Climate mitigation policy, not climate change, poses the gravest strategic threat

- **Even worldwide net zero by 2050 would reduce global temperature by less than 0.1 C.**
- **Each $1 billion spent would reduce warming by less than one ten-millionth of a degree.**
- **UK installed wind and solar capacity exceeds total mean grid demand by 16% and counting.**
- **After correcting a grave, long-standing error of climate physics, there is no climate emergency.**

HIS EXCELLENCY Sultan Ahmad al-Jabar of the United Arab Emirates, Chair-designate of the 28th Conference (2023) of States Parties to the Framework Convention on Climate Change, calls for businesslike performance indicators. Three are here assessed –

A. How much global warming would even worldwide net zero emissions really prevent by 2050, and at what cost? Would the warming prevented be large enough to justify the cost? **Pages 2 to 4.**

B. Is there a fundamental limit on the installed nameplate capacity of wind and solar generation, in a national grid, above which no further reduction in CO_2 emissions is attainable? **Pages 4 to 7.**

C. Does a systemic error of physics explain why the world is warming at below half prediction? Since IPCC's first report in 1990 the world has been warming at well below half the then-predicted midrange rate. Does a systemic error of physics explain the discrepancy and, if so, after correction is there any residual need for action to abate greenhouse-gas emissions? **Pages 8 to 12.**

The scientific papers **A**-**C** in the present intelligence assessment consider these three performance indicators. Are current climate policies **A) affordable, B) attainable,** or **C)** even **necessary?**

A. Attainment even of worldwide net zero emissions by 2050 would prevent only 0.1 C warming, even if net zero were attainable, which it is not. Therefore, value for money is the worst in history: **each $1 billion spent on net zero prevents only a ten-millionth of a degree of global warming.**

B. An iron demand limit on installed nameplate wind and solar capacity in any electricity grid greatly reduces the above 0.1 C estimate: for adding wind and solar capacity in excess of the limit would not further abate emissions. In nations (such as the UK) that have exceeded this limit, **installing further wind and solar power cannot further reduce emissions or global warming.**

C. Climatologists perpetrated a systemic error of feedback analysis in control-theoretic physics in 1984 when they borrowed feedback mathematics from engineering physics and thus over-predicted future warming. Correction shows any predictions reliant on feedback analysis (IPCC 2021 mentions "feedback" **more than 2500 times**) are merely speculative. Feedback analysis, though relied on in official predictions, cannot constrain climate sensitivity. Instead, observational methods not requiring knowledge of feedback strengths must be used. They cohere in finding that global warming will be less than half the long-standing official midrange estimate. Therefore, **unabated greenhouse-gas emissions may well not cause enough warming to be net-harmful.**

Each conclusion, if true, constitutes on its own a definitive argument against any further action to mitigate global warming. Since even worldwide net-zero emissions would prevent only 0.1 C global warming by 2050, so that each $1 billion spent on abating emissions would prevent only one ten-millionth of a degree of warming; since the demand limit on renewables penetration renders wind and solar power (the chief method of abating emissions today) ineffective, and since the notion of rapid, dangerous warming arose from a grave error of physics, Western nations that have set themselves at a terms-of-trade disadvantage against Paris-exempt nations expanding coal-fired generation may wish to **end all mitigation policies and undo the self-inflicted economic damage those policies are causing.**

A. How much global warming would worldwide net zero emissions prevent by 2050, and at what cost?

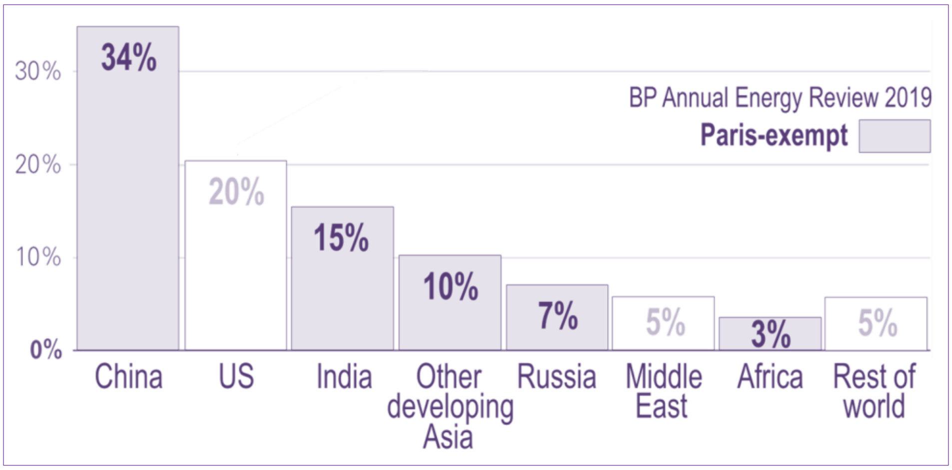
SOME 70% of new CO_2 emissions arise (BP 2019) **in Paris-exempt nations, such as China** (France24 2022), **India** (Reuters 2022) **and Pakistan** (Reuters 2023), **that are fast expanding coal-fired capacity so as to serve factories priced out of Paris-obligated nations by onerous emissions-abatement measures driving high electricity and compliance costs; electricity costs in Western nations are eight times those in China or India. Output emissions intensity in Paris-exempt nations exceeds that of Western nations, whose growing sacrifices of businesses, jobs and profits thus paradoxically help to sustain the undiminished near-linear uptrend therein** (NOAA AGGI 2023) **since 1990 despite heavy spending on emissions abatement. Here, mainstream methods and data show that the uptrend in temperature since 1990** (UAH 2023) **is well below half the then-predicted midrange rate** (IPCC 1990, p. *xi*), **so that even worldwide net zero emissions would prevent less than 0.1 C warming by 2050. The West has set itself at a strategic and yet pointless terms-of-trade advantage. Each $1 billion spent on aiming for net zero would prevent less than one ten-millionth C warming.**

A1. Context

Some **70%** of new greenhouse-gas emissions arise in nations exempt from the Paris climate accord (BP 2019 and Fig. A1). Emissions-abatement legislation in the chiefly Western nations selectively targeted by the accords has greatly increased their electricity and compliance costs, setting them at a severe and deepening terms-of-trade disadvantage against the Paris-exempt nations. Electricity prices (Globalpetrolprices.com 2023) in Germany, Denmark and Italy, at **$0.80 kWh^{-1}** for households and **$0.60 kWh^{-1}** for businesses, and in the UK, at **$0.41 kWh^{-1}** and **$0.34 kWh^{-1}**, exceed the **$0.10 kWh^{-1}** for households and **$0.08 kWh^{-1}** for businesses in India and China by up to an order of magnitude.

Figure A1

Contributions to primary energy growth by region, 2018



China (France24 2022), India (Reuters 2022) and Pakistan (Reuters 2023), with more than one-third of global population, are greatly expanding their coal-fired generating capacity, not least so as to accommodate production priced out of Paris-obligated nations by those nations' increasingly costly and intrusive emissions-abatement measures, the chief cause of the large and rapidly-growing disparity between Western and Eastern electricity prices. Particularly where the manufactures displaced are energy-intensive, Eastward transfer of Western jobs and industries increases global emissions (the opposite of what was intended): for manufacturing in Paris-exempt nations emits more per unit of production than in Paris-obligated nations.

A2. Methods

Since the *First Assessment Report* of the Intergovernmental Panel on Climate Change (IPCC 1990), anthropogenic greenhouse-gas forcing has increased at an undiminished, near-linear rate (NOAA AGGI 2023) of **1.1 Watts per square meter** in 33 years, or **1/30th W m^{-2} year^{-1}** (Fig. A2). Substantial sums spent by Paris-obligated nations on abatement over a third of a century have thus exerted no discernible mitigating effect at all on our influence on climate. If greenhouse forcing (NOAA 2023) continues its uptrend for 27 years to 2050, **some 0.9 W m^{-2}** will be added, of which half, **ΔQ_{aba}** on **0.45 [0.35 to 0.55] W m^{-2},** would be abated if all nations moved straight from current emissions to net zero.

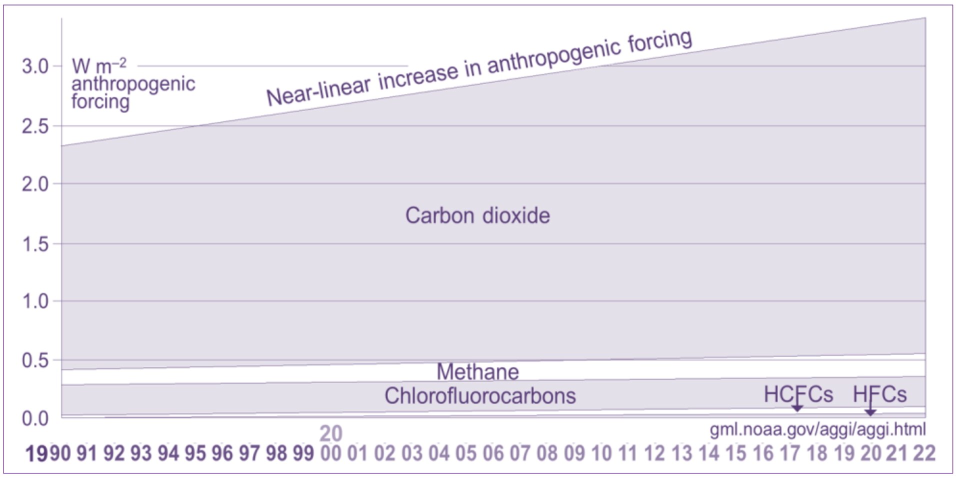


Figure A2

Near-linear cumulative uptrend: anthropogenic GHG forcing, 1990-2021 (NOAA 2023)

For **3.93 [3.46 to 4.4] W m**$^{-2}$ doubled-CO_2 forcing **ERF** (IPCC 2021, p. 925) and **1.8 [1.2 to 2.4] C** transient doubled-CO_2 climate response **TCR** thereto (*ibid.*, p. 93), Monte Carlo distribution (Fig. A3) via **(A1)** shows **worldwide net zero would prevent 0.2 [0.1 to 0.3] C global warming ΔT_X by 2050:**

$$\Delta T_X = \Delta Q_{\text{aba}} \frac{\text{TCR}}{\text{ERF}} = \mathbf{0.2}\ [0.1 \text{ to } 0.3]\ \text{C} \qquad \textbf{(A1)}$$

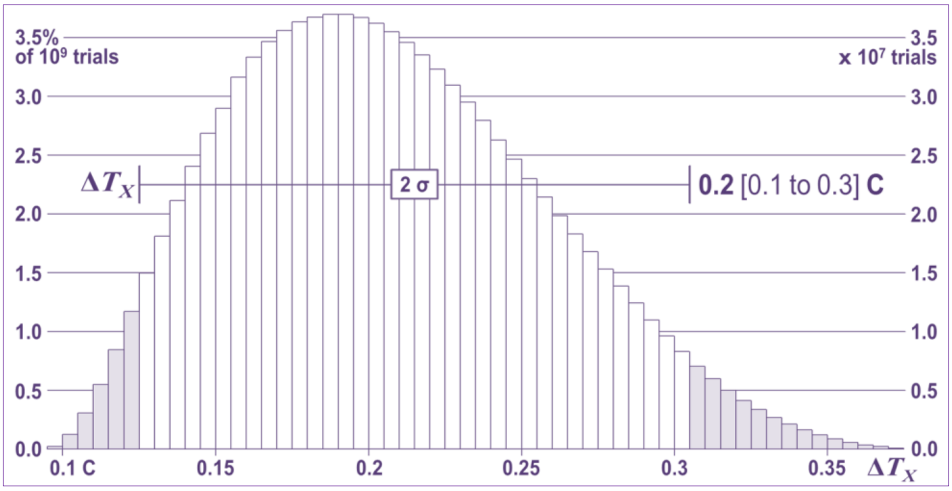


Figure A3

Global warming ΔT_X that worldwide net zero would prevent by 2050

(Monte Carlo distribution: 1 billion trials)

A3. Results

In the 33 years since IPCC 1990, when the global scientific community first predicted the likely evolution of temperature based on four emissions scenarios A-D, emissions have tracked (Friedlingstein 2022) the business as usual Scenario A, which had predicted **0.3 C decade**$^{-1}$ midrange transient warming ΔT_{prdc} (IPCC 1990, p. *xi*). Yet observed warming ΔT_{obs} (UAH 2023) was just **0.136 C decade**$^{-1}$ (with no warming trend in the last nine years, *ibid.*). After making corrections to account for this factor-2 excess of originally-predicted over subsequently-observed warming, **(A2)** shows that **true midrange warming ΔT_C prevented by worldwide net zero would be less than 0.1 degree:**

$$\Delta T_C = \Delta T_X \frac{\Delta T_{\text{obs}}}{\Delta T_{\text{prdc}}} = \Delta Q_{\text{aba}} \frac{\text{TCR}}{\text{ERF}} \frac{\Delta T_{\text{obs}}}{\Delta T_{\text{prdc}}} < \frac{\mathbf{1}}{\mathbf{10}}\ \text{C} \qquad \textbf{(A2)}$$

McKinsey (Kumra 2022) have estimated the capex cost alone of worldwide net zero as **$275 trillion,** half of global corporate profits. For opex at least twice capex, total cost might be **$1 quadrillion.** Then **every $1 billion spent would prevent one ten-millionth of a degree of warming (A3):**

$$\Delta T_{\text{bill}} = \Delta T_X \frac{\$1 \text{ billion}}{\$1 \text{ quadrillion}} < \frac{\mathbf{1}}{\mathbf{10,000,000}}\ \text{C} \qquad \textbf{(A3)}$$

However, the UK's national grid authority (National Grid ESO 2000) estimates the cost of net-zeroing the grid as **$3.6 trillion.** Since the grid contributes only 23.6% of national emissions (ONS 2021), UK net zero might cost **$15 trillion** – more than six years' annual GDP over 27 years. Since the UK represents **1%** of global emissions (OurWorldInData CO_2 emissions 2023), UK net zero would prevent only **1/1000th C** of warming by 2050, before accounting for the eastward transfer of UK manufactures and jobs, increasing global emissions. On the basis of the probably-underestimated cost of net-zeroing the UK grid, worldwide net zero might cost **$1.5 quadrillion** (100 times the UK cost). **Every $1 bn spent on abatement would prevent only one 16-millionth of a degree of warming.**

The US represents **15%** of global emissions (EPA 2023). Even if the US were to attain net zero, its contribution to reduced warming by 2050 would be only **1/70th C**, and considerably less than that after adjustment for manufactures, jobs, profits and thus emissions exported to Paris-exempt nations.

A4. Conclusions

If the present **0.136 C decade^{-1}** global-temperature uptrend (UAH 2023) persists to 2050, by then the planet will be **less than 0.4 C warmer** than now, even if no further abatement measures are taken. Even after worldwide net zero the planet would be **less than 0.3 C warmer** than now. However, since the most populous Paris-exempt nations are greatly increasing coal-fired capacity, keeping their electricity prices up to an order of magnitude below Western prices, even **the theoretically-achievable 0.1 C reduction will not occur.** Instead, exporting Western emissions to the Paris-exempt nations will continue, actually adding to global warming. Therefore, net zero would deepen the West's already-worsening terms-of-trade disadvantage without conferring any benefit on the climate. Even worldwide net zero is unachievable, unaffordable and incapable of significantly reducing future global warming. On the trend since 1990, **global warming is proving to be small, harmless and net-beneficial.**

B. The demand limit on renewable-energy generation

EXCESS CAPACITY is a growing problem of wind and solar power. Renewables generate excess power where their nameplate capacity (their output in ideal weather) exceeds mean grid demand. Above the limit, installing further capacity much increases renewables' levelized cost of electricity, but abates no further CO_2 emissions without costly battery backup or green-hydrogen generation. Many nations already exceed the limit, but without benefiting the climate.

B1. Context

Wind and solar generating capacity is increasing, particularly in Western countries. In the UK, these weather-dependent sources contributed **24% of all electricity generated** in the third quarter of 2022 (Harris 2022). However, that year the grid operator paid **$4.5 billion** to stabilize the grid, including $100 million a month to wind generators to disconnect during periods of surplus supply (Matson 2022), wasting enough power to supply 800,000 homes. Such costly excess generation will increase as wind and solar power expands. Poor grid interconnection and intermittently favorable weather were hitherto thought to be the chief reasons for excess capacity and hence the growing frequency and cost of capacity-curtailment payments, below-cost or negative-priced dumping to interconnected grids and payments to thermal stations for rotating reserve backup. The true cause is a hitherto-unappreciated **fundamental demand limit on installed nameplate capacity of renewables in a grid.**

B2. The fundamental demand limit on wind and solar capacity

Renewables contribute excess generation E to a grid where their installed nameplate capacity N, their output in ideal weather, exceeds mean hourly grid demand D; or, equivalently, where their source-weighted penetration factor f, the fraction of total generation that their installed capacity contributes, exceeds their regional mean source-weighted capacity factor Z, the fraction of nameplate capacity attainable in typical annual weather:

$$E = N - D \tag{B1}$$

Above that fundamental nameplate-capacity limit $N = D$ or $f = Z$, which is weather-dependent and thus grid-specific, excess generation is either exported or prevented by capacity-curtailment payments or do-not-generate orders. No further CO_2 emissions will be abated unless the surplus is directed to extremely costly backup by static batteries or green-hydrogen production, whose presence, however, would not alter the limit. Exceeding the demand limit will, on its own, very greatly increase the levelized cost of wind or solar electricity (LCOE), and thus of overall grid LCOE, but it will do so **without abating grid CO_2 emissions.**

Grid electricity costs rise as wind and solar expand their penetration because weather-dependent generation is intermittent and unpredictable, the environmental costs of its low energy density are high and, since thermal generation sufficient to power the whole grid must in any event be retained at all times as inefficient, high-emission rotating reserve, the entire financial burden of their installation and operation constitutes **a deadweight cost on any grid.**

Hitherto, however, it had not been appreciated that, once the demand limit ***D*** on nameplate capacity ***N*** is breached, all the known problems of wind and solar – especially electricity cost – will increase, but without further emissions abatement. Several nations already exceed their capacity limits ***N*** = ***D***, some by a large and costly margin (Table B1). For instance, Germany's penetration coefficient ***q*** **(B2)** is **1.84: Germany's renewables' nameplate capacity exceeds mean hourly demand by five-sixths.**

The renewables penetration factor ***f*** is the ratio of renewables generation W_R to total grid generation ***W*** **(B3)**. The renewables capacity factor ***Z***, the fraction of nameplate capacity attainable in typical annual weather, is the ratio ***f*** / ***q*** **(B4).**

$$q = N / D = f / Z \quad \text{(B2)} \qquad f = W_R / W \quad \text{(B3)} \qquad Z = f / q \quad \text{(B4)}$$

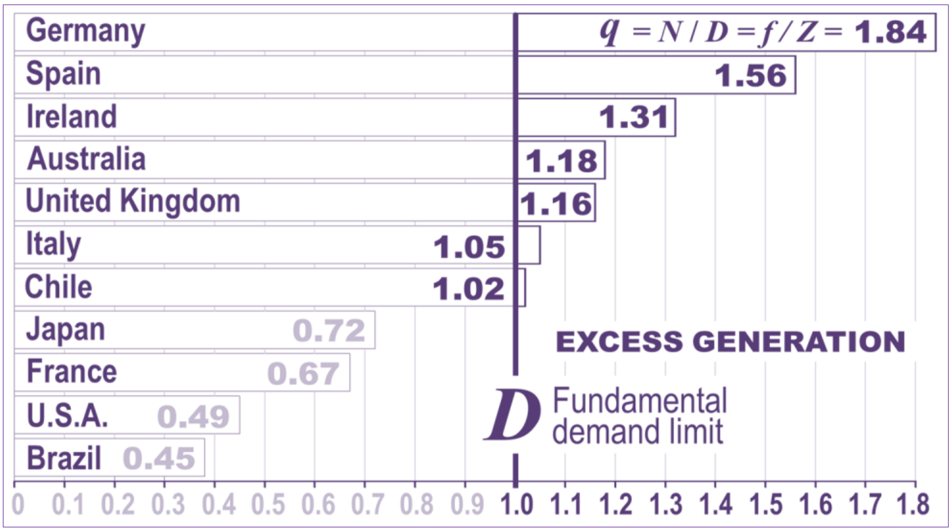
Table B1. Excess capacity ***E*** and its derivation in 11 Paris-obligated nations (OurWorldInData Electricity Mix 2023; IRENA 2023)

	Installed nameplate capacity *N*	Mean hourly demand *D*	Excess renewables generation *E*	Excess factor *N / D* *q*	Annual renewables generation W_R	Annual total generation *W*	Renewables penetration factor *f*	Mean capacity factor *Z*
Units	GW	GWh/h	Unitless	Unitless	TWh	TWh	Unitless	Unitless
Germany	122.2	66.5	55.7	**1.84**	163.9	582.9	0.28	0.15
Spain	46.2	29.7	16.5	**1.56**	86.2	260.0	0.33	0.21
Ireland	4.5	3.4	1.1	**1.31**	9.5	29.9	0.32	0.24
Australia	30.0	25.5	4.5	**1.18**	54.5	223.4	0.24	0.21
UK	40.8	35.2	5.6	**1.16**	76.8	308.1	0.25	0.22
Italy	34.0	32.3	1.7	**1.05**	46.5	282.9	0.16	0.16
Chile	9.4	9.2	0.2	**1.02**	17.3	80.2	0.22	0.21
Japan	78.7	109.4	(30.8)	0.72	97.7	958.5	0.10	0.14
France	42.2	62.9	(20.8)	0.67	51.7	551.4	0.09	0.14
USA	227.9	469.0	(241.0)	0.49	493.5	4108.3	0.12	0.25
Brazil	34.2	75.6	(41.4)	0.45	88.3	662.6	0.13	0.29

Fig. B1 shows excess generation in seven nations. In the first five, wind and solar capacity much above mean demand has already proved costly as well as destabilizing. Germany, for instance, has for many years made curtailment payments not only to its own wind and solar generators but also to those of its interconnected neighbor, Denmark (Bloomberg 2015). Ireland issues frequent do-not-generate orders: in 2021 (Eirgrid/SONI 2022) **the nation discarded one-twelfth of wind and solar output.**

Figure B1

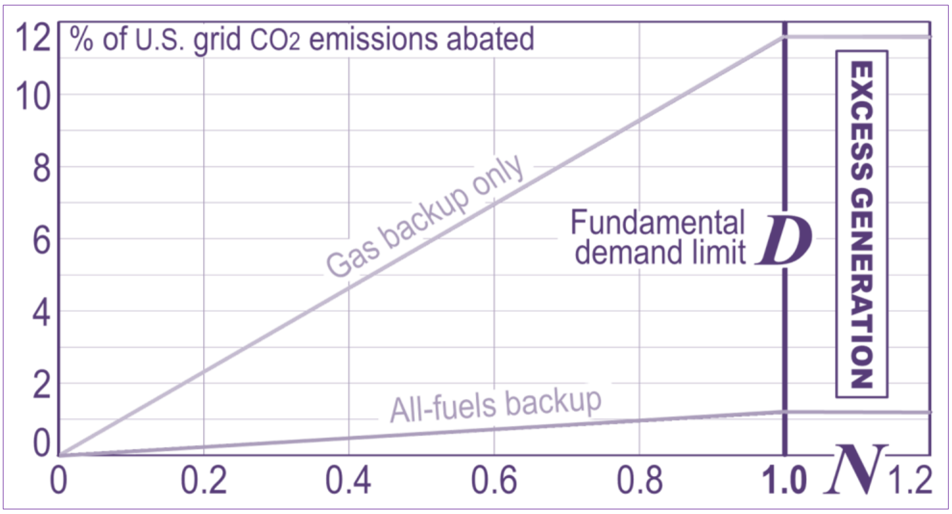
Excess generation in several nations, for nameplate capacity ***N*** > ***D***



In the United States, with the current mix of coal and gas backup, installation of renewables up to the grid's capacity limit ***N*** = ***D*** would abate grid CO_2 emissions by at most **1.2%** (Fig. B2), equivalent to **0.42%** of United States and **0.06%** of global emissions. However, if combined-cycle gas turbines provided all backup in the United States renewables at to the demand limit ***D*** would abate grid CO_2 emissions by up to **11.6%** (equivalent to **4.1%** of United States and **0.6%** of global emissions). thus, **abatement would be small up to the demand limit and zero thereafter.**

Figure B2

United States grid emissions abated (%) for renewable nameplate capacities **0 ≤ *N* ≤ 1.2*D***



Costly replacement of coal-fired with gas-fired power at less than half the unit emissions but twice the unit fuel cost would make some contribution to global emissions abatement, but installation of wind and solar power capacity ***N*** exceeding the demand limit ***D*** on any grid would not abate emissions any further after the limit was breached unless extremely expensive static-battery backup or green-hydrogen production plants were installed to absorb surplus output.

B3. Results

Even before allowing for renewables' demand limit, global warming prevented worldwide and in various illustrative territories (see paper A above) would be infinitesimal (Table B2). The fundamental grid-specific demand limit on the nameplate capacity of renewables in a grid greatly diminishes the already small reductions in global warming that are possible.

Table B2. Global warming prevented by attainment of net zero emissions

Territory	**World**	China	**West**	USA	**UK**	Chile
Share of global emissions	**100%**	30%	**30%**	15%	**1%**	0.1%
Warming prevented by 2050	**1/10 C**	1/30 C	**1/30 C**	1/60 C	**1/1000 C**	1/10,000 C
Warming prevented by 2100	**1/3 C**	1/10 C	**1/10 C**	1/20 C	**1/300 C**	1/3000 C

In the United States, renewables' penetration is below **50%** of mean hourly grid demand. If penetration were doubled, setting nameplate capacity equal to demand, the cost would be heavy and the terms-of-trade penalty against Paris-exempt nations greatly increasing cheap and reliable coal-fired generation would do strategic economic harm by pricing out energy-intensive steel and heavy manufacturing. Displacement of Western industries to countries expanding coal and gas generation would also increase global CO_2 emissions, the opposite of what was intended. Return on investment would be small. Table B3 shows the warming the United States would prevent if it doubled its current nameplate wind and solar capacity ***N*** to reach the hourly-demand limit ***D***, abating **0.42%** of its CO_2 emissions in 2019 with the current fuel mix as backup, or abating 4.1% with gas backup alone (EPA 2023).

Table B3. Warming prevented by doubling renewables capacity in the United States

Warming prevented	All-fuels spinning-reserve backup		Gas-only spinning-reserve backup	
By 2050	0.42% of 0.015 C°	**1/16,000 C**	4.1% of 0.015 C°	**1/1600 C**
By 2100	0.42% of 0.045 C°	**1/5000 C**	4.1% of 0.045 C°	**1/500 C**

B4. Conclusions

The objective of installing wind and solar generation throughout the West is to abate CO_2 emissions. Even with gas generation alone, the most efficient backup, CO_2 emissions abatement by further wind and solar installations would be minuscule up to the fundamental limit ***D*** and nil above it. Therefore, **wind and solar power will contribute very little towards the attainment of worldwide net zero.**

In most grids, with a typically less efficient mix of backup fuels, CO_2 emissions may significantly rise, expensively achieving the very opposite of the objective. Even the United States grid, one of the world's most efficient, which deploys various technologies and fuels to back up renewables, negligibly abates CO_2 emissions. Nearly all other national grids are less efficient. On those grids, then, **expanding renewable generation would increase CO_2 emissions.**

Indeed, on any grid, as the penetration of renewables increases towards their fundamental demand limit ***D*** on that grid, though their LCOE remains constant the overall LCOE of the grid rises because maintaining sufficient thermal rotating reserve generation to meet the entire demand on the grid at all times increases the LCOE of the thermal contribution to the grid.

Once the fundamental demand limit ***D*** is exceeded, the thermal contribution no longer increases, but renewables' LCOE rises sharply (Fig. B3), since beyond this limit any additional installed wind or solar capacity is increasingly wasted, elevating the capital element in grid LCOE, while the current-account element is also elevated by capacity-curtailment payments, grid stabilization costs, dumping of surplus power at a loss via interconnectors, and the heavy additional operating costs of thermal backup for renewables.

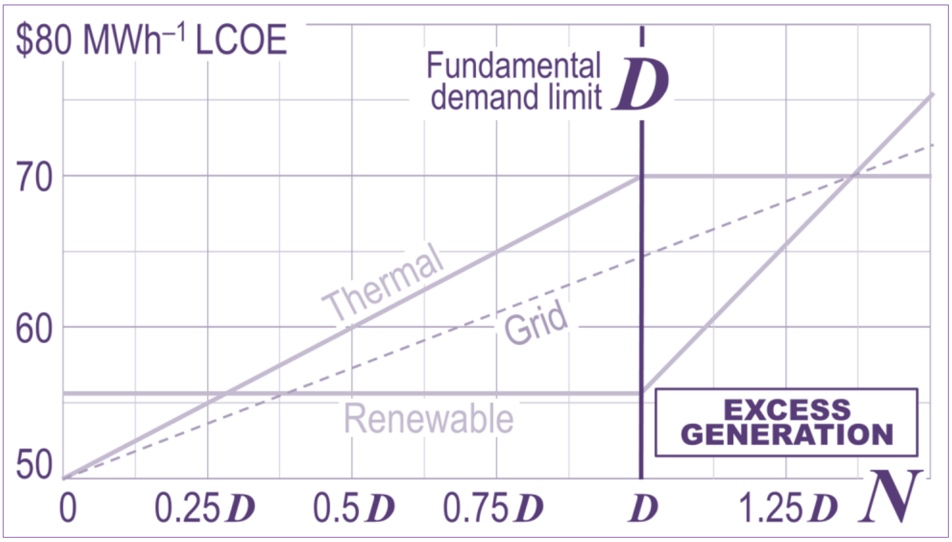


Figure B3

Renewable, thermal and overall grid levelized cost of electricity (LCOE) for $0 \leq N \leq 1.5D$

Excess wind or solar generation could theoretically be sent to grid battery storage or green-hydrogen production, but only at a very costly further elevation of grid LCOE. Wind and solar power are already expensive.

Global replacement of thermal by weather-dependent generation is in any event impossible, because reserves of techno-metals are insufficient. Every 15 years, these multiples of the 2019 global output of seven key techno-metals would be needed for global net-zero energy infrastructure:

> Copper **180 years**; nickel **>380 yr**; cobalt **>1600 yr**; graphite **>6700 yr**; lithium **>9400 yr**; germanium **>29,000 yr**; vanadium **>67,000 yr** (Michaux 2023).

The existence of the hitherto-unsuspected demand limit ***D*** on generation by weather-dependent renewables renders infinitesimal the already minuscule quantum of warming (see paper A) that is realistically preventable even by the attainment of worldwide net zero emissions.

In the light of the existence and effects of the demand limit, governments and grid authorities should **urgently reappraise the benefits and costs of renewable against thermal generation.**

C. An error of climate feedback analysis and its consequences

EQUILIBRIUM doubled-CO_2 sensitivity (ECS) was derived (IPCC 2021) by four methods each dependent on feedback analysis, mentions "feedback" 2500 times. Though feedback response was thought to constitute 40-75% of ECS, temperature feedbacks respond not only to 1.2 K direct warming by doubled CO_2 but also to 8 K reference sensitivity to preindustrial greenhouse gases and to 260 K emission temperature. Corrected feedback strength implicit in the 3 [2 to 5] K ECS projected *ibid.* falls not on the current 2 [1.5 to 2.5] but on 0.24 [0.23 to 0.26] W m^{-2} K^{-1}: each 0.01 W m^{-2} K^{-1} increment adds 1 K to ECS. Since feedback strength is indeterminable to such precision, all projections dependent on feedback analysis, including those of IPCC, are irremediably speculative. Several observational methods not thus dependent cohere in yielding 1.3 K ECS. There may be no climate crisis.

C1. Introduction

Equilibrium doubled-CO_2 sensitivity (ECS) is warming after short-term feedbacks have responded to a **3.93 W m^{-2}** radiative forcing ΔQ_1 (IPCC, 2021) equivalent to doubling CO_2 concentration since 1850. ECS projections greatly exceed observation. IPCC (1990) predicted **0.3 [0.2 to 0.5] K/decade** anthropogenic warming to 2090; IPCC (2021) projects **3 [2 to 5] K** ECS ΔE_1, equivalent to ten decades' projected medium-term warming. Emissions (Friedlingstein et al., 2022) are closer to scenario A (IPCC 1990) than to B-D, but the **0.3 K/decade** scenario-A midrange prediction (*p. xi ibid.:* 10% of midrange ECS) is twice outturn: observed warming from 1990-2023 was only **0.14 K/decade** (UAH 2023), suggesting **1.4 K** midrange ECS. Since reference doubled-CO_2 sensitivity RCS ΔR_1 (direct warming before feedback response) is **1.2 K,** feedback response (chiefly to more water vapor in warmer air) was thought to contribute as much as **60% [40% to 75%]** of ECS.

Feedback formulism borrowed from control theory in 1984 was misunderstood. It was not realized that feedbacks respond to the entire input signal: in climate, not only to the **1.2 K** RCS ΔR_1 but also to the **7.9 K** natural reference sensitivity NRS ΔR_0 to preindustrial noncondensing gases (derived from Meinshausen et al., 2017, via IPCC, 2007, table 6.2) and, above all, to the **259.6 K** emission temperature ET R_0 that would prevail without them. Feedbacks respond to the entire **268.7 K** reference temperature R_2, the sum of ET, NRS and RCS, and proportionately to these three components' amplitudes. Nearly all feedback response is to R_0 (97% of R_1), so that true feedback strength is an order of magnitude less than hitherto realized. Here, the widespread control-theoretic error of neglecting the feedback responses to ET and NRS, effectively miscounting them as part of RCS, is described and its consequences discussed.

C2. Definitions

Though **[1.2 to 1.3] K** RCS ΔR_1 (Hansen 1984) is well constrained, currently-projected ECS ΔE_1 falls on **3 [2 to 5] K.** The large uncertainty in feedback response ΔB_1, the difference between ECS and RCS, accounts for the interval breadth of ECS. To constrain ECS, one must constrain ΔB_1, currently thought to contribute **60% [40% to 75%]** of ECS.

Let t = **0** at emission temperature; **1** in 1850; and **2** after a doubled-CO_2-equivalent forcing ΔQ_1.

Inbound top-of-atmosphere radiative flux density Q_0, for **1363.5 W m^{-2}** total solar irradiance S (DeWitte & Nevens, 2016) and mean planetary albedo α (Stephens, 2015), is **242 W m^{-2}:**

$$Q_0 = S(1-\alpha)\,/\,4. \qquad \text{(C1)}$$

Emission temperature ET R_0, for the **5.6704 x 10^{-8} W m^{-2} K^{-4}** Stefan-Boltzmann constant σ (Rybicki & Lightman 1979) and mean surface emissivity ε = **0.94,** is **259.6 K:**

$$R_0 = [Q_0\,/\,(\varepsilon\sigma)]^{1/4}. \qquad \text{(C2)}$$

The Planck response P falls on **3.22 [3.4 to 3.0] W m^{-2} K^{-1}** (IPCC, 2021, table 7.10): here, P is taken as positive (Roe 2009). Near-invariant in the industrial era, P is the first derivative of the Stefan-Boltzmann equation with respect to Q_0 and **288 K** mean industrial-era surface temperature T:

$$P = dQ_0\,/\,dT = 4Q_0\,/\,T. \qquad \text{(C3)}$$

A radiative forcing ΔQ_t at time t is a change in Q_0, such as **25.3 W m^{-2}** forcing ΔQ_0 by naturally-occurring, noncondensing gases in 1850, or **3.93 W m^{-2}** doubled-CO_2 forcing ΔQ_1.

Reference temperature R_t (e.g., **259.6 K** ET R_0) would prevail at the surface given today's insolation in the absence of any feedback response, while –

Reference sensitivity ΔR_t is a direct warming compared with R_t, such as the **7.9 K** natural reference sensitivity ΔR_0 to ΔQ_0. Thus, reference temperature R_1 in 1850 was the **267.5 K** sum of R_0 and ΔR_0, while R_2 is the **268.7 K** sum of R_1 and –

Reference doubled-CO_2 sensitivity RCS ΔR_1 to ΔQ_1, the **1.2 K** ratio of ΔQ_1 to P:

$$\Delta R_1 = \Delta Q_1 \,/\, P = 3.93 \,/\, 3.22. \qquad \text{(C4)}$$

Equilibrium temperature E_t **(or sensitivity** ΔE_{t-1}**)** is the sum of R_t and B_t (or ΔR_{t-1} and ΔB_{t-1}), where B_t, ΔB_{t-1} are feedback responses. Thus, temperature E_1 at the 1850 equilibrium was the **287.5 K** sum of R_1 and B_1, while E_2 is the sum of R_2 and B_2; and –

Equilibrium doubled-CO_2 sensitivity ECS ΔE_1 is the sum of ΔR_1 and ΔB_1. IPCC (2021) posits ECS on **3 [2 to 5] K**, implying ΔB_1 on **1.8 [0.8, 3.8] K,** representing **60% [40%, 76%]** of ECS ΔE_1 and **150% [65%, 315%]** of RCS ΔR_1.

Feedback responses B_t, ΔB_t are the differences between equilibrium and reference signals E_t and R_t, or ΔE_{t-1} and ΔR_{t-1} (thus, in 1850, B_1 was the **20 K** difference between E_1 and R_1):

$$B_t = E_t - R_t; \quad \Delta B_t = \Delta E_t - \Delta R_t. \qquad \text{(C5)}$$

C3. Dependence of ECS on feedback strength

Temperature-feedback strength Λ_t is a forcing responsive to R_t, proportional to E_t and thus expressed in W m^{-2} per Kelvin of E_t.

The feedback factor H_t, the unitless ratio of feedback response B_t to E_t, is equal to $\Lambda_t \,/\, P$.

The system-gain factor A_t, the unitless ratio of E_t to R_t, is equal to $(1 - \mathrm{H}_t)^{-1}$, i.e., $(1 - \Lambda_t \,/\, P)^{-1}$.

Feedback strength Λ_t is an independent variable upon which the feedback factor H_t and system-gain factor A_t, and consequently ECS ΔE_t, are successively dependent (Table C1a). Implicit feedback strength Λ_t may be derived from published ECS projections (Table C1b). Climatologists' defective variants of the feedback variables Λ_t, H_t, A_t are λ_t, h_t, a_t.

Table C1. Dependence of ECS on feedback strength, and of implicit feedback strength on projected ECS

a) Derivation of ECS ΔE_1 from feedback strengths λ_2, Λ_2

Feedback variable		*Current method*		*Corrected method*
Feedback factor	h_2:	$\lambda_2 \,/\, P$	H_2:	$\Lambda_2 \,/\, P$
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 ΔE_1

Feedback variable		*Current method*		*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:	$1 - 1 \,/\, a_2 = 1 - \Delta R_1 \,/\, \Delta E_1$	H_2:	$1 - 1 \,/\, A_2 = 1 - R_2 \,/\, E_2$
Feedback strength	λ_2:	$P\, \mathrm{h}_2 = P\, (1 - \Delta R_1 \,/\, \Delta E_1)$	Λ_2:	$P\, (1 - 1 \,/\, A_2) = P\, (1 - R_2 \,/\, E_2)$

C4. Results

At any moment t, short-acting feedback processes (chiefly the water-vapor, lapse-rate, cloud and surface albedo feedbacks) respond to reference temperature R_t, and thus proportionately to its elements R_{t-1}, ΔR_{t-1} (this proportionality does not imply time-invariance in Λ_t). In 1850, feedback responses B_0, ΔB_0 to R_0, ΔR_0, summing to the 20 K feedback response B_1 to R_1, were **19.4 K** and **0.6 K** respectively:

$$B_0 = R_0\, B_1 \,/\, R_1; \quad \Delta B_0 = \Delta R_0\, B_1 \,/\, R_1. \qquad \text{(C6)}$$

In 1850, Λ_1 was **0.224 W m^{-2} K^{-1}:**

$$\Lambda_1 = P\, B_1 \,/\, E_1 = P(1 - R_1 \,/\, E_1). \qquad \text{(C7)}$$

For $\Lambda_2 = \Lambda_1 =$ **0.224** as in 1850, ECS would be **1.3 K:**

$$\Delta E_1 = E_2 - E_1 = (R_1 + \Delta R_1) \,/\, (1 - \Lambda_2 \,/\, P) - E_1. \qquad \text{(C8)}$$

For ECS ΔE_1 on **3 [2 to 5] K,** implicit Λ_2 falls on **0.24 [0.23, 0.26] W m^{-2} K^{-1}:**

$$\boldsymbol{\Lambda_2} = \boldsymbol{P}\,\boldsymbol{B_2}/\boldsymbol{E_2} = \boldsymbol{P}(1 - \boldsymbol{R_2}\,/\,\boldsymbol{E_2}) = \mathbf{3.22}\,[\mathbf{1} - \mathbf{268.7}\,/\,(\mathbf{287.5} + \boldsymbol{\Delta E_1})]. \qquad \textbf{(C9)}$$

Hitherto, however, temperature-feedback strength λ_2 was erroneously treated as responding solely to the **1.2 K** reference *sensitivity* RCS ΔR_1**.** In reality, Λ_2 responds to the entire **268.7 K** reference *temperature* R_2**.** The interval **2.06 [1.59, 2.49] W m^{-2} K^{-1}** of climatologists' feedback strength λ_2 (IPCC, 2021) implicit in the **3 [2 to 5] K** ECS interval *ibid.* exceeds Λ_2 by an order of magnitude, and is comparable (Table C2, box) to the **1.93 [1.29, 2.45] W m^{-2} K^{-1}** now derived:

$$\boldsymbol{\lambda_2} = \boldsymbol{P}\,\boldsymbol{\Delta B_1}\,/\,\boldsymbol{\Delta E_1} = \boldsymbol{P}(1 - \boldsymbol{\Delta R_1}\,/\,\boldsymbol{\Delta E_1}). \qquad \textbf{(C10)}$$

Table C2. Variant and true **2 σ** feedback strengths λ_2**,** Λ_2 compared

ECS (IPCC, 2021, p. 978)	ΔE_1	How derived	**2**	**3**	**4**	**5**	K
Planck response	P	$\|p\|$	3.40	**3.22**	–	3.00	W m^{-2} K^{-1}
Feedback sum	$\Sigma\lambda$	*loc. cit.*	–1.81	**–1.16**	–	–0.51	W m^{-2} K^{-1}
Feedback strength as hitherto	λ_2	$\Sigma\lambda + P$	+1.59	**+2.06**	–	+2.49	W m^{-2} K^{-1}
cf. as in **(C10)** (*P* held fixed)	λ_2	P = 3.22	+1.29	**+1.93**	–	+2.45	W m^{-2} K^{-1}
cf. true feedback strength **(C9)**	Λ_2	P = 3.22	+0.23	**+0.24**	+0.25	+0.26	W m^{-2} K^{-1}
Increment implying **+1 K** ECS		**0.24** – **0.23,** etc.	+0.01	**+0.01**	+0.01	+0.01	W m^{-2} K^{-2}

Each **0.01 W m^{-2}** increment in Λ_2 would add as much as **1 K** to ECS (Table C2), yet uncertainties in climatic data prevent derivation of Λ_2 to anything like **0.01 W m^{-2} K^{-1}** precision. To constrain feedback response, and hence ECS, one must find the derivative $dE\,/\,dR$**,** which requires knowledge of E_t**,** R_t at two successive moments t of equilibrium in the industrial era:

$$\boldsymbol{dE}\,/\,\boldsymbol{dR} = (\boldsymbol{E_t} - \boldsymbol{E_1})\,/\,(\boldsymbol{R_t} - \boldsymbol{R_1}) \;:\; \mathbf{1} < \boldsymbol{t} < \mathbf{2} \qquad \textbf{(C11)}$$

At the 1850 temperature 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. The slow, long-run warming trend continues, so that subsequent values of E_t**,** R_t are unknown. Even if known, they would not be known to a precision sufficient to derive feedback strength Λ_t to within **0.01 W m^{-2} K^{-1}.** Feedback analysis is thus valueless for constraint of ECS. Accordingly, several methods of estimating ECS not reliant on feedback analysis are now outlined.

The 1850 temperature equilibrium: ECS for feedback strength Λ_1 unchanged since 1850 would be **1.3 K (C8),** but even a small increase in Λ_1 compared with 1850 would increase ECS significantly.

Observed against projected temperature change: Midrange warming predicted in IPCC (1990) was **0.3 K/decade,** implying **3 K** ECS, but only **0.14 K/decade** is observed, implying **1.4 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 K** ECS derived observationally suggests feedback response may contribute little to ECS.

The energy-budget method: Gregory (2004: see also Bates, 2016) proposed the energy-budget method of deriving ECS reliably. Lewis & Curry (2014) simplified the method so that it no longer depended on feedback analysis. Table C3 sets out the current intervals of the initial conditions.

Table C3. Initial conditions for the energy-budget method

Anthropogenic fraction	M	**0.85 [0.75 to 1]**	Derived from Wu (2019, table 2).
Observed warming to date	ΔT_{obs}	**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_{obs}	**3.2 [2.8 to 3.5] W m^{-2}**	NOAA (2023).
Earth energy imbalance	ΔN_{obs}	**0.79 [0.71 to 1.00] W m^{-2}**	IPCC (2021, p. 91); von Schuckmann (2020); Raghuraman (2021).

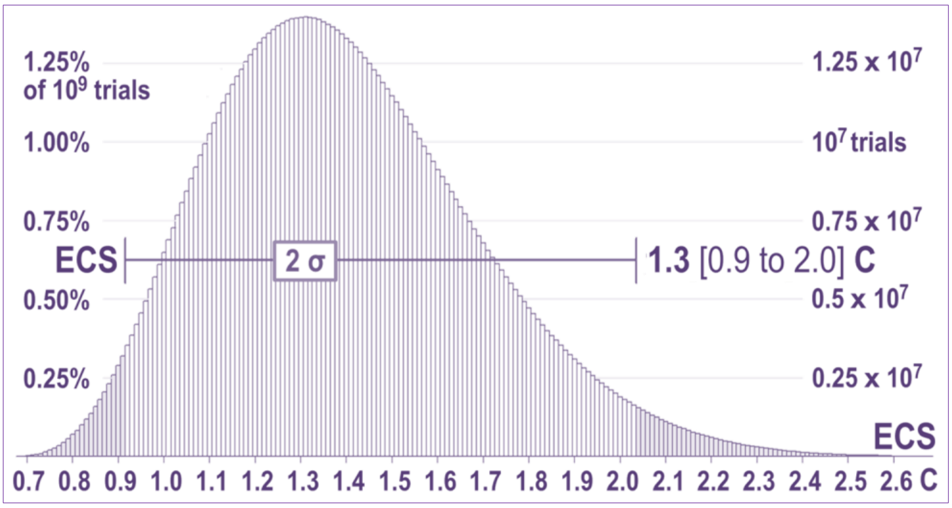
Midrange initial conditions informing the simplified energy-budget equation yield **1.3 K** ECS:

$$\Delta E_1 = \boldsymbol{M}\,\Delta\boldsymbol{T_{obs}}\,\Delta\boldsymbol{Q_1}\,/\,(\Delta\boldsymbol{Q_{obs}} - \boldsymbol{M}\,\Delta\boldsymbol{N_{obs}}). \qquad \textbf{(C12)}$$

Monte Carlo distribution: The **2 σ** intervals of the initial conditions in Table C3, informing a billion-trial Monte Carlo distribution, yield **1.3 [0.9, 2.0] K** ECS to **95%** confidence (Fig. C1):

Figure C1

Monte Carlo simulation (10^9 trials) yielding **1.3 [0.9 to 2.0] K** ECS to **2 σ**



All four methods, each independent of feedback analysis, cohere in yielding **1.3-1.4 K** ECS at midrange, not the **3 K** predicted in Charney (1979) and IPCC (1990, 2021).

C5. Discussion

Feedbacks respond not only to the **1.2 K** RCS but also to the **7.9 K** NRS and to the dominant base signal, the **259.6 K** ET. Yet current definitions (*e.g.*, IPCC, 2021, p. 2222) do not say so –

> "**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."

Such incomplete definitions are widespread (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 can be discovered, no climate-sensitivity study acknowledges that feedbacks at any time $\boldsymbol{t}$ act on the entire reference temperature and proportionately on each component therein.

Early ECS estimates (e.g., Arrhenius, 1906) predated control theory (Black, 1934; Bode, 1945). The error arose when Hansen et al. (1984) borrowed feedback formulism from control theory.

The true system-gain factor $\boldsymbol{A_t}$ shows feedback response depends on reference temperature $\boldsymbol{R_t}$:

$$\boldsymbol{A_t} = \boldsymbol{E_t} \,/\, R_t = 1 + \boldsymbol{B_t} \,/\, \boldsymbol{R_t}. \quad \textbf{(C13)}$$

However, Hansen (1984) gave variant $\boldsymbol{a_1}$ as the ratio **3-4** of ECS to RCS. Sure enough, $\boldsymbol{a_1}$ would be **3.5** if at the temperature equilibrium in 1850 the entire **20 K** feedback strength $\boldsymbol{B_1}$ responded solely to the **7.9 K** natural reference *sensitivity* $\boldsymbol{\Delta R_0}$ (rather than to the **267.5 K** reference *temperature* $\boldsymbol{R_1}$):

$$\boldsymbol{a_1} = 1 + \boldsymbol{B_1} \,/\, \boldsymbol{\Delta R_0} \quad \textbf{(C14)}$$

Equation (4) *ibid.* [notation adjusted to conform hereto] thus implies the **4 K** ECS found *ibid.*:

$$\boldsymbol{\Delta E_1} = \boldsymbol{a_1}\, \boldsymbol{\Delta R_1} \; [= \mathbf{3.5} \,/\, \mathbf{1.2}]. \quad \textbf{(C15)}$$

It is likely that the error led to the notion that midrange ECS is of order **3 K.** It is certain that correctly-implemented feedback formulism cannot constrain ECS.

Since feedback strength $\boldsymbol{\Lambda_2}$ acts not on RCS $\boldsymbol{\Delta R_1}$ alone but on reference temperature $\boldsymbol{R_2}$, changes in $\boldsymbol{\Lambda_2}$ well below any observable resolution would drive large changes in ECS. For instance, for **3.93 W m^{-2}** ERF $\boldsymbol{\Delta Q_1}$ and **0.224 W m^{-2} K^{-1}** feedback strength $\boldsymbol{\Lambda_1}$ as in 1850, ECS is **1.3 K:** yet **0.24 W m^{-2} K^{-1}** $\boldsymbol{\Lambda_2}$, only **7%** above $\boldsymbol{\Lambda_1}$, would elevate ECS by **130%** to **3 K.**

Fig. C2 illustrates the extreme sensitivity of temperature even to tiny changes in true feedback strength Λ_2. ECS in response to **[0.23 to 0.26] W m^{-2} K^{-1}** feedback strength Λ_2 falls on **[2 to 5] K.**

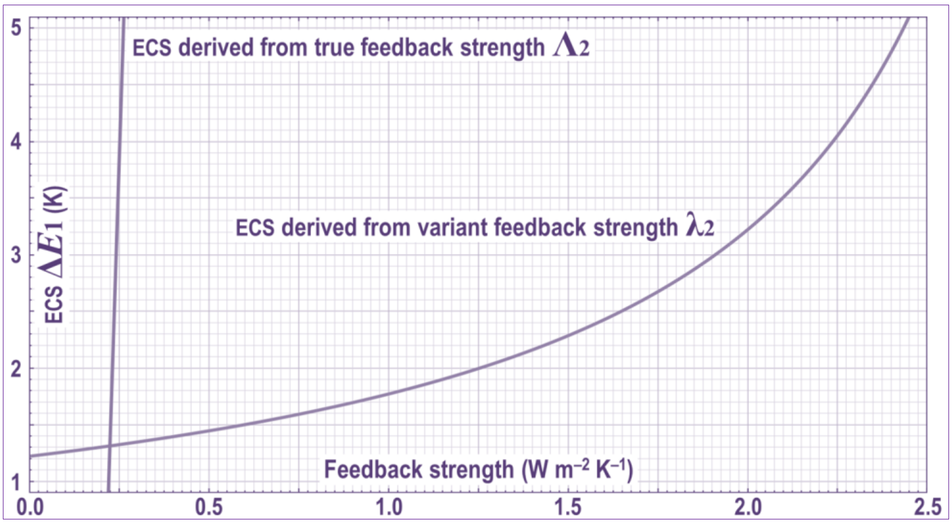


Figure C2

ECS from feedback strengths Λ_2, λ_2 for the **3.22 W m^{-2} K^{-1}** Planck response ***P*****, 3.93 W m^{-2}** RCS ΔR_1, **287.5 K** temperature E_1 in 1850 and **20 K** feedback response B_1 that year. The two rectangular hyperbolae intersect at **1.3 K** ECS. The curve of Λ_2 is near-linear across the interval of interest.

C6. Conclusion

Since feedback strength obtaining at any moment acts upon the entire reference temperature and is thus small, neglecting emission temperature and natural reference sensitivity in deriving feedback strength and hence equilibrium sensitivity has led to error. After correction, the small amplitude, narrow interval, large uncertainty, observational immensurability and unknown time-variance of true feedback strength, taken with the hypersensitivity of ECS even to minuscule changes therein, renders feedback analysis valueless for constraining climate sensitivities.

All ECS projections arrived at by feedback analysis – including IPCC projections founded on diagnosis (e.g. Vial et al., 2013) of feedback strengths from the outputs of models, which do not incorporate feedback analysis directly, are irremediably speculative: yet IPCC (2021) mentions "feedback" more than 2500 times. Observational methods cohere in finding ECS harmlessly low, implying perhaps 1 K further anthropogenic warming this century.

Overstatement of feedback strength by an order of magnitude, taken with the rectangular-hyperbolic system-response curve (Fig. C2), accounts for the excessive upper-bound equilibrium sensitivities pleaded in justification for current global mitigation strategies. The present result reinforces the conclusion in Frank (2019) that, due to propagation of uncertainty in a single climate variable, any model-derived ECS projection within a **±12 K** envelope of uncertainty is speculative. Both errors – the control-theoretic and the statistical – arise from interdisciplinary compartmentalization.

The diminished probability of elevated ECS swings the risk-reward ratio against climate action. On correcting the long-standing control-theoretic error identified here, 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, probably unnecessary. Adaptation, to the limited extent that may be required, is the rational economic choice. For energy security and affordability while coal, oil and gas reserves endure, thermal generation may, after all, safely be retained, as India and Pakistan, China and Russia are retaining it and greatly expanding it. The planet will come to little net harm thereby.

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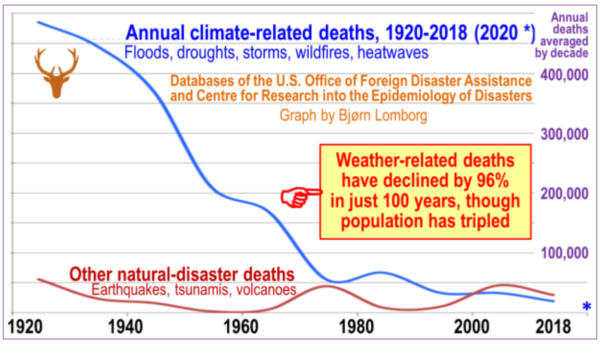
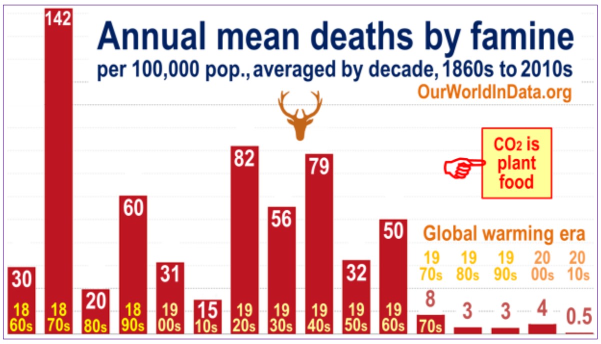
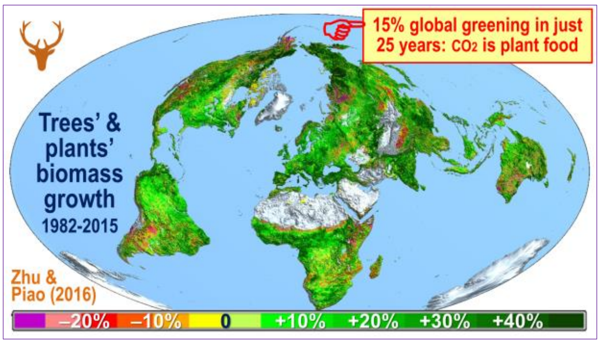
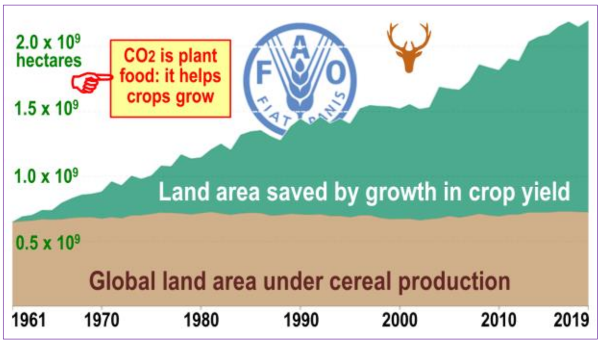
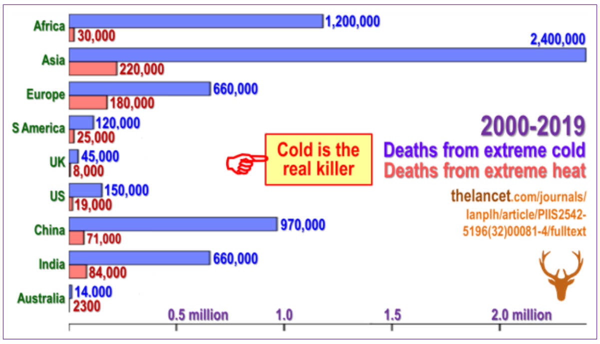
Evidence that warmer worldwide weather is not an emergency

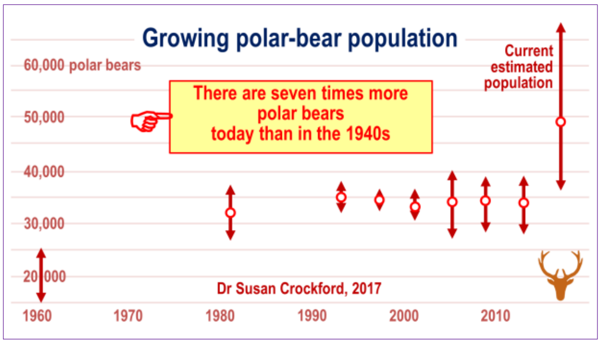


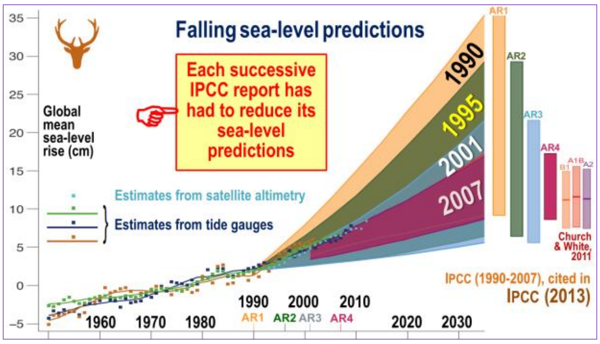


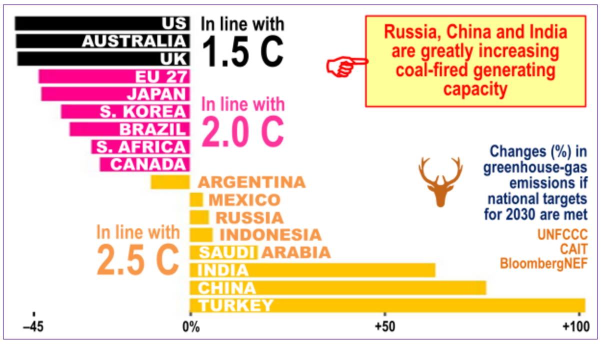












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Why reporting is one-sided

"1.25 In considering whether an issue is one of 'political or industrial controversy" or has been broadly settled, broadcasters should consider relevant factors. These may include, as appropriate, independent reports commissioned by, for example, the UK Parliament and whether the issue has already been scientifically established and does not appear to be challenged by, for example, established political parties or other significant domestic or international scientific institutions. An example of an issue which Ofcom considered to be broadly settled is the scientific principles behind the theory of Anthropogenic Global Warming."

Ofcom Guidance Notes (Issue 6: 22 March 2017)