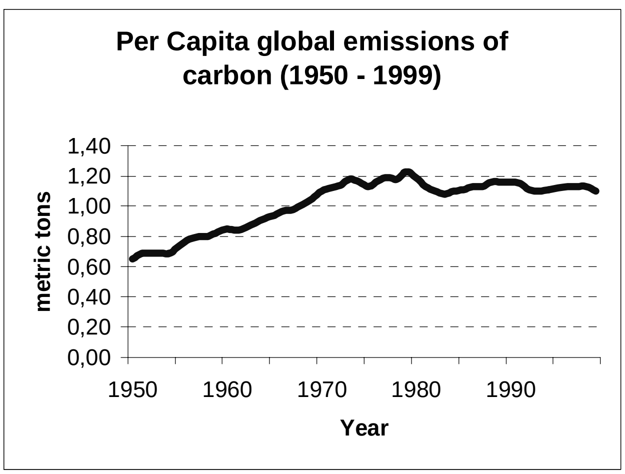
Figure 1



At the low end, the B1 scenario produces cumulative emissions by 2100 of 983 gigatons. At the high end the A1FI scenario produces emissions of 2.189 gigatons, more than twice as much.

How do those results compare with historic emissions? Figure 2 shows emissions per capita over the past half century[12].

Figure 2



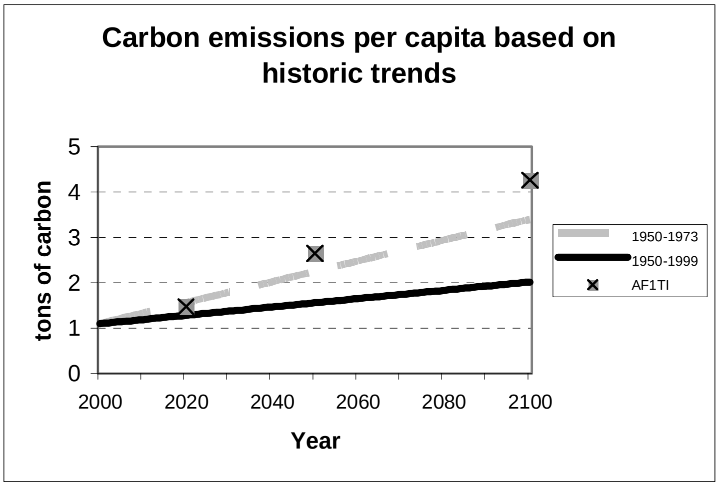
Until the beginning of the seventies carbon emissions per capita grew, but since then they have stabilised and even declined slightly. This has happened despite considerable economic growth. Ross McKitrick, Associate Professor at the University of Guelph, concludes that:

> …there is reason to believe that per capita CO_2 emissions are somewhat invariant to economic growth, at least at a globally averaged level. [13]

It would seem reasonable, therefore, if at least some scenarios had per capita carbon consumption at around the current level of 1.1 tonnes of carbon. Nevertheless, the SRES scenarios are all *above* 1.2Ct per capita by 2020. Not one scenario follows the current trend of no growth!

The high end scenarios produce some results which are improbable. Figure 3 is based on two historic trend lines of carbon consumption per capita. One projects the high growth trend from 1950-73. It's certain that no period in human history has had a higher growth rate in carbon consumption per capita than this period. The other line shows the lower growth trend for the whole period from 1950 to 1999.

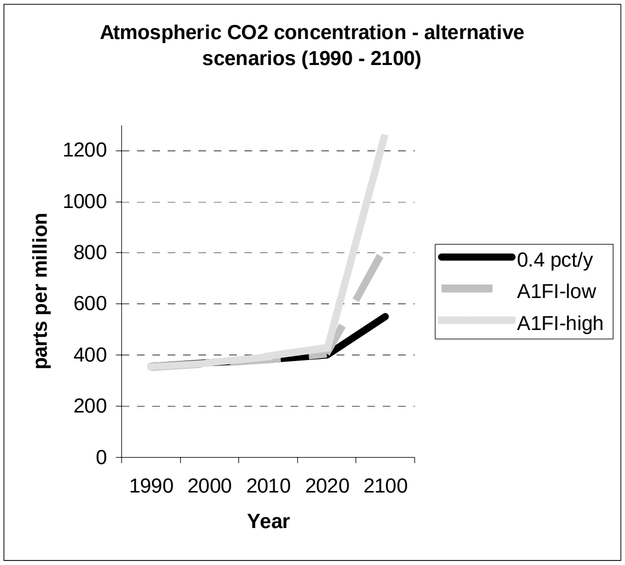
Figure 3



The figure shows how the A1FI scenario[14] overtakes even the fast growth trend by 2050. By 2100 the A1FI scenario has per capita emissions more than four times the current level and 25 percent above the high growth historic trend which was only sustained for a couple of decades in real life.

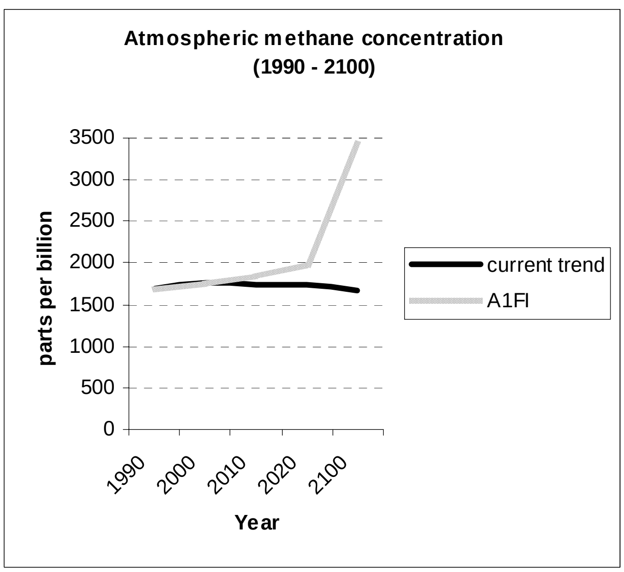
Not surprisingly the scenario also arrives at very high estimates of atmospheric concentration of CO_2. Currently, CO_2-levels are increasing by approximately 0.4 percent a year.[15]. Figure 4 shows how the high end of the A1FI scenario by 2100 reaches a level 2.27 times what the current trend would imply.[16]. The fact that the 1990's had high global economic growth and is likely to have been the decade with the highest nominal population growth ever, including all of the 21st century,[17] suggests that annual CO_2-growth may not increase much above the current 0.4 percent.

Figure 4



The current trend for the second most important GHG, methane, is that the rate of growth has been decreasing and the actual concentration is currently falling. Yet, none of the scenarios follow that trend. Figure 5 below shows how the A1FI scenario predicts a concentration more than double the current trend.[18]

Figure 5

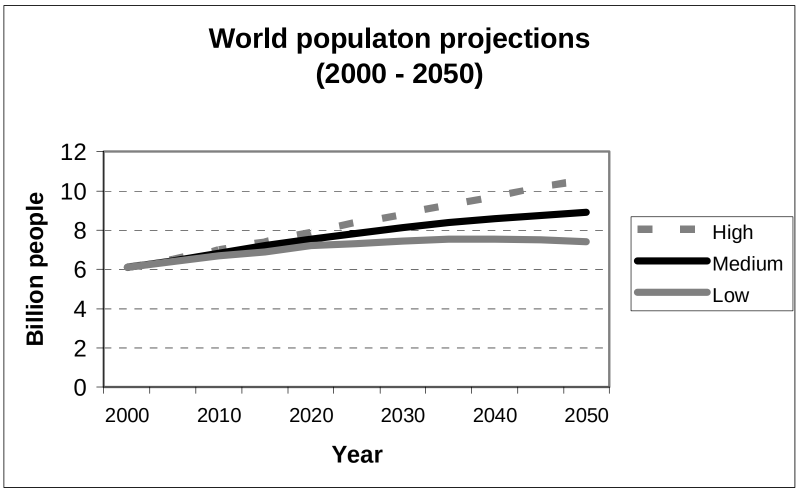


The A1FI scenario depicts an extremely unlikely future. Nevertheless it is this scenario – and this scenario alone – which is responsible for the high end of the IPCC TAR temperature range of 1.3 to 5.8 degrees Celsius for the year 2100. The 5.8 degrees forecast is arrived at by running the GHG concentration figures of the A1FI scenario through the climate model with the highest sensitivity to increased CO_2. If it wasn't for this scenario, the top temperature would be one degree Celsius lower.[19]

If we ignore the one degree Celsius which is produced by the A1FI scenario, we get a high temperature estimate of approx. 4.8 degrees Celsius. This is generated by running the A2 scenario through the climate model most sensitive to GHGs. The A2 scenario predicts yearly CO_2 emissions by 2100 which are almost as exorbitant as the A1FI figures. But this scenario gets there in a different way. One of the tricks of the A2 scenario is a very high population projection.

Figure 6 shows the 2002 UN Population projection[20]. The medium population projection for 2050 is 8.9 billion. The high estimate is 10,6 billion. Nevertheless, the A2 scenario has 11.3 billion people in 2050 – far above the UN's high estimate.

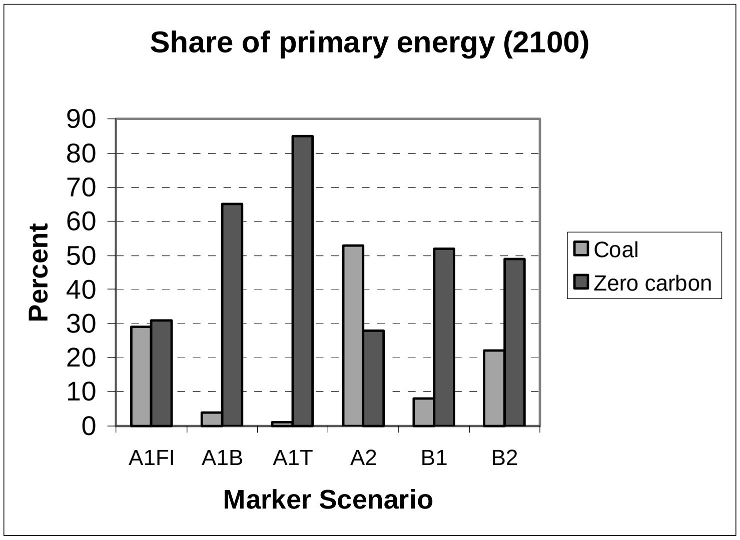
Figure 6



Unfortunately, the latest UN projection doesn't go beyond 2050. But the 2000 median projection had world population at 10.4 billion in 2100. In the new projection, the median figure for 2050 is revised downward from 9.3 to 8.9 billion[21] which implies that the forecast for 2001 would also be lower today. The A2 scenario assumes a world population in 2100 of 15.1 billion[22] - 50 percent above the median estimate. The A2 population is below the UN high projection of 18 billion, but few people consider that to be a likely outcome. It's not really a projection but a kind of "business-as-usual" scenario.

Secondly, and much more importantly, as figure 7 illustrates, the A2 scenario has a much higher share of coal than any of the other scenarios. This is very significant since coal emits more carbon per unit of energy than oil and especially gas. On top of that A2 has a much lower share of zero carbon energy (renewable sources, nuclear etc.).[23] In short, the A2 scenario assumes virtually no advances in energy technology over the next century. In fact, the scenario assumes that a trend towards less carbon intensive energy sources – a trend which has persisted for over a century – is reverted.

Figure 7



It is interesting to compare the A2 scenario with the A1T scenario. By 2100, the A2 has the second lowest world GDP of all six marker scenarios: 243.000 billion (measured in US dollars at 1990). In comparison the A1T scenario forecasts a world economy of 550.000 billion (1990 USD) - more than twice that size.[24] Still, the A2 world emits 28.9 Gt of carbon per year, which is 6.7 times more than the 4.3 Gt emissions that the A1T world produces. In other words, the carbon intensity of the A2 economy is 15 times higher. The A2 world needs fifteen times more carbon per unit of GDP.

This difference illustrates the importance of expectations concerning energy technology. The A2 and the A1T scenarios represent two extremes in this respect. In A2 there is very little technological development, and so the world returns to coal as the primary source of energy. In A1T there is rapid technological development, and non-carbon energy technologies begin to replace fossil fuels by the middle of the century. The question is: are both scenarios likely? In my opinion the answer is no. The A1T scenario is likely, whereas the A2 scenario is not. The reason for this is that the A2 scenario reverses a very long term trend whereas the A1T scenario merely continues (and maybe accelerates) an existing long term trend.

Despite the fact that the share of coal in world energy supply has been decreasing over the whole of the 20th century[25] and no reversal of that trend seems in sight, the share of coal increases in the A2 scenario from the current level of 23.5 percent[26] to 53 percent.

For more than a hundred years the global carbon dioxide intensity of energy has been decreasing steadily, by almost a third[27]. The A2 scenario inexplicably reverses this trend of decarbonisation.

Most of the literature on the subject of energy technology expects that one or more non-carbon technologies will become competitive in the course of the 21st century. Both photovoltaics (solar energy) and windmills show historic learning curves with a learning rate of approximately 20 percent. In other words, a doubling of cumulative installed capacity gives a 20 percent reduction in costs. At that rate, wind energy will be competitive within a decade or two and photovoltaic energy around 2050. Even models which are less optimistic about the learning curve have alternative non-carbon energy sources overtaking fossil fuels before the end of the 21st century.[28]

For the time being, gas is becoming an increasingly attractive alternative in much of the world and the price of gas-generated electricity is falling. This is another trend which is reversed in the A2 scenario.

While nuclear energy has stumbled in Europe for political reasons, other parts of the world are expanding their nuclear energy base rapidly, particularly Asia. Nuclear energy's percentage share of global energy supply has expanded from 0.9 percent in 1973 to 6.8 percent in 2000. There is also a learning curve for nuclear energy, so the expansion of this energy source results in it becoming ever cheaper, so nuclear energy could be expected to play a much larger role in the future.[29]

To sum up, while both the A1FI and the A2 scenarios are possible scenarios and maybe even "good" scenarios within a framework of six very different marker scenarios, they are not suitable for the forecast exercise that the emissions output constitutes. Both scenarios have a very low probability since they are based on a number of assumptions which seem unlikely given historical trends.

Conclusion: How much warmer will the climate be by 2100?

Table 2 sums up the basic steps that the IPCC needs to undertake in order to achieve the expected warming interval (left hand column) and for each step it lists what are widely considered to be the principal uncertainties given current scientific understanding (right hand column).

Table 2:

Forecast exercise	Principal uncertainties
Create scenarios for future emissions of CO_2	• World GDP growth per capita and its distribution among Low, Middle and High income countries. • Population growth • Composition of different fossil fuels in total consumption • Technological change, including shifts to non-carbon or low-carbon energy sources, energy efficiency, carbon sinks etc.
Convert emissions to atmospheric concentrations	• The life time of different GHGs in the atmosphere
Model radiative forcing and convert this forcing to a projected temperature	• The sensitivity of the climate system to increased CO_2 (feedback effects of clouds, aerosols etc). • Natural climate effects enhancing or counterbalancing manmade effect

Through the forecast exercise total uncertainty compounds as each new uncertainty is added. Let me illustrate this with an example. Let's imagine that, for some reason, we want to know how many grams of carbohydrates Uncle Peter eats every day. To calculate that we need to know how many meals he eats a day and how many grams of carbohydrates he eats per meal. However, both of these parameters are uncertain. We estimate that Uncle Peter eats 2-4 meals a day and that he eats 100-200 grams per meal. So we conclude that Uncle Peter eats between 200 and 800 grams of carbohydrates a day.

The point is this: Each of the parameters has a factor 2 uncertainty. The highest estimate is double the lowest estimate. But the result has a factor 4 uncertainty. The highest estimate is four times higher than the lowest. Adding a third parameter with a factor 2 uncertainty would give us a high estimate which was 8 times higher than the low estimate. Uncertainty compounds.

The short answer to the question is that we simply do not know how much warmer climate will be in 2100. In fact, the degree of (compound) uncertainty is so large that the fact that merely by providing temperature intervals, the IPCC is extremely misleading. For many of the parameters even the degree of uncertainty is controversial, despite the IPCC's phoney confidence intervals. Climate science is not at a stage where it is capable of providing confidence intervals, especially not for the earth's climate almost one hundred years into the future. In fact even the term "uncertain" is often misleading when it comes to climate science. A lot of things are not uncertain but simply *unknown*.

For all climate scientists know, climate might have cooled by the year 2100!

The NAS report concludes:

> "Because there is considerable uncertainty in current understanding of how the climate system varies naturally and reacts to emissions of greenhouse gases and aerosols, current estimates of the magnitude of future warming should be regarded as tentative and subject to future adjustments (either upward or downward)."[30]

In fact, given current knowledge, downward adjustments seem to be by far the best bet. There are strong indications that the IPCC has a systematic bias in favour of exaggerated temperature increases. The climate sensitivity of the models is largely based on a number of positive feedbacks, whereas negative feedbacks are probably underestimated or completely ignored.

On top of that, the emissions scenarios produce growth rates of carbon emissions which are not in line with recent history. Especially the high end scenarios, such as the A1F-scenario, seem completely unrealistic. Nevertheless, the A1F-scenario provides the basis for the high end of the IPCC temperature range. According to the guidelines for scenario use that most forecasters and futurists refer and adhere to, a scenario must be both *possible* and *probable*. While the A1F-scenario is theoretically possible (and even that is debatable), it simply isn't probable.

As mentioned, temperature intervals do not make sense given current knowledge about the climate system. However, since this is the game that the IPCC has forced upon us, we should examine the interval of 1.5 – 5.8 degree temperature increase which is the central IPCC projection. This interval is almost certainly way too high. The upper estimate should be decreased by about 1 degree because it is based on the unrealistic emissions of the A1F-scenario, and by a further 1 degree results from the unrealistic A2 scenario.

On top of that, the temperature range should be lowered considerably because climate models almost certainly overestimate the sensitivity of the climate system to increased levels of CO_2.

ENDNOTES

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[2] Henderson (2003)
[3] Corcoran (2002). See Webster et.al. (2001) for a more in-depth analysis of projected emissions of carbon dioxide.
[4] *Ibid.*
[5] The *Economist* (2003)
[6] A spreadsheet with the scenario data is available at: http://sres.ciesin.org/
[7] Henderson (2003)
[8] UNDP (2002), Human Development Indicators, p. 193
[9] Maddison (1991), David Landes (1999)
[10] IPCC (2000), p. 3
[11] IPCC 2000, Table SPM-3a, p. 17 Link: http://www.ipcc.ch/pub/sres-e.pdf
[12] Marland (no date)
[13] McKitrick (2003), p14
[14] Own calculations based on tables SPM 1a and SPM 3a in the SRES Summary for Policymakers
[15] McKitrick (2003)
[16] Gray (2002).
[17] Lomborg (2001), Figure 13, p. 47.
[18] Gray (2002).
[19] IPCC (2001), Technical Summary of Working Group I Report, Figure 22, p. 70
[20] UNPP (2002)
[21] http://www.un.org/News/Press/docs/2003/pop850.doc.htm
[22] Table SPM 1a in IPCC (2000)
[23] Table SPM 2a in IPCC (2000)
[24] Table SPM 1a in IPCC (2000)
[25] IPCC (2000), chapter 2.4.11 Carbon Intensity and Decarbonisation
[26] IEA (2002),
[27] IPCC (2000), chapter 2.4.11 Carbon Intensity and Decarbonisation, Figure 2-11
[28] Nakicenovic and Riahi (2002); Chakravorty and Tse (no date).
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