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A critique of the Stern and IPCC analyses of CO2 mitigation: Consumer-capitalist society cannot solve the problem.

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The Reports the Third Working Group of the IPCC[1], (hereafter TAR) and Fourth Assessment[2] (referred to as 4AR) align with the Stern Review[3] in asserting highly optimistic conclusions regarding the possibility and cost of solving the greenhouse problem. The Fourth Assessment Report says, "In 2050 global averaged macro-economic costs for multi-gas mitigation towards stabilization between 710 and 445 ppm CO-eq, are between a 1% gain to a 5.5% decrease of global GDP."[4]

These conclusions have received extensive global publicity and appear to have been taken as crucial and confident givens in official and popular thinking about the nature of the greenhouse problem and the steps that are appropriate for dealing with it.

This paper argues that both these conclusions are mistaken. The argument is not one of degree, i.e., that the cost and difficulty will be significantly greater than is foreseen by these two studies. The argument is that the greenhouse problem cannot be solved without large scale reductions in the volumes of economic production and consumption taking place, and therefore cannot be solved at any cost within a society committed to affluent "living standards", maximum levels of economic output, and economic growth. If this argument is valid then it would be difficult to exaggerate the seriousness of the policy mistakes that will be premised on the Stern and IPCC reports.

The following critique does not deal with or question the climate science embodied in the IPCC Reports from Working Groups 1 and 2, or in the Stern Review. These are accepted as valid and valuable scientific and political contributions documenting the urgency of the problem. This paper is only focused on the conclusions in Working Group 3 reports regarding mitigation possibilities and costs.

The magnitude of the mitigation task

a. The energy target assumed

It is commonly assumed that in view of current rates of increase in energy consumption by 2050 demand for energy services will be approaching 1100 Exajoules (EJ), about 2+ times as great as at present. It will be assumed that by 2050 energy efficiency, saving and conservation effort will reduce the need for energy by 25% (Stern assumes 18%).

This means that energy sources would have to provide 825 EJ of energy services.

If we take the above 2050 projection for Australian energy consumption per capita in 2050 and if 9 billion people were to rise to that per capita amount of energy consumption then world energy production might have to be 4,500 EJ, possibly 10 times as great as at present. In other words, if we were to take as our target an equitable world providing enough energy to give all people the amount per capita that Australians are likely to have in 2050, the target would have to be around 4+ times as high as that assumed by Stern and most conventional analysts. Stern has therefore made the task much easier than he should have.

b. The carbon emission target

The 2050 carbon emission target Stern adopts corresponds to18 GT/y of carbon dioxide p.a. There are grounds for regarding this as much too high. The most common view is that if serious ecological consequences are to be reduced to a low (but still worrying) probability, then the global temperature should not be allowed to increase by more than 2 degrees centigrade over the 1990 level. This requires atmospheric concentration to be kept below 450 ppm. The IPCC's range of emissions for 450 ppm is 5.7 - 14 GT/y by 2050, but their diagrams at Fig. SPM 7 and Table SPM 5, (p. 16) state that for a 2 – 2.4 degree centigrade limit by 2100 emissions must be kept between 4 and minus 15 GT/y. In effect the longer term goal probably has to be the complete elimination of emissions.

It is likely that before long these targets will be regarded as too high. There is increasing evidence that the IPCC's expectations regarding climate change have been too conservative and that effects are tending to occur well before they were predicted, most obviously accelerating arctic ice melting and glacial melting.[5] The IPCC has not yet attempted to take into account the effects of feedback mechanisms, such as the reducing carbon absorption capacity of the oceans. Hansen, et. al.[6] argue that the appropriate target has to be 350 ppm, although the present level is 385 ppm.

Let us assume that it is "safe" to release 5.7 GT/y of CO2 in 2050, and that 80% of CO2 generated can be captured (below.) That would correspond to about 80 EJ of electricity. The basic quantities arrived at above for use in the following analysis are summarised in Table 1.

Table 1.

World 2050 primary energy equivalent, i.e., assuming c. 2% p.a growth and therefore c. x 2.5 early 2000s c. 450 EJ.	1100 EJ
Energy services enabled due to increased conservation, efficiency of use, etc. (c. 25% of b.a.u. primary.	275 EJ
Energy services or final energy to be provided.	825 EJ

Low temperature heat, mostly water and space (...assuming this is 25% of final energy.)	206 EJ
Transport energy, 35% of final.	290 EJ
Electrical energy, 25% of final.	205 EJ
Primary energy via Carbon Capture and Storage, assuming 5.7 GT CO_2/y safe release and 80% capture rate, as electrical energy	250 EJ
...corresponding to electricity supplied	93 EJ
Carbon Capture and Storage, assuming no release by 2100.	0 EJ
Energy needed to provide 9 billion people with the per capita amount Australians are likely to average by 2050.	4000+ E

The focus on potential improvements in energy use efficiency

Mitigation involves two domains, the first being reducing the energy needed to perform operations, and the second being reducing CO_2 produced in the process of generating energy. The IPCC explicitly focuses its mitigation case mostly on the potential for reducing the carbon dioxide emissions from various sectors of the economy, e.g., buildings, forestry, agriculture.

The possible total reduction stated in the 4AR Tables SPM 1 and 2 (p. 9), 7.4 GT/y, is not a very reassuring prospect in view of the present 26 GT/y emission rate, the 61 GT/y rate Stern anticipates by 2050 for business as usual, and the probable need to completely eliminate greenhouse gas emissions by the end of the century.

It is not that the IPCC assumes that heavy dependence on fossil fuels will be offset by Carbon Capture and Storage, because the report does not expect geosequestration to be making a significant contribution by 2030. (Table 4.19 has it accounting for only .81 GT by then.)

The savings the Report refers to are the easiest ones to make, the "picking of the low hanging fruit" after decades of abundant cheap energy in which wasteful habits have developed. It should not be assumed that the rate at which savings can be made in the years to 2030 can be continued thereafter. There is weighty evidence in the IPCC 4AR Fig. SPM 10 that there will be markedly diminishing returns for energy saving and conservation effort. It shows that increasing the cost of carbon 5-fold, from $20/t to $100/t would not increase CO_2 saving much, compared with the initial effect of the $20/t cost. (In the best sector savings are doubled.)

Although the report states that we are not on a path that would solve the problem (p.255), it is puzzling why the IPCC does not stress that the conservation and savings achievements it anticipates and which are the focus of its mitigation discussion would fall far short of a satisfactory goal.

The misleading goal statement

Both the Stern Review and the 4AR have been widely taken to be saying that it will be possible, without significant economic cost, to solve the greenhouse problem. However it is crucial to recognise that this is not what the documents are saying. Both are actually saying that the steps we need to take by 2030 (2050 in Stern's case), in order to be on the path that will eventually lead to stabilisation of atmospheric CO2 can be taken and will not be costly. What is not made clear in these statements that little needs to be done by 2030/50 if the (eventual) goal is stabilisation at 550 ppm, but a great deal would then need to be done after 2030/50.

Consider again the statement quoted above, "...In 2030 macro-economic costs for multi-gas mitigation, consistent with emissions trajectories towards stabilisation between 445 and 710 ppm CO2-eq, are estimated at between a 3% decrease of global GDP and a small increase, compared to the baseline." (See also the statement in SPM p. 19.) The key and misleading term here is "consistent with". The statement does not say that the steps envisaged are sufficient for stabilisation; it merely says they are "consistent with" moving to eventual stabilisation.

The fourth diagram in the 4AR SPM 7, (p. 16) makes the situation clear. It represents emission levels necessary to achieve the 550 ppm target and it shows that CO2 emissions might be allowed to rise to 60 GT/y by 2050 which is 2.5 times present levels. Thus it could appear that their analysis of the 2030 situation in which emissions have risen considerably does not warrant alarm. However the diagram shows that even to achieve 550 ppm stabilisation emissions must be reduced greatly after 2050, and by 2100 must be down to 25 GT (the centre of the range of estimates.)

It would seem to be clear therefore that both Stern and the IPCC Working Group 3 have given seriously misleading impressions regarding the magnitude of the steps that need to be taken. They have done this, a) by taking much too low an energy provision target, b) taking too high an emission target, and c) by not emphasising their targets are only for 2030/50 and that dramatic emission reduction must be achieved later in the century. When these factors are combined it is evident that the task these reports should have focused on is many times more difficult than the 2030/2050 task they have set themselves and claim can be achieved at negligible cost.

Can the non-fossil sources be scaled up sufficiently?

Given the need for almost complete elimination of emissions, and the limits to savings and energy use, the only options are the very large scale geo-sequestration of carbon from coal use, and/or use of nuclear energy, and/or reliance on renewable energy sources. This leads to the crucial issue of "scale-ability", i.e., can these sources be scaled up sufficiently. This question is almost completely ignored by Stern, the IPCC, Garnaut and ABARE.[7] The issue firstly requires a critical discussion of the use made by these studies of economic modelling.

The non-economic determinants; the invalidity of the economic modelling.

Both Stern and the IPCC are led to overlook the problem of scale-ability by basing their optimistic cost conclusions solely on "top down" and "bottom up" economic modelling. Studies of the former kind ask what it costs to generate 1KW by wind for instance, and multiply this by the number of kWh required from wind particular scenario. "Top down" approaches estimate general effects on the economy from the imposition of a tax or quota, such as carbon taxes and caps.

Stern's Figure 9.4 shows that 2050 energy supply is assumed to be made up of specified proportions of nuclear, wind, solar, CCS, etc. The essential logic of his cost argument involves taking each of these sources, finding what the cost would be to replace 1 kW of coal-fired generating capacity, and multiplying this by the amount of coal-fired energy the source in question is assumed to replace by 2050. (Likely technical advances and changes in present costs are taken into account.)

Thus Stern arrives at the conclusion that by 2050 the total cost of replacing sources generating 43 GT of CO2 will be about 1% of GDP p.a. (Other economic modellers have criticised Stern, especially for incorrect assumptions about the discount rate, and concluded that the cost will be much lower than Stern states[8]).

At first sight this might appear to be a straight forward and sound approach, i.e., determining the unit cost and multiplying this by the number of units needed. However, this approach involves the crucial assumption that measures that can be taken now on a small scale can be geared up by the required (huge) amount. It will be explained below that with respect to all of the replacement technologies involved in the IPCC's and Stern's analyses this assumption is highly dubious or false. Achievement of the quantities of energy supply stated in Table 1 above and in Stern's Fig. 9.4 would involve very large scale application of alternative energy technologies. When this issue is attended to difficulties and limits that have little or nothing to do with economics or dollar costs become apparent. These problems are to do with the physical and biological limits and difficulties associated with energy technologies and the quantity and integration limits that the alternatives to fossil fuels run into when very large scale use is taken into account. It will be explained that when these issues are considered it becomes evident that to rely on economic modelling in this area is inappropriate and leads to conclusions that are incorrect and conducive to seriously mistaken policies.

This failure would seem to be due in large part to the fact that there has been almost no literature focusing critically on the basic question underlying this issue, i.e., the limits to the use of renewable energy. There seems to have been only one book previously published on the topic, i.e., Howard's *The Solar Fraud*.[9] Two papers by Trainer[10] represent early and partial attempts to clarify aspects of the issue. Trainer 2007[11] offers a more detailed summary and interpretation of evidence accessible in the early years of this century. Trainer[12] advances the analysis in the light of more recent evidence.

Following are notes indicating the difficulties neither source considers.

Wind: Stern expects wind power to provide 62 EJ in 2050. This is about 120 times as much electricity wind contributed in the early 2000s. It is not plausible that enough sites could be found, on-shore or off-shore, within tolerable distances of population centres. Trieb (a strong believer in renewables) estimates European wind potential at about 2 EJ/y from onshore sites and another 2 EJ/y from offshore sites.[13] Some European regions are probably close to their limits now. Note also that a very large increase in wind capacity would mean use of decreasingly favourable and increasingly distant sites, and therefore a reduction in the present average capacity and significant loss in long distance transmission.

The IPCC's 4AR Table 4.2 assumes global wind potential is 600 EJ, 10 times as great as Stern assumes, without explanation.

Biomass: Stern's figure 9.4 indicates 110 EJ of biomass energy. This is optimistic as it corresponds to 850 million ha when all cropland totals only 1,400 million ha. Very large scale biomass energy production would have to come predominantly from cellulosic inputs. Chapter 5 of Trainer 2007 reports what seem to be the most plausible estimates, i.e., that the yield for very large scale cellulosic biomass production is not likely to exceed 7 tonnes per ha, and that ethanol production is likely to be around 7 GJ net per tonne of biomass.[14] It should be noted however that there is doubt whether it will be economically or technically viable to produce ethanol from woody inputs.[15] Land, forest and water resources are already stretched and likely to deteriorate, population is going to increase by 50% and food demand by a greater amount, increasing scarcities and costs for metal and synthetic resources will increase demand for wood, and the greenhouse problem is likely to reduce yields markedly. Stern's figure would yield only c. 33 EJ of transport fuel, or 3.7 GJ per person for 9 billion people, when Australian Transport consumption is about 65 GJ per person, and rising.

Nuclear energy: If we take the proportion of energy demand Stern assumes will be met by nuclear reactors, 115 EJ would be provided. This is about 14 times the world's present nuclear contribution. If the estimates of Uranium resources commonly quoted, e.g., by Leeuwin and Smith[16] and Zittel [17] are correct they would be exhausted in less than a decade. (The 4AR Table 4.2 lists energy from Uranium resources 3 times as great, and refers to a quantity 50 times as great, which must assume fuel recycling and breeder technology).

Geo-sequestration: Although not a renewable technology it is appropriate to discuss the geo-sequestration of carbon dioxide (or Coal Capture and Storage, CCS) here as it is often seen as the solution to the greenhouse problem, and a large role for it would reduce the load on renewables. The IPCC does not expect geo-sequestration to have been implemented significantly by 2030 but Stern assumes that by 2050 CCS will account for 18% of the 43 GT of carbon dioxide saved, i.e., 7.7 GT/y.

CCS is only applicable to stationary generating sources and would therefore not apply to at least 40% of carbon fuel use. It is likely to have an energy cost between 10 and 40% of energy output.[18] and between .1 and 1% of the CO2 stored is likely to leak out each year. [19]

According to Hendricks, Graus and van Bergen[20] the best estimate of available land sites is 1700 GT. (The IPCC's uncertain estimate of the maximum theoretical potential is 6 times as great; see Metz, et al.[21]) If 9 billion people were to have the probable 2050 Australian per capita energy consumption of 500 GJ/person and if CCS dealt with 80% of this, annual CO_2 production would be 96 GT and the storage capacity might only last 18 years (there is greater capacity in deep ocean storage but use of this would seem to be ecologically unacceptable.).

However the main problem with geo-sequestration is that it is not likely to extract more than 80% - 90% of the carbon dioxide generated. If the 2050 emission limit is 5 GT/y, (the low end of the IPCC's range), if geo-sequestration captures 80% of CO_2 generated, then 25 GT/y could be generated, corresponding to about 250 EJ of primary energy or 80 GJ of electricity. This would provide 9 billion people with 7 GJ per capita p.a., about 20% of the present Australian per capita electricity consumption, leaving none to meet transport demand. Note again that by 2100 no release of CO_2 is likely to be permissible, which would eliminate use of geo-sequestration because it cannot capture all CO_2 generated. Also 250 EJ of primary energy from coal would be about twice the present rate of use, and some estimate that at the present rate coal supply will plateau within two decades. (Energy Watch Group[22])

Solar PV: It would be possible to build and site the 110 EJ of solar capacity Stern assumes, but this source too is subject to limits, due to its variability (see below) At average Sydney radiation levels 110 EJ corresponds to 15 square metres of PV panels per person for a world of 9 billion, for 10% of energy.

Solar thermal: Could the capacity of solar thermal systems to store heat energy get around the above storage and integration problems? Some believe this capacity will enable solar thermal technologies to plug the gaps left by the intermittency of other renewables, and thereby make possible a wholly renewable energy supply.[23] There is no doubt that these systems will be major contributors but their capacity to deliver in winter is problematic. (for a detailed discussion see Trainer[24])

In winter, trough output falls to 20% or less of summer output. The ratio for dishes is better, but they are not well-suited to heat storage and European and US dish developers therefore do not regard this option as viable.

The most promising possibility seems to be to store energy via the dissociation of ammonia.[25] A plant of this kind is being developed at Whyalla, South Australia, but it has not been possible to get technical detail from the project developers. It seems that they are not yet clear how effective the system will be but it is estimated that under ideal conditions half the solar energy would be available as heat after storage. An (uncertain) derivation from these figures suggests that in winter such a system might deliver a constant flow of c. 20+ W/m over long distances, net of all energy costs. If so a plant capable of delivering 1000 MW in winter would need a 50 million square metre collection area, corresponding to some 100,000 Whyalla big dishes.

There would seem to be some major problems in the big dish-ammonia strategy. The first concerns the greater structural strength required in big dishes (500 square metres proposed for Whyalla) to take wind stress and thus the disproportionately greater embodied energy costs. These seem to be three times those of the much smaller and more common European and US dish-Stirling systems. The second problem concerns the embodied energy cost of the plant to process the ammonia, especially that for storing large volumes under pressure.

The third problem is to do with the frequency of occurrence of sequences of cloudy days. Climate data for Daggett, a US dish-Stirling site, shows that one third of the days in a winter month solar energy is too low for significant generation. Runs of 4 days in a row at such levels are not uncommon, e.g., averaging 1.5 – 2.5 kWh/m/day with hardly any hours in which solar radiation is over 700 W/m. (Further climate evidence is given in Trainer 2008a.) Thus despite their capacity to store heat solar thermal systems suffer a significant intermittency problem. Fairly often in winter they would need back up from some other energy source.

It would seem therefore that solar thermal systems would have low net output in winter, and suffer a serious intermittency problem despite their storage capacity. Above all, it seems clear that there would be no possibility of them being the means for overcoming the gaps in supply from other elements in a wholly renewable electricity supply system.

Conclusions on renewables

These have been comments on problems to do with sheer quantities. Even more difficult can be problems involved in integrating renewable sources into the supply system. For instance, it would not be possible to integrate a very large amount of such a highly variable source as PV into a supply system, phasing the other components down as all the PV came on stream within an hour or so on a summer morning, and then having to turn to coal or nuclear sources at night or on a cloudy day. A more recent attempt to summarise the limits of renewables is given in Trainer[26]. Neither Stern nor the IPCC deal with any of these complex and crucial issues. The difficulties outlined above seem to seriously challenge or clearly invalidate a number of the unexamined assumptions evident in the Stern, IPCC, and Garnaut Reports dealing with mitigation.

Attempting a 2050 world energy budget

The unsatisfactory nature of those analyses can be made evident by attempting to explain how the 2050 1100 EJ energy budget might be composed. The following analysis is based on the table on p. 4. above.

Energy saving/conservation effort: It will be assumed that this cuts 25% off the amount of energy required.

Low temperature space and water heat: It will be assumed that one-quarter of the total, 206 EJ, is in this category, and can be easily delivered from solar sources (although this is too optimistic for many mid to high latitude countries.)

Electricity: From Table 1 above this sector would require 205 EJ. Let us assume that in 2050 this is met by 93 EJ of "safe" coal use via geosequestration as derived above (higher assumptions will be made below),15 EJ of hydroelectricity (a questionable almost doubling of the present amount), and 50 EJ each of wind and solar. This could be 100 times early 2000s wind capacity, and it is likely that by 2100 geosequestration could not be used at all. If the lignin in biomass residues can be used after ethanol production, 5 EJ of electricity might be derived from this source, taking Stern's assumption of 110 EJ of primary biomass energy. Thus we have explained the quantity of electricity needed, but we have not dealt with the huge problems of integration, storage and back-up set. Nuclear energy cannot make a significant long term global difference in view of limited Uranium resources, unless breeders and/or fusion are employed.

Transport: This sector, accounting for 35% of the total, would require 290 EJ (in the form of petrol). (Let us ignore the fact that air and sea transport cannot be powered electrically, except via hydrogen; see below.) If we take Stern's assumed amount of biomass energy, 110 EJ, this would produce about 35 EJ of ethanol, leaving 255 EJ of transport energy to be found. This could not be provided via the production of liquid fuel from coal as the CO_2 in vehicle exhausts could not be captured. In any case the geosequestration quota has been allocated to electricity, above. Petrol driven cars are c. 40% energy efficient meaning that some 102 EJ would be driving wheels, and thus if electric vehicles were assumed this would be the quantity of energy that would have to reach the wheels. However, because the energy efficiency of the electricity-to-wheels path is c. 50%[27], some 204 EJ would have to be generated, almost 3.5 times the present world electricity production.

If this load is divided between wind and solar sources and each meets half of combined electricity plus transport demand, then wind would have to provide around 150 EJ/y, requiring at perhaps 300 times the early 2000s installed wind capacity. (Again, Trieb estimates European combined on- and off-shore potential at c. 4 EJ.) Similarly, the task for solar would be 3 times that stated above.

Hydrogen powered transport would probably double the amount of electricity to be generated, to 408 EJ, given Bossell's estimate that efficiencies and losses on that path are twice those for electric vehicles. (That this is plausible is evident if we optimistically assume .7 efficiency of hydrogen production from electricity, .8 for distribution, and .5 efficiency for future fuel cell drive, yielding an overall efficiency of 28%.)

Thus neither an electric nor a hydrogen powered transport option would seem to be viable.

At this point in the attempt to construct an energy budget we have accounted for low temperature heat, and electricity (by making some implausible assumptions) but we are far from explaining how transport could be fuelled. In addition there would be the remaining 124 EJ to provide for, 15% of the total 825 EJ energy demand. None of this is for electricity, which is all accounted for above, so if it is to come from wind or sun the energy losses in conversion (e.g., from electricity to hydrogen) would greatly multiply the primary quantity that needed to be generated, probably to 250 EJ. We have already assumed use of all the permissible coal (and that amount will not be permissible by 2100.) There would be special difficulty explaining how to provide the approximately half of liquid fuel demand that is not for transport, (i.e., half of some 60 GJ per person in Australia at present), given the above limits to ethanol from biomass, and to hydrogen.

It is evident from this discussion that conversion issues and loses are very important in the estimation of the potential of renewables. These are not taken into account in the Stern or IPCC Reports.

If we had taken much higher assumptions regarding geosequestration, 90% capture and the IPCC's mean estimate of 9 GT/y release permissible for 2050, we would have raised electricity production by 240 EJ, but at that rate of use coal resources would be exhausted in under two decades. The deficit would still be perhaps 200 EJ.

Again this has been a discussion of where sheer amounts might come from but it does not deal with the major problems which is how these sources might be stored and integrated. For instance on calm nights wind plus PV would be providing no energy at all. Evidence on the magnitude of the gaps likely to be left by wind and sun indicate that almost as much coal/nuclear capacity would have to be built as wind plus solar, in order to back up these renewables.[28] A lot of coal would have to be burned to plug those gaps. In addition coal plants cannot be ramped up to full output quickly. Oswald Consulting[29] finds that within a few hours there can be dramatic falls in the wind power output from a UK national wind system, in January which is the best month of the year for wind energy.

This failed exercise indicates that even assuming 9 GT/y of "safe" CO2 release it will not be possible to achieve an expected 2050 world energy target of 1100 EJ.

Conclusions on the reports

The argument has been that the conclusions these reports assert regarding the possibility and cost of greenhouse gas mitigation are seriously mistaken. It would be difficult to exaggerate the importance of this. Like the Stern Report, the IPCC Working Group 3 Reports have given the world three highly confident implicit conclusions. The first is that the greenhouse problem can be solved, the second is that it can be solved at negligible cost, and the third conclusion is that it can be solved without any need to question the commitment to affluent living standards and economic growth. This paper has argued that all these conclusions are clearly and profoundly mistaken. Whereas people within the "limits to growth" school have been arguing for half a century that consumer societies are fundamentally unsustainable, the Stern Review and the IPCC Working Group 3 Reports have reinforced the dominant faith and have therefore, seriously reduced the chances of the essential nature of the global sustainability predicament being recognised or of effective strategies being adopted.

The Simpler Way perspective on the global situation is that the alarming greenhouse, energy, equity etc. problems now threatening us cannot be solved within capitalist/consumer society but require vast and radical transition to very different economic, political and value systems and structures. This vision is detailed at The Simpler Way website.[30]

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