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Alberta's Climate Plan: A Burden with No Benefit

Technical version

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Alberta's Climate Plan: A Burden with No Benefit

By Ken Gregory

The Alberta Government imposed a carbon tax of C\$20/tCO₂ on of January 1, 2017, increasing to C\$30/tCO₂ on January 1, 2018. This action is not based on the most recent and best quality climate science and economic evaluations. The expected warming from 2016 to 2100 due to greenhouse gas emissions is only 0.6 °C using the best climate science. The net social benefit of emissions is about 5 US\$/tCO₂. A carbon tax will harm all Albertans for no benefit. The climate plan is forecast to reduce global temperatures by 0.00007 °C by 2030.

Summary

Alberta's proposed carbon tax of \$30/tonneCO₂ as of January 1, 2018 is not based on the most recent and best quality climate science and economic evaluations. The carbon tax, restrictions of oil sands emissions and the phase-out of coal-fired power plant is forecast to reduce carbon dioxide (CO₂) in the atmosphere by 0.026 parts per million by 2030 and would reduce global temperatures by a meaningless 0.00007 °C by 2030. Alberta's climate change plan will harm all Albertans for no benefit.

The Alberta Panel report relied on estimates of the social cost of carbon dioxide by a politically motivated report from the US Interagency Working Group (IWG) that is flawed by numerous reasons. It used far too high climate sensitivity to greenhouse gases and 2 of the 3 economic models used failed to include the benefits of warming and CO₂ fertilization. CO₂ is plant food and is greening the planet Earth.

High estimates of climate sensitivity to greenhouse gases assume aerosols caused a large cooling effect, which canceled some of the previous warming effect, and little or no natural climate change. Recent research indicates that the aerosol effect is much less than previously

thought. The transient climate response (TCR) to greenhouse gas emissions, the warming when CO₂ doubles in about 125 years, is estimated at 0.85 °C by using an energy balance approach, new aerosol estimates and accounting for the natural warming since the Little Ice Age and the urban development effects on temperature.

Using the FUND integrated assessment model (IAM) results, the mean estimate of the social cost of carbon (SCC) on a global basis is determined to be -5.19 US\$/tonne of CO₂, and is extremely likely to be less than -1.34 US\$/tonne of CO₂. The benefits of CO₂ fertilization, longer growing season, greater arable land area, reduced mortality and reduced heating costs greatly exceed harmful effects of warming. The results indicate that governments should subsidize fossil fuels by about 5 US\$/tonne of CO₂, rather than impose carbon taxes.

Wind and solar energy is extremely variable, intermittent and unreliable. Wind costs 4 times and solar about 14 times more than conventional electricity and may cause Alberta power prices to double if they supply 19% of our power requirements.

Greenhouse gas emissions would enhance Canada's gross domestic product (GDP) by \$190 Billion per year by 2100 when assuming a high climate sensitivity of 3 °C. This is the UN panel's central estimate, which is three times too high according to this report. In Canada, anthropogenic CO₂ emissions are beneficial, with benefits continually increasing throughout the 21st century.

Alberta's Climate Change Plan

The Alberta Climate Leadership Panel produced a report in November 2015 which proposed actions to reduce greenhouse gas emissions, [here](#).¹ Alberta's climate change plan is based on that report and includes an economy wide carbon tax, restrictions on methane emissions and oil sands emissions, the phase-out of coal-fired electricity generation and subsidies to businesses for renewable energy projects. The plan is a misguided attempt to affect climate change by reducing greenhouse gas emissions. The panel report falsely assumed that the COP21 conference in Paris in December 2015 would produce binding commitments to reduce CO₂ emissions, but in fact there are only voluntary intentions. The top 12 emitters, representing 72% of all emissions, have pledged to increase their CO₂e emissions from 7.83 GtC to 9.59 GtC, or by 23% from 2012 to 2030, [here](#).²

The plan will impose a 6.73 ¢/L tax on gasoline and 1.52 \$/GJ tax on natural gas by January 2018. The phase-out coal plan will cost approximately \$22 billion, including \$11 billion in compensation to industry and \$11 billion to build equivalent natural gas generating plant capacity, [here](#).³ The plan calls for \$3.4 billion in payments to businesses over the next 5 years to produce intermittent and unreliable solar and wind power. Conventional power plants must be rapidly ramped up and down to offset the enormous variability of solar and wind power, which

reduces their efficiency and increases CO₂ emissions per unit of energy produced. The plan also requires billions of dollars to upgrade the electrical grid to accommodate the intermittent power sources.

The climate leadership report did not contain any analysis of the climate sensitivity or natural climate change. It did not do an analysis of the social cost and benefit of greenhouse gas emissions, but apparently relied on the a report from the US Interagency Working Group on Social Cost of Carbon, which produced estimates of the SCC to support US President Obama's war on fossil fuels. That report is seriously flawed for numerous reasons:

- The climate sensitivity to CO₂ emissions used by the IWG is much too high. Most of the damages occur at the high end of the probability range which is 4 times too high.
- The IWG uses climate sensitivity estimates by a United Nations panel that is run by a group of natural climate change deniers. All 20th century natural climate change is falsely attributed to greenhouse gas emissions in the models and in the UN reports.
- The 2.5% real discount rate used is much too low.
- The IWG used the average of three IAMs, but the PAGE and DICE models should not be used as they do not include the significant benefits of warming and CO₂ fertilization. Only the FUND model should be used to determine social costs and benefits of emissions. CO₂ is plant food and its increase has greened the Earth. The IWG modified the FUND model to give higher SCC values.
- The PAGE and DICE models assume future society takes no action to mitigate climate change regardless of how much the global average temperature rises.
- Most damages occur outside of North America. Alberta's climate policy should be based on the cost and benefits of emissions to Canadians.
- The IWG estimates fail to account for leakage. High carbon costs imposed on one nation to reduce emissions will result in increased emissions from another nation to provide energy intensive products for export.

The Alberta Climate Leadership Panel and the Alberta Government failed to do any cost-benefit analysis of the proposed climate change policy.

The Panel forecast that the proposed measures will cause emissions in 2030 to be 50 Mt of CO₂ equivalent less than the status quo case. Total Alberta emissions would increase from 263 Mt in 2013 to 270 Mt in 2030. The cumulative emission reduction compared to the status quo case is estimated at 425 Mt CO₂e. As 47% of emissions remain in the atmosphere, the plan would reduce CO₂e in the atmosphere by 200 Mt, and reduce the CO₂ concentration by 0.026 parts per million. Using the TCR of 0.85 °C as given in Table 6, the **global temperature reduction would be 0.00007 °C by 2030**, which is insignificant and undetectable.

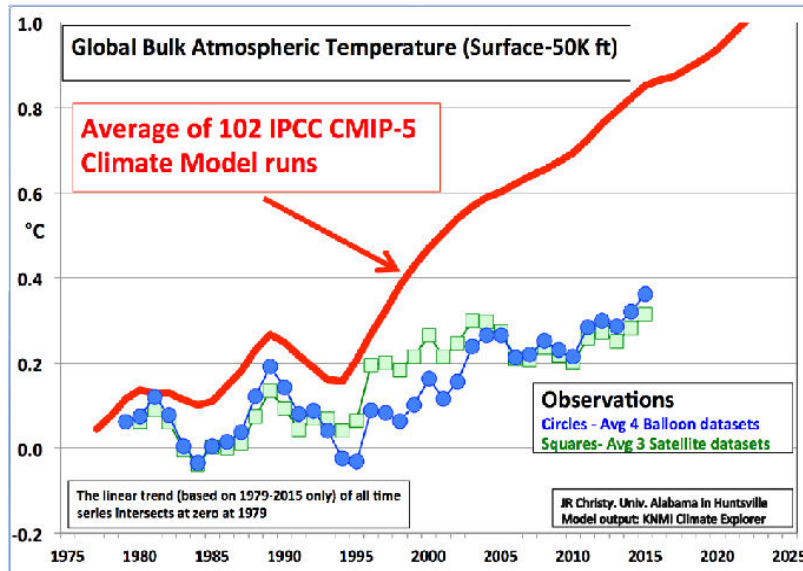


Figure 1. Comparison of the average climate model warming to that of satellite and weather balloon datasets. Models are too sensitive to CO₂ emissions.

simulated by the models is 2.5 times that measured by satellites and weather balloons as shown in Figure 1, see [here](#).⁵ In the tropics, the models over-warm the atmosphere by a factor of 3, indicating the models are far too sensitive to our CO₂ emissions. The greenhouse warming effect should be most apparent at about 7 km altitude. The Canadian climate model warming rate at 7 km altitude is 6 times that of the satellite measurements, see [here](#).⁶ The Canadian climate model results bears no resemblance to planet Earth!

Germany has the highest solar plus wind capacity in Europe, and their electricity prices in 2015 were **more than twice** the price in Canada, [here](#).⁷ If Alberta increases the wind and solar share of electricity generation to the 19% share that Germany had in 2015, our electricity prices are likely to more than double, sending industry fleeing and causing hardship on all Albertans.

The proposed carbon tax and associated subsidies to crony capitalists to build wind and solar power facilities will raise the price of electricity and the price of all goods and services. This will impact the poor much more than the wealthy and enrich only the capitalists looking for government subsidies.

The IWG predicts the world's income per person will be 5 times higher in 2100 than today despite its excessive climate warming forecasts, [here](#).⁸ The large increase in energy costs imposed on Albertans now will transfer wealth from us to our much wealthier descendants.

Empirical-based estimates of climate sensitivity to CO₂ emissions have been declining dramatically in recent years, but the IWG failed to reduce the estimate of climate sensitivity to the most recent estimates. They instead chose to use high estimates from climate models.

Climatologist Dr. Judith Curry of Georgia Tech says [here](#),⁴ **“The US IWG used indefensible values of climate sensitivity as input into the integrated assessment models.”** The global warming rate of the bulk atmosphere from 1979 to 2015 (37 years) as

The purpose of a social cost of carbon calculation is to determine the optimum tax or subsidy to be applied to CO₂ emissions such that marginal benefit of purchasing energy equals the total costs and benefits to society of producing the energy. This would create a “level playing field” for all energy sources as long as there are no subsidies on renewable energy and no other restrictions on CO₂ emissions. The subsidies to renewables and the closure of coal-fired power plants completely destroys the logic of the carbon tax. It is appalling that the members of the Alberta Climate Panel are unaware of this. Government should never subsidize industry other than to compensate for externalities, which a carbon tax is intended to do.

The cost to replace fossil fuels with renewable energy globally is \$100 trillion to \$300 trillion. The capital costs of renewable energy plants are almost 30 times as high as those of the natural gas plants. Including operating costs, on-shore wind farms are 4 times, and solar photovoltaic plants are 14 times as expensive as natural gas plants, [here](#).⁹ In addition, the extreme volatility of wind and solar power imposes large costs on back-up power systems and the electricity grid. Wind and solar don't provide power when needed, so they need 100% back-up. Energy storage is incredibly expensive and impractical, so where hydro power is not plentiful, fossil fuel back-up is required. In the UK, every "green" job causes 3.7 job losses, [here](#)¹⁰ and results in lower incomes.

The FUND model shows that Canada **benefits** from emissions by 1.9% of gross domestic product by 2100, equivalent to a benefit of \$190 billion annually in 2015 dollars when assuming a high climate sensitivity of 3 °C. Anthropogenic greenhouse gas emissions will have **only positive impacts in Canada which increase throughout the 21st century**.¹¹ Therefore there is no reason for Canada to have any carbon taxes.

New research shows that CO₂ emissions will cause global temperatures to increase from 2016 to 2100 by only 0.6 °C, which is very beneficial on a global basis. According to the FUND model, this is equivalent to a **social net benefit of 5 US\$/tCO₂**.

Energy Balance Climate Sensitivity

The most important parameter in determining the economic impact of climate change is the sensitivity of the climate to greenhouse gas emissions. Climatologist Nicholas Lewis used an energy balance method to estimate the Equilibrium Climate Sensitivity (ECS) best estimate at 1.45 °C from a doubling of CO₂ in the atmosphere with a likely range [17 - 83%] of 1.2 to 1.8 °C, see [here](#)¹². This analysis is an update of a previous paper by Nicholas Lewis and Judith Curry [here](#)¹³. ECS is the global temperature change resulting from a doubling of CO₂ after allowing the oceans to reach temperature equilibrium, which takes about 3000 years in the models.

A more policy-relevant parameter is the Transient Climate Response (TCR) which is the global temperature change at the time of the CO₂ doubling. A doubling of CO₂ at the current growth

rate of 0.55%/year would take 126 years. The analysis gives the TCR best estimate at 1.21 °C with a likely range [17 - 83%] of 1.05 to 1.45 °C.

Energy balance estimates of ECS and TCR use these equations:

$$\text{TCR} = F_{2\times\text{CO}_2} \frac{\Delta T}{\Delta F} \quad \text{ECS} = F_{2\times\text{CO}_2} \frac{\Delta T}{\Delta F - \Delta Q},$$

where $F_{2\times\text{CO}_2}$ is the forcing from a doubling of CO_2 , estimated at 3.71 W/m^2 . ΔT is the change in global average temperature between two periods, ΔF is the change in forcing between the two periods, and ΔQ is the top-of-atmosphere radiative imbalance, which is the rate of heat uptake of the climate system. The oceans account for over 90% of the climate system heat uptake. The two periods used for the analysis were 1859-1882 and 1995-2011. They were chosen to give the longest early and late periods free of significant volcanic activity, which provide the largest change in forcing and hence the narrowest uncertainty ranges. The long time between these periods has the effect of averaging out the effect of short-term ocean oscillations such as the Atlantic Multi-decadal Oscillation (AMO) and the Pacific Decadal Oscillation (PDO), but it does not account for millennium scale ocean oscillations or indirect solar system influences.

The 5th assessment report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) gave a best estimate of aerosol forcing of $-0.9 \text{ W}/\text{m}^2$ (for 2011 vs 1750) with a 5 to 95% uncertainty range of -1.9 to $-0.1 \text{ W}/\text{m}^2$, [here](#).¹⁴ Aerosols have a direct effect and an indirect effect from aerosol-cloud interactions, both of which are estimated to cause cooling. Aerosols are the dominant contribution to uncertainty in climate sensitivity estimates. The AR5 has substantially reduced this uncertainty compared to AR4, but this reduced uncertainty was not available soon enough to be incorporated into the climate models used in AR5. Consequently, those models used large aerosol cooling to offset greenhouse gas warming in the historical period, and assumes aerosol cooling will decline in the future. This allows climate models to have high sensitivity to greenhouse gases while still roughly matching the historic temperature record. Aerosol forcing depends strongly on very uncertain estimates of the level of preindustrial aerosols.

Nicholas Lewis writes, "In this context, what is IMO a compelling new paper [here](#)¹⁵ by Bjorn Stevens estimating aerosol forcing using multiple physically-based, observationally-constrained approaches is a game changer." Stevens is an expert on cloud-aerosol processes. He published a new, lower estimate of aerosol forcing of $-1.0 \text{ W}/\text{m}^2$ in June 2015. The new aerosol forcing best estimate from 1750 is $-0.5 \text{ W}/\text{m}^2$ with a 5 to 95% uncertainty range of -1.0 to $-0.3 \text{ W}/\text{m}^2$.

Lewis used this estimate for aerosol forcing and used estimates of other forcings given in AR5 [here](#)¹⁶. Ocean heat content is from Box 3.1, Figure 1 of AR5. The likely 83% upper bound of ECS was reported by the IPCC in AR5 at 4.5 °C, but this drops to 2.45 °C when calculated with

the AR5 reported forcings, and drops to only 1.8 °C when substituting the Stevens estimate of aerosol forcing. The IPCC did not provide a 95% upper estimate of ECS, but estimates the 90% upper limit at 6 °C. The upper 95% limit dropped dramatically from 4.05 °C using AR5 forcing to only 2.2 °C when using the new Stevens aerosol forcing estimates. In terms of TCR, using the Stevens aerosol forcing causes the upper 95% limit to be reduced from 2.5 °C to 1.65 °C.

According to HadCRUT4.4, the temperature change between the two periods (1859-1882 and 1995-2011) was 0.72 °C. Using the equations for TCR and ECS, the total forcing change ΔF during the interval was 2.21 W/m² and the heat uptake ΔQ was 0.365 W/m².

Adjustment for Millennium Cyclic Warming

This analysis by Lewis does not account for the long-term natural warming from the Little Ice Age (LIA), likely driven by indirect solar activity. The temperature history shows an obvious millennium scale temperature oscillation, indicating that natural climate change accounts for a significant portion of the 20th century warming. Climatologist Dr. Richard Lindzen writes, "Lewis does not take account of natural variability, and, I suspect, his estimates are high."

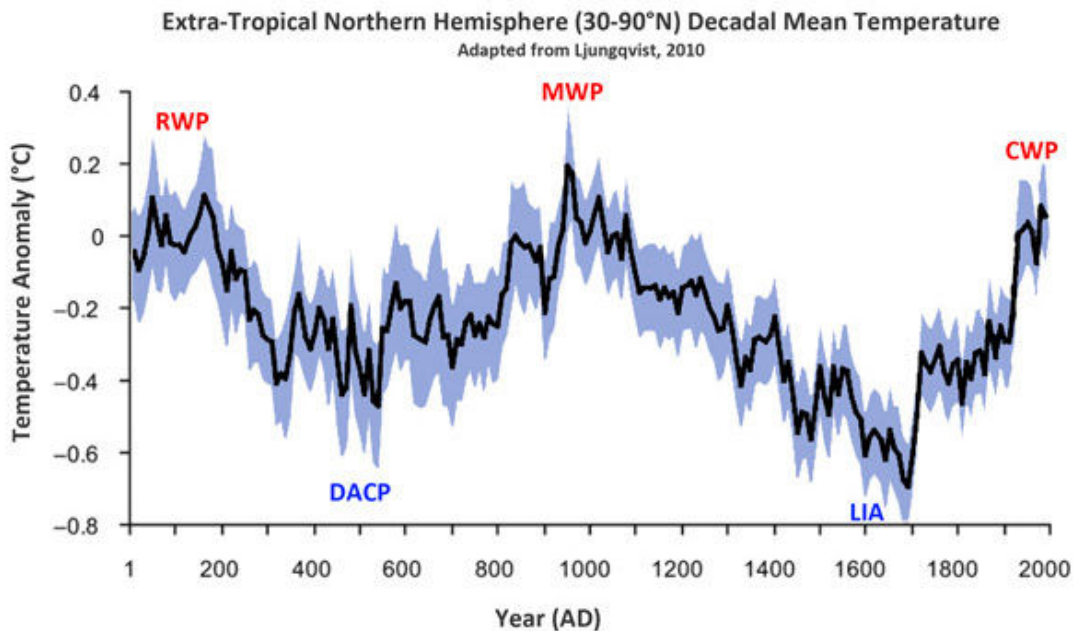


Figure 2. Extra-tropical Northern Hemisphere temperatures utilizing many palaeo-temperature proxy records, adapted from Ljungqvist 2010. The shading represents 2 standard deviation errors. RWP = Roman Warm Period AD 1-300; DACP = Dark Age Cold Period 300-900; MWP = Medieval Warm Period 800-1300; LIA = Little Ice Age 1300-1900.

Fredrik Ljungqvist prepared a temperature reconstruction of the Extra-Tropical Northern Hemisphere (ETNH) during the last two millennia with decadal resolution [Ljungqvist 2010] [here](#)¹⁷. The results are shown in Figure 2.

	Begin	End	Change	Period	absolute
	°C	°C	°C	centuries	°C/century
RWP-DACP	0.06	-0.37	-0.43	4.0	0.108
DACP-MWP	-0.37	0.01	0.38	5.2	0.073
MWP-LIA	0.01	-0.55	-0.56	6.1	0.092
LIA-1900	-0.55	-0.25	0.30	2.8	0.107
Average					0.095

Human-caused greenhouse gas emissions did not cause significant temperature change to the year 1900 because cumulative CO₂ emissions to 1900 were insignificant. The approximate temperature trends during each of the periods identified in figure 2 were estimated. The average of the absolute natural temperature change over the four periods was 0.095 °C/century, as shown in Table 1 and Figure 3.

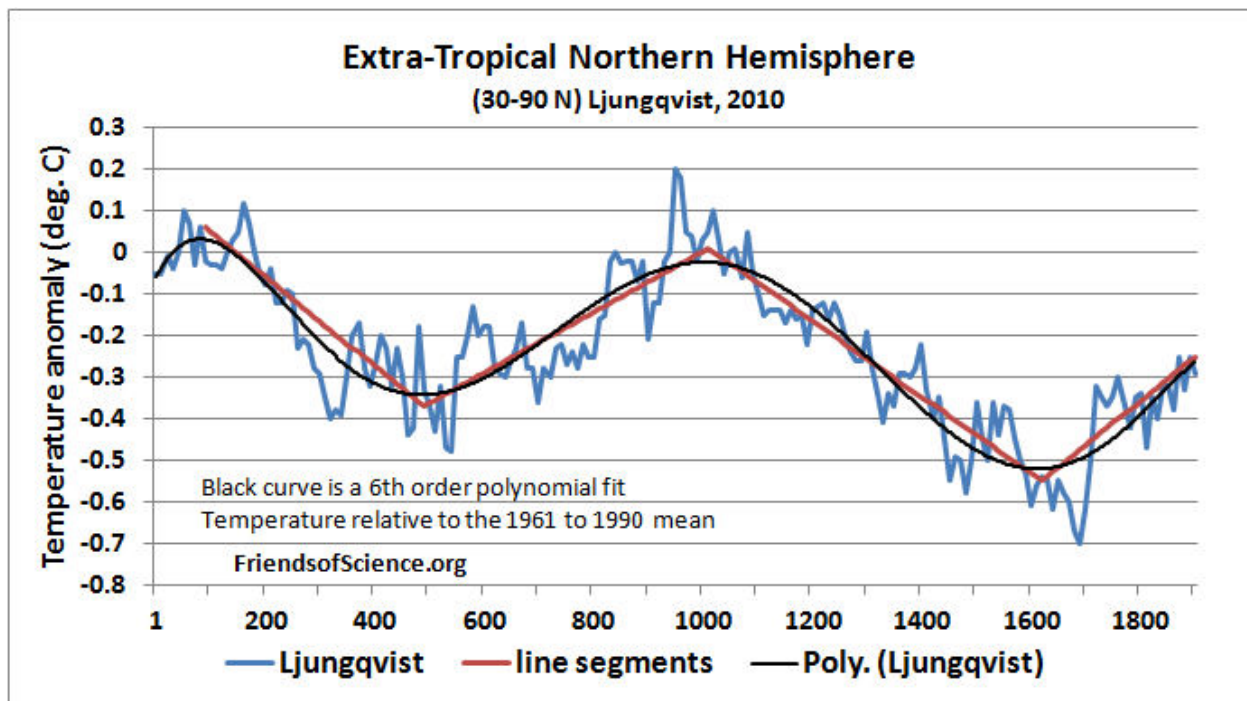


Figure 3. Extra-tropical Northern Hemisphere temperature change with a 6th order polynomial fit and line segments.

The warming from 1859 to date of the ETNH attributable to natural climate change is deemed to be the average of the absolute temperature changes during each of the periods identified in Table 1.

The Ljungqvist 2010 paper gives several reasons why the reconstruction likely "seriously underestimates" the temperature variability but does not make any corrections to his reconstruction. The author assumed a linear relationship between the temperature and the proxy, but the proxy response is often non-linear. The tree-ring proxies are biased toward the summer growing season. If the Little Ice Age cooling was more pronounced during winter months the annual estimate would be biased too warm. The large dating uncertainties of the sediment proxies has the effect of "flattening out" the temperatures so the true magnitude of the warm and cold periods are underestimated.

The proxy temperature did not rise as sharply during the 20th century as the thermometer record did, indicating the instrument temperature record is biased high due to the uncorrected urban heat island effect (UHIE) and/or underestimated reconstructed temperature variations from the proxies.

The Ljungqvist reconstruction will be adjusted here to account for the summer tree ring bias and the "flattening out" effect of the sediment proxies.

Adjustment for Summer Tree-ring Bias

The growing season in the ETNH is assumed to be from May through September. The Global Historical Climate Network (GHCN) CAMS gridded 2m analysis shows that the July temperatures are 29 °C warmer than the January temperatures, averaged over 2005-2015.

The annual temperatures were compared to the weighted average of the growing season months during two decades of the coldest part of the record, 1960 to 1979 and the warmest part to the record, 1995 to 2014, to determine the seasonal growing bias. The weighting factors were taken from an analysis of tree growth in Oregon, USA, [here](#).¹⁸ The tree growth rates relative to June are shown in Table 2.

Table 2 - Tree Growth Rates Factors by Month					
	May	June	July	August	September
Growth rate relative to June	0.75	1	0.7	0.35	0.18

The actual annual and weighted monthly growing season temperature history over land in the ETNH is given in Figure 4.

The annual and tree growth rate weighted average growing season temperatures during two cold decades and two warm decades are given in Table 3.

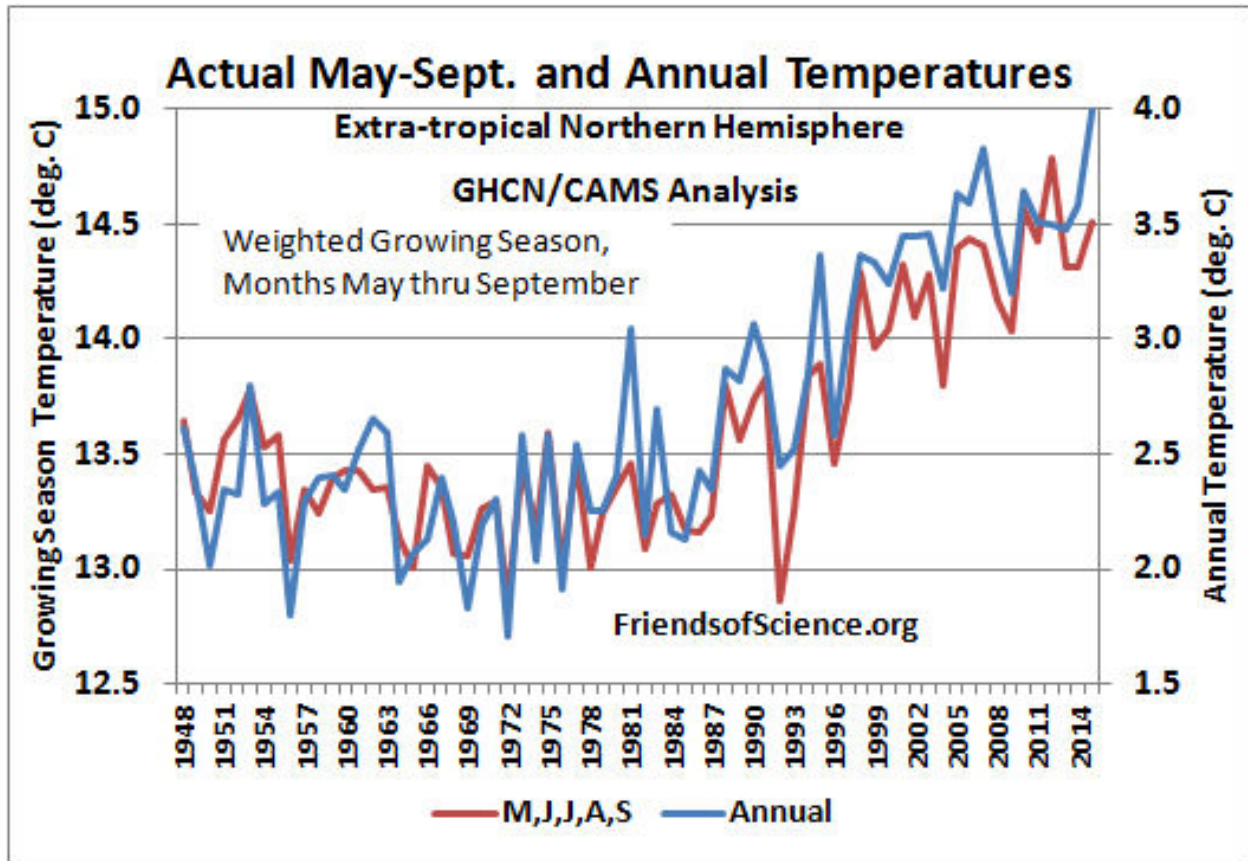


Figure 4. Actual annual and weighted average May through September temperatures of the extra-tropical Northern Hemisphere (30 - 90°N). The annual temperatures are indicated by the right vertical axis and the May - September growing season temperatures are indicated by the left vertical axis.

Table 3 - Growing Season Bias of Tree-ring Proxies			
	Annual °C	Growing Season °C	Annual/Growing Season
1960 - 1979	2.25	13.42	
1995 - 2014	3.40	14.35	
Difference	1.15	0.93	123%

The annual temperatures show more change than the tree growing season temperatures indicating that the tree-ring proxies underestimate the temperature variability. Assuming that the seasonal temperature variability over the last century is similar to that over the last two

millennia, the table indicates that tree-ring proxy temperature variability should be increased by 23%. Eight of the 30 proxies have this tree-ring seasonal bias.

In addition to the tree-ring proxies, Ljungqvist identified 11 non-tree-ring proxies that are also subject to the summer seasonal bias. These proxies likely also underestimate the annual temperature variations and the Little Ice Age cooling, but no adjustment for them is made.

Adjustment for Sediments Dating Uncertainty

The dating uncertainty of sediment proxies are typically +/- 160 years. Ljungqvist writes, "The dating uncertainty of proxy records very likely results in 'flattening out' the values from the same climate event over several hundred years ... so they are unable to capture the true magnitude of the cold and warm periods in the reconstruction."

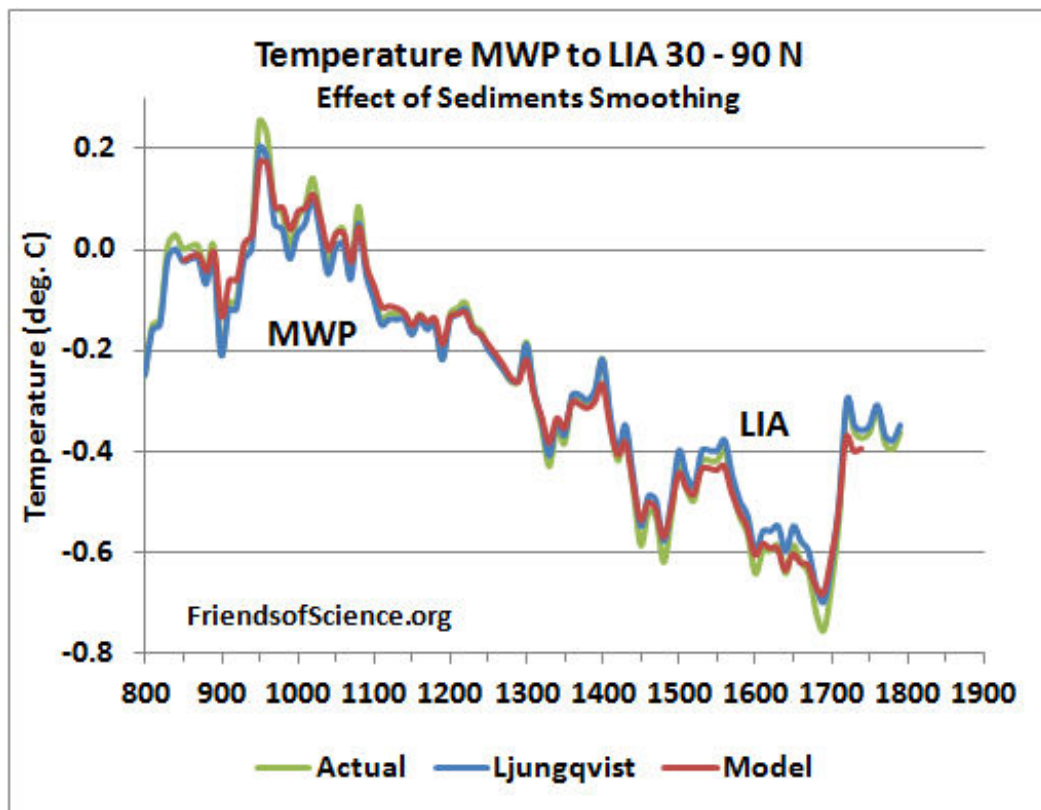


Figure 5. Estimated Effect of Sediment proxy smoothing due to dating uncertainty. The actual temperature variation was estimated at 1.12 times the Ljungqvist reconstruction variation about the mean temperature of the MWP and the LIA extremes.

The actual decadal temperature variation is assumed to be some factor greater than the reconstruction variation. The smoothed sediment temperatures are assumed to be an average of all the actual temperatures from 50 year earlier to 50 year after the recorded time. A model of the reconstruction was created as a weighted average of the smoothed temperatures of the 12 sediment proxies and the actual temperatures of the 18 non-sediment proxies. The factor of 1.12 was choose such that the difference between the model and the reconstruction summed over 50 years centered on each of the MWP maximum and the LIA minimum, is minimized. The result of this is shown in Figure 5.

Total proxy adjustment

The weighted average proxy bias adjustment is shown in Table 5.

Table 5 - Proxy Bias Adjustments		
Type	Number Proxies	Bias Adjustment Factor
Tree-ring season bias	8	122.8 %
Sediment smoothing bias	12	112 %
Other proxies	10	100 %
Total	30	110.9 %

Adjustment for Global Temperatures

The southern hemisphere and tropics temperature variability is less than the northern extra-tropics due to its larger ocean area, so the global temperature variations over the last 2000 years would be less than the northern exotropics. Ideally we should use a temperature reconstruction for the entire globe, but there are too few proxies for the tropics and southern hemisphere. Table 4 shows the temperature for the ETNH and the globe for the coolest and warmest two-decade period as recorded by HadCRUT4.4. The table indicates that the global temperatures vary by only 80% of the ETNH. It is assumed that this holds true during the last two millennia.

Table 4 - Global and Extra-tropical Northern Hemisphere Temperature Variations			
	Global °C	ETNH °C	Global/ETNH
1900 - 1919	-0.392	-0.280	
1990 - 2009	0.396	0.667	
Change	0.761	0.948	80.3%

Total Millennium Cycle Adjustment

The global natural recovery from the LIA from 1859 is determined by the average temperature change rate over the four segments of the last two millennia in the ETNH, adjusted for the tree-ring seasonal bias and the sediment smoothing bias, and converted to global values.

The global natural recovery from the LIA is estimated at 0.084 °C/century, which is the product of the 0.095 °C/century for the ETNH, the proxy bias of 110.9 % and the global adjustment of 80.3%. Note that this doesn't include the seasonal biases of the sediment proxies, so it might underestimate the actual natural warming. The temperature change over the 1.33 centuries between the midpoints of the two periods used in the climate sensitivity analysis is reduced from 0.72 °C by the 0.11 °C natural warming to 0.61 °C of anthropogenic warming.

The best estimate of ECS is reduced to 1.22 °C [likely range 0.95 - 1.55 °C] and the best estimate of TCR is reduced to 1.02 °C [likely range 0.85 - 1.25 °C]. These estimate do not include an adjustment for the UHIE. These uncertainty ranges have the same spread as determined by Lewis and do not include additional uncertainty due to the millennium warming cycle.

Adjustment for the Urban Heat Island Effect

Numerous papers have shown that the UHIE contaminates the instrument temperature record. A study by McKittrick and Michaels 2007, summary [here](#)¹⁹, showed that almost half of the warming over land in instrument data sets is due to the UHIE. A study by Laat and Maurellis 2006 came to identical conclusions. Note that the IPCC dismissed the overwhelming evidence of UHIE contamination by falsely claiming "the locations of greatest socioeconomic development are also those that have been most warmed by atmospheric circulation changes". That is, our cities were built where there was going to be the most natural warming, a nonsensical claim. Climate models do not show such correlation which refutes the claim.

A study by Watts et al presented at the AGU fall meeting 2015 showed that bad siting of temperature stations has resulted in NOAA overestimating US warming trends by 59% since 1979. The HadCRUT4 analysis does not have a specific correction of the UHIE. The GISS temperature dataset uses an UHIE adjustment routine that applies a temperature trend change in the wrong direction in 45% of the adjustments. Instead of eliminating or reducing the urbanization effects, these "wrong way" corrections make the urban warming trends steeper, as shown [here](#)²⁰.

The McKittrick and Michaels 2007 result show that the HadCRUT temperature index trend from 1979 to 2002 over land would decline from 0.27 °C/decade to 0.13 °C/decade. The UHIE over

land is about 0.14 °C/decade, or 0.042 °C/decade on a global basis since 1979. The UHIE correction over the period 1980 to 2008 is 0.10 °C. This reduced the temperature change due to greenhouse gas forcings to 0.51 °C over the two periods 1859-1882 and 1995-2011 used in the analysis. We assume no UHIE before 1980 and the UHIE warming trend continues to 2011.

Adjusting the Lewis estimate by the millennium warming cycle and urban development gives a best estimate of ECS of 1.02 °C and a best estimate of TCR of 0.85 °C.

Summary of Climate Sensitivity Estimates

Table 6 summarizes the ECS and the TCR best estimate, likely and extremely likely confidence intervals for 5 cases. All forcing-based estimates use initial and final periods of 1859-1882 and 1995-2011, respectively. Ranges are to the nearest 0.05°C.

Table 6 - Estimates of Equilibrium Climate Sensitivity and Transient Climate Response with Uncertainty Ranges.						
	ECS Best Estimate	ECS 17-83% range °C	ECS 5-95% range °C	TCR Best Estimate	TCR 17-83% range °C	TCR 5-95% range °C
USA IWG	3.0	NA	1.70-7.15	NA	NA	NA
Using AR5 Forcings	1.64	1.25-2.45	1.05-4.05	1.33	1.05-1.80	0.90-2.50
As above but with Stevens' Aerosol Forcing	1.45	1.20-1.80	1.05-2.20	1.21	1.05-1.45	0.90-1.65
As above but with Natural Millennium Warming	1.22	0.95-1.55	0.80-1.95	1.02	0.85-1.25	0.70-1.45
As above but with UHIE Correction	1.02	0.75-1.35	0.60-1.75	0.85	0.70-1.10	0.55-1.30

The best estimate TCR of 0.85 °C implies that the global temperature will increase from 2016 to 2100 due to anthropogenic CO₂ emissions by only 0.57 °C if atmospheric CO₂ continues to increase at the current rate of 0.55%/year. Actual temperatures may rise or fall depending on the magnitude of natural climate change. The IWG best estimate of ECS is too high by a factor of 3. Most of the predicted damages occurs at the high end of the probability range. The IWG 95% estimate is too high by a factor of 4.

Note the discrepancy between the IWG upper 95% limit of 7.14 °C versus the calculated upper limit of 4.05 °C using the AR5 reported forcings and heat uptake estimates. The IWG reported value is based on the IPCC AR4 report "expert judgment" using clues from the paleoclimate record and from climate model outputs. Climate sensitivity estimates based on the paleoclimate record assumes the only natural forcing is from tiny changes in the total solar irradiance, however it is extremely likely that indirect solar effects due to changes in solar ultraviolet intensity and the solar magnetic field have a much greater effect on climate, so these estimates have little value.

The climate model estimates only reflect the modelers' biases and guesses of how aerosols, clouds and upper atmosphere water vapor will change in response to warming. Modelers observe that the amount of clouds have generally declined with warming during the 20th century, and assumed that the cloud decline was caused by the warming, interpreting the change as a positive cloud feedback. But detailed analysis of clouds show that the amount of clouds declined due to natural causes that allowed more sunlight in to warm the planet. Radiosonde and satellite measurements show that upper atmosphere water vapour declines with warming, but climate models predict the opposite behaviour.

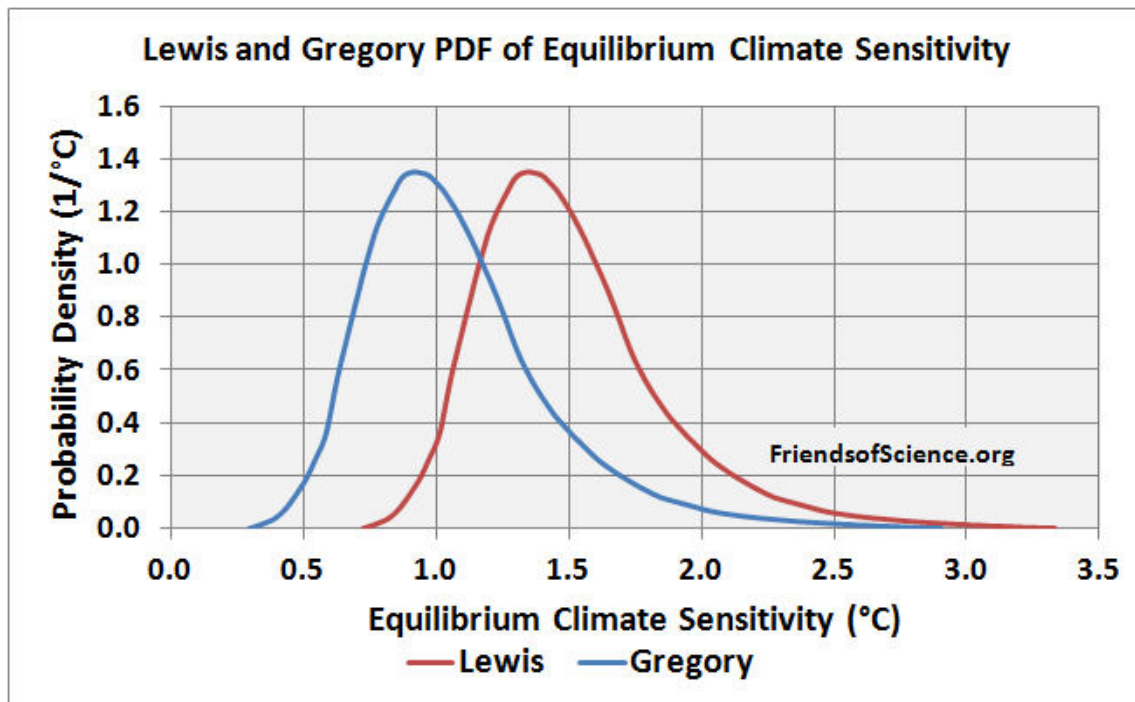


Figure 6. Probability density functions of equilibrium climate sensitivity as estimated by Lewis with Steven's aerosol forcing and by Gregory including natural millennium warming and urban heat island effects.

Figure 6 shows the probability density function (PDF) of the Lewis and Gregory evaluations. The Gregory PDF has the same shape as the Lewis PDF as it does not include additional uncertainty due to the millennium warming cycle or the UHIE.

The scientific method requires that when theory conflicts with empirical measurements, the theory should be modified to agree with the measurements. The IPCC falsely treats computer model output as evidence of climate sensitivity. Climate sensitivity estimates should be based only on observational studies during the instrument period, and climate models should be changed to agree with the lower observation based climate sensitivity estimates.

Social Cost of Carbon

The US Government's Interagency Working Group on Social Cost of Carbon uses three IAM to determine the social costs and benefits of greenhouse gas emissions. Two of these models, DICE and PAGE, do not include the benefits of CO₂ fertilization and other benefits of warming, and fail to account for adaptation which grossly exaggerates the harm of warming.

The FUND model does include these benefits, but arguably underestimates the benefits of CO₂ fertilization. Idso (2013) found that the increase in the atmospheric concentration of carbon dioxide that took place during the period 1961-2011 was responsible for increasing global agricultural output by \$3.9 trillion (in constant 2015 US\$). According to written testimony for the House of Representatives Committee on Natural Resources by Dr. Patrick Michaels [here](#)²¹, the FUND model may have underestimated the CO₂ fertilization effect by a factor of 2 to 3.

The IWG acknowledges that the three IAMs treat CO₂ fertilization very differently, but they claim the IAMs were selected "to reflect a reasonable range of modeling choices and approaches that collectively reflect the current literature on the estimation of damages from CO₂ emissions." Michaels wrote here, "This logic is blatantly flawed. Two of the IAMs do not reflect the 'current literature' on a key aspect relating to the direct impact of CO₂ emissions on agricultural output, and the third only partially so. CO₂ fertilization is a known physical effect from increased carbon dioxide concentrations. By including the results of IAMs that do not include known processes that have a significant impact on the end product must disqualify them from contributing to the final result. Results should only be included when they attempt to represent known processes, not when they leave those processes out entirely."

The DICE model assumes that the optimum climate for humanity was the pre-industrial climate of 1900, which was near the end of the Little Ice Age, and any temperature increase since then is harmful. Testimony by Dr. Mendelsohn to the Minnesota Public Utilities Commission [here](#)²² shows that there is no evidence that the temperature increase since 1900 caused any damages, and such damages would be easily detectable. He suggests that net damages would not occur

until temperatures are 1.5 to 2.0 °C above pre-industrial levels, equal to 0.7 to 1.2 °C above current temperatures. This model does not include benefits of warming.

Heat and cold related mortality is a major component of the SSC. An international study analyzing over 74 million deaths across 13 countries found that cold weather kills 20 times as many people as hot weather. Statistics Canada 2007-2011 data shows that there are Canadian death rate in January is 100 deaths/year greater than in August, as shown [here](#)²³. Clearly the optimum temperature is greater than current temperatures.

The DICE model produces future sea level rise values that far exceed mainstream projections and exceed even the highest end of the projected sea level rise by the year 2300 as reported in the AR5 report.

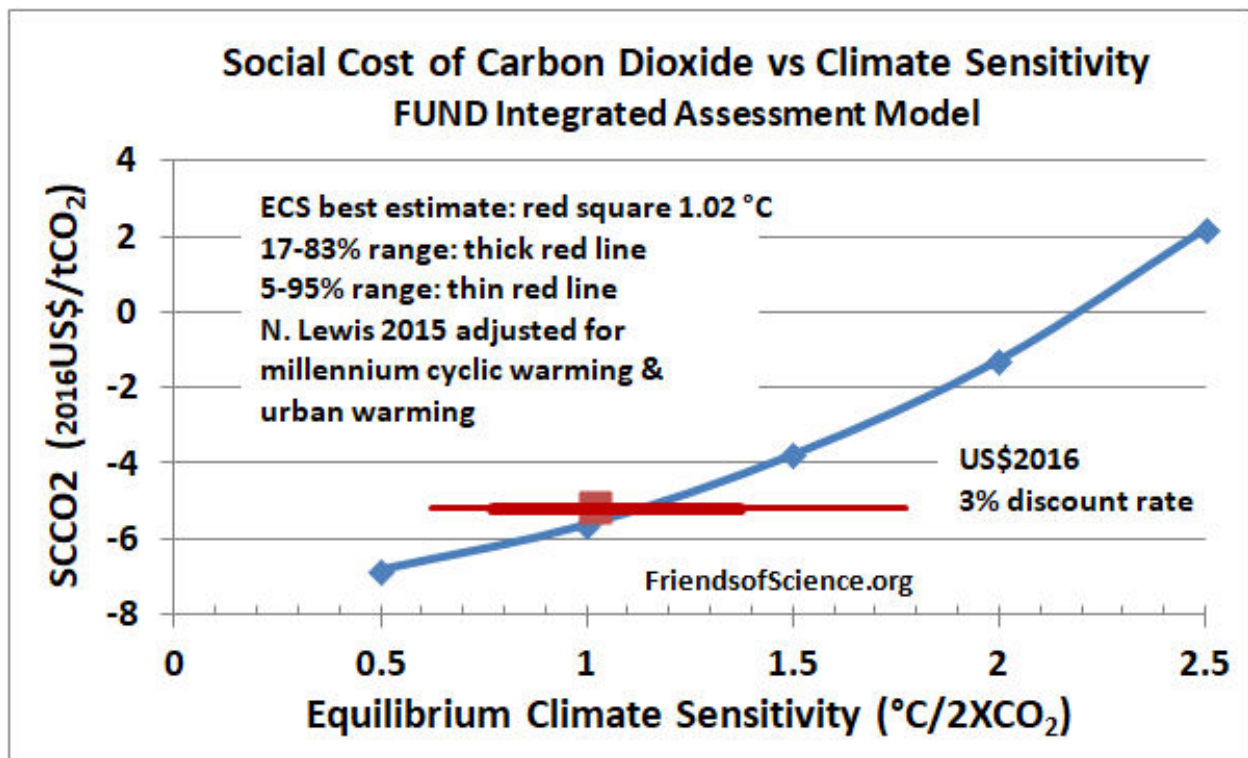


Figure 7. The equilibrium climate sensitivity (ECS) as calculated by N. Lewis using aerosol forcing by Stevens, other forcings and heat uptake by IPCC AR5 and global surface temperatures adjusted to account for natural millennium cyclic warming and urban warming from 1980. The ECS best estimate is shown by the red square, uncertainty ranges by the red lines. Social cost of carbon as determined by the FUND integrated assessment model is shown by the blue line for emissions in 2020 in constant US\$2016.

Dr. Robert Mendelsohn testified that the PAGE model is “not well grounded in economic theory” and it uses an "uncalibrated probabilistic damage function".²² Mendelsohn says [here](#)²⁴, "The version of the PAGE model used by the IWG explicitly does not include adaptation. Failing to include adaptation vastly overstates the damage that climate change will cause."

For these reasons this report uses only the FUND model to determine the SCC. The FUND model was developed by Dr. Richard Tol, Professor of Economics at the University of Sussex, UK.

Figure 7 shows the SCC (blue line) as a function of ECS. The ECS best estimate is indicated by the red square. The thick red line shows the 17-83% probability range, and the thin red line shows the 5-95% probability range of the ECS estimate. The FUND model values were provided by Dr. Richard Tol in testimony to the Minnesota Public Utilities Commission, Table 3, [here](#)²⁵. The SCC values assume a real discount rate of 3%. Warming is beneficial up to an ECS of 2.2 °C.

SCC values were calculated for all values of ECS and weighted by the PDF of the ECS to determine the cumulative probabilities. The PDF of the SCC is given in Figure 8. Note that the best estimate of the SCC is greater (less negative) than the SCC corresponding to the best estimate of the ECS due to the curvature of the SCC versus ECS relation. The best estimate and confidence intervals of the SCC is shown Figure 9.

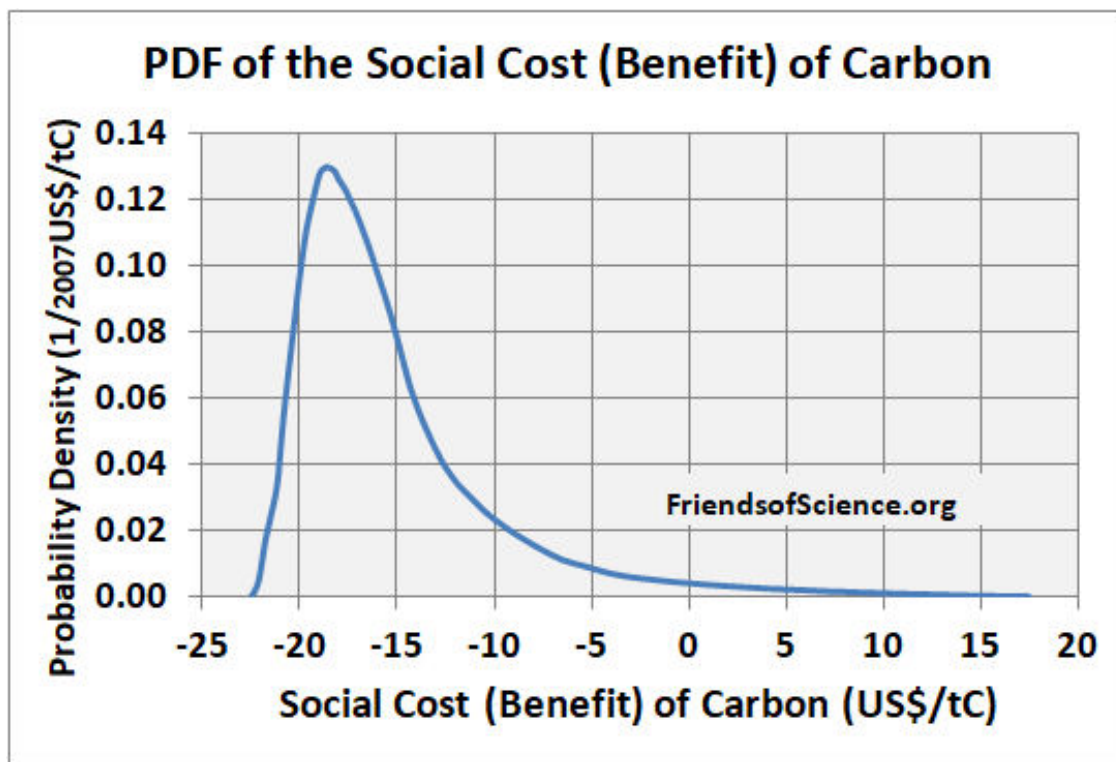


Figure 8. Probability density functions of the social cost (benefit) of carbon as estimated by Gregory using the FUND model results and including the natural millennium warming and urban heat island effects.

The analysis shows that on a global basis, the best estimate of the SCC is -5.19 US\$/tCO₂, which is very beneficial. The likely range is -6.04 to -3.58 US\$/tCO₂, and it is extremely likely to be less than -1.34 US\$/tCO₂. These results show that instead of imposing a carbon tax on fossil fuels, there should be a subsidy equal to about 5 US\$/tCO₂.

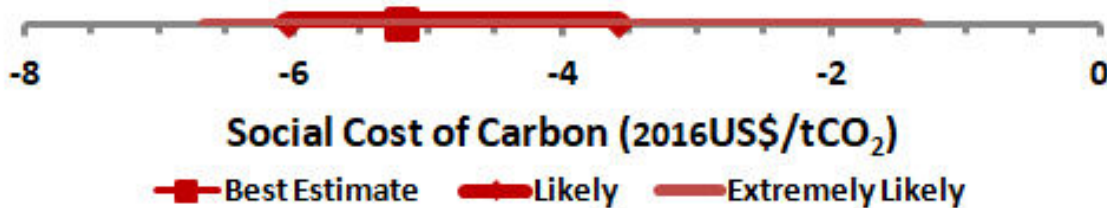


Figure 9. Social Cost of Carbon in US\$/tCO₂ indicating best estimate, likely 17-83%, and extremely likely 5-95% uncertainty ranges. The uncertainty ranges do not include uncertainty associated with the millennium warming cycle or the urban warming effect. The values assume incremental emissions in 2020, 3% discount rate and in constant US\$2016.

Contrary to news media scare stories, a warming world reduces the tropics to poles temperature gradient, which reduces the temperature difference that powers storms, leading to fewer and less intense storms. During the past 40 years, global hurricane energy (sum of intensity and longevity) undergoes significant variability but exhibits no significant trend. Hurricane energy has declined by 38% from 1994 to 2015 despite an increase in temperature as shown [here](#).²⁶ The global weather-related death rate declined from the 1920's to the 2000-2006 period by 99%, see [here](#).²⁷

The benefits of CO₂ fertilization, reduced cold-weather-related mortality, lower outdoor industry costs (e.g. construction costs), increased arable land area and reduced heating costs greatly exceed harmful effects of warming on a global basis.

The social cost of carbon as determined by IAMs requires numerous assumptions that are not based on science or economics. It depends on assumption of choices future consumers, voters and politicians make many decades and centuries into the future. The SCC in part assumes governments fail to take appropriate action to mitigate flooding due to sea level rise.

Dr. Tol explains, "the causal chain from carbon dioxide emission to social cost of carbon is long, complex and contingent on human decisions that are at least partly unrelated to climate policy. The social cost of carbon is, at least in part, also the social cost of underinvestment in infectious disease, the social cost of institutional failure in coastal countries, and so on." ²⁵

The U.N. IPCC Loss of Credibility

The Intergovernmental Panel on Climate Change (IPCC) is a U.N. panel that prepares reports on climate change about every 6 years. The panel primarily considers human causes of climate change and ignores most natural causes. About 770 peer-reviewed scientific papers published from January 2014 to June 2016 contradict the IPCC "consensus" view on global warming, see [here](#).²⁸

Contrary to IPCC statements, fully one-third of the IPCC's references in the 2007 report are to non-scientific-journal literature such as Greenpeace promotional material, see [here](#).²⁹ Government representatives remove any hints of skepticism from the draft Summary For Policymakers, then the main report is changed to match the political summary. After key changes were made to one main report, Frederick Seitz writes, "In my more than 60 years as a member of the American scientific community ... I have never witnessed a more disturbing corruption of the peer-review process than the events that led to this IPCC report.", [here](#).³⁰

A large archive of emails and files related to IPCC work was released on the internet in November 2009. The emails show a group of scientists working for the IPCC manipulated, hid or misrepresented data and evidence in official reports. They also obstructed freedom of information requests, and blocked publication of scientific papers that show nature is responsible for much of 20th century warming, see [here](#).³¹

In Conclusion

The climate is much less sensitive to greenhouse gas emissions than is commonly believed. The expected anthropogenic climate change from 2016 to 2100 is about 0.6 °C. The social cost of carbon, is likely in the range of -6.0 to -3.6 US\$/tCO₂, with a best estimate of -5.2 US\$/tCO₂. The benefits of CO₂ fertilization and warming are much greater than the harmful effects of warming. Emissions are very beneficial.

The Alberta Government imposed a carbon tax of C\$20/tCO₂ as of January 1, 2017, increasing to C\$30/tCO₂ as of January 1, 2018. The Alberta climate change plan may cause global temperatures to be 0.00007 °C lower than the status quo case by 2030. This action is not based on the most recent and best quality climate science and economic evaluations. A carbon tax will harm all Albertans for no benefit.

"CO₂ is not a control knob that can fine tune climate"

Judith Curry, Atmospheric Scientist, Georgia Tech



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http://www.friendsofscience.org/assets/files/SCC_Lewis_CS_2.xls Excel spreadsheet.

This article is available in PDF format at;

<http://www.friendsofscience.org/index.php?id=2205>

A shorter, non-technical version of this article is at;

<http://www.friendsofscience.org/index.php?id=2230>



Ken Gregory is President of Friends of Science Society with decades of experience in assessing models and climate science. Mr. Gregory has written numerous scientific assessments and commentaries, including Friends of Science Society's in-depth Climate Science Essay, featured on the website home page.

About

Friends of Science has spent a decade reviewing a broad spectrum of literature on climate change and have concluded the sun is the main driver of climate change, not carbon dioxide (CO₂). Friends of Science is made up of a growing group of earth, atmospheric and solar scientists, engineers, and citizens.

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