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Methane Leakage Makes Australia a World Leading Per Capita Greenhouse Gas Polluter

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Methane (CH4) is 85% of natural gas, leaks, and has a Global Warming Potential (GWP) 105 times that of the same mass of carbon dioxide (CO2) on a 20 year time frame with aerosol impacts included. Such considerations reveal that Australia with 0.33 % of the world population has revised annual Domestic greenhouse gas (GHG) emissions that are 2.5% of the world's, and annual Domestic plus Exported GHG emissions that are 5.4% of the world's annual GHG pollution.

Australia is among world leaders in annual per capita greenhouse gas (GHG) pollution [1, 2], is a major exporter of GHG pollution-implicit coal, gas and iron ore, and has become the world's largest exporter of Liquid Natural Gas (LNG) as well as of coal. However, depending upon the degree of systemic gas leakage, burning gas for power may be worse greenhouse gas (GHG)-wise than burning coal because methane (CH4, about 85% of natural gas) has a global warming potential (GWP) that is 105 times that of the same mass of carbon dioxide (CO2) on a 20 year time frame with aerosol impacts included [3-6]. However a remorselessly neoliberal, anti-science and anti-environment Australia is committed on a bipartisan political basis (i.e. with the support of the Right-Extreme Right Liberal Party-National Party Coalition Government and the Right-Centrist Labor Party Opposition) to massive exploitation of conventional and non-conventional natural gas reserves for Export and Domestic use. Only the Greens oppose this Gadarene, ecocidal, speciescidal, and potentially omnicidal and terracidal profligacy that is driven by remorseless neoliberal greed and racism.

Australia is a world leader in annual per capita GHG pollution [1, 2] and both its Coalition Government and Labor Opposition are committed to unlimited coal and gas exploitation for Export [1, 2]. Australia is a key player in a dangerous global coal to gas transition that is a deadly and dishonest neoliberal alternative to the complete cessation of fossil fuel exploitation demanded by scientists in the face of the worsening climate emergency. The ideal target of no more than a 1.5C temperature rise agreed to at the 2015 Paris Climate Change Conference is now set to be exceeded on present trends within 10 years [3, 4]. A plus 2C temperature rise – that all governments (except for the idiotic, dangerous, anti-science and climate change denialist US Trump Administration) agree would be catastrophic – is now effectively unavoidable [5-7]. While Humanity can still take action to make the now inevitable plus 2C future "less bad", there is a looming threat of global warming causing massive release of methane (CH4) from the Arctic, a ticking "Methane Bomb" set to utterly devastate Humanity and indeed all life on earth in the coming century because CH4 has a Global Warming Potential 105 times greater than that of carbon dioxide (CO2) on a 20 year time frame with aerosol effects included [8-11].

Australia continues to be devastated by high intensity, destructive and deadly 2019-2020 bushfires across the continent [6], conflagrations that recently threatened lives and homes

in Australia's national capital Canberra in which an unprecedented emergency was declared. Scientists have been warning for decades that global warming and consequent increased temperature, dryness and drought will increase the probability of forest fires [6, 13-19]. However this is variously contested by the climate change denialist or effective climate change denialist Coalition politicians ruling Australia [20, 21]. Indeed at the height of the Australian bushfire catastrophe, pro-coal PM Scott Morrison (who notoriously flourished a lump of coal in Parliament, idiotically declaring "This is coal. Don't be afraid, don't be scared" [22]) announced Government underwriting of 2 new gas-fired power stations next to population centres, and raised the possibility of backing some new coal-fired power stations as well [23]. Utter stupidity.

Thanks to the homicidal greed of climate criminal countries such as Australia, the present plus 1.1C temperature rise is already devastating Island Nations, and a catastrophic plus 2C warming is now effectively unavoidable on present trends. Climate criminal Australia is among world leaders for the following 16 climate criminal activities or parameters: (1) annual per capita greenhouse gas pollution, (2) live methanogenic livestock exports, (3) natural gas exports, (4) recoverable shale gas reserves that can be accessed by hydraulic fracturing (fracking), (5) coal exports, (6) land clearing, deforestation and ecocide, (7) speciescide or species extinction], (8) coral reef destruction , (9) whale killing and extinction threat through global warming impacting on krill stocks , (10) terminal carbon pollution budget exceedance, (11) per capita Carbon Debt], (12) ultimately GHG generating iron ore exports, (13) climate change inaction, (14) climate genocide and approach towards omnicide and terracide, (15) increasing Domestic GHG pollution despite Paris commitments to lower GHG pollution, and (16) complicity in 8 million annual air pollution deaths from burning carbon fuels, Australia's share being 75,000 overseas and 10,000 Domestically [24-26](for detailed documentation see [27]). Australia with 0.3% of the world's population contributes about 4.5% of global GHG pollution (including that due to the burning of Australia's world leading gas and coal exports) [1].

Australian actions to "tackle climate change" would involve mitigatory action in all 16 areas but for the climate criminal Australian Coalition Government it is "business as usual" (BAU) – the climate criminal Australian dog-in-the-manger is simply BAU-wowing to a world facing a worsening Climate Emergency and a worsening Climate Genocide (already 1 million people die from climate change each year in a worsening Climate Genocide that will involve 10 billion deaths this century en route to a sustainable human population in 2100 of merely 0.5-1.0 billion) [28].

Now in his latest anti-science atrocity Australian PM Scott "Scomo" Morrison has announced a $2 billion [Australian dollars] "gas deal" with Premier Gladys Berejiklian of Australia's largest state, New South Wales (NSW). Phillip Coorey of the Australian Financial Review: "The federal government and NSW have reached a $2 billion energy deal which will require NSW to free up massive amounts of gas for domestic use in return for the construction of new interconnectors, the underwriting of new non-coal power generation, and funding for emissions reduction projects.…Pivotal to the deal will be the NSW government having to find an extra 70 petajoules of gas per year [1.29 Mt gas per year] for the east coast domestic market. This could be done by either the government importing more gas through Port Kembla but it is far more likely to give the green light to extract gas from the Narrabri [NSW coal seam] gas fields" [29].

Prime Minister Scott Morrison utterly incorrectly stated: "There is no credible plan to lower emissions and keep electricity prices down that does not involve the greater use of gas as

an important transition fuel" [30] . However his utterly false position has been slammed by science-informed critics. Thus Georgina Woods (from the anti-fracking, anti-coal seam gas, farmer's group "Lock The Gate": "Rural communities should not be forced to sacrifice land, water and their economic security in the name of quick and dirty resource exploitation. Coal seam gas is a heavily polluting industry that leaks vast amounts of methane and won't do anything to bring down carbon emissions" [30]. NSW Greens senator Mehreen Faruqi : "It threatens the Great Artesian Basin, farmer's livelihoods, food security and the mighty biodiverse Pilliga Forest. It's clear that the federal and NSW governments have already made a political decision to allow this project to go ahead" [30]. Adam Bandt (Federal Greens MP): "NSW is doing a climate deal with the devil, locking in pollution that will blow Australia's emissions targets and put us on a path to climate catastrophe. As a global warming gas, methane is up to 86 times more powerful than carbon dioxide. The Prime Minister is trying to hoodwink people with his supposed climate action, but today's announcement amounts to little more than climate criminality" [30].

How does this latest bit of Australian Coalition climate criminality stack up with the science? Set out below is a detailed quantitative analysis showing (among many other surprising things) that the investment of a once-off A$2 billion of taxpayer funds into the PM Morrison-Premier Berejiklian "gas deal" will result in an inescapable annual Carbon Debt of A$3.1 billion for future generations, or A$31 billion over the next decade (noting that the annual Australian defence budget is about A$35 billion and a similar amount is spent annually on subsidies for organized religion).

(1) 2.6% CH4 leakage is as polluting GHG-wise as burning the remaining CH4

Methane (CH4) is the major constituent of natural gas and has a molecular weight of about 16, CO2 has a molecular weight of about 44, and carbon (C) has an atomic weight of 12. Combustion of CH4 yields CO2 and H2O (CH4 + 2O2 -> CO2 + 2H2O) and thus 16 tonne CH4 yields 44 tonnes of CO2 and combustion of 1 tonne CH4 yields 2.75 tonne CO2. By way of comparison, combustion of coal (carbon, C) yields CO2 (C + O2 -> CO2) and thus 12 tonnes C yields 44 tonnes CO2 and combustion of 1 tonne C (coal) yields 3.7 tonnes CO2. Thus per tonne combusted, coal yields 1.3 times more CO2 than gas. Further, coal burning produces more toxic pollutants than gas burning, notably carbon monoxide (CO), sulphur dioxide (SO2), nitrous oxide (N2O), nitrogen dioxide (NO2), radioactivity, heavy metals and fine carbon particulates (notably PM2.5). Accordingly the fossil fuel industry and their Mainstream media, politicians, academic and commentariat supporters advocate a transition from coal to an assertedly "cleaner" gas en route to an eventual zero fossil fuels future. However they are wrong – while gas burning produces less toxic pollutant than coal burning, massive systemic gas leakage(5.4% in the US) and a Global Warming Potential for CH4 105 times that of CO2 (on a 20 year time frame) means that gas burning can be dirtier than coal burning GHG-wise, as set out below.

(2) At 2.6% systemic gas leakage, burning gas yields 2 times more CO2-equivalent as burning coal

CH4 is a gas, leaks and has a Global Warming Potential (GWP) 105 times that of the same mass of CO2 on a 20 year time frame and with aerosol impacts considered [8]. One can readily calculate (assuming gas to be 100% CH4 or CH4 equivalent) that on this basis a systemic gas leakage of 2.6% would contribute as much GHG pollution as generating the greenhouse gas CO2 by burning the remaining 97.4% of the gas [9]. Thus burning 1 tonne carbon yields 3.7 tonnes CO2 and combustion of CH4 with zero leakage yields yields 2.75

tonne CO2. However combustion of 1 tonne CH4 with 2.6% leakage yields 2.68 tonne CO2 (from burning 97.4% of the CH4) plus 2.68 tonne CO2-equivalent (from the GHG effect of the leaked CH4) = 7.2 tonnes CO2-equivalent . One can crudely estimate that with a mere 2.6% of systemic leakage, burning 1 tonne of gas generates nearly 2 times the CO2-equivalent produced from burning 1 tonne of coal.

(3) Australian Government and business grossly under-estimate CH4 leakage from unconventional production at 0.1% (54 times less than overall gas leakage in the US)

One notes that systemic gas leakage in the Boston urban region in the US is about 2.7% [31]. It is estimated that gas leakage in the US is about 2.3% of overall production [34]. Dr Robert Howarth (Nobel Laureate Cornell University) in an extensive review states (2015): "Over the past decade, shale gas production has increased from negligible to providing .40% of national gas and 14% of all fossil fuel energy in the USA in 2013… emissions from the natural gas industry, including both conventional gas and shale gas, could best be characterized as averaging 5.4% (±1.8%) for the full life cycle from well to consumer" [33, 34]. However according to a report from the Melbourne Energy Institute authored by gas expert Tim Forcey, Australia claims gas leakage from unconventional gas production at a mere 0.1% [35], 54 times less than the 5.4% overall gas leakage in the US [33, 34]. Tim Forcey: "Looking specifically at methane emission rates from unconventional gasfields, measurements in the US are up to 10-25 times higher than rates reported by the Australian Government to the UNFCCC [United Nations Framework Convention on Climate Change]" [35].

(4) Damage-related Carbon Price US$200 per tonne CO2-equivalent (considering all major GHGs excepting H2O)

Climate economist Dr Chris Hope of 90-Nobel-Laureate Cambridge University has estimated a damage-related Carbon Price (in US dollars) of $200 per tonne CO2-equivalent [16]. Professor James Hansen (of 96 Nobel Laureate Columbia University): "One ppm of CO2 is 2.12 billion tons of carbon or about 7.77 billion tons of CO2. Recently Keith et al. (2018) achieved a cost breakthrough in carbon capture, demonstrated with a pilot plant in Canada. Cost of carbon capture, not including the cost of transportation and storage of the CO2, is $113-232 per ton of CO2. Thus the cost of extracting 1 ppm of CO2 from the atmosphere is $878-1803 billion. In other words, the cost, in a single year, of closing the gap between reality and the IPCC scenario that limits climate change to +1.5°C is already about $1 trillion. And that is without the cost of transporting and storing the CO2, or consideration of whether there will be citizen objection to that transportation and storage. This annual cost will rise rapidly, unless there is a rapid slowdown in carbon emissions… cost of CO2 storage… has been estimated as $10-20/tCO2" [37]. Taking Professor Hansen's data, and including his estimates of the cost of transport and storage of CO2, indicates that this "best so far" cost of atmospheric CO2 draw-down is $123-252/tCO2, similar to Dr Chris Hope's econometrics-based estimate of $200 per tonne CO2-equivalent [36].

(5) For a 300 ppm CO2 draw-down target, the world has an upper estimate Carbon Debt of $200 trillion that is increasing at $13 trillion per year

Many scientists and science-informed activists demand a reduction of atmospheric CO2 to a safe and sustainable level for all peoples and all species of about 300 ppm CO2 (roughly the pre-Industrial Revolution level and the maximum observed over the last 1 million years until recent decades) [38, 39]. The upper estimate of the Carbon Debt for a transition from the

present monthly mean of 412 ppm CO2 (and increasing a 2-3 ppm CO2 per year) [40] to 300 ppm CO2 is 112 ppm CO2 x $1,803 billion per ppm CO2 = $202 trillion.

This inescapable Carbon Debt for future generations is increasing at 2-3 ppm per year x $1,803 billion per ppm CO2 = $3.6-5.4 trillion per year. [40]. However this estimate does not take other GHGs, notably CH4, into account. World Bank analysts have reconsidered annual GHG pollution taking land use into account and assuming a GWP for CH4 of 86 on a 20 year time frame, this estimate increasing annual GHG pollution from 41.8 Gt O2-e per year to 63.8 Gt CO2-e per year [41]. Thus on this basis the global Carbon Debt is increasing annually at 63.8 billion tonnes CO2-e x $200 per tonne CO2-e = $12.8 trillion per year.

(6) Australia's 2017-18 Domestic and Exported GHG emissions from natural gas exploitation alone totalled 471 Mt CO2-e

Australian liquefied natural gas (LNG) exports totalled 59.7 Mt in 2017–18 [42]. Assuming for computational and didactic simplicity that this is all CH4 (or CH4 equivalents) , then on combustion it would yield 59.7 Mt CH4 x 44 t CO2/ 16 t CH4 = 164.2 Mt CO2. However assuming a gas leakage of only 2.6%, the warming effect of the leaked CH4 equals that from burning the remaining CH4 (see (1)). Thus the total warming effect of Australia's LNG Exports in 2017-18 is that of 2 x 0.974 x 164.2 Mt CO2 = 320 Mt CO2.

However gas used Domestically in Australia in 2017-18 totaled 28.2 Mt CH4 [43] that on combustion yielded 28.2 Mt CH4 x 44 t CO2/ 16 t CH4 = 77.6 Mt CO2. The total warming effect of Australia's Domestic gas use in 2017-18 is that of 2 x 0.974 x 77.6 Mt CO2 = 151.2 Mt CO2.

Accordingly the GHG emissions due to Australia's Domestic and Exported gas alone in 2017-18 = 320 Mt CO2 + 151 Mt = 471 Mt CO2 as compared to the total annual GHG emissions of about 535 Mt CO2-e in 2017-18 reported by the Australian Government (it has been steadily rising contrary to Paris Agreement demands since the Coalition Government was elected in 2013) [44-48]. One notes that the Australian Government conveniently ignores Australia's huge Exported GHG emissions, largely ignores huge fugitive CH4 emissions, ignores huge GHG contributions from bushfires [49], and assumes a GWP for CH4 on a 100 year time frame (initially 21, now 25 and 4-5 times lower than the 105 on a 20 year time frame with aerosol impacts considered).

(7) Australia's 2018-19 Domestic and Exported GHG emissions from natural gas exploitation alone totalled 502 Mt CO2-e (similar to the government's asserted total Domestic emissions of 540 Mt CO2-e in 2018-19)

In 2018-19 total Australian gas production was 93.6 Mt CH4 (5,082 petajoules) and there was a record LNG output of 75 Mt million tonnes (4,070PJ). Domestic gas use in 2018-2019 was accordingly 18.6 Mt CH4 (1,012 PJ) [50]. In 2019 Australia exported 77.5 Mt LNG worth A$49 billion and became the largest LNG exporter in the world [51].

The 75 Mt gas exported in 2018-19 would on combustion yield 75 Mt CH4 x 44 t CO2/ 16 t CH4 = 206.3 Mt CO2. Again, assuming a gas leakage of only 2.6%, the warming effect of the leaked CH4 equals that from burning the remaining CH4 (see (1)). Accordingly the total warming effect of Australia's LNG Exports in 2017-18 is that of 2 x 0.974 x 206.3 Mt CO2 = 401.9 Mt CO2.

The gas used Domestically in 2018-19 = 18.6 Mt CH4 x 44 t CO2/ 16 t CH4 = 51.2 Mt CO2 on combustion. The total warming effect of Australia's Domestic gas use in 2018-19 is that of 2 x 0.974 x 51.2 Mt CO2 = 99.7 Mt CO2. Accordingly the GHG emissions due to Australia's Domestic and Exported gas alone in 2018-19 = 402 Mt CO2 + 100 Mt = 502 Mt CO2. By way of comparison, the Australian Government's asserted total annual GHG emissions totalled about 540 Mt CO2-e in 2018-19 [52].

Several scholars have predicted that Australia's Domestic GHG emissions are set to fall to about 530 Mt CO2-e by mid-2021 if renewables deployment continues at the present rate [52]. However Australian LNG export production may max out at about 88 Mt LNG per year [53] with this translating (if realized in the coming decade) to an annual 472 Mt CO2-e Exported plus about 100 Mt CO2-e from Domestic use for a total of 572 Mt CO2-e in emissions from gas alone in the coming few years.

(8) Australian Coalition Government's one-off A$2 billion investment for gas exploitation in New South Wales (NSW) will add an estimated Carbon Debt of A$2 billion per year, A$20 billion per decade…

Australian PM Scott Morrison is spending $2 billion on a "gas deal" that will a inject an extra 70 petajoules of gas per year (1.29 Mt gas per year) for Domestic use [28, 29]. This means CO2 release on combustion of 1.29 Mt CH4 x 44 t CO2/ 16 t CH4 = 3.5 Mt CO2. Assuming a leakage of 2.6% the GHG effect of this = 2 x 0.974 x 3.5 Mt CO2 = 6.8 Mt CO2-e. At a damage-related Carbon Price of US$200 per tonne CO2-e (A$299) the cost of this climate criminal adventure to future generations will be A$299 per tonne CO2-e x 6.8 Mt CO2-e per year = A$2.0 billion per year. However while the Australian Government is making a once-off investment of A$2 billion, the cost to young Australians of the future will be A$2 billion per year, A$20 billion for the next decade, and A$100 billion over the 50 year life-time of the gas-exploiting infrastructure (coal seam gas extraction systems, pipelines and gas-fired power stations) [54-56].

(9) Revised annual GHG emissions (Gt CO2-e): 1.57 (Australia Domestic), 3.15 (Australia Domestic plus Exported) and 63.8 (world)

Australia's annual per capita GHG pollution as reported by the Australian Government is presently (2018-19) 538.9 Mt CO2-e / 25.2 million people = 21.4 tonnes CO2-e per person per year [57]. The world population is presently 7.7 billion (2019) and the world's greenhouse gas emissions total 43.1 Mt CO2 (2019) [58, 59]. Wikipedia reports that in 2017 Australia's GHG emissions totalled 580 Mt CO2-e and represented 1.3% of the world's total of 45.3 Gt CO2-e [60], noting that Australia's population is 25.2 million x 100/ 7,700 million = 0.33% of the world's population i.e. rich Australia disproportionately pollutes the world GHG-wise by a factor of 3.9. However this disparity gets much worse if one considers the global warming impact of fugitive emissions (leakage) of CH4 from natural gas exploitation as set out below.

The present Australian Government in estimating annual GHG emissions of 540 Mt CO2-e conveniently ignores or underestimates GHG contributions from (a) land use (Australia is among world leaders in land clearing [61, 62], (b) fugitive emissions of CH4 (it formerly estimated this at 0.1%, and more recently revised this to 0.7% [57,] whereas it is 5.4% in the US [33, 34]), (c) global warming potential of CH4 (it assumed 21 and revised this recently to 25 relative to the same mass of CO2 on a 100 year time frame, whereas it is 105 on a 20 year time frame with aerosol impacts included [8]), and (d) it ignores emissions

from bushfires (that have, so far, added an estimated 750 Mt CO2-e to Australia's annual GHG pollution in financial year 2019-2020 [63]).

World Bank analysts carefully re-evaluated the contribution of livestock production to world annual GHG pollution and found that the world's annual total rose from 41.76 billion tonnes CO2-equivalent (CO2-e) as estimated by the Food and Agricultural Organisation (FAO) to 63.80 billion tonnes CO2-e, with livestock production contributing over 51% of the higher figure [41]. A key element of their analysis was to use a Global Warming Potential (GWP) of methane (CH4) relative to that of carbon dioxide (CO2) of 72 on a 20-year time frame rather than the 25 on a 100 year time frame used by the FAO [41]. Indeed the World Bank analysis evidently still understates the GHG pollution because NASA scientists have re-evaluated the GWP of CH4 as 105 on a 20 year time frame with aerosol impacts considered [8].

Accordingly, more properly taking land use into account Australia's revised annual per capita GHG pollution was estimated in 2015 (t CO2-e per person) at 52.9 and 116 if including its huge GHG-generating exports [1, 2]. Assuming a population of 25 million this adjusts Australia's annual GHG pollution to 1,323 Mt (Domestic) and 2,900 Mt (Domestic plus Exported).

However to this we must add a further 250 Mt CO2-e due to the fugitive emissions of CH4 from gas exploitation (assuming 2.6% leakage and thus contributing about 50% of Australia's 500 Mt CO2-e of GHG emissions due to Australia's Domestic use and Export of gas as set out in (7) above). Assuming Australian responsibility for gas fugitive emissions both at home and on route to foreign consumers, then this adjusts Australia's annual GHG pollution to 1,573 Mt (Domestic) and 3,150 Mt (Domestic plus Exported).

(10) Australia (0.33% of world population) generates 2.5% of upwardly revised global GHG emissions (Australian Domestic use only) and 5.4% (Australian Domestic plus Exported GHG emissions)

Assuming the revised estimate of global GHG emissions of 63.8 Gt CO2-e [1, 2, 41], and revised estimates of Australia's GHG pollution taking land use into account [1, 2], one can estimate that Australia (0.33% of world population) has Domestic emissions that are 1.573 Gt x 100/63.8 Gt = 2.5% of the world total, and Domestic plus Exported emissions that are 3.15 Gt x 100/63.8 = 4.9% of global emissions. Thus Australia disproportionately pollutes GHG-wise 7.6 fold more (Domestic pollution) and 14.8-fold more (considering Domestic plus Exported pollution). However it gets worse on closer inspection.

(a). The land use-accommodating, revised estimate of Australian annual Domestic GHG emissions (1,323 Mt CO2-e; see section 9) must be revised upwards by adding the fugitive emissions from Domestic gas exploitation (99.7 Mt CO2-e; see section 7) to yield a total of 1,423 Mt CO2-e.

(b). The revised estimate of Exported GHG emissions (1,577 Mt CO2-e ; see section 9) must be updated as follows:

(i). Australian coal exports totalled 391.2 Mt (2016) and on combustion generated 996.8 Mt CO2-e [64].

(ii). Australian oil crude exports totalled 10.3 Mt (2016), and on combustion generated 33.4

Mt CO2-e [64].

(iii) Australian exported liquefied petroleum gas (LPG) in 2016 that on combustion generated 3.5 Mt CO2-e [64].

(iv) Australia exported 75 Mt LNG in 2017-18 corresponded on combustion to 401.9 Mt CO2-e (this taking an assumed 2.6% leakage into account; see section 7).

(v) Australia exported 830 Mt of iron ore (Fe2O3) in 2018 [65], this corresponding to 579.2 Mt CO2-e (based on an upper estimate of steel manufacture being responsible for an upper estimate of 5% of global CO2 emissions)[65, 66] .

The total Exported GHG emissions is 2015 Mt CO2-e. Domestic GHG plus Exported GHG = 1,423 + 2015 = 3, 438 Mt CO2-e , this corresponding to 3,438 x100/ 63,800 = 5.4% of the global annual total of 63,800 Mt CO2-e [41].

(11) Australia's Domestic plus Exported GHG pollution make it the third worst annual per capita GHG polluter in the world

Australia's annual per capita GHG pollution (t CO2-e per person per year) taking fugitive emissions into account is 1,423 Mt CO2-e/25 million persons = 56.9 (considering Domestic pollution only) and 137.5 (considering Domestic plus Exported GHG pollution). By way of comparison, 137.5 t per person per year puts Australia third in the world after Belize (366.9) and, Guyana (203.1). In t CO2-e per person per year China is 7.4 and India 2.1 (2015 analysis) [1, 2].

This is set to get worse. Thus Australia's Domestic and Exported GHG pollution through gas exploitation is set to increase significantly in coming years [53], notwithstanding pleas from scientists that the world must rapidly stop fossil fuel exploitation [9, 11, 67-71]. Eminent physicist and cosmologist Professor Stephen Hawking (90-Nobel–Laureate University of Cambridge) has succinctly identified the 2 existential threats to Humanity and the solutions: "We see great peril if governments and societies do not take action now to render nuclear weapons obsolete and to prevent further climate change" [71].

(12) Gas is dirty energy, gas burning can be dirtier GHG-wise than coal burning, a coal-to-gas transition is disastrous: stop burning all fossil fuels ASAP

Gas is not clean energy [9-12, 64] and, as outlined above, gas burning can be dirtier GHG-wise than coal burning. However pro-gas politicians and commentators arguing for a coal-to-gas transition are arguing for massive investment in 30-year-lifetime gas-fired power plants that may be worse GHG-wise than coal-fired power plants depending upon the degree of gas leakage [9]. Yet in climate criminal Australia the Coalition PM Scott Morrison responded to the horrific bushfire tragedy by promising government support for 2 new gas-fired power stations and indeed did not rule out such support for new coal-fired power stations [23, 72]. Indeed President Barack Obama oversaw a massive shift from coal to gas in the US based on the false premise that gas was "clean-er" whereas it is not only dirty but can in fact be much dirtier than coal GHG-wise depending on the degree of gas leakage (see section 2 above) [73].

There is indeed a strictly limited interim role for gas as an emergency back-up for solar and wind-based power until hydrological, battery, solar thermal and hydrogen-based storage systems are emplaced on a large scale. Australia's Chief Scientist Dr Alan Finkel: "But, there

is a limit to how much solar and wind we can use and still retain a reliable system. Ultimately, we will need to complement solar and wind with a range of technologies such as high levels of storage, long-distance transmission, and much better efficiency in the way we use energy. But, while these technologies are being scaled up, we need an energy companion today that can react rapidly to changes in solar and wind output. An energy companion that is itself relatively low in emissions, and that only operates when needed. In the short-term, as the Prime Minister and Minister [for Energy and Emissions Reduction] Angus Taylor have previously stated, natural gas will play that critical role. In fact, natural gas is already making it possible for nations to transition to a reliable, and relatively low emissions, electricity supply" [74]. However as demonstrated in this essay, gas is not "relatively low in emissions" as asserted by Dr Finkel because (a) combustion of 1 tonne of CH4 (85% of natural gas) yields 2.75 tonne CO2 as compared to combustion of 1 tonne of carbon (about 90% of coal) yielding 3.7 tonne CO2, and (b) depending upon the degree of gas systemic leakage, gas burning can actually be much dirtier GHG-wise than coal burning (see section 2).

Final comments on combatting falsehood, deceit and climate change inaction

As perceived by the 2-day Australian National Climate Emergency Summit 2020 held on Friday 14 and Saturday 15 February 2020, Australia and the world are facing a Climate Emergency demanding urgent action (see [75, 76]). Unfortunately the fossil fuel Lobby supported by an army of Mainstream journalist, politician, academic, commentariat and lobbyist supporters has the political upper hand, most notably in climate criminal Trump America under climate change denialist Donald Trump and in its pro-coal, pro-gas lackey Australia under an effective climate change denialist pro-coal Coalition Government. Nevertheless the science is clear and indeed is obvious to any sensible, science-informed high school student, as exampled by the wonderfully articulate and straight-talking Greta Thunberg [77].

The success of the denialists and effective climate change denialists is a deadly and disastrous example of Polya's Second Law of Economics, to whit "Deceit about the Cost of Production strives to a maximum". The Second Law of Economics is based on the fundamental Second Law of Thermodynamics that states that entropy (disorder, chaos, lack of information content) strives to a maximum [78]. The International Monetary Fund (IMF) has exposed massive deceit in stating that while a damage-related Carbon Tax of $75 per tonne CO2 would be an effective way of addressing the climate threat, the present global average Carbon Price is only $2 per tonne CO2. The average price on global emissions is currently $2 a ton, a tiny fraction of what is needed for the 2°C target" [25, 54, 79]. Science-trained Pope Francis has stated: "Yet only when the economic and social costs of using up shared environmental resources are recognized with transparency and fully borne by those who incur them, not by other peoples or future generations, can those actions be considered ethical" [54, 80, 81]. Climate economist Dr Chris Hope (of 120-Nobel-Laureate Cambridge University) and climate scientist Professor James Hansen (of 96-Nobel-Laureate Columbia University) have independently estimated a damage-related Carbon Price of about $200 per tonne CO2-e [36, 37, 54].

Eminent economist Lord Nicholas Stern has described this massive deceit thus: "The problem of climate change involves a fundamental failure of markets: those who damage others by emitting greenhouse gases generally do not pay. Climate change is a result of the greatest market failure the world has seen. The evidence on the seriousness of the risks from inaction or delayed action is now overwhelming. We risk damages on a scale larger

than the two world wars of the last century. The problem is global and the response must be a collaboration on a global scale" [82]. This massive corporate and political deceit in ignoring the gigantic economic externality measured by a damage-related Carbon Price has created a huge, inescapable and assiduously ignored Carbon Debt for future generations of $200-250 trillion that is increasing each year by 63.8 Gt CO2-e per year x $200 /t CO2-e = $13 trillion annually [55, 64].

Young Australians will have to pay a gigantic Carbon Debt that has been estimated at $40,000 per head per year for under-30 year old Australians [54]. However this estimate needs correction taking fugitive emissions, land use and a 20 year-based Global Warming Potential (GWP) for CH4 into account. Thus Australia's revised annual Domestic plus Exported GHG pollution is 3,438 Mt CO2-e that corresponds to 3,438 Mt CO2-e x $200 /t CO2-e = $688 billion per year. The Carbon Debt for Australian is thus increasing at $27, 520 (A$41,000) per head per year for every Australian, at $70,000 (A$105,000) per head per year for 9.816 million under-30 year old Australians [83], and at $146,000 (A$218,000) per head per year for 4.7 million 0-14 year old Australian children [84]. The annual increase in Australia's Carbon Debt of $688 billion will ultimately be borne by these 0-14 year old children and is increasing at the rate of $146,000 per head per year (A$218,000).

Young Australians are increasingly aware of how badly they have been betrayed by their profligate elders but when they are cognizant of an inescapable Carbon Debt that is increasing at over A$100,000 per head per year for under-30s they will be out in the streets in their millions. Unlike Conventional Debt , which can be expunged by default, bankruptcy or printing money, Carbon Debt is inescapable because, for example, unless sea walls are built at huge expense, arable land and cities will be inundated as the world heads towards a long-term equilibrium sea rise of 25 +/- 12 metres from present conditions of increased CO2 and warming similar to those of the Pliocene era 4 million years ago [85]. Young Greta Thunberg's "How dare you!" just begins to express the indignation to come over this massive intergenerational injustice [55, 86] that is heading towards a Climate Revolution (peaceful and non-violent one hopes) [84]. For the world as a whole (population 7.6 billion) the inescapable Carbon Debt is increasing at about $12.8 trillion annually or at $1,684 per head per year, noting that the GDP (nominal) per capita for the World is merely $11, 355 and that for India is merely $2, 171 [87]. Global warming is a commonly shared imposition and many countries are already failing to match the Carbon Debt imposed on them annually by rich, profligate countries like Australia.

A damaging plus 1.5C of warming will come in the coming decade, and a catastrophic plus 2C temperature rise is now effectively unavoidable [68-71], but we are obliged to do everything we can to make the future "less bad" for future generations. In Australia and other profligately climate criminal countries, decent people will utterly reject the climate criminal climate change deniers and effective climate change deniers at the ballot box. Decent people around the world will subject disproportionately climate criminal people, politicians , parties, collectives, corporations and countries to Boycotts, Divestment and Sanctions (BDS). Decent countries will subject climate criminal people, corporations and countries to legal actions via the International Criminal Court and the International Court of Justice. Time is running out.

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