ELECTRICITY PRICE REVIEW

SUBMISSION FORM

How to have your say

We are seeking submissions from the public and industry on our first report into the state of the electricity sector. The report contains a series of questions, which are listed in this form in the order in which they appear. You are free to answer some or all of them.

Where possible, please include evidence (such as facts, figures or relevant examples) to support your views. Please be sure to focus on the question asked and keep each answer short. There are also boxes for you to summarise your key points on Parts three, four and five of the report – we will use these when publishing a summary of responses. There are also boxes to briefly set out potential solutions to issues and concerns raised in the report, and one box at the end for you to include additional information not covered by the other questions.

We would prefer if you completed this form electronically. (The answer boxes will expand as you write.) You can print the form and write your responses. (In that case, expand the boxes before printing. If you still run out of room, continue your responses on an attached piece of paper, but be sure to label it so we know which question it relates to.)

We may contact you if we need to clarify any aspect of your submission.

Email your submission to energymarkets@mbie.govt.nz or post it to:

Electricity Price Review

Secretariat, Ministry of Business, Innovation and Employment

15 Stout Street

PO Box 1473

Wellington 6140

Contact details

Name	**Geoff Henderson**
Organisation	**Windflow Technology Ltd**
Email address or physical address	**geoff@windflow.co.nz**

Use of information

We will use your feedback to help us prepare a report to the Government. This second report will recommend improvements to the structure and conduct of the sector, including to the regulatory framework.

We will publish all submissions in PDF form on the website of the Ministry of Business, Innovation and Employment (MBIE), except any material you identify as confidential or that we consider may be defamatory. By making a submission, we consider you have agreed to publication of your submission unless you clearly specify otherwise.

Release of information

Please indicate on the front of your submission whether it contains confidential information and mark the text accordingly. If your submission includes confidential information, please send us a separate public version of the submission.

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Private information

The Privacy Act 1993 establishes certain principles regarding the collection, use and disclosure of information about individuals by various agencies, including MBIE. Any personal information in your submission will be used solely to help develop policy advice for this review. Please clearly indicate in your submission whether you want your name to be excluded from any summary of submissions we may publish.

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Summary of questions

Part three: Consumers and prices

Consumer interests

1. *What are your views on the assessment of consumers' priorities?*

2. *What are your views on whether consumers have an effective voice in the electricity sector?*

3. *What are your views on whether consumers trust the electricity sector to look after their interests?*
In the sense of "interests" being in keeping the lights on, they generally do. In the sense of "interests" being in keeping prices down, they don't.

Prices

4. *What are your views on the assessment of the make-up of recent price changes?*

5. *What are your views on the assessment of how electricity prices compare internationally?*

6. *What are your views on the outlook for electricity prices?*

Affordability

7. *What are your views on the assessment of the size of the affordability problem?*

8. *What are your views of the assessment of the causes of the affordability problem?*
I agree except it omits excessive pricing across the sector, both by the monopoly parts and the generator-retailers. Non-transparent monopoly pricing of the long-term value of hydro storage needs to be addressed, along with the problems caused by vertical integration and the "Clayton's" wholesale electricity market (WEM).

9. *What are your views of the assessment of the outlook for the affordability problem?*

I agree but with the important caveat that solar panels and EVs are very desirable, and care needs to be taken to avoid the trap of letting old sunk costs act as a brake on progressive new technologies. Therefore the review needs to come up with ways to:

a) Stop distribution company and gentailer pricing structures extracting high monopoly rents which protect their sunk cost assets and disincentivize solar panels (regulated rates of return using ODV etc tend to be higher than commercial rates of return, whereas they should be lower to reflect the fact that they are monopoly businesses)
b) Apply user pays to EV charging infrastructure that is installed to enable charging during peak hours (in some cases this will fit with use of solar panels). Conversely, EV charging in off-peak hours should be incentivized.

Also if something would improve affordability in the long term (as the report asserts for time varying prices), it needs to be pursued. Change always causes "winners and losers" in the short term. The review needs to keep clarity about the two distinct reasons for time-varying prices:

a) Monopoly sectors (distribution and transmission) have peak <u>power</u> limits (MW) so it is good to incentivize things that smooth <u>daily</u> peaks and maximise off-peak usage
b) Generation has <u>energy</u> (MWh) (hydro storage) limits, which do not vary on a daily basis. Thus it makes sense to vary generation prices on a weekly or monthly basis, but not necessarily (or at least not so strongly) on a daily basis. This is particularly the case when wind power is added to the system, which has the effect of supplementing the hydro storage. A rational path forward for NZ (as more wind power is added) will be to increase the MW of hydro plant at existing lakes (not changing the dams, but adding penstocks and turbo-alternators) at dams where this can be done at relatively low cost. This will enable hydro to take more of a peaking role to utilize the extra MWh that wind farms allow to be stored, and minimize the need for thermal peaking.

Summary of feedback on Part three

10. *Please summarise your key points on Part three.*

Affordability for consumers cannot be separated from the issue of excessive pricing across the sector.

Solutions to issues and concerns raised in Part three

11. *Please* briefly describe any potential solutions to the issues and concerns raised in Part three.

a) Reduce monopoly rents in the distribution and transmission sectors by reducing allowable asset values and rates of return.
b) If ODV allows monopolies to value assets up to the cost of duplication (as implied by the name “optimized deprival value”), it is antithetical to good regulation of monopolies and should be scrapped.
c) Reinstate net metering for small renewables up to a certain limit (maybe as low as 5 kW) so as to incentivize household solar panels
d) Dedicated new EV charging infrastructure for peak-hour charging needs to be funded on a user pays basis (note that I drive an EV and have never needed to charge during peak hours). This comment does not apply to new generation and transmission, which can be funded more conventionally.
e) The vision of a zero-emission future needs to be embraced and the things that will go with it, i.e. solar PV on residential rooftops, EVs, and a massive investment in wind farms (nearly 5 GW according to Transpower) which will justify a re-optimisation of the country’s existing hydro power stations (by which I mean increasing the MW capacity, not the extreme lake levels, so that the addition of wind power gets treated as if hydro inflows, i.e. rain and snowfall, were reliably increased).
f) If a market design element has pros and cons in terms of tilting the playing field in favour of this vision versus tilting the playing field in favour of sunk costs, the market should err in favour of enabling this vision. (Nothing is ever perfect after all, and trade-offs have to be made. For nearly 30 years of establishing and running the WEM, those trade-offs have favoured the owners of existing assets.)

Part four: Industry
Generation

12. *What are your views on the assessment of generation sector performance?*

I disagree with many of the assertions about efficient competition. Obviously there has been more competition than previously in the old NZED/ECNZ days, but that is not saying much.

The focus on wholesale contract prices in Figure 14 is misplaced for two reasons:

a) the sector is dominated by gentailers. The focus should be on total margin for the gentailers which would then reveal the "weak competition among generators" that is the reality.
b) There has been very little liquidity in long-term contracts, which has acted as a barrier to real competition. The test of the market should be whether it enables independent generators to enter. NZ Windfarms's 48 MW project at Palmerston North is the only significant case in point and it has suffered commercially because of the cross-subsidisation that gentailers enjoy. NZ Windfarms could have been reasonably successful if, as implied by Figure 14, it had received 8 c/kwh (the figure it used for capital raising purposes) during 2010-2018. But the actual price in the spot market has been typically 4-6 c/kWh, while gentailers have built competing wind farms (at glut inducing scale) at costs more like 10-12 c/kWh, and geothermal plants (at glut inducing scale) at around 8 c/kWh, but free-riding on both carbon costs (due to negligible prices in the ETS 2008-2017) and resource-proving costs.

These projects have not been macro-economically wise (smaller wind farms of 30-50 MW would have been) and have served mainly to entrench the market position of the existing gentailers. The macro-economic folly of inducing gluts has undoubtedly fed through to high retail prices.

Generation is the only segment of the electricity sector where competition should yield significant macro-economic benefits. The competition to build the next increment of generation should be a real competition to install the smallest lumps necessary to get both economies of scale and a multitude of players to keep long-term prices down.

Instead we have a Clayton's competition where:

a) large gentailers take turns every few years to build another glut-inducing project
b) they can pass on the costs of any over-investment to their retail customers
c) the wholesale market only "discovers" the short-run marginal cost (state of the lakes that week/month/season)
d) most transactions in that market are "between the pockets" of gentailers, i.e. not with third-parties
e) there is little liquidity in long-term contracts
f) most years there is a cross-subsidy from each gentailer's retail arm to its generation arm (hence high retail prices). This suppresses competition by any independent generators
g) occasionally the cross-subsidy can go the other way. Thus independent retailers are equally vulnerable to being squashed by the large gentailers. This can be presented as a natural cycle to reflect the need for new generation, but how can a long-run decision be properly signalled by a short-run price?

The review panel is right to have "concerns about short-term market power", and how this has become long-term market power. One needs to ask "who has the power to set prices?". It is the vertically integrated oligopoly of the big five generators. Not to say that they collude, they do not need to - their natural behaviour has oligopolistic effects.

13. *What are your views of the assessment of barriers to competition in the generation sector?*

The assessment seems to have asked the question "are there numerous generators of more than 1 MW in New Zealand?" Finding the answer is 34 (most of them simply self-generating in dairy factories or whatever), it states that this "suggests relatively low barriers to competition".

I would suggest instead that the review panel needs to ask a different question, based on the fact that New Zealand typically installs 100-500 MW of new generation each year, and it is macro-economically important not to over-invest: "how many generators of more than 30 MW are there in New Zealand, and how many of them competed to build the last time 100 MW was installed in a year?"

The answer to the first part is a much smaller number (fewer than 10 I would estimate). As for the second part, it's normally only one. The large generators don't compete in the sense that a project costing 12 c/kWh gets shut out by a project costing 8 or 10 c/kWh. Projects have gone ahead at both levels, and at a scale that is too large for an economy the size of New Zealand's to realise true competition.

I agree with the assessment that vertical integration is a major barrier to competition and would suggest that the review panel embraces a vision of multiple projects of 30-50 MW scale per year (number per year depending on demand growth) as being the objective and yardstick of competition in the generation sector.

If glut-inducing projects continue to be built as they have been, one has to ask what the point of a competitive market has been. Why not revert to a single-generator model?

14. *What are your views on whether current arrangements will ensure sufficient new generation to meet demand?*

I agree with the review's comments in general, but with two qualifications:

- wind farms will be built more cost-effectively if they are built in 30-50 MW increments in a more competitive market (as set out above)
- re-consenting to enable larger wind turbines is a bad idea. Landscape effects are the biggest barrier to wind power's acceptability worldwide and New Zealand's experience is no exception. Mid-size turbines produce 5 to 10 times more energy per square kilometre of visual impact than large turbines. Large turbines have been developed for offshore wind farms which are irrelevant to New Zealand. At onshore sites globally, they manage to offset the square-cube law which would otherwise make them more expensive than mid-size turbines, but only by installation on the flat plains of northern Europe, the US Midwest and China. Mid-size turbines could in fact be more cost-effective than large turbines at many ridge-top sites in New Zealand. This should at least be tested seriously at the project finalization stage. Therefore if anything, re-consenting for mid-size turbines should be considered.

Retailing

15. *What are your views on the assessment of retail sector performance?*
I like what Flick and others are doing, though I worry that they will be squashed by the big gentailers whenever it suits them to allow WEM prices to rise (eg at present).

16. *What are your views on the assessment of barriers to competition in retailing?*
Long-term prosperity for retailers like Flick will require either: a) They join the club of gentailers and acquire some hydro storage, or b) The market structure is changed (eg as a result of this review) to remove the market power of the big 5 gentailers.

Vertical integration

17. *What are your views on the assessment of vertical integration and the contract market?*

See above under questions 12 and 13. New Zealand's wholesale market has failed in its primary objective of creating a free market for new generators because it has been structured so that only vertically-integrated gentailers with hydro storage can prosper. Thus it has become a club of five, with market power to shut out both competing independent power producers (IPPs) and retailers. Not at the same time of course, these things move in cycles. Five years or so of artificially low wholesale prices will do the trick of killing any IPPs. Then a few months of artificially high wholesale prices will do the trick of killing the "Flick"s who have dared to enter during the period of low WEM prices.

This objective of creating a free market for new generators is macro-economically important for two reasons:

a) In general it is important because generation is the only sector that involves large infrastructure investments <u>and</u> is not a natural monopoly
b) In times of rapid technological change, new entrants are far more likely than incumbents to challenge the status quo and bring in new ways of generating power and meeting customer's needs for energy services.

For example, New Zealand has so far squandered the opportunity that Windflow presented of establishing local turbine manufacturing. In part this has occurred because the WEM handed market power to incumbents who have reluctantly embraced wind power, and then worked to squash the visionary IPP that Windflow established by building wind farms at glut-inducing scale.

As a side note, this was done with exclusively foreign wind turbines, not because the foreign turbines are better or delivered lower cost of energy than Windflow's turbines (they aren't and didn't), but because of a combination of the "buy IBM" (big companies like buying from big companies and thus the glut-inducing scale becomes self-reinforcing) and the "techno-cultural cringe" that New Zealand still suffers from.

18. *What are your views on the assessment of generators' and retailers' profits?*

See above under question 12. Focus on contract prices is misplaced as the focus needs to be on gentailer margins. Also there has been no liquidity in those contracts. It is not accurate to say that any significant volume has been bought at the contract prices shown in Figures 14 and 20. Thus they are not a good guide to gentailer profitability. Figure 20 has the qualification "net cash flows are volume-weighted". It is unclear what this means but if (for example) it means that all gentailers are assumed to have the same cost structure and profit margin per kWh, then this is inherently not going to reveal anything about gentailer profitability. This looks to be an example of "begging the question".

Given that a major purpose of the review is to determine whether the retailers are making excess profits, the failure to provide a "definitive assessment" would seem to be a major shortcoming.

Transmission

19. *What are your views on the process, timing and fairness aspects of the transmission pricing methodology?*

Overdue and muddled by the attempts to reconcile different interest groups.

The right answer is to charge generators for 100% of the transmission network. Taken to its fundamentals, this is because it is cheaper to move generation to the North Island than it is to shift Auckland to the South Island. Cities have more inertia and longer time-constants than power stations.

In other words, we cannot incentivise cities to move closer to generators, therefore we should not try to. We can incentivise generators to move closer to the load, therefore we should try to.

To a great extent this principle applies to new generation in that it has to pay the full costs of new connection. To level the playing field (new generation vs existing generation) the same rule needs to apply across the board. It is not fair to have a competition between existing generators (for whom the transmission assets were put in by the taxpayer) and new generators, who have to meet the incremental cost of adding to the transmission and distribution systems. It is not appropriate to say "the end consumer pays in the end" and thus allow existing generation a free-ride by lumping the consumer with these costs directly.

As regards the drawn-out EA process, I agree this has been unacceptable. Perhaps the best solution is to transfer responsibility for this issue to the Commerce Commission.

Distribution

20. *What are your views on the assessment of distributors' profits?*

Asset values are the elephant in the room. Further scrutiny of these is warranted and especially the philosophy of ODV if it has the effect of over-valuing sunk costs to the detriment of socially beneficial new investments like solar PV.

21. *What are your views on the assessment of barriers to greater efficiency for distributors?*

22. *What are your views on the assessment of the allocation of distribution costs?*

23. *What are your views on the assessment of challenges facing electricity distribution?*

Consolidation (fewer distributors) is an obvious issue to address, though I can not comment on whether this would overall deliver significant benefits. If it resulted in some of the bigger ones re-entering the gentailer market, this would be a good thing.

Summary of feedback on Part four

24. *Please summarise your key points on Part four.*

The biggest problem to be addressed is the market power of the vertically-integrated gentailers. It has prevented healthy competition (as judged by the ability of new entrants to prosper) in the only competition that is macro-economically important, which is the competition to build new generating capacity.

Solutions to issues and concerns raised in Part four

25. Please briefly describe any potential solutions to the issues and concerns raised in Part four.

The review panel should embrace a vision of multiple projects of 30-50 MW scale per year (number per year depending on demand growth), **some of which are built by IPPs**, as being the objective and yardstick of competition in the generation sector.

Cross-subsidies between the generation and retail parts of the gentailers need to be eliminated. Much greater depth and liquidity of long-term wholesale electricity contracts needs to be created, so that all generators are able to purchase long-term hydro capacity as backup (5-10 year horizon), not only those who own the country's hydro power stations. There is a case for splitting the generators and retailers (as has happened in other countries) as a step to achieving this. There is also a case for putting all the large generators back together and re-nationalising them, so that the hydro storage (which was created by the NZ taxpayer) can become a shared market resource.

However a less draconian measure, which may be sufficiently effective, would be to require a transparent market be established for the value of long-term hydro capacity. Thus all players could buy cover on a 5-10 year horizon, instead of each player having to own his own hydro storage. This would then signal the need for new generation on a long-term basis which would ensure a healthy market for long-term power purchase agreements (PPAs), which are needed to finance an independent power project.

Part five: Technology and regulation

Technology

26. *What are your views on the assessment of the impact of technology on consumers and the electricity industry?*

27. *What are your views on the assessment of the impact of technology on pricing mechanisms and the fairness of prices?*

28. *What are your views on how emerging technology will affect security of supply, resilience and prices?*

Regulation

29. *What are your views on the assessment of the place of environmental sustainability and fairness in the regulatory system?*

New Zealand (and the world) needs a market where zero-net emissions of greenhouse gases (GHGs) competes against zero-net emissions. I have written many submissions on this over the years, including three this year to the Productivity Commission, Zero Carbon Bill and ETS consultation processes. I attach a summary of my thoughts on climate change.

It is government's role to ensure that this level-playing field is created so that fossil-fuelled businesses and others that profit from GHG emissions (for example the owners of geothermal power stations) cease to free-ride on the climate insecurity of future generations.

Ideally this will be achieved by measures separate from the WEM. To the extent that it is not, and to the extent that government has responsibility for the operation of the WEM, it would be appropriate for government to ensure that the WEM (which is 80-85% zero CO_2 already) at least moves quickly to zero net emissions.

Technologically this can be achieved by adding wind power and solar PV to meet demand growth, increasing the capacity (MW, not storage) of our existing hydro power stations, and replacing the country's thermal stations with wood-fired power to provide back-up for dry, calm months or years.

If the WEM incentivises these things, it will be seen as environmentally successful. If coal-firing continues, it will not.

30. *What are your views on the assessment of low fixed charge tariff regulations?*

31. *What are your views on the assessment of gaps or overlaps between the regulators?*

32. *What are your views on the assessment of whether the regulatory framework and regulators' workplans enable new technologies and business models to emerge?*

33. *What are your views on the assessment of other matters for the regulatory framework?*

Summary of feedback on Part five

34. *Please summarise your key points on Part five*.
If the WEM incentivises the rapid transition to a zero emission future, it will be seen as environmentally successful. If coal-firing continues, it will not.

Solutions to issues and concerns raised in Part five

35. *Please briefly describe any potential solutions to the issues and concerns raised in Part five.*

New renewable energy systems need two things:

a) A level playing field as regards emissions, i.e. zero-net needs to compete against zero-net
b) A level playing field for progressive new technologies (like solar PV, EVs and wind farms) that tend to be championed by “early adopter”, disruptive thinkers, and are often resisted by incumbents with interests tied to large sunk cost assets. Thus there needs to be real competition that allows new entrant IPPs a real chance to build the next increments of power generation.

Additional information

36. *Please briefly provide any additional information or comment you would like to include in your submission.*

Three Statements on Global Warming:

Science of Ice Melting, Fallacy of Denial and the Economic Solution

Background: I wrote two papers in 1998, about the fallacy of scepticism (denial) and the logical solution to climate change/global warming. These summarised what I had been saying and writing since 1988, that we can and should act to minimise climate disruption, and phase out fossil fuels (as we must inevitably, but shouldn't risk waiting for depletion to force us to). Given the abundance and proven status of sustainable solar energy (direct solar, wind, hydro and biofuels), the problem is clearly economic, not technical. We choose to burn fossil fuels because they seem cheaper. Therefore the solution must be economic, and the polluter-pays-principle leads one logically to Prof. Peter Read's TAO (tradeable absorption obligation).

The early 90s seemed hopeful that this message would be picked up globally and in NZ. Some landmark events:

- 1992: the United Nations Framework Convention on Climate Change (FCCC) and New Zealand's Resource Management Act (RMA)
- 1994: the Stratford hearings recommended the 400 MW Taranaki Combined Cycle (TCC) station go ahead only if they accepted a tree-planting obligation at 100% mitigation (but Minister Upton emasculated that recommendation and no trees have been paid for by TCC)
- 1997: the Kyoto Protocol, which clarified the "gross vs net" issue from the FCCC.

Since then two more decades have come and gone with little progress except the Kyoto Protocol achieved its limited aim among some developed nations (proof of concept, including afforestation as a mitigation measure being valued by nascent carbon markets) and inadvertently accelerated the development of the developing nations (carbon leakage, writ large). Paris 2015 was a sunny day in December, but still, we have the grotesque spectacle of powerful people appealing to society at large by promising that global warming is a hoax.

So I have added a statement about the science of global warming, being my attempt at a "zeroth" paper to act as a prequel to the other two. It provides this engineer's understanding of the science, based on undergraduate engineering thermodynamics and astronomy, combined with general reading over the years. That understanding is necessarily incomplete about the future (like everyone's) and cannot claim professional climate science expertise, but is perhaps better than average. Importantly it is informed by a professional engineer's appreciation of risk and probability.

All three statements herein are as accurate as I can make it, while staying within a limit of one page per statement (in the interests of brevity). However the word "isothermal" needs more explanation.

The first statement on the science uses the term "isothermal warming" in two senses. "Isothermal" applied to heat transfer processes means heat transfer that occurs across a zero temperature difference. While it is a theoretical ideal that mathematically requires infinite area across which the heat is transferring, it is an everyday reality that occurs at the phase boundary in any process where substances change state (e.g. water boiling to steam, refrigerants evaporating and condensing, and ice melting to water). Engineers thus use the term for system processes which involve circulating fluids which change state as they circulate.

The first statement, which is very much about ice melting, extends this idea to describe as "isothermal" how global warming, seen over a decadal time scale, could be an almost constant temperature process, rather than the relentless upwards trend of the thermometer. It is not sufficiently appreciated that ice melting and sea level rise could dominate in the 21st century, with further temperature rises (as measured by the atmosphere's global mean surface temperature - GMST) being relatively muted.

It seems plausible that GMST could stabilise temporarily in coming decades in a scenario where:

- Ice melting and sea-level rise take off exponentially
- Viewed on a decadal time scale, global warming will appear "isothermal" in the sense that I use the word
- Policy decisions based on a target to stabilise GMST will seem very foolish retrospectively.

Having said that, I would stress that currently only around 5% of net warming is going into ice melting. In future this could increase many times, and my purpose is to explain how and why it could, not to assert any certainty that it will.

In any event, it needs to be borne in mind that my use of the term "isothermal" is an engineering approximation in the context of an averaging period for which, as with the question of GMST rise, decade-long or longer average changes in the parameter (% of net global warming going into ice-melting) are most appropriate. For example, the third and fourth graphs below statement 1 illustrate how temperature could go up and down depending on how quickly the ice melts. In the third graph two points that are 300 years apart have the same temperature but sea level is 23 metres higher. One might say that represents 300 years of isothermal warming, although temperature is always changing during that time. Similarly in the fourth graph two points that are 70 years apart have the same temperature but sea level is 6 metres higher.

In the way that idealised processes (especially those that approximate natural processes) can be useful to our understanding, it is useful to ask "what if it were 100% isothermal", "what would it look like if it were significantly isothermal[1]", "could it become more so" and "could it approach or temporarily exceed[2] 100%". Engineering thermodynamics emphasises the efficiency of isothermal heat transfer, making it a preferred outcome for heat flows if the geometry allows and temperature and pressure are right for a phase change to occur.

The important message is to explain how large sea level rise may be more of a threat in the 21st century (at least to coastal cities) than large temperature rise. I hope these pages help to explain

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[1] Melting ice in a pot on a stove is significantly, but not completely, isothermal. The temperature of the water does not stay perfectly at 0°C, but goes up and down depending on how well it is mixed with the ice, how close the thermometer is to a piece of ice, and how much ice remains to be melted. But the resulting graph of temperature versus time is much closer to a horizontal line while the ice is melting, than it is subsequently when all the ice has melted and the water can then heat up linearly towards boiling point. Similar things may happen to the planetary temperature-time trace as the oceans slowly heat and ice-melt rates vary up and down around an accelerating trend line. **The slope of the temperature-time trace will be lower than what it would be in an ice-free planet.**

[2] Temporarily exceeding 100% is quite possible in principle. As an example, a "thermal bank account" of (say) five decades of 90% of the 400 TW going into ocean temperature could suddenly be drawn down, if very large amounts of formerly land-based, now floating ice, melt over one decade. If only a third of that "thermal bank account" were withdrawn, it would be 150% of the net global warming for that decade and would result in global ocean temperature reducing temporarily, though not to current levels. Noting that it would take a 10-fold or 20-fold increase in the water-ice area interface for ice-melting to account for 100% of net global warming, how much weight do we attach to news reports (around a large iceberg off Newfoundland) that iceberg counts in Atlantic sea-lanes in April 2017 were about six times the average for April? A sign of things to come?

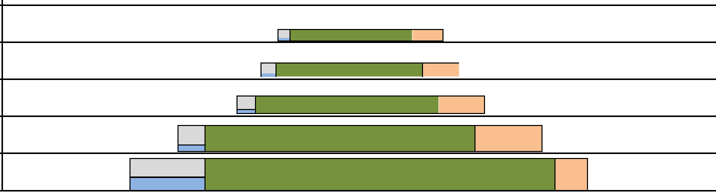
how atmospheric temperature and sea level are to some extent interchangeable threats of global warming. The atmosphere may not warm this century as much as the IPCC is saying, but if so it will be because ice is melting and sea level is rising. And conversely sea level may not rise this century as much as Jim Hansen is saying, but if so it will be because the energy is all going into temperature rise and hasn't yet soaked through to the ice. And in either case, there could be temperature pauses while ice-melting dominates for a while. As the little poem on the next page says, "ice has no agenda – it just melts".

Another way to express this point graphically is with a shaded chart showing what global warming (being the rate of thermal energy accumulation, in terawatts, TW) breaks down into:

Global Warming (Net Response to Extra GHGs – not to scale)		
Latent Warming (Ice-melt, no temperature rise)	Sensible Warming (Temperature Rise)	
Floating Ice (no sea-level rise)	Ocean	Air (including GMST)
Land-based Ice (sea-level rise)		

Using the same colour key as above, the following chart is indicatively scaled to show that mainly ocean warming has taken place in the four quarters of the 20th Century and in the first quarter of the 21st Century. The bars are also indicatively scaled to the changing rate of global warming (note that the CO_2 concentration drives the amount of warming, hence the bars for the early 20th century are a lot smaller). At the right of each bar is the resulting approximate value of GMST, based on a 19th Century value being estimated at 13.5ºC, and sea-level relative to the 19th Century.

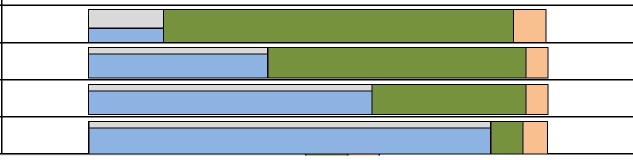
Global Warming 1900-2025



Quarter Century		GMST (ºC)	Sea-level rise (m)
1900-1925		13.6	0.02
1925-1950		13.7	0.05
1950-1975		13.9	0.09
1975-2000		14.2	0.15
2000-2025		14.5	0.23

The next chart illustrates what could happen in the 21st Century, now that the air and ocean have warmed up a bit, if this is sufficient (as the great scientist, James Hansen, maintains) to drive rapid ice break-up from Greenland and West Antarctica. A simplifying assumption is that the net global warming (~400 TW) somehow remains constant. Note that this is for illustrative purposes only. Predicting the TW requires knowing the non-equilibrium combination of CO_2 concentrations (which "force" the warming), and GMST, ice-melt and the other response functions, requiring models which are beyond this author's expertise, and arguably remains an elusive goal of the best climate models.

Global Warming 2000-2100?



Quarter Century		GMST (ºC)	Sea-level (m)
2000-2025		14.5	0.23
2025-2050		14.6	0.75
2050-2075		14.7	1.75
2075-2100		14.8	3+

At 14.8°C, GMST would have only risen 1.3°C since 1900, illustrating how a 2°C or even 1.5°C limit may not protect us from sea-level rise that we have now "locked in" for subsequent centuries, even if not as rapid in the 21st century as indicated above. This would be very costly for countries like New Zealand that are highly urbanised around the coast.

Urgent and radical action is needed in any event, with focus needed on parameters other than GMST; being CO_2 concentrations, TW of warming and metres of sea-level rise. These may become decoupled from GMST (°C) because ice-melting is an isothermal process.

Structure of this Document: With this 4-page background and its explanation of how the word "isothermal" is used in Statement 1 behind us, the rest of this 16-page document consists of:

- A very brief poem about ice (below) to introduce Statement 1
- Three 1-page statements, each accompanied by a page of illustrations, so 6 pages total
- 4 pages of frequently asked questions about Statement 3, the Economic Solution
- 1 page of bibliography/suggested further reading and viewing
- 1 page for a postscript on dynamic modelling.

Every sentence is as accurate as I can make it. I chose 1-page statements in the interests of brevity. If anyone finds an error of logic or fact, please let me know.

Geoff Henderson, October 2018

Ice has no agenda – it just melts.

Ice asks no questions, presents no arguments, reads no newspapers, listens to no debates.
It's not burdened by ideology, and carries no political baggage
as it crosses the threshold from solid to liquid.
It just melts.

Dr Henry Pollack
Emeritus Professor of Geophysics, University of Michigan
Author of "A World without Ice", 2009
https://www.youtube.com/watch?v=ZY-pO_zTVvU

1. Climate Science: Warming = Heat Transfer, Ice Melts and Temperature Barely Changes

400 parts carbon dioxide per million has not been natural for many epochs. For a million years, 200 to 300 parts per million have been the norm, while Sapiens has taken over, an even narrower range in the last ten thousand, when stable climate has allowed civilisation to develop. So Earth's energy balance has been disturbed. The sun pours 178,000 terawatts on Earth, and 178,000 normally leaves. For millennia the net gain has averaged zero. Since 1900 it has grown to 400 terawatts. Global warming's 400 dwarfs the 30 terawatts used by humanity (a rate itself many million times faster than some biofuel has fossilized over a billion years).
How then is the warming not sensible, and so many people not sensible to it?

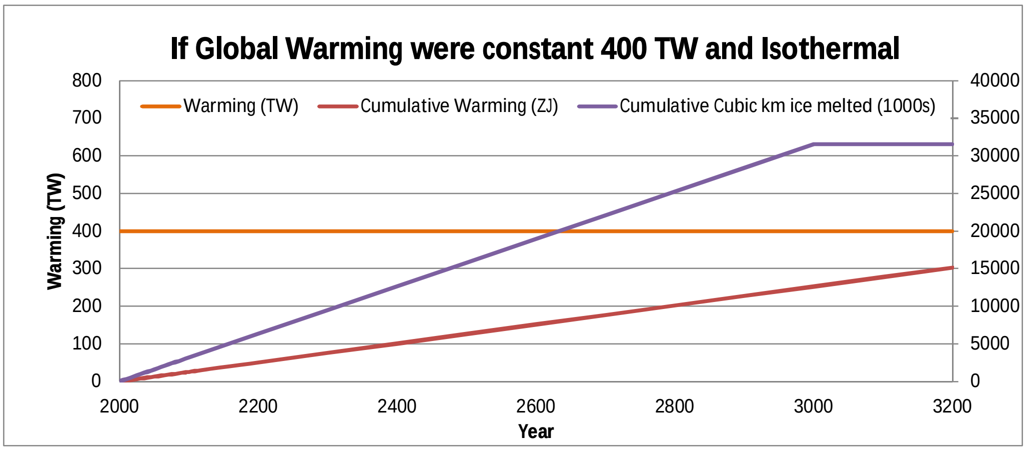
"Warming", "heating", "cooling" are words about energy, not necessarily temperature. The oceans keep the air cool, and the ice keeps them both cool while melting isothermally. The 400 terawatts is mainly being taken up by the oceans. Were global warming all isothermal, (in part it is), it would always all go to the ice. To date it's a small part, in future the ice will take it more. And melting ice takes a lot of energy: local temperature doesn't change but for one kilogram, the energy is enough to raise a kilogram of water's temperature by eighty degrees Celsius, or reduce eighty kilograms' by one. So zero Celsius is a dynamic attractor at some latitudes.

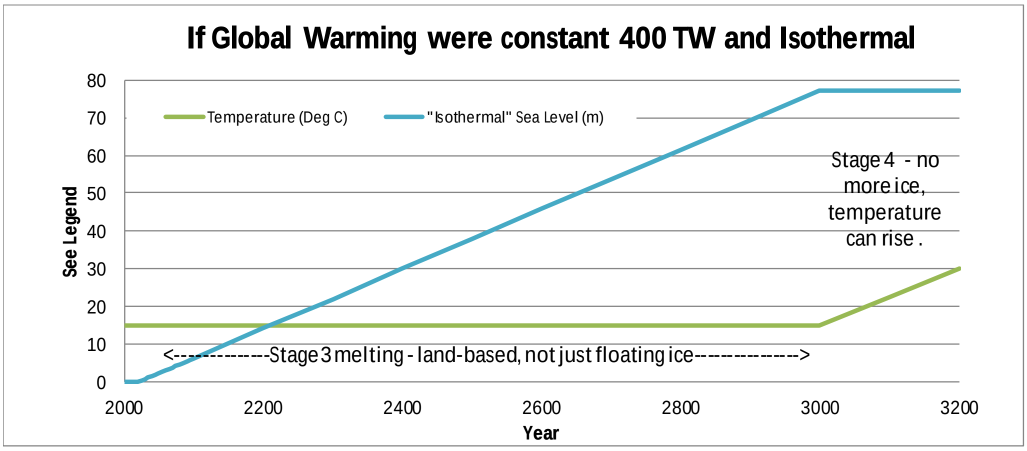
Isothermal warming of Earth would have four stages: 1) it would require a small temperature rise to get it started; 2) only floating ice would melt, while temperature and sea level would barely change; 3) the land-based ice would also melt, temperature would barely change, sea level would increase eighty metres; 4) with all ice gone, the warming no more isothermal, the world Jurassic again, temperature would ramp up more quickly – like the esky when the ice pads have thawed. The 20th century's warming has been a lot like stages one and two. Any wonder we find pauses in temperature and argue about millimetre measurements on tide gauges? Are we now moving into stage three as the 20th century has become the 21st?

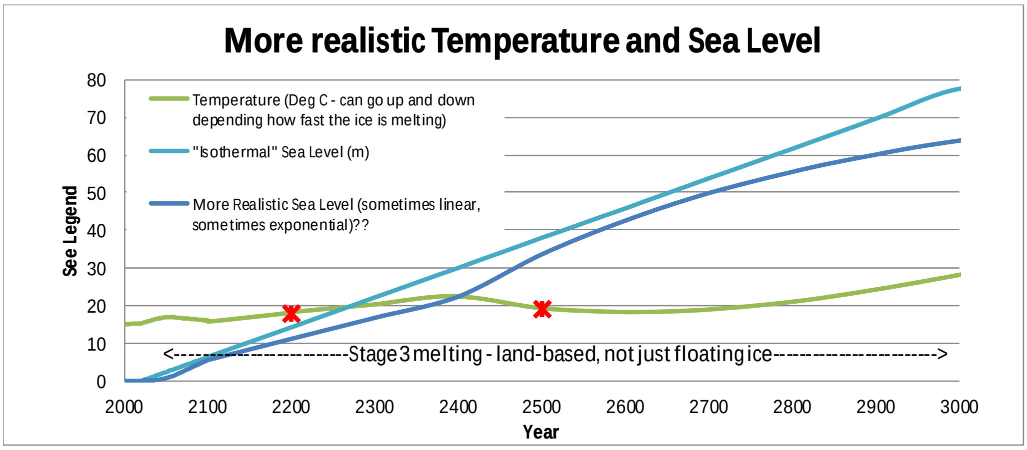
The planet, an oblique, orbiting rotisserie, mixes the heat around better than the atmosphere and oceans (each a millimetre deep for every metre across) could otherwise. Large ice shelves and bits of ice sheets melt and refreeze each year. How much then is global warming isothermal? How much will it be? These are big questions, the same as asking how quickly all ice would melt if we don't phase out fossil fuels quickly.

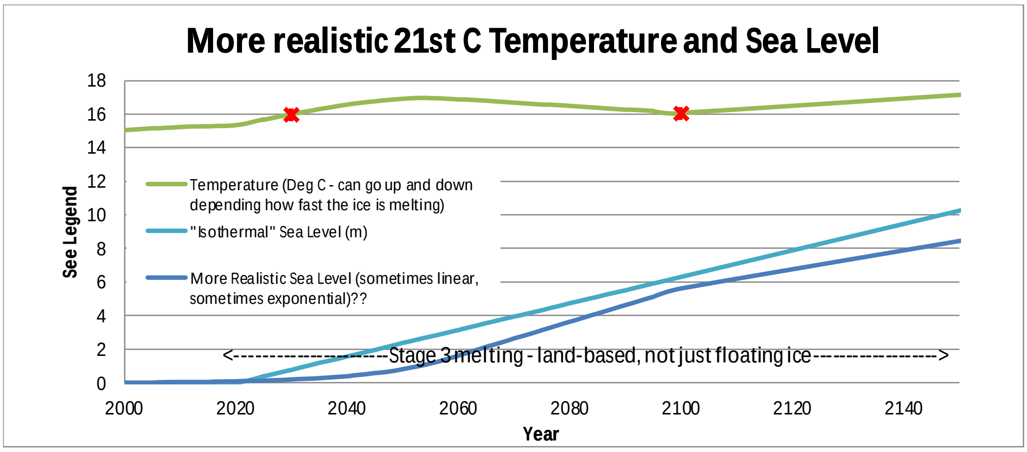
Air-ocean models can't model this, air-ocean-ice ones are a work-in-progress. Gravity satellites can measure the melting from land: Greenland looks exponential. The doubling period will be clear with another decade's data. Without strong action now, Jim Hansen says sea level will rise, by 2100, five metres from Antarctic and Greenland ice. I'd not bet against this great scientist. 400 terawatts is enough to do it. While the ice/water interface area needs to increase ten-or twenty-fold, there's more than one mechanism for that to happen. Ironically (for those politicians whose ignorance of science leads them to think this would disprove global warming), global air temperature may change little, may reduce at times. Mid-latitudes may get more snow, as the poles shed great chunks of ice.

That's how ice melts: it perforates and breaks into smaller pieces, and turns to water while temperature barely changes. Who wants to risk 5 metres by 2100? Cui bono est? Will the fossil fuel companies pick up the tab, if all those coastal city-dwellers are forced inland?


If Global Warming were constant 400 TW and Isothermal
Warming (TW)
Cumulative Warming (ZJ)
Cumulative Cubic km ice melted (1000s)
Warming (TW)
Year


If Global Warming were constant 400 TW and Isothermal
Temperature (Deg C)
"Isothermal" Sea Level (m)
Stage 4 - no more ice, temperature can rise .
<---------------Stage 3 melting - land-based, not just floating ice--------------->
See Legend
Year


More realistic Temperature and Sea Level
Temperature (Deg C - can go up and down depending how fast the ice is melting)
"Isothermal" Sea Level (m)
More Realistic Sea Level (sometimes linear, sometimes exponential)??
<--------------------------Stage 3 melting - land-based, not just floating ice------------------------->
See Legend
Year


More realistic 21st C Temperature and Sea Level
Temperature (Deg C - can go up and down depending how fast the ice is melting)
"Isothermal" Sea Level (m)
More Realistic Sea Level (sometimes linear, sometimes exponential)??
<--------------------Stage 3 melting - land-based, not just floating ice------------------>
See Legend
Year

2. The Logic of Action - Based on 1998 paper – "The Fallacy_of_Climate_Skepticism".

Climate denial uses uncertainty about climate modelling to justify international inaction on reversing emission trends. This is not a respectable position. Uncertainty over climate outcomes from 400 terawatts of energy imbalance is an argument for action, not inaction. Uncertainty means different scenarios are possible in the 21st century. Proper risk analysis requires the full range of probabilities to be considered. The outcomes (rationally) must be some measure of cost:benefit ratio, the cost of inaction versus the benefit of inaction to the economy. The probabilities (rationally) must add to 100%. Let's consider four types of outcome of inaction, and estimate the probabilities.

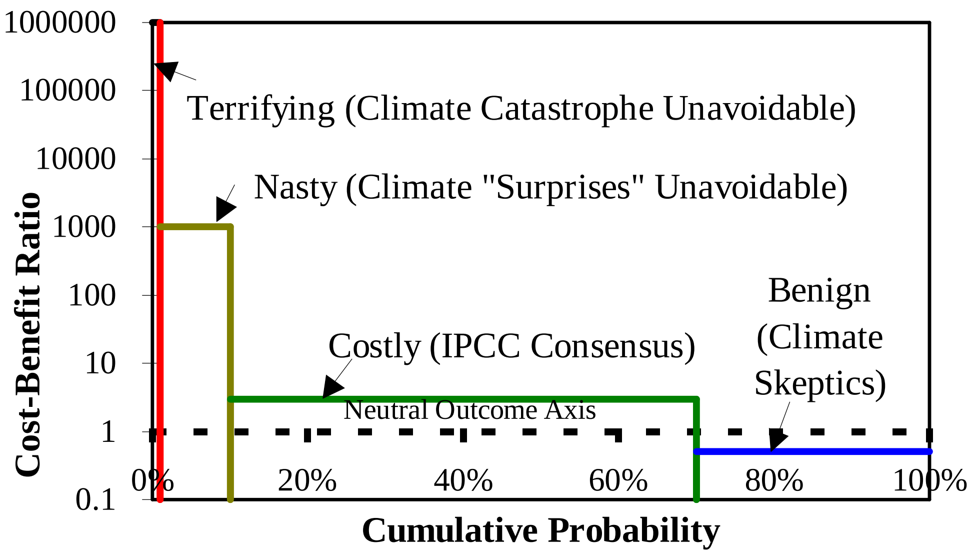
Denial amounts to asserting the outcome will be benign, a cost:benefit ratio less than one because we'll be better off allowing it (more than 450 ppm or whatever) to happen than acting to reverse it. So give "Benign" the first bar on the cumulative probability graph, and the benefit of the doubt that Benign is a serious probability, say 30%.

The second type of outcome is "Costly", a cost:benefit ratio greater than one, whereby we'll be worse off allowing it (more than 450 ppm) to happen than acting to reverse it. This is what the scientists whose job it is, commissioned by the governments of the world to advise us, are saying. I suppose the Intergovernmental Panel on Climate Change (IPCC) could just be job-creating public servants, but let's give them the benefit of the doubt that they know what they're doing and they don't have obvious conflicts of interest. (Or read Statement 1 if you want to understand more of the science for yourself.) They should be more correct than the denialists who are driven by their personal interests to wilful ignorance and wishful thinking. (And who doesn't wish at times for an infinite planet, and the easy road of fossil fuels?) Call the probability of "Costly" 60%.

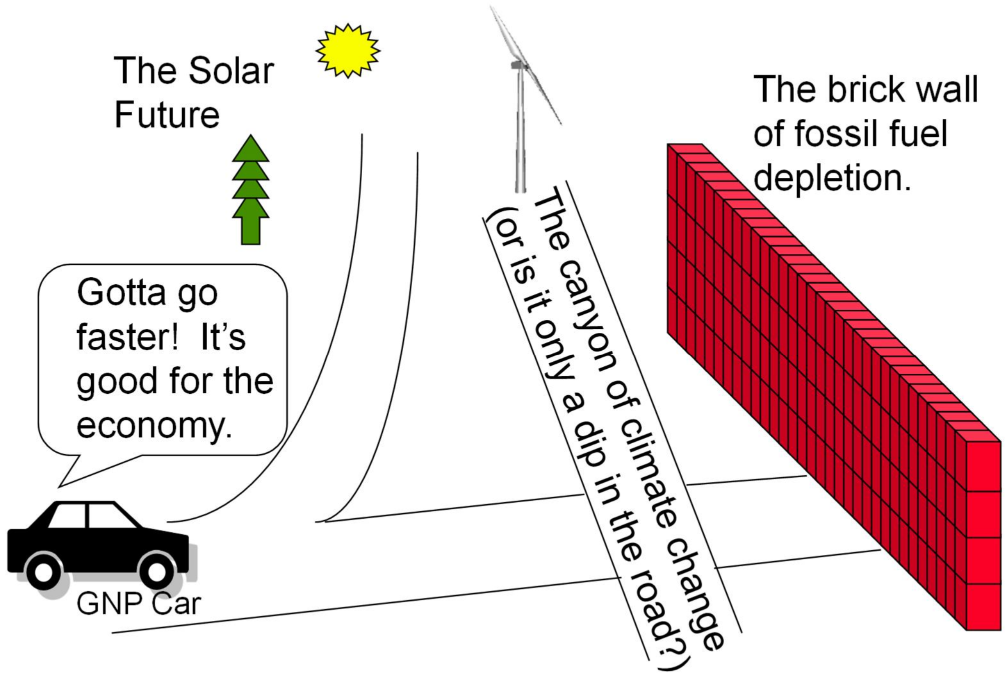
Then there is "Nasty". There are top scientists outside the IPCC (like Jim Hansen) who were saying 350 ppm is the safe limit long before the IPCC said 450 might be safer than 600. Some top scientists were less surprised than the IPCC that the ice is melting faster than their models say. Five metres sea level rise this century (as Jim Hansen predicts if inaction continues) would displace hundreds of millions of people and destroy millennia of human history in London, Shanghai and the rest. The bar on the cost:benefit graph is much higher (costlier - and note that the scale is logarithmic to accommodate this) - so costly we are talking about breaking the bank of human civilisation - though we'll call the probability (in deference to the IPCC's rigorous work estimating 1 m) only 9%.

That leaves a 1% probability to remind us that they have to add up to 100% and (like responsible engineers who design planes and boilers this way) we have to ensure Murphy's Law doesn't bite us when the consequences are high. Call it "Terrifying" and, if you like, break it up further into fractions of a percent for Lovelock's "population less than 1 billion", or "Mass extinction" or "Runaway Greenhouse Effect". The bar is very skinny, but very tall - an experiment in logarithmic consequences we should not be messing with – though planet Earth is less at risk than our 'civilisation', built (as the Latin derivation suggests) by citizens of coastal cities.

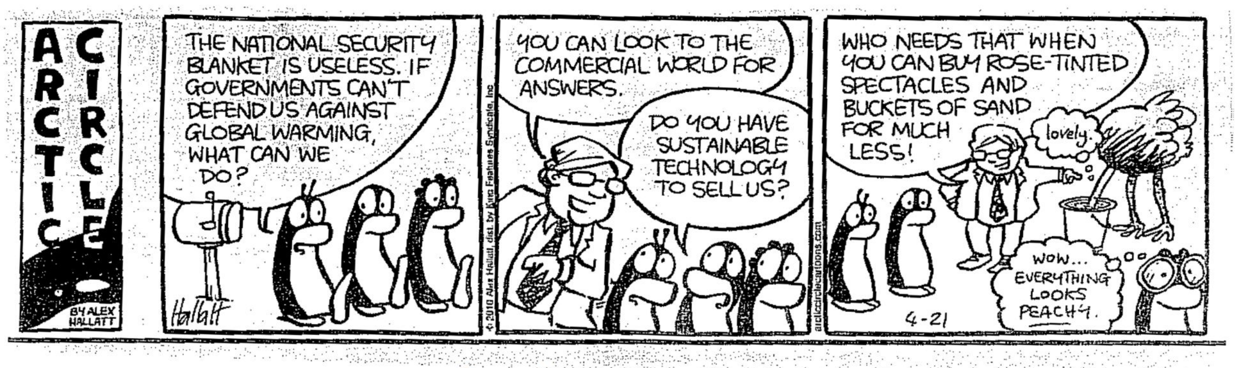
The fallacy of climate denial is that it assumes only one of these scenarios. Another common, related fallacy, is that action is macro-economically costly. But creating new industries will offset the phase-out of old industries. We didn't leave the Stone Age 'cos we ran out of stones. We won't leave the Fossil Age 'cos we're running out of fossils.



Atmospheric Carbon Dioxide >450 ppm by 2100: Possible Outcomes from Inaction



How about a change of direction?



Sums it up really ....

3. The Solution is Economic - [1998 Paper – "Creating the Right Climate: The Economic_Solution"].

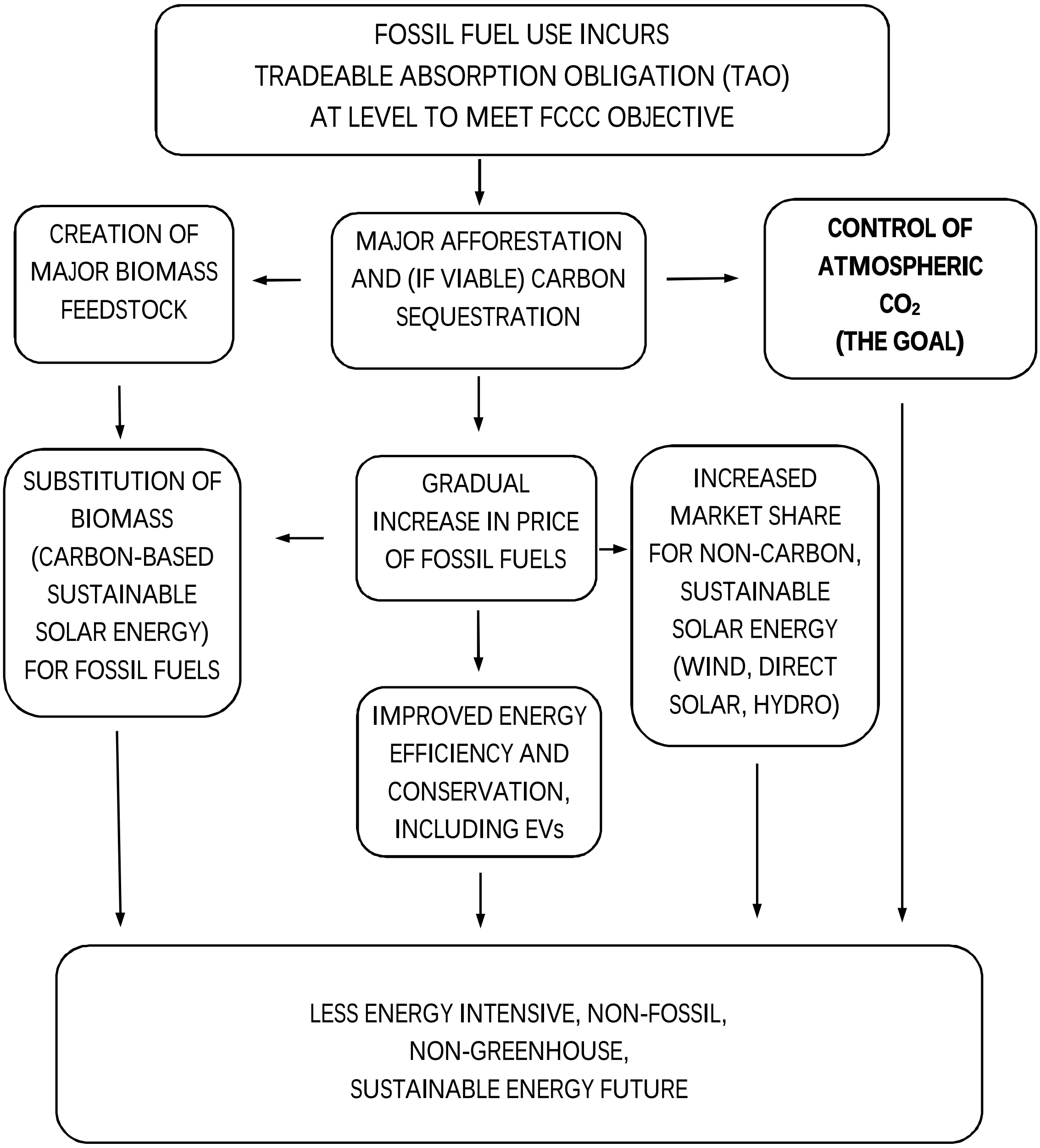
Global warming is an economic problem. We use fossil fuels because they seem low-cost, and the energy released by oxidising their carbon and hydrogen has powered 300 years of human industry. Fossil fuels are solar energy stored over hundreds of millions of years that we are burning in hundreds, a million times faster than they can be sustained. They provide a massive bank account, whose principal we deplete and, in so doing, return the atmosphere toward its Paleozoic state. The technical solution is to use sustainable solar energy: direct solar, wind, hydro and biofuels (the latter two providing storage). It is an abundant resource: the sun pours 178,000 terawatts on Earth 24 hours a day, 365¼ days a year, more than 5,000 times more than humanity "uses", or more accurately "converts more or less wastefully to low-grade heat" before Earth re-radiates it to space.

With such abundance, five billion times the rate that solar becomes fossil energy, why do we use fossil solar instead of sustainable solar? I'll say it again – because the fossil solar seems cheaper. More than that, fossil solar is cheaper in the short term, because nobody has to pay the cost of harnessing the solar energy and storing it in a conveniently dense form. Sustainable solar having to compete with fossil solar is like an honest beekeeper having to sell honey in a market where you can buy stolen honey: the stolen honey will always be cheaper. Until one notices that the stolen honey causes long-term problems. To burn fossil fuels without absorbing their emissions is to free-ride at the expense of the climate security of future generations. This is the economic problem of global warming: how to regulate the market so that long-term costs are properly accounted for, or in the parlance "externalities are internalised" so as to avoid a "tragedy of the commons".

The economic solution to this economic problem is to ensure the polluter pays to absorb emissions, which will create a level playing field for the "honest beekeepers", the sustainable solar businesses. Zero-net emissions needs to compete with zero-net emissions. This idea has had many names since 1988: 100% remediation in accordance with the Resource Management Act, as recommended by the commissioners for the Taranaki Combined Cycle power station (but subverted by the NZ Government in 1994 so that not one tree has been planted by the station's owners), a carbon tax applied to afforestation, tradeable carbon certificates or emissions trading with sink credits. My favourite name is the one given by Prof. Peter Read, the Tradeable Absorption Obligation or TAO.

The TAO will push everything in the right direction. First it will cause major afforestation and (if viable) other forms of carbon sequestration. In turn that will cause three things to happen: atmospheric CO_2 levels will actually be controlled (which is the most urgent and important overall goal); a large biomass feedstock will be created (which will be able to be substituted for fossil fuels); and the price of fossil fuels will gradually, but faster and faster, increase by the Law of Supply and Demand. The increasing price of fossil fuels will also cause two things to happen: it will increase the market share for sustainable solar energy, both carbon-based (biomass) and non–carbon forms (wind, direct solar and hydro), and it will stimulate energy efficiency and conservation. Overall these responses will lead to a less energy intensive, non-fossil, non-greenhouse, sustainable energy future.

In summary, regulation so that the polluter pays the cost of achieving zero-net emissions, by the TAO or by any other name, will provide a least-cost, durable transition to a future of stable climate and sustainable energy. Its foundational rationale is as simple as the duty to clean up one's mess, not leave it for others, especially our children and grandchildren, to have to clean up.



The TAO pushes everything in the right direction.

Frequently Asked Questions about the TAO

1. Isn't forestry just a temporary solution?

No. This is a misunderstanding of the dynamics (flows, stocks, feedbacks) of the economic solution which has transient and steady-state elements. The transient will apply while we continue to burn fossil fuels, the steady-state will apply when we are using biofuels for our combustion fuel requirements instead (together with non-carbon sustainable solar energy, i.e. wind, hydro and direct solar power). The transient will require increasing amounts of land in forest, the steady-state won't. The power of this solution is that it internalises into the human economy the unsustainability of continuing to burn fossil fuels. Competition for the next hectare of land will force the price of fossil fuels up non-linearly to a level which will force them out of the market-place.

2. Won't it stimulate the wrong kind of forestry? What if it competes with land for agriculture?

In the context of the overriding need to control atmospheric CO_2 levels, the best kind of forestry is the one that grows fastest in each climate and terrain. This might offend the aesthetics of those who like slow-growing forests, and certainly national parks and other conservation areas should be preserved. Importantly, a price signal will be given to prevent deforestation. As for afforestation, it will normally take place on marginal lands, where it competes with neither national parks nor arable land. In the final analysis though, market competition (in the widest sense of that concept) will decide what land is used for, while proper regulation of the TAO will ensure sustainability. We can rely on the fact that food is more basic in humanity's hierarchy of needs than combustion fuel. We need to achieve sustainable combustion fuel production, closing the carbon cycle, just as we do (or rather need to, to the extent that we don't) for our food requirements.

3. What about other biofuels?

Liquid biofuels (mainly cane ethanol and vegetable oils/biodiesel) and gaseous biofuels (methane from sewage plants, landfill and agricultural sources) will have an important role in a sustainable solar future. Their market share will be determined according to abundance of local resources and the advantages of liquid and gaseous fuels. Thus when I use the term "afforestation" as a response to the TAO, it could equally be conversion of land-use to such purposes, or coppicing plantations rather than the normal type of commercial forest.

However, relative to liquid and gaseous biofuels, forestry can absorb more carbon per hectare during the transient period before fossil fuels can be phased out.

Furthermore wood-fired power is fundamentally cheaper than liquid or gaseous biofueled power. There will be growing demands for electricity world-wide (particularly with the upsurge of EVs), and wood-fired power has been developed at large scale in the last 30 years. Coal-fired power dominates generation in many countries, and wood-firing (in particular circulating fluidised bed combustion technology) is able to be directly substituted for it. It will not be as dominant as coal-firing has been, since wind power and PV power are lower-cost and will continue to gain market share rapidly world-wide. But wood provides energy storage, which complements the attributes of wind and solar power. It also suits combined heat and power systems, which are commonly built into New Zealand's many dairy factories that are presently coal or gas-fired.

4. Isn't trading carbon morally repugnant like selling indulgences?

No, this is a false equivalence. Selling indulgences involved taking money from people in exchange for a purported cancellation of guilt for moral crimes, weighing the material against the spiritual, and as immoral as a judge taking bribes. Trading carbon weighs the material against the material and (regulated properly) achieves desired outcomes of net emission. Energy, money and the carbon cycle are very closely interlinked and therefore should be traded against each other:

- One view of money is that it is the tradeable value of human energy. This is consistent with the observation that the economy (absent regulation to correct for the following effect) does not internalise the correct value of fossil solar energy. Not to say that sustainable solar energy will internalise the value of the actual solar energy, but it does inherently internalise the human energy required to harness that energy sustainably (unlike fossil fuels with their present degree of insufficient regulation).
- The Industrial Revolution has enabled us to harness other forms of energy than human and animal energy, and primitive biofuel, solar, wind and water devices, thus increasing productivity hugely. In the process we have become sufficiently sophisticated that sustainable solar forms can take over from fossil solar in providing the labour-saving and life-enhancing benefits of industrialisation. Modern synchronous wind turbines and foiling catamarans are hugely more efficient than 18th century windmills and schooners
- The carbon cycle is above all an energy cycle: photosynthesis takes in solar energy to remove oxygen atoms from CO_2 and H_2O to form organic compounds; respiration (or burning) releases that energy again by turning organic compounds back into CO_2 and H_2O.

Trading carbon is an economic way to address a very real problem of how to close the carbon cycle, weighing the material against the material. And what could be more moral than taking responsibility for cleaning up one's mess? "I will take a benefit by using energy which emits greenhouse gases into the atmosphere in one place, but (to the extent required by law) I will make sure I pay the cost of taking greenhouse gases out of the atmosphere somewhere else."

There is an argument that a carbon tax would be morally repugnant if the funds be not applied to absorbing the CO_2, because of the prospect of losing the funds in a government's consolidated accounts without a kilogram of CO_2 being absorbed. And there is an argument that governments are morally bankrupt while they procrastinate and prevaricate about putting laws in place to protect future generations. Governments should look after the interests of future generations, remembering that individuals all have a century at most to live, while nations should be around many centuries into the future. Certainly governments should aim for the least-cost way to absorb carbon, and thus "leave this to the market" as much as possible. If this means that the fossil-fuel companies should pay directly for afforestation, and own the future carbon credits/obligations as a result, this should be a good thing, as it would create an interest for the fossil-fuel companies to become tomorrow's biofuel providers.

5. Does the absorption obligation have to be 100%?

Logically speaking, the TAO will work at any absorption level, from 1% of emissions (99% net) to 100% (zero-net). It will also work at more than 100% to enable net absorption (which some experts say will be needed in future to lower atmospheric CO_2 levels), but in that case the costs would need also to be borne by energy users in general (not just fossil energy users), especially if by then the use of fossil fuels has been substantially phased out. In practice, governments seem likely to adopt trajectories of net emissions reductions. This suits the flexibility of the TAO. It can be also used for other greenhouse gases than CO_2 (eg agricultural methane).

6. Which is better, the TAO or a carbon tax?

The TAO (properly implemented) will provide certainty of the net emission quantity (tonnes of CO_2 and other GHGs) achieved, whereas a carbon tax will provide certainty of the price ($/tonne). In practice "certainty" is somewhat illusory as governments have been anything but constant in their policy settings and can change in 3 years or less. My strong view is that the "certainty" of the emissions quantity is the decisive factor in favour of the TAO, and I believe its political durability will be better than a carbon tax. This is because of its logical and moral foundation, which society will "buy into" more than another tax. People will understand the argument that we need to clean up our mess. A carbon tax, by contrast, requires people to trust government's ability to set the correct price of carbon (it can't, any more than it can set the correct price of a loaf of bread), as well as to understand that, over time, the government will adjust the price of carbon to obtain the desired emissions trajectory in order to clean up our mess (why have an indirect role in controlling the emissions trajectory when government can simply regulate the emissions trajectory directly?).

The only benefit of a carbon tax is to put a ceiling on the price of carbon so that fossil-reliant business has some certainty as to the forward cost. Even so, given the long timescales of energy-related investments, this is illusory at best, because the political cycle is so much shorter. In practice, governments seem likely to adopt a "hybrid" approach which will combine trading with a carbon tax acting as a price ceiling. This will work with a trajectory approach since the TAO will be cheaper than the tax predicts, and thus we will overperform relative to any trajectory, provided we enable the TAO in any regulations.

7. Isn't a fiscally neutral carbon tax easier because it provides tax cuts elsewhere to ease the political pain?

It's easier but less effective as a result. A fiscally neutral carbon tax, in theory, could result in no net emissions reductions. Imagine a consumer at a petrol pump. Last year it cost him $80 to fill his tank, which emits 140 kg of CO_2 every time he empties it by driving however many kilometres. This year a $100/tonne tax is introduced so it now costs him an extra $14 to fill his tank. But he knows he will get that back through the tax system, as surely as if the forecourt attendant simply handed him the $14 back. What incentive does he have to buy a hybrid car or an electric car? Not much. Does anyone have an incentive to invest in wind farms, or plant trees? Not as far as I can see.

In practice, the psychology of a fiscally neutral carbon tax could be slightly better than that, and it seems a good way to introduce a carbon tax to get people used to the idea. Back in the 1990s, that was not unreasonable. Nowadays the world has moved beyond the need for this, especially since fiscal recycling (without a penny going to the forestry sector for the absorption work of tree-planting!) will necessitate a very high nominal level (perhaps $1000/tonne?) for the psychological effects to be measurable in terms of emission changes. In turn, those very high levels will create political opposition of the usual "big government vs small government" kind.

8. Can you have both the TAO and a carbon tax?

Yes, as set out under question 6, a hybrid solution is quite possible. However it is expected that the TAO is the one that will drive net emission results, with the tax being there as a ceiling to enable political buy-in.

9. Won't carbon credits of dubious merit be mixed with respectable ones as happened with the Kyoto Protocol?

When Kyoto was being negotiated the principle of differentiated responsibility was predicted to create "carbon leakage". I remember being naïve enough to discount this, as I thought the developed "Annex 1" nations would not want to shut down whole industries to exploit the "carbon havens" that were being created by the others having no obligations. However the effect has been massive and has thwarted real progress in controlling atmospheric GHGs. An important benefit however has been the accelerated development of the developing nations as they (particularly China and India) have become the "factory of the world". In spite of all the air pollution and other ills of industrialisation, it is overall a good thing for the developing world to have significantly developed, with hundreds of millions being lifted out of poverty. And nowadays China leads the world in renewable energy (by a long way). The post-Paris settings are much more comprehensive, and the global challenge is at the same time more urgent but also more achievable, so the degree to which international trading can bring the price of carbon down will be much reduced. Thus Kyoto will prove to be a one-off product of its times.

At the end of the day, the Kyoto Protocol achieved its targets under its rules. The post-Paris rules will be tighter. Without an agreed international process, this issue cannot be addressed.

Ultimately a jurisdictional issue will come into play. Governments will be held to account by a combination of the UN process and political pressure from its citizens, local governments and corporate sector. What can a government control? It can only control what happens in its own country with any great certainty. The TAO lends itself well to government administrative processes through the land registry system. Absorption credits are tied to a piece of land through afforestation. While they can be separately traded from actual ownership of the land, the land registry processes can prevent double-dipping etc. By contrast, international trading will carry a greater risk and should only be undertaken with reliable counter-parties and under UNFCCC rules.

10. What about other government programmes like subsidies and targets for renewables (i.e. sustainable solar energy)?

These can supplement a TAO especially when the absorption obligation is less than 100%. Until zero-net emissions are regulated and achieved, there is no "level playing-field" for renewables and thus other complementary measures (like Australia's mandatory renewable energy target, MRET, scheme) should be continued.

Bibliography/Suggested Further Reading and Viewing

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Falconer W. (1996). "*Climate Change and CO_2 Policy: A Durable Response.*" the Discussion Document of the Working Group on CO_2 Policy, Ministry for the Environment, Wellington.

James Hansen's web-site and magnum opus, "*Ice melt, sea level rise and superstorms: evidence from paleoclimate data, climate modeling, and modern observations that 2°C global warming could be dangerous":*

http://www.columbia.edu/~jeh1/

https://www.atmos-chem-phys.net/16/3761/2016/

Dr Kevin Trenberth (National Center for Atmospheric Research, Colorado) web-site and video, "*Extreme Weather and the Changing Climate":*

http://www.cgd.ucar.edu/staff/trenbert/

http://www.cgd.ucar.edu/staff/trenbert/Presentations/Trenberth_Steamboat_Jan18.pptx

Professor Jennifer Francis (Rutgers University, New Jersey) web-site and video, "*Crazy Weather and the Arctic Meltdown: how are they connected?":*

https://www.jenniferafrancis.com/

https://www.youtube.com/watch?v=wtmuBoolHQg

Professor Paul Beckwith (University of Ottawa) web-site and video, "*Zero Arctic Sea-Ice by 2020?":*

https://paulbeckwith.net/

https://www.youtube.com/watch?v=ezdiqPEDXKE

A Postscript on Dynamic Modelling

Regarding Statement 1 and the use of the term "isothermal", I am aware that some dynamicists may take exception to the way that I use this term. Some will say that I am simply restating the well-known fact that ice-melting will introduce a time lag in the GMST trend.

This would be a correct observation at one level, because that is indeed another way of looking at it. However it also highlights a few big problems in the context of global warming science:

- Existing models are known to be weak in how they quantify this "lag". This follows from the fact that the best existing models are primarily fluid dynamic models of the ocean-atmosphere system. The solid modelling of structural break-down, ice perforation, glacial flow and heat transfer from water and air into ice is relatively unvalidated because of its inherent computational difficulty. To date, the evidence shows that the modellers have underestimated the rate of ice-melting. I am not qualified to comment, but I have my doubts that the models will overcome this problem in the time required. In other words, the only validation possible may be by continuing to run the global warming experiment, putting at risk human civilisation which has developed in a stable climate. This is not acceptable.
- The fact that the lag in GMST is a major unknown invalidates the use of GMST as a policy objective. Somehow this simple logic has been overlooked in the IPCC process as "stabilising GHG concentrations" has become "avoiding 2^{o}C rise in GMST". Is that the measured GMST in (say) 2050 or 2100, or the equilibrium GMST which might be 200 years later (or is the lag 50 or 500 years)? If the latter, how do we know in 2050 or 2100 that we are on the right track? If the former, how do we reconcile the GMST rise yet to come with the original objective of the FCCC (avoiding dangerous interference with the climate system)? As Hansen says, "2^{o}C global warming is dangerous." Among other reasons this is because the lag issue creates confusion, which will cause further procrastination on action to control GHG concentrations.

I must emphasise that I do not claim dynamical accuracy of the "modelling" inherent in the graphs produced herein. These are engineering level calculations, somewhat better than "back-of the-envelope", but illustrative in their intent to show that 400 TW (the planet's current thermal imbalance) <u>is</u> enough to produce rapid ice-melting without changing GMST (up or down) from now until ice-melting has caused major sea-level rise.

I am not a climate modeller, but I have some appreciation of the issues involved, having managed an intensive multi-year computer modelling project which involved three-fold dynamic complexity:

- Dynamic modelling of the spatial and time-domain variations in the wind
- Aero-elastic wind turbine modelling from the blades down to the geotechnical properties of the ground
- Time-domain modelling of the turbine control system in steady and transient events.

All of the above had to be validated against empirical data from strain gauges. This gave first-hand experience as to how sensitively dependent such modelling can be on parameters that can only be empirically validated.

So, while I am not a climate modeller, I can appreciate the significance when (for example) Jim Hansen writes in https://www.atmos-chem-phys.net/16/3761/2016/, "High resolution ocean models are needed to realistically portray deepwater formation around Antarctica, penetration of warm waters into ice shelf environments, and, eventually, ocean–ice sheet feedbacks. More detailed models should also include the cooling effect of ice phase change (heat of fusion) more precisely, perhaps including iceberg tracks." We are a long way from having accurate models of ice melting! Meanwhile, it just melts.

Finally we should never forget (though it seems we can never remember) that in 1992 the nations of the world signed up to the precautionary principle in the UNFCCC. This means (appropriately given the consequences) that we <u>must ignore the denialists</u> (unless they can prove global warming is a benign human experiment), and <u>not</u> ignore the warnings of the scientists because they have yet to achieve "full scientific certainty".