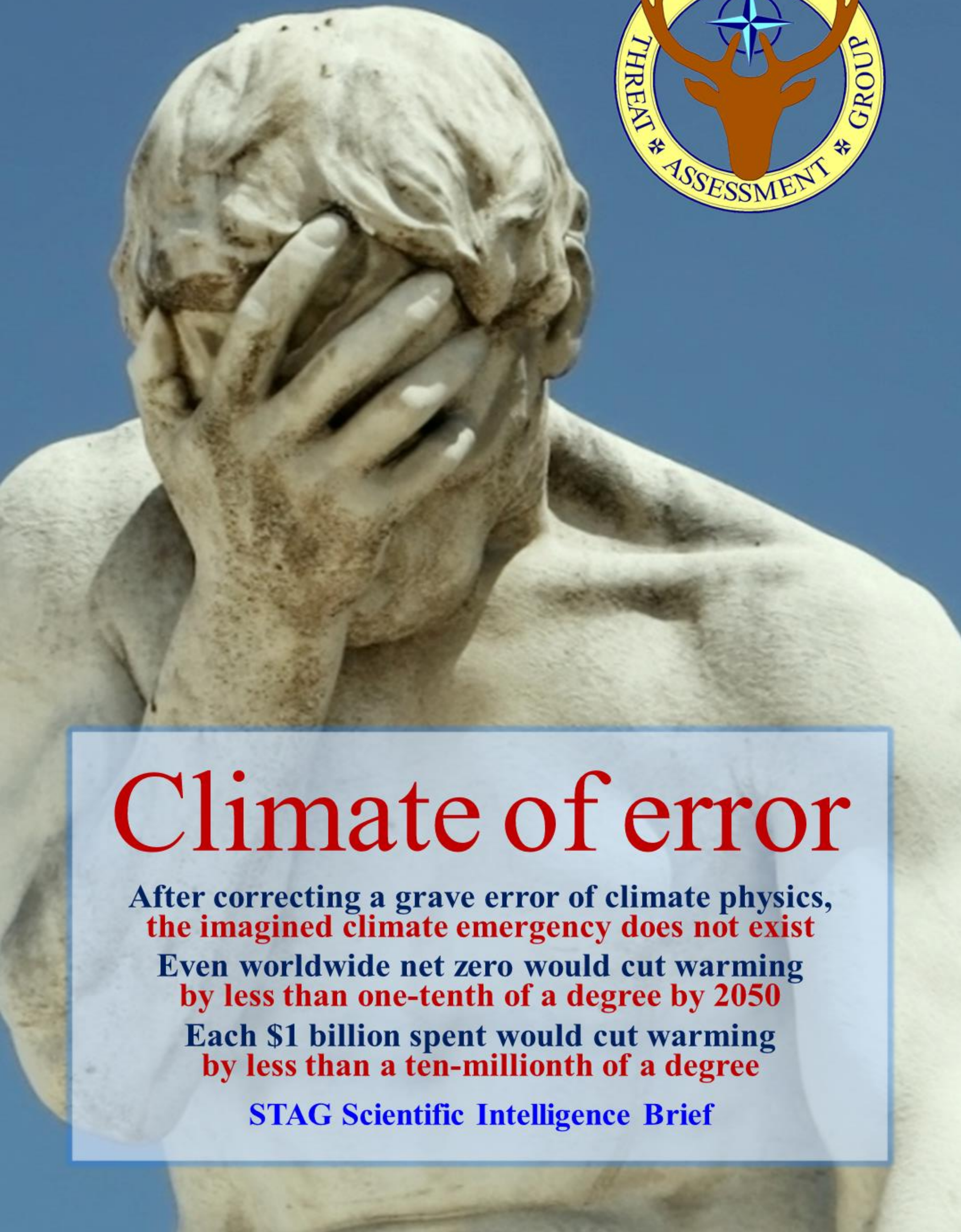
STRATEGIC THREAT ASSESSMENT GROUP



Climate of error

After correcting a grave error of climate physics,
the imagined climate emergency does not exist

Even worldwide net zero would cut warming
by less than one-tenth of a degree by 2050

Each $1 billion spent would cut warming
by less than a ten-millionth of a degree

STAG Scientific Intelligence Brief

Contents

Context

WESTERN NATIONS set themselves at a significant terms-of-trade disadvantage by acting all but alone to reduce greenhouse-gas emissions. The largely totalitarian East continues greatly to expand its coal, oil and gas infrastructure, while the largely democratic West installs costly and unreliable wind and solar power. Electricity prices in the West are thus already six to eight times those in the East, to which our overpriced energy drive out our businesses. The question arises whether the West's sacrifice is essential.

Concern about global warming is indeed misplaced. For some years, embarrassed climate scientists have suppressed a learned paper by an international team of eminent researchers. The paper exposes a grave error at the heart of the calculation of how much warming we may cause. The present scientific intelligence brief explains the error and its severe economic consequences for the West. A copy of the paper follows STAG's plain-language explanation.

The researchers who discovered the error have suffered greatly at the hands of scientists supporting the official narrative, who are reluctant to admit their embarrassing error. STAG's assessment is that they were mistreated not because they are wrong but because they are right.

> **A professor of climatology** and ex-director of the U.S. Global Change Research Program was bullied by his dean until he retired early from his professorship.
>
> **A German professor of control theory,** the field of engineering physics borrowed and misunderstood by climate scientists, was ordered by the president of his university to remove his name from the paper, though the president admitted he could find no fault with it. The professor appealed to his regional government, whose duty is to uphold academic freedoms. He was told free speech no longer exists in Germany.
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> **An award-winning solar astrophysicist** was hounded out of his institution because in an earlier paper he was among those hinting at the existence of the error described here. He was also libeled in major U.S. and European newspapers and scientific journals.
>
> **A member of a UK university** was expelled on a trumped-up charge when a reviewer of the paper told the vice-chancellor of his university that he could not refute it. The vice-chancellor ordered the environmental-sciences faculty to drop everything and refute the paper. When they could not refute it, the author was expelled.

Peer review is failing. Several climate journals have refused to publish the paper, though the reviewers could find no real fault with it. One journal kept it for two and a half years, refusing to answer any follow-up letters from the lead author, before rejecting it and ignoring the authors' appeal. Another journal, which rejects any paper that questions the official narrative, refused to send the paper out for review. A third journal provided two anti-scientific reviews. A fourth raised several formulaic queries, easily answered by the authors.

STAG's assessment is that the paper has merit. If it is sound, climate mitigation is unnecessary.

An error of physics: neglecting the Sun

The attached learned paper shows that in the 1980s climate scientists erred when they borrowed feedback math from control theory in engineering physics without understanding it. Though the Sun, the dominant influence on climate, drives 90% of global temperature directly, at a vital point in their global-warming calculations they neglected to allow for the fact that the Sun is shining. Their error misled them into predicting 2 to 3 times too much global warming.

In 1850, average surface temperature was 287.5 Kelvin (15 °C), the sum of the 259.6 Kelvin sunshine temperature that would prevail without greenhouse gases and before any feedbacks had acted, 7.9 degrees' natural direct warming by preindustrial gases, and 20 degrees' feedback response. The sunshine temperature thus represented 90% of the temperature in 1850:

$$\underbrace{259.6\text{ K}}_{\text{Sunshine temperature}} + \underbrace{7.9\text{ K}}_{\text{Natural direct warming}} + \underbrace{20\text{ K}}_{\text{Feedback response}} = \underbrace{287.5\text{ K}}_{\text{Global mean surface temperature in 1850}}$$

In 2007 Sir John Houghton, the first science chairman of the Intergovernmental Panel on Climate Change (IPCC), was asked why little more than 1 degree of direct warming from doubling CO_2 in the air might become as much as 4 degrees' final warming. He said feedback response, an extra warming driven by and proportional to a direct temperature, drove the extra 3 degrees. The only feedback process that matters is the water-vapor feedback. If we directly warm the air, it can carry more water vapor, itself a greenhouse gas, driving an extra warming – a feedback response. All other feedback responses broadly cancel each other out.

Sir John multiplied the 1.2 degrees' direct doubled-CO_2 warming by a system-gain factor to allow for feedback response and yield the final warming after the climate resettles to a new final temperature. In 1850, the natural greenhouse effect was 27.9 degrees: 7.9 degrees' direct warming by natural greenhouse gases plus 20 degrees' feedback response. His system-gain factor was thus 27.9 / 7.9, or 3.5, so that his final warming was 1.2 x 3.5, or 4.2 degrees:

Incorrect method

$$\underbrace{1.2}_{\text{Direct warming by doubled } CO_2 \text{ since 1850}} \; \frac{7.9 + 20}{7.9} = 1.2 \times 3.5 = 4.2\text{ K}$$

Corrected

$$1.2 \; \frac{\overbrace{259.6 + 7.9 + 20}^{287.5}}{259.6 + 7.9} = 1.2 \times \underbrace{1.075}_{\text{System gain factor}} = \underbrace{1.3\text{ K}}_{\text{Final warming by doubled } CO_2 \text{ since 1850}}$$

Sir John had not realised that feedbacks respond not just to direct warming by greenhouse gases but also to the **259.6 Kelvin** sunshine temperature. The system-gain factor for 1850 was not 27.9 / 7.9, or 3.5. It was (**259.6** + 27.9) / (**259.6** + 7.9), or just 1.075. Then final warming by doubled CO_2 would not be 1.2 x 3.5, or 4 degrees: it would be 1.2 x 1.075, or only 1.3 degrees.

Elements of control theory, the rocket science of the feedback loop

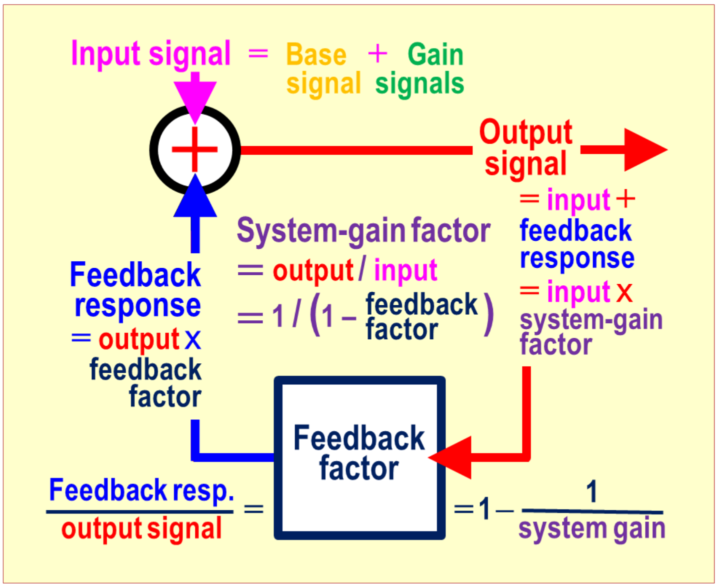
Feedback analysis is central to all the official methods of predicting global warming. Feedback math is the same for all dynamical systems (systems that change their state over time), from clocks, rockets and electronic amplifiers to the climate.

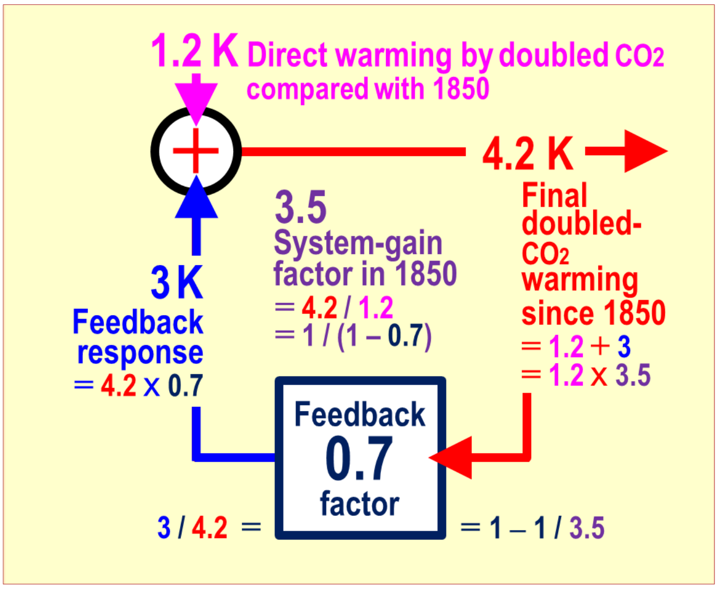
Temperature feedbacks operate as in an electronic circuit, but the feedback signals in the climate are temperatures rather than voltages.

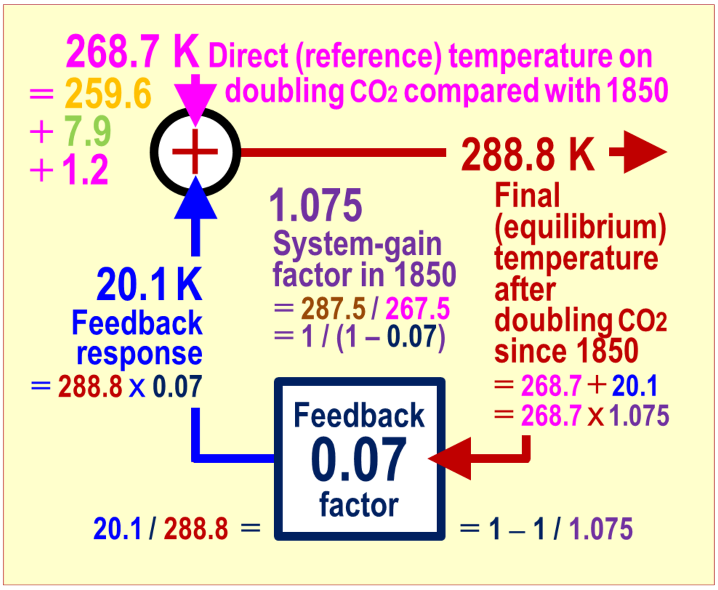
The base plus gain signals form the **input** (top right). The signal follows the arrows infinitely around the loop. Then the feedback response plus the input is the **output**; the output times the feedback factor is the **feedback response**; the output divided by the input is the **system-gain factor**; and 1 minus the reciprocal of the system-gain factor is the **feedback factor**. Visibly, the feedback factor must respond to the entire input signal. Feedbacks are inanimate. They cannot choose which part of the input temperature they will respond to.

Let us put some numbers into our climate circuit diagram, first by climate scientists' method (centre), omitting the 259.6 Kelvin sunshine temperature, and then (bottom) by the correct method, including it.

The error is corrected by adding the sunshine temperature of 259.6 Kelvin and the direct 7.9 degrees' natural greenhouse-gas warming to the 1.2 degrees' direct warming by doubled CO_2 to give a true input signal of 268.7 degrees. Then the true feedback factor, an impossibly large 0.7 in climate scientists' method, is in reality just 0.07, a tenth of theirs. Their error is large.







True feedback response is 20.1 degrees, just 0.1 degrees above the 20 degrees in 1850. If, as is likely, the feedback regime remains as in 1850, feedback response will add very little to global warming. Final temperature after doubling CO_2 is 288.8 Kelvin, 1.3 degrees above the 267.5 degrees in 1850. That 1.3 degrees is less than a third of the 4.2 degrees that climate models predict, and below half of IPCC's best estimate of 3 degrees. Net zero emissions policy is currently made on the basis of the high-end predictions in climate models. However, after correction of the error those extreme predictions become so unlikely that mitigation of global warming becomes unnecessary, as some widely-unreported facts already indicate:

- Though global population has quadrupled in the past century, yearly deaths by extreme weather have declined by 96%, according to the U.S. Office for Foreign Disaster Assistance and the Centre for Research into the Epidemiology of Disasters.
- Several papers in *The Lancet* show that in every region death from cold is ten times likelier than death from heat: in Africa, 40 times likelier. Cold is the real killer.
- Crop yields are at a record high. Famine is now rare. By CO_2 fertilization, the total biomass of trees and plants has risen by 15% in recent decades, for CO_2 is plant food.

Why feedback analysis cannot be used for global-warming predictions

In the corrected calculation, it was assumed (not unreasonably) that the feedback regime has not changed since 1850. But it could have changed. That possibility makes feedback analysis valueless for predicting global warming. To see why, work backward from the 2 to 5 degrees' predicted range of final warming to find the implicit range of corrected feedback factors:

Corrected feedback factor implicit in [2 to 5] K doubled-CO_2 warming

Sunshine temperature (259.6 K); Natural GHG warming (7.9 K); Direct warming by doubled CO_2 (1.2 K); Temperature in 1850, HadCRUT4 (287.5 K); Final warming by doubled CO_2, Range in IPCC 2021 ([2 to 5] K)

$$1-\frac{259.6\text{ K}+7.9\text{ K}+1.2\text{ K}}{287.5\text{ K}+[2\text{ to }5]\text{ K}} = [0.07\text{ to }0.08] \quad \text{Corrected}$$

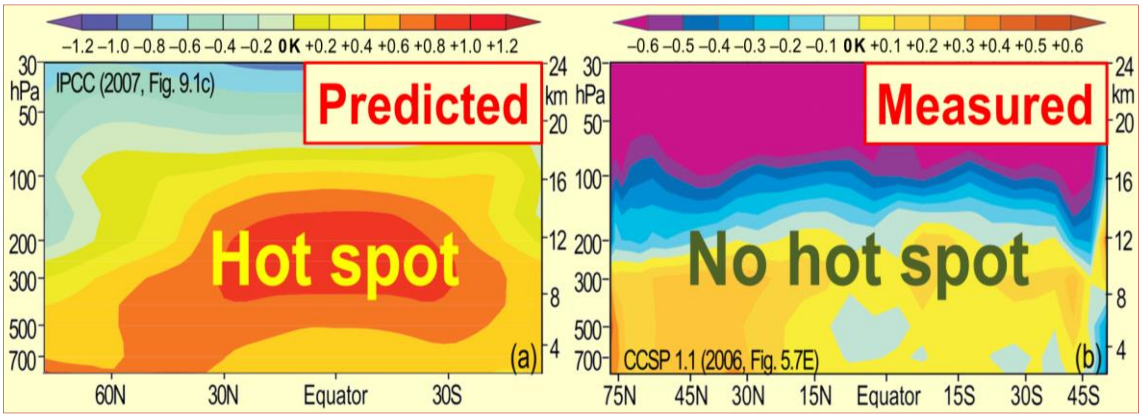
cf. IPCC (2021) [0.40 to 0.76] Erroneous

Thus, a true feedback factor of 0.07 to 0.08, with a range of just 0.01, would yield a final warming of 2 to 5 degrees. Yet, since climate measurements are uncertain, feedback factors can neither be directly measured nor deduced by theoretical methods to a precision anything like as fine as 0.01. For comparison, implicit feedback factors in IPCC (2021) are 0.40 to 0.76, up to 8 times too large, with a range 36 times too broad.

After correction, the feedback factor is so small and its range so narrow that all official predictions, including all those in IPCC's six *Assessment Reports*, are no better than guesswork.

The missing 'hot spot': real-world evidence of the error

Climate scientists think water vapor feedback is large because their models predict that if we warm the air directly the water vapor content six miles up in the tropics will increase, warming the upper air up at twice the rate at the tropical surface. In reality, water vapor in the upper air has been declining for a century. Therefore, temperature measurements show the tropical upper-air "hot spot" is absent, confirming that feedback response must indeed be small:



How to predict global warming without using feedback analysis

Several methods of predicting global warming independent of feedback analysis receive less attention than they should, since they cohere with one another in showing a great deal less warming than climate scientists' erroneous method dependent on flawed feedback analysis:

Method 1: Officially-predicted final warming by doubled CO_2 compared with 1850 – the standard metric – is 2 to 5 degrees, but after including the sunshine temperature the corrected value is just 1.3 degrees, of which 0.4 degrees has already occurred, leaving less than 1 degree further warming by 2100. That is simply not enough to do anything but good.

Method 2: In 1990 IPCC predicted 0.2 to 0.5 degrees/decade global warming from 1990-2090 (one-tenth of its 2 to 5 degrees' predicted final doubled-CO_2 warming). However, only 0.14 degrees/decade has been observed since 1990. Thus, final warming by doubled CO_2 compared with 1850 (about the same as predicted final 21st-century warming) may well be only 1.3 degrees, confirming the 1.3 degrees' corrected estimate based on the feedback regime in 1850.

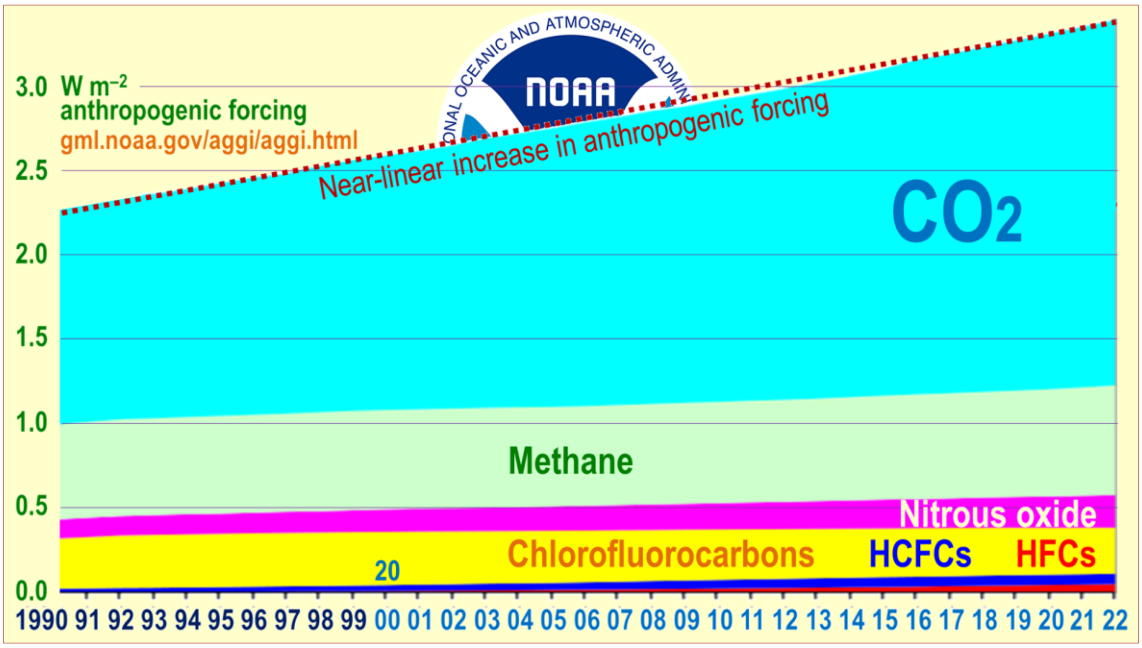
Method 3: The Monte Carlo statistical method can be used to input random values within the bounds of the five parameters in the energy-budget equation. A billion trials show that – to 95% confidence – 21st-century warming will be 1.3 degrees, with a range of 0.9 to 2 degrees.

An error of physics: Conclusion

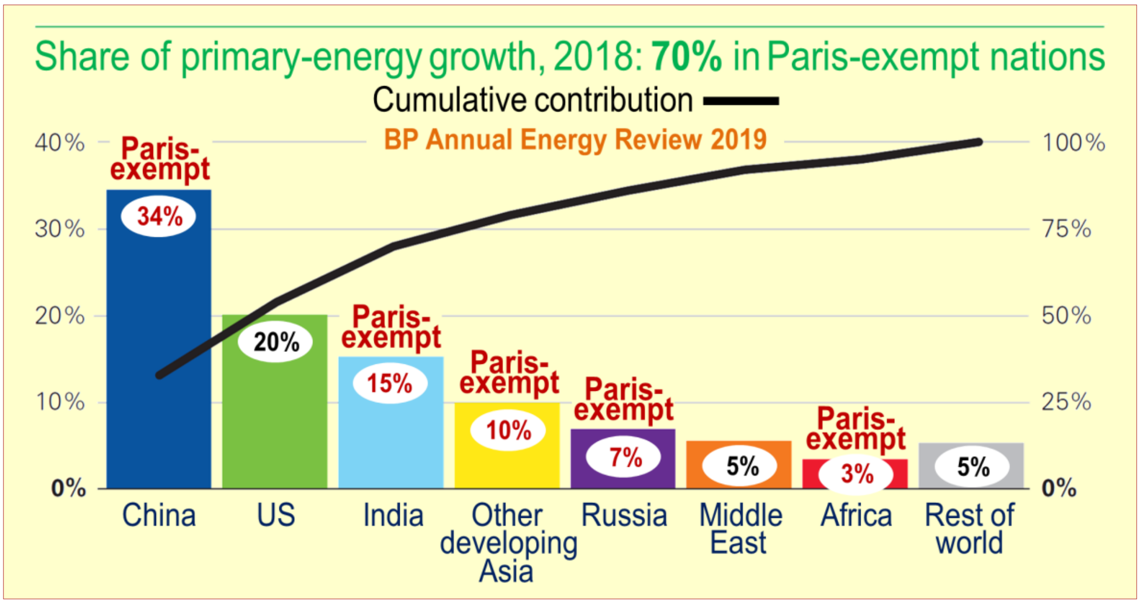
The West has been misled by a grave error of physics that climate scientists, who forgot the Sun is shining, are reluctant to correct. Those who discovered the error have suffered for questioning what has become an unchallengeable orthodoxy. They are not named here: their result speaks for itself. Meanwhile, the nations of the largely totalitarian East are profiting by their continuing – though climatically harmless – expansion of coal-fired power, keeping their electricity prices less than one-sixth of ours, which are inflated by the absurdly high costs of attaining net zero, to which we shall now turn. Nor should the role of certain nations' agents of influence in promoting the official climate narrative in the West, and in harming the reputations of those researchers who have dared to question that narrative, be underestimated.

An error of economics: The cost-ineffectiveness of net zero

Climate scientists' grave error of physics is costly. The trillions needlessly spent on trying to mitigate global warming have made no difference at all to the rate of increase in our influence on climate. It has risen in a straight line at an undiminished rate for a third of a century:

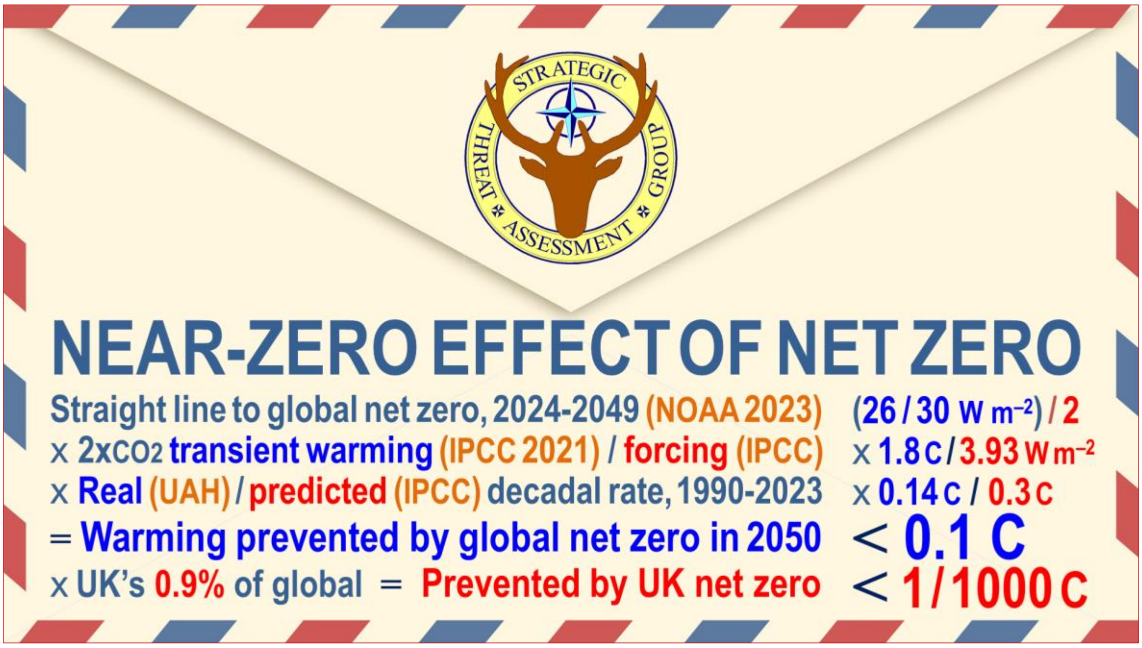


The Paris climate accords selectively target the West. The large nations of the East – Russia and China, India and Pakistan – continue to build cheap, efficient and, these days, clean coal fired stations. Yet, thanks to the error of physics, the democracies of the West are driving out their manufacturing businesses to the largely totalitarian East, where electricity prices are less than a sixth of ours. Thus, some 70% of growth in primary energy is in Paris-exempt nations:

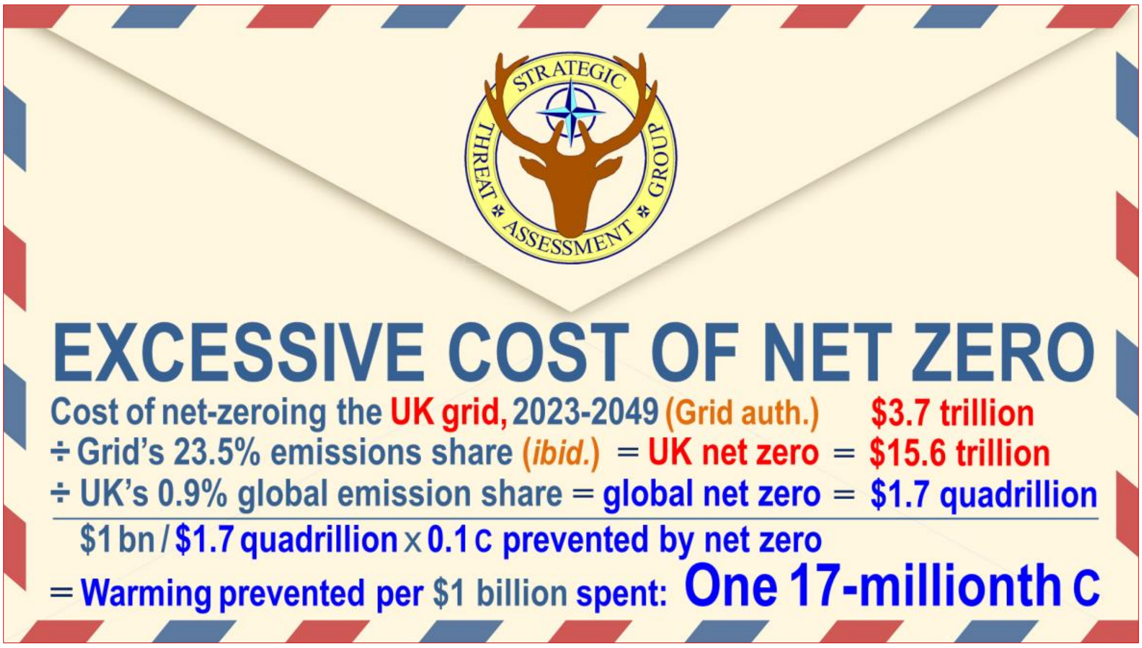


If the whole world were to destroy its economies and thereby achieve net zero greenhouse-gas emissions by the target year of 2050, how much global warming would be prevented by then? Our influence on climate has been increasing at 1/30th of a unit per year. Thus, over the 26 years to 2049, global net zero would abate about half of the next 26/30^{ths} of a unit.

Convert units to temperature change using the ratio of officially-predicted 21st-century warming by doubled CO_2 to the CO_2 forcing. Just a fifth of a degree of warming would be prevented – or less than a tenth of a degree after correction for persistent over-prediction in climate models. Net zero in the UK, on its own, would cut global warming by just a thousandth of a degree:



What of the cost? Let us use the back of a second envelope. The British power grid authority calculates that the cost of preparing the grid for net zero will be $3.7 trillion. But the grid accounts for only 23.5% of Britain's total emissions. Pro rata, then, the cost of preventing that one-thousandth of a degree in Britain would be $15.6 trillion. But Britain emits only 0.9% of global emissions, so global net zero would cost more than $1.5 quadrillion:



Thus, every $1 billion spent worldwide on attempting to attain net zero would prevent less than one ten-millionth of a degree of global warming by 2050 – the worst value for money in history, to address what the learned paper that follows shows to be a non-problem anyway.

An error of temperature feedback analysis and its consequences

Since 1990, 0.14 to 0.2 K decade^{-1} global warming has been observed, but 0.2 to 0.5 K decade^{-1} had long been predicted. That factor-2 excess of prediction over observation suggests a systemic error in deriving climate sensitivity. Since feedback response was hitherto thought to represent 40-75% of final warming, predictions were founded chiefly upon feedback analysis. It is here that an error indeed arose. In the 1980s, when feedback formulism was borrowed from control theory in engineering physics, 99.5% of the input to the temperature-feedback loop was overlooked, so that the feedback factor was thought to fall on 0.60 [0.40 to 0.75], an interval manifestly excessive in the near-thermostatic climate. In reality, temperature feedbacks must respond not only to 1.2 K direct warming by doubled CO_2 but also to 7.9 K direct warming by preindustrial greenhouse gases and, above all, to the predominant 259.6 K solar emission temperature. After correction, the interval of feedback factors that would yield the currently-predicted 2 to 5 K interval of final warming is 0.07 to 0.08. Since the feedback factor cannot be constrained to any such precision, all projections dependent on feedback analysis are irremediably speculative. Methods not thus dependent cohere at 1-2 K final warming. Global net zero is unnecessary. It would prevent only 0.1 to 0.2 K global warming by 2050, but would cost $1.5 quadrillion, preventing less than one 10-millionth of a degree of warming per $1 billion spent.

1 Introduction

Temperature-feedback response is an additional, indirect temperature change responsive to a direct temperature signal. Feedback response constitutes the entire difference between direct (reference) and final (equilibrium) temperature signals. Direct warming by doubled CO_2 before adding feedback response (reference doubled-CO_2 sensitivity RCS) is estimated at 1.2 to 1.3 K (*e.g.*, Hansen 1984), with little uncertainty. IPCC (2021) predicts 3 [2 to 5] K final warming by doubled CO_2 after including feedback response (equilibrium sensitivity ECS). Accordingly, for 1.2 K RCS, currently-projected feedback response falls on 1.8 [0.8 to 3.8] K, or 60% [40% to 75%] of ECS; the large uncertainty in predicted global warming is chiefly attributable to uncertainty in feedback response; and the large projected feedback response is the principal reason why large and potentially dangerous warming is predicted. Difficulties in constraining feedback response account for the failure to constrain the 3 K breadth of the interval of ECS in almost half a century since Charney (1979), followed by IPCC (1990), predicted 3 [1.5 to 4.5] K ECS, similar to the 3 [2 to 5] K projected in IPCC (2021).

The principal temperature feedback is the water-vapor feedback, "an even more powerful absorber of terrestrial radiation" than direct warming by CO_2 (Charney *op. cit.*). At midrange all other feedbacks broadly self-cancel (*e.g.*, IPCC 2013, table 9.5). Though Arrhenius (1896, 1906) attempted to allow for water-vapor feedback in deriving ECS, at that time the governing equations of control theory, a discipline in engineering physics (Black 1934, Bode 1945) had not yet been formalized. Current definitions of temperature feedback (*e.g.*, IPCC 2021, p. 2222) neglect to state that feedbacks must at any moment respond to the entire direct reference temperature then prevailing, and not merely to a *perturbation* thereof –

> "**Climate feedback:** An interaction in which a *perturbation* in one climate quantity causes a change in a second, and the change in the second quantity ultimately leads to an additional change in the first. A negative feedback is one in which the initial *perturbation* is weakened by the changes it causes; a positive feedback is one in which the initial *perturbation* is enhanced. The initial *perturbation* can either be externally forced or arise as part of internal variability." [authors' emphases]

Such defective definitions, and the order-of-magnitude error consequent thereupon, are universal: e.g., Hansen et al. (1984); Schlesinger (1988), Bony et al. (2006); Soden & Held (2006); IPCC (2007, 2013); Roe (2009); Lacis et al. (2010, 2013); Schmidt et al. (2010); Lindzen & Choi (2011); Knutti & Rugenstein (2015); Dufresne & St-Lu (2015); Prentice et al. (2015); Heinze et al. (2019); AMS (2020); Sherwood et al. (2020).

As far as is known, no climate-sensitivity study has hitherto acknowledged that feedbacks at any moment t must perforce respond to the entire direct temperature R_t, and proportionately to each component therein. It is this error of feedback analysis that led to the notion that midrange ECS would be of order 3 to 4 K, though observationally-based methods independent of feedback analysis suggest less than half that value.

Hansen et al. (1984) first explicitly deployed control theory in deriving ECS. It was concluded that, after feedback response, 1.2 K RCS would become ~4 K ECS. The implicit system-gain factor (taken *ibid.* as the ratio of ECS to RCS) was thus given as 3 to 4. However, after correcting the grave control-theoretic error, ECS based on feedback strength as in 1850 would be ~1.3 K, not ~4 K.

2 Theory

2.1 The control-theoretic feedback amplifier

Feedback formulism in control theory is universally applicable to feedback-moderated dynamical systems, from electronic circuits (for which the theory was originally developed in the 1930s) to rockets (without which we could not have reached the Moon), and to the Earth's climate. In the classical feedback amplifier (Fig. 1a), an input line sends a base or originating signal via a summative input node into a feedback loop, around which the signal passes infinitely via the **G** gain block and the **H** feedback block to become the output signal.

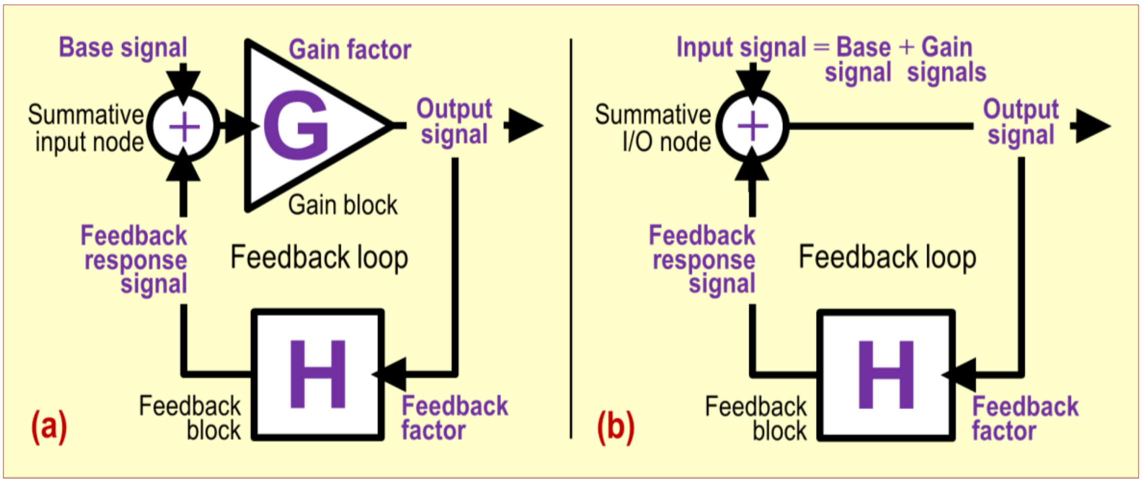


Figure 1: (a) The classical feedback amplifier; (b) The simplified block diagram

In dynamical systems such as climate, which possess no differencer permitting the **H** feedback block to act on the gain signal but not also on the base signal, it is simpler to dispense with the **G** gain block and instead to add any gain signals (in climate, direct warmings by natural and by anthropogenic greenhouse gases) to the base signal (the predominant direct solar emission temperature). Then their sum, the input signal sent into the feedback loop via a summative input/output node (Fig. 1b), is the direct or reference signal (the entire absolute temperature before adding feedback response).

For given base and gain signals and feedback factor, the outputs of circuits 1(a) and 1(b) are identical. Here, for simplicity and clarity, circuit 1(b) will be used.

Hitherto, temperature-feedback analyses have neglected to send the base signal (the 259.6 K emission temperature) and the natural gain signal (the 7/9 K direct warming by preindustrial noncondensing greenhouse gases) into the feedback loop. It will be seen that these substantial omissions have led to significant error.

2.2 Proof of the closed-form sum $(1 – \mathrm{H}_t)^{-1}$ of powers of the feedback factor H_t

The feedback factor H_t is the unitless ratio not only of **feedback strength Λ_t,** in W m^{-2} per Kelvin of the output signal to the 3.22 W m^{-2} K^{-1} Planck response P (IPCC, 2021), but also of **feedback response B_t** to final (equilibrium) temperature E_t. **The system-gain factor A_t** is the ratio of E_t to the direct (reference) temperature R_t. Thus, B_t is the difference between E_t and R_t. Time-subscripts t are **0** at emission temperature; **1** in 1850; **2** after a subsequent doubled-CO_2 forcing. Current variants of true feedback variables H_t, Λ_t, A_t are h_t, λ_t, a_t. Successive powers of H_t modify the signal as it passes infinitely around the feedback loop. The proof that the infinite geometric series $\{r^0 + r^1 + \ldots + r^\infty\}$, of common ratio $|\, r \,| < 1$, converges to the closed-form sum $(1 – r)^{-1}$ predates control theory by a century. Equation 1 proves that, since feedback response B_t is the product of E_t and H_t, the ratio A_t of E_t to R_t is equal to $(1 – \mathrm{H}_t)^{-1}$.

$$R_t \coloneqq E_t - B_t \coloneqq E_t - E_t\mathrm{H}_t = E_t(1 - \mathrm{H}_t) \quad \Rightarrow \quad A_t \coloneqq E_t \,/\, R_t = (1 - \mathrm{H}_t)^{-1}. \qquad (1)$$

At any time t, then, all successive powers of H_t *ad infinitum*, and thus the system-gain factor A_t, must perforce act upon the entire input signal R_t, and proportionately to each component therein. This proportionality need not imply time-invariance in the feedback variables.

3 Methods

3.1 The predominant emission temperature

The base signal in the temperature-feedback amplifier, found using the Stefan-Boltzmann equation (Eq. 2), is the predominant 259.6 K direct solar emission temperature R_0 (*cf.* 255 K *e.g.* in Lacis *et al.* 2010) that would prevail at the Earth's surface in the absence of any greenhouse gases or feedback response, given the 1363.5 W m^{-2} solar irradiance S (DeWitte & Nevens, 2016), 0.29 mean albedo α (Stephens, 2015), the 5.6704 x 10^{-8} W m^{-2} K^{-4} Stefan-Boltzmann constant σ (Rybicki & Lightman 1979) and 0.94 mean surface emissivity ε.

$$R_0 \coloneqq [S(1 - \alpha) \,/\, (4\varepsilon\sigma)]^{1/4}. \qquad (2)$$

3.2 The temperature equilibrium in 1850

In 1850, global temperature was at equilibrium: there would be no trend for 80 years. The 267.5 K direct (reference) temperature R_1 was the sum of the 259.6 K emission temperature R_0 and the 7.9 K direct warming ΔR_0 by preindustrial, noncondensing greenhouse gases. The 287.5 K observed final (equilibrium) temperature E_1 was the sum of R_1 and the 20 K total feedback response B_1. Neglecting the predominant emission temperature $\boldsymbol{R_0}$ suggested a variant system-gain factor a_1 in 1850 equal to 3.5 (Eq. 3), while including $\boldsymbol{R_0}$ yields a true system-gain factor A_1 equal to only 1.075 based on the feedback regime that year (Eq. 4).

$$\text{Current:} \quad a_1 = (\Delta R_0 + B_1) \,/\, \Delta R_0 = \Delta E_0 \,/\, \Delta R_0 \qquad (3)$$

$$\text{Corrected:} \quad A_1 = (\boldsymbol{R_0} + \Delta R_0 + B_1) \,/\, (\boldsymbol{R_0} + \Delta R_0) = (R_1 + B_1) \,/\, R_1 = E_1 \,/\, R_1 \qquad (4)$$

3.3 Doubled-CO_2-equivalent direct warming since 1850

After an anthropogenic direct warming (RCS) ΔR_1 equivalent to doubling CO_2 concentration since 1850, the true input signal R_2 (the entire 268.7 K direct temperature before adding feedback response) is the sum of the 267.5 K direct temperature R_1 in 1850 and the 1.2 K RCS. Hitherto, however, only RCS, representing less than 0.5% of R_2, served as the entire input signal to the feedback loop.

The standard climate-sensitivity metric is equilibrium sensitivity (ECS) ΔE_1 to direct warming ΔR_1. The model in Hansen *et al.* (1984) yielded ~4 K ECS by doubled CO_2, with a stated system-gain factor a_2 of 3 to 4 given ~1.2 K RCS. Fig. 2 reflects this erroneous method. Ny which RCS alone enters the feedback loop. Then, holding the variant system-gain factor a_2 equal to a_1 in 1850, i.e., 3.5, variant ECS (the product of a_2 and the 1.2 K RCS) is 4.2 K.

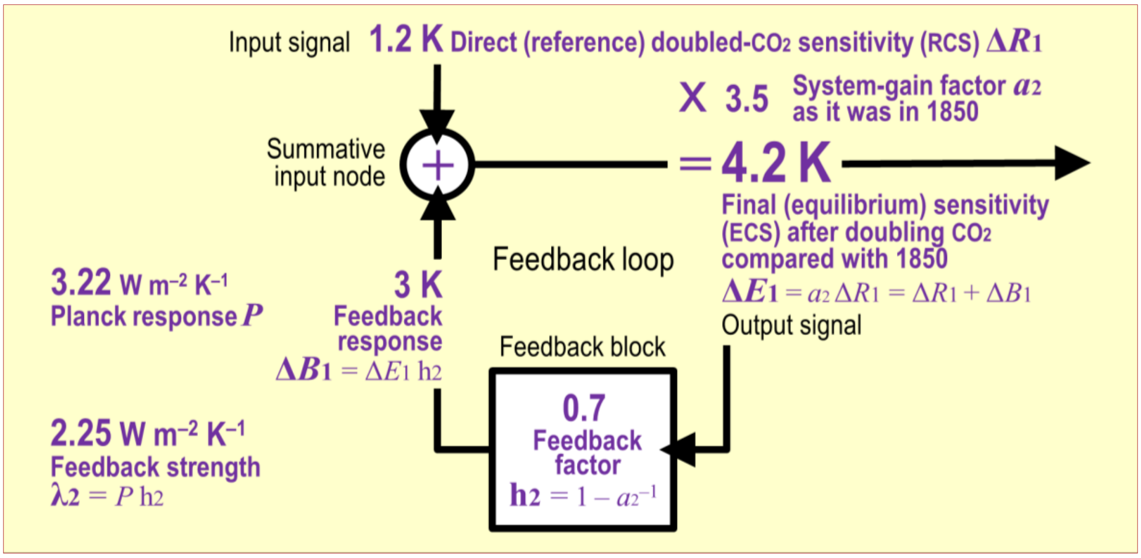
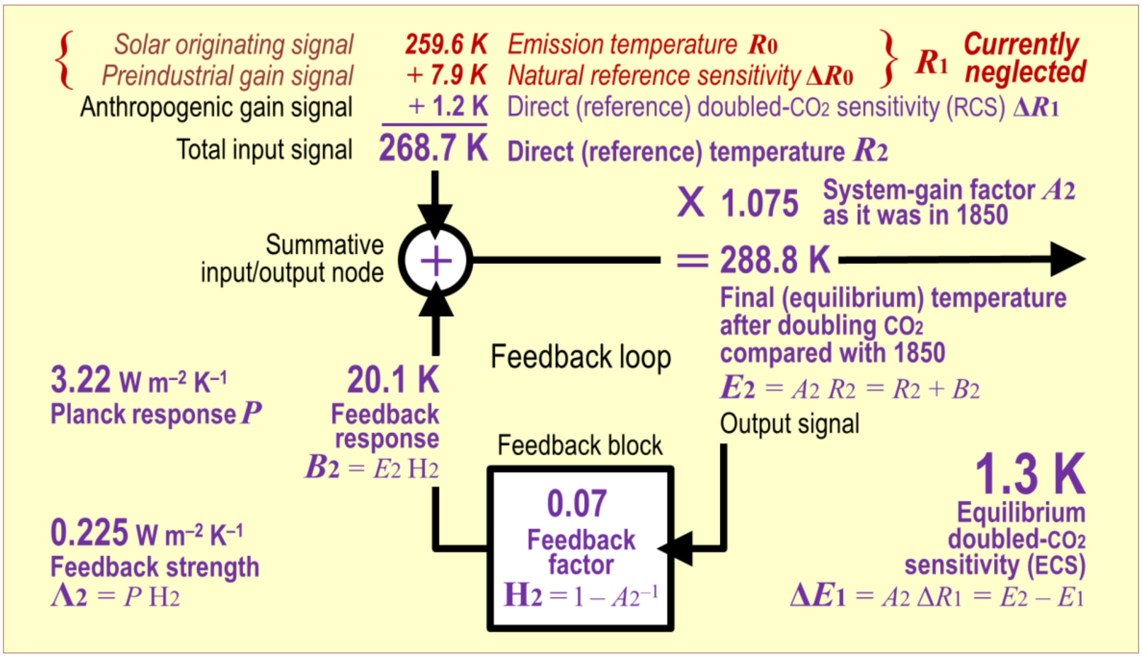


Figure 2 (above): Variant feedback method. **Figure 3 (below): Corrected method**



In the corrected diagram (Fig. 3), the 267.5 K reference temperature R_1 for 1850, neglected in Fig. 2, is added to the 1.2 K RCS ΔR_1 to form the entire 268.7 K reference temperature R_2. Then ECS falls from 4.2 K to 1.3 K. Fig. 3 shows why the feedbacks at time t must respond to the entire direct temperature R_t. They are inanimate: they cannot respond solely to the 1.2 K RCS (less than 0.5% of R_2), but not also to the 267.5 K R_1 (the remaining 99.5%). They must also respond proportionately to each component in R_2. For example, in 1850 the feedback responses B_0, ΔB_0 to the 259.6 K emission temperature R_0 and the 7.9 K natural reference sensitivity ΔR_0 were 19.4 K and 0.6 K respectively, summing to the 20 K total feedback response B_1 to the 267.5 K reference temperature R_1 (Eq. 5).

$$B_0 = R_0\, B_1 \,/\, R_1; \quad \Delta B_0 = \Delta R_0\, B_1 \,/\, R_1. \qquad (5)$$

In 1850, since the system-gain factors A_1, a_1 were 3.5, 1.075, the feedback factors H_1, h_1 were 0.07, 0.7 (Eq. 6). Neglecting 99.5% of the true input signal thus overstated the feedback factor by an order of magnitude.

$$\mathrm{H}_1 \coloneqq 1 - A_1^{-1}; \quad \mathrm{h}_1 \coloneqq 1 - a_1^{-1}. \qquad (6)$$

3.4 Governing equations of the temperature-feedback amplifier

Table 1 sets out the governing equations of the feedback amplifier when the climate resettles to equilibrium after a forcing equivalent to doubling CO_2 concentration compared with 1850, and after any feedback response. Table 1(a) successively derives the corrected feedback factor H_2, system-gain factor A_2 and ECS ΔE_1 from the true feedback strength Λ_2, while variant h_2, a_2 and ΔE_1 are derived from λ_2. Table 1(b) runs the equations in reverse, successively deriving from ECS and RCS the implicit system-gain factors A_2, a_2, the feedback factors H_2, h_2, and the feedback strengths Λ_2, λ_2. By this method it will be found instructive later to derive the interval of the true feedback factor H_2 that would yield the published 3 [2 to 5] K ECS.

Table 1: Governing equations of the temperature-feedback amplifier

a) Derivation of ECS ΔE_1 from variant and corrected feedback strengths λ_2, Λ_2		
Variable	*Climatologists' variants*	*Corrected method*
Feedback factor	**h_2:** λ_2 / P	**H_2:** Λ_2 / P
System-gain factor	**a_2:** $(1 - \mathrm{h}_2)^{-1} = (1 - \lambda_2 / P)^{-1}$	**A_2:** $(1 - \mathrm{H}_2)^{-1} = (1 - \Lambda_2 / P)^{-1}$
ECS	**ΔE_1:** $\Delta R_1\, a_2 = \Delta R_1\, (1 - \lambda_2 / P)^{-1}$	**ΔE_1:** $R_2\, A_2 - E_2 = R_2\, (1 - \Lambda_2 / P)^{-1} - E_2$
b) Derivation of implicit feedback strengths λ_2, Λ_2 from projected ECS		
Variable	*Climatologists' variants*	*Corrected method*
System-gain factor	**a_2:** ECS / RCS = $\Delta E_1 / \Delta R_1$	**A_2:** $E_2 / R_2 = (E_1 + \Delta E_1) / (R_1 + \Delta R_1)$
Feedback factor	**h_2:** $1 - a_2^{-1} = 1 - \Delta R_1 / \Delta E_1$	**H_2:** $1 - A_2^{-1} = 1 - R_2 / E_2$
Feedback strength	**λ_2:** $P\ \mathrm{h}_2 = P\ (1 - \Delta R_1 / \Delta E_1)$	**Λ_2:** $P\, \mathrm{H}_2 = P\, [1 - R_2 / (E_1 + \Delta E_1)]$

4 Results

4.1 Corrected ECS

Hitherto, the variant feedback factor h_2 was treated as responding solely to 1.2 K reference *sensitivity* RCS ΔR_1: yet the true feedback factor H_2 necessarily responds to the entire 268.7 K reference *temperature* R_2. Feedback variables in Figs. 2, 3 were derived assuming that feedback factors remain unchanged at the 0.07 for 1850. Thus, for $\mathrm{H}_2 = \mathrm{H}_1 = 0.07$, midrange ECS would be 1.3 K (Eq. 7).

$$\Delta E_1 = E_2 - E_1 = R_2\, A_2 - E_1 = R_2\, (1 - \mathrm{H}_2)^{-1} - E_1. \quad (7)$$

The interval of variant feedback factors h_2 implicit in 3 [2 to 5] K ECS is 0.60 [0.40, 0.76] (Eq. 8).

$$\mathrm{h}_2 = \Delta B_1 \,/\, \Delta E_1 = 1 - \Delta R_1 \,/\, \Delta E_1. \quad (8)$$

Equation (9) derives from the published 3 [2 to 5] K ECS interval the implicit interval of the true feedback factor H_2: namely, 0.075 [0.072, 0.081], of breadth only 0.009 (Table 2).

$$\mathrm{H}_2 = B_2 \,/\, E_2 = 1 - R_2 \,/\, E_2 = 1 - R_2 \,/\, (E_1 + \Delta E_1) = 1 - 268.7/(287.5 + \Delta E_1). \quad (9)$$

However, uncertainties in climatic data prevent derivation of H_2 to anything like so fine a precision. It is for this reason that feedback analysis is valueless for constraining climate sensitivities, and that all attempts at prediction of future temperature change dependent upon feedback analysis – including all climate-sensitivity estimates in IPCC's *Assessment Reports* – are speculative.

Table 2: Variant and corrected 2 σ intervals of feedback factors h_2, H_2 compared

ECS (IPCC 2021)	**ΔE_1**	**How derived**	**2 K**	**3 K**	**4 K**	**5 K**	**Units**
Feedback sum	$\Sigma\lambda$	*Ibid.*	–1.81	**–1.16**	—	–0.51	$\mathrm{W m^{-2} K^{-1}}$
Planck response	P	*Ibid.*	–3.40	**–3.22**	—	–3.00	$\mathrm{W m^{-2} K^{-1}}$
Feedback strength	λ_2	$\Sigma\lambda - P$	+1.59	**+2.06**	—	+2.49	$\mathrm{W m^{-2} K^{-1}}$
Feedback factor	h_2	$\lambda_2 / \lvert P \rvert$	+0.47	**+0.64**	—	+0.83	Unitless
cf. as derived herein	h_2	Eq. (8)	+0.40	**+0.60**	—	+0.76	Unitless
True feedback factor	H_2	Eq. (9)	+0.071	**+0.075**	+0.078	+0.081	Unitless
Increment in H_2 per K	$\Delta \mathrm{H}_2$	3 K – 2 K etc.	—	**+0.003**	+0.003	+0.003	Unitless

4.2 Inutility of feedback analysis in constraining ECS

To constrain feedback response, and thus ECS, one must find the derivative dE / dR, requiring knowledge of E_t, R_t at two successive moments t of equilibrium in the industrial era (Eq. 10).

$$dE / dR = (E_t - E_1) / (R_t - R_1) \quad : \quad 1 < t < 2. \tag{10}$$

For $t = 2$, dE / dR = ECS / RCS. At the 1850 equilibrium (there would be no trend in surface temperature for 80 years), E_1, R_1 were 287.5 K and 267.5 K. However, since 1930 temperature has been rising, so that subsequent values of E_t, R_t are unknown. Even if known, they would not be known to enough precision to derive the feedback factor H_t to within 0.003. All projections dependent on feedback analysis are thus irremediably speculative. Some methods not thus dependent are now outlined.

4.3 Feedback-independent methods of constraining ECS

4.3.1 Derivation of ECS from data for 1850

Though ECS for a feedback factor H_2 unchanged at 0.07 since 1850 would be 1.3 K (Eq. 7), even a small increase in H_2 compared with H_1 would elevate ECS significantly. If H_2 were 0.08 rather than 0.07, ECS would increase by 350% to 4.6 K. This example illustrates why, after correcting the error, feedback analysis cannot assist in the constraint of ECS.

4.3.2 Observed against projected temperature change

Midrange warming predicted in IPCC (1990) was 0.3 K/decade, implying 3 K ECS, but only 0.14-0.2 K/decade is observed since 1990, implying 1.4-2 K ECS. Though feedback response (chiefly to more water vapor in warmer air) was thought to contribute up to 75% of ECS, the 1.4 to 2 K ECS derived observationally suggests feedback response contributes little to ECS.

4.3.3.1 Energy-budget method (midrange values)

Gregory (2004: see also Bates, 2016) proposed the energy-budget method of deriving ECS. Lewis & Curry (2014) simplified the method, which is independent of feedback analysis. Table 3 derives anthropogenic fraction M by period-weighting. Then Table 4 sets out the illustrative intervals of the five initial conditions for the simplified energy-budget analysis.

Table 3. Derivation of the anthropogenic fraction *M* (data from Wu et al. 2019, table 2)

Period	Yrs.	Total	Anth.	Resid.
1900-1912	13	–0.153	0.024	–0.177
1913-1927	15	0.118	0.025	0.093
1928-1952	25	0.070	0.020	0.050
1953-1960	8	0.056	0.101	–0.045
1961-1970	10	–0.036	0.071	–0.108
1971-1990	20	0.147	0.136	0.012
1991-2009	19	0.163	0.115	0.048
2010-2013	4	0.313	0.136	0.176
Weighted totals		**0.965**	0.709	0.253
Percentages		**100%**	73.5%	26.5%

Table 4. Parameters for the energy-budget method

Anthropogenic fraction	M	**0.85** [0.75 to 1]	Based on Wu (2019, table 2).
Observed warming to date	ΔT	**1.00** [0.93 to 1.27] K	Morice (2012, 2021); IPCC (2021).
Doubled-CO_2 forcing	ΔQ_1	**3.93** [2.75 to 4.15] W m^{-2}	Zelinka (2020).
All-causes forcing to 2023	ΔQ_{anth}	**3.2** [2.8 to 3.5] W m^{-2}	NOAA (2023).
Earth energy imbalance	ΔN	**0.79** [0.71 to 1.00] W m^{-2}	IPCC (2021, p. 91); von Schuckmann (2020); Raghuraman (2021).

Midrange values informing the energy-budget equation (Eq. 11) yield 1.3 K ECS ΔE_1.

$$\Delta E_1 = M\, \Delta T\, \Delta Q_1 / (\Delta Q_{\text{anth}} - M\, \Delta N). \tag{11}$$

4.3.3.2 Energy-budget method (bounds) by Monte Carlo distribution

The 2 σ bounds of the initial conditions in Table 4, informing a billion-trial Monte Carlo distribution using Eq. (11), yield 1.3 [0.9, 2.0] K ECS to 95% confidence (Fig. 4):

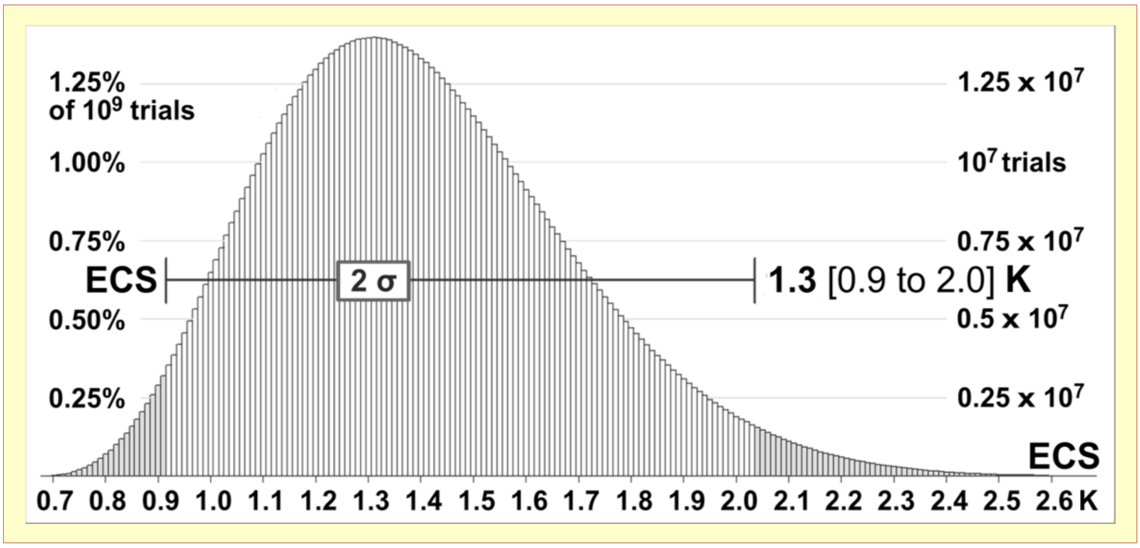


Figure 4: Monte Carlo distribution (10^9 trials)

All these methods, independent of feedback analysis but reliant on mainstream methods and values, cohere at 1 to 2 K ECS, below predictions in Charney (1979) and IPCC (1990, 2021).

5 Discussion

5.1 Confirmations

5.1.1 Test apparatus

A control engineer designed an electronic feedback-amplifier circuit to emulate feedback in the climate. Experiments confirmed that at any moment the feedback processes then subsisting must perforce respond to the entire direct or reference temperature obtaining at that moment.

A national laboratory of physics was then invited to construct its own apparatus, with which it conducted 23 experiments, further confirming that feedbacks perforce respond to the entire input signal rather than merely to some minuscule and arbitrarily-selected fraction thereof.

5.1.2 The absence of the tropical mid-troposphere 'hot spot'

GCMs misrepresent the altitudinal profile of water-vapor feedback. Though by the Clausius-Clapeyron relation the atmospheric space may carry 7% K^{-1} more water vapor at current temperatures (Wentz et al. 2007), specific humidity is rising at that rate only in the lower troposphere (Kalnay et al. 1996, updated), where, however, the spectral lines of water vapor are already close to saturation: as humidity increases, only the far wings add to infrared absorption (Harde, 2017), which, in any event, varies logarithmically with specific humidity. In the mid-troposphere, specific humidity has been declining for almost a century (Kalnay *op. cit.*), while GCMs predict that it should increase with warming. It is only at the surface that specific humidity is increasing, but near-surface non-radiative transports limit its influence. Though GCMs project a "hot spot" warming at twice the surface rate in the tropical mid-troposphere (e.g., IPCC 2007, fig. 9.1c), so that 90% of global warming is projected to arise there, it is absent from nearly all radiosonde, drop-sonde and satellite datasets (e.g., Lanzante et al. 2006, fig. 5.7E). The decline in mid-troposphere specific humidity explains its absence. Unsurprisingly, then, mid-troposphere warming has proven to be one-third of GCMs' mean prediction (UAH, 2023). Without the hot spot, the water-vapor feedback is necessarily small, providing an interesting physical confirmation of the present theoretical result.

5.2 System-response curves

Since the true feedback factor H_2 acts not only on RCS ΔR_1 but on the entire reference temperature R_2, changes in H_2 well below any observable or theoretically-derivable resolution would drive large changes in ECS. Figure 5 illustrates this hypersensitivity even to small changes in H_2, showing the evolution of the response curves of ECS ΔE_1 from feedback factors H_2, h_2 given 1.2 K RCS ΔR_1, 287.5 K temperature E_1 in 1850 and 20 K feedback response B_1 that year. The variant and corrected rectangular hyperbolae intersect at the ~1.3 K ECS derived in section 4.3 above.

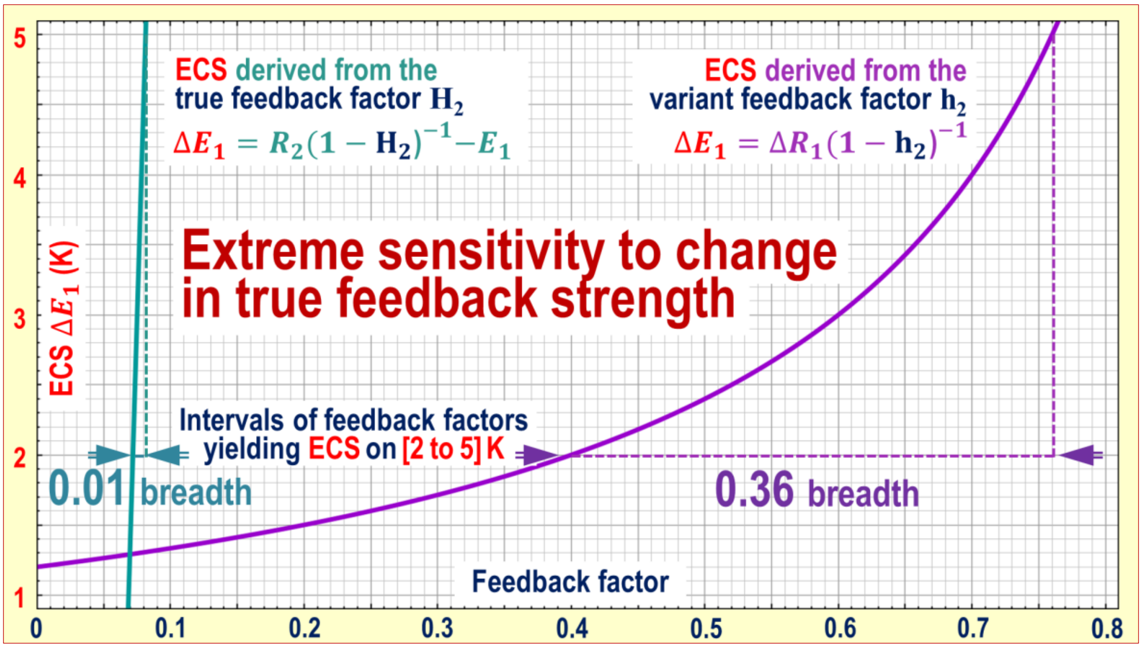


Figure 5: Variant and corrected system-response curves

5.3 Consequences of the control-theoretic error and of its correction

Since feedback strength acts upon the entire reference temperature and is thus small, neglect of emission temperature and of natural reference sensitivity in deriving feedback strength and thence equilibrium sensitivity has led to a large error.

After correction, all ECS projections by feedback analysis – including those by diagnosis (e.g.. Vial et al., 2013) of feedback strengths from the outputs of models (which do not incorporate feedback analysis directly) – are unreliable.

The small amplitude, narrow interval, large uncertainty, observational immensurability and unknown time-variance of true feedback strength, with the consequent hypersensitivity of climate even to very small changes therein, render feedback analysis valueless for constraint of climate sensitivities.

Nevertheless, IPCC (2013) mentions the word "feedback" more than 1100 times, while IPCC (2021) mentions it more than 2500 times. Observational methods cohere in finding ECS well below the long-predicted 3 [2 to 5] K interval, implying only 1-2 K further anthropogenic warming from now to 2100.

Understatement of the input signal by two orders of magnitude, and consequent overstatement of feedback strength by an order of magnitude and of the system-gain factor by a factor 3, taken with the rectangular-hyperbolic shape of the variant system-response curve (Fig. 5), explains why the high-end equilibrium sensitivities upon which current mitigation strategies are founded have proven so excessive. The present result reinforces by a distinct method the conclusion in Frank (2019) that propagation of uncertainty in a single climate variable renders speculative any GCM-derived ECS projection within a ±12 K uncertainty envelope.

The two errors – the control-theoretic and the statistical – sprang from the interdisciplinary divide in the sciences, which has significantly delayed their identification and correction. Once the errors are removed, the reduced probability of elevated ECS swings the risk-reward ratio decisively against climate action. Since IPCC (1990), anthropogenic greenhouse forcing has risen at a near-linear 1.1 W m^{-2} in 30 years, or 1/30th W m^{-2} yr^{-1} (NOAA AGGI 2023). If that uptrend continues for 27 years to 2050, some 0.9 W m^{-2} will be added, of which 0.45 W m^{-2} would be abated if all nations now moved directly from current emissions to net zero by then. For 3.93 W m^{-2} doubled-CO_2 forcing (IPCC 2021, p. 925) and 1.8 K transient response thereto (*ibid.*, p. 93), global net zero would prevent only 0.45 (1.8 / 3.93), or 0.2 K, by 2050. Since transient warming since 1990, equivalent to 0.14 to 2 K $decade^{-1}$, is significantly below the long-predicted midrange 0.3 K $decade^{-1}$ (IPCC 1990), by 2050 as little as 0.1 K global warming might be prevented. Yet the cost of net zero, extrapolated globally from the UK grid authority's $3.7 trillion estimate for net-zeroing the power grid, which represents 23.5% of UK grid emissions, which in turn are 0.9% of global emissions, might exceed $1.7 quadrillion. Then each $1 billion spent would prevent less than one 17-millionth of a degree of warming by 2050. Yet all such spending is unnecessary: it was predicated on the errors herein identified.

6 Conclusion

On correcting the long-standing error of control theory detailed here, without which concern about global warming large enough and rapid enough to be net-harmful would not have arisen, global-warming mitigation inexpensive enough to be affordable will be ineffective, while mitigation expensive enough to be effective will be as unaffordable as it is unachievable and, in the light of the present result, unnecessary. Adaptation, to the limited extent that may be required, is the rational economic choice.

The nations of the West, against whose economies the international climate accords are near-exclusively targeted, set themselves at a damaging terms-of-trade disadvantage by the ever costlier but inevitably futile and ultimately unnecessary climate-mitigation measures that they, and they almost alone, are inflicting upon themselves. For energy security, affordability and terms-of-trade competitiveness while coal, oil and gas reserves endure, thermal generation may, after all, safely be retained in the West, as China and Russia, India and Pakistan, are retaining it and greatly expanding it in the East. The planet will come to little harm thereby.

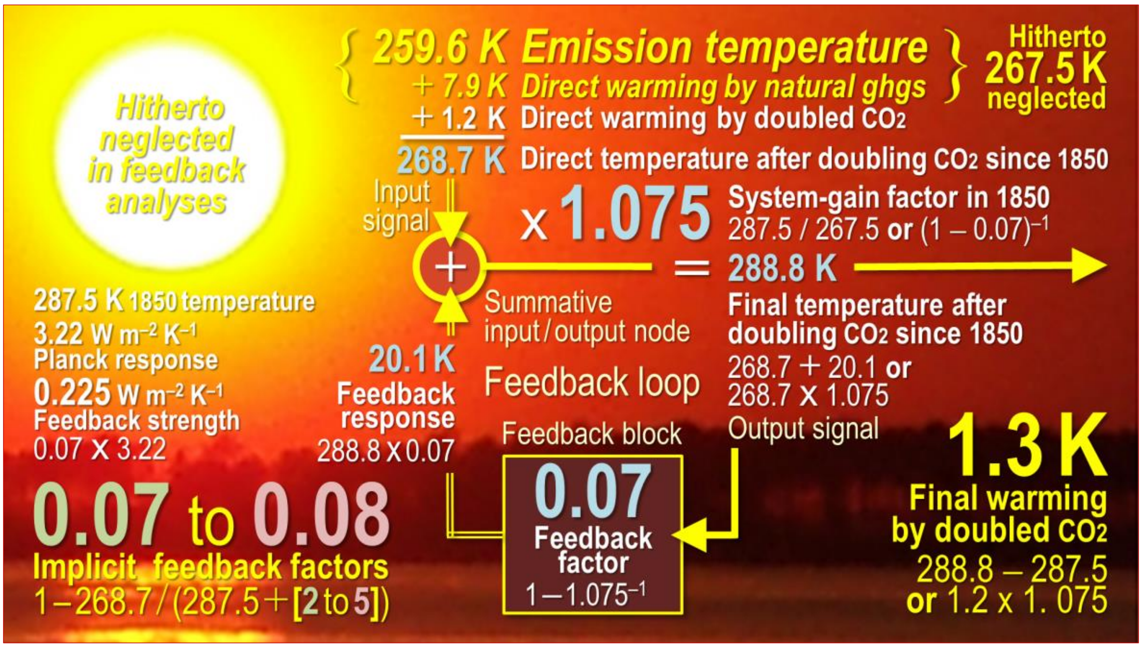


Figure 6: Correcting climate scientists' error in forgetting that the Sun was shining

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