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A Green New Deal: The Economic Benefits of Energy Transition

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Abstract. After explaining the current climate emergency, this survey article summarises financial cost estimates for transition to zero carbon by 2050, which even in the medium term, neglecting catastrophic climate collapse, are much less than the cost of 'business as usual' (BAU). Standard economic modelling of continued GDP growth with only minor costs of climate change and limited mitigation investment which still guides policy is shown to be completely unrealistic, simply ignoring current climate science, health costs and the welfare economics of economic growth. The global health benefits from phasing out fossil fuels will also exceed the costs of transition to renewable energy in the medium term, and these co-benefits are widely neglected. The major investment and fiscal expansion required for rapid transition will help to attain full employment, further reducing the net financial cost of the policies necessary for energy transition to avoid catastrophic climate change, policies often summarised as a 'Green New Deal'.

Keywords. Climate catastrophe, energy transition, renewable energy, fossil fuel, pollution.

1. INTRODUCTION

Atmospheric CO_2 concentrations have been rising steadily, with a 2- 3 ppm increase p.a., reaching a record 415 ppm in May 2019 (the highest for about 3 million years), although estimated carbon emissions from fossil fuels (FF) remained roughly constant for 3 years, mainly due to the substitution of cleaner gas for coal,[1] before increasing again in 2017. Emissions of greenhouse gases from land use change and biomass burning are more difficult to estimate and probably account for the steady growth of atmospheric CO_2.

[1] UK emissions in 2017 were 42% below 1990 levels due mainly to replacing coal by gas, according to official accounts, but neglecting the outsourcing of 'dirty' production to China and other developing countries, as well aviation and shipping. Including these factors means that consumption-related emissions have declined by only about 10%, as pointed out by climate activist Greta Thunberg (Carbon Brief, 2019; Anderson, 2019). China remains the world's largest emitter and user of coal by a wide margin, as well as being the largest investor in RE, and though coal production seems to have peaked, there is no sign yet of the rapid reduction needed to reduce even appalling local pollution with health costs from 9 – 13 % of GDP , let alone mitigate climate change (LSE, 2018).

The really bad news is that the Arctic is warming twice as fast as the temperate zones, under the influence of positive feedbacks – albedo effects as ice and snow cover recede, and growing methane emissions from rapidly thawing permafrost – thus threatening eventually irreversible, runaway warming without drastic and rapid mitigating action. Otherwise the result could be a largely uninhabitable, 'hothouse earth' with much higher temperatures than previously predicted, or experienced for millions of years, and resulting collapse of current civilization (Steffen et al, 2018; Berners-Lee, 2019; McKibben, 2019; Wallace-Wells, 2019). '*The only rational response to the scientific evidence on climate change, is to declare a global emergency – to mobilise all of society to do whatever it takes to fix it*' (Paul Gilding, 2018).

Mean global temperature is already more than 1 degree C above the pre-industrial level, and '*… paleoclimatology has revealed that in the longer run each 1°C of warming will result in 10 to 20 metres of sea-level rise and that the current level of greenhouse gases is sufficient to produce warming that would likely end human civilisation as we know it…*' (Spratt, 2019)

Yet the latest, 2018 report by the Intergovernmental Panel on Climate Change, *Global Warming of 1.5°C: An IPCC Special Report*, warns of serious consequences from exceeding 1.5°C, but neglects the major threats already posed by current warming, not to mention further warming triggered by Arctic methane release and other positive feedback effects. Loss of Arctic and Antarctic ice has been accelerating in recent years, and only a rapid drawdown of existing atmospheric CO_2 has a chance of averting major, long term sea level rise. Lack of policy recommendations follows the conservative tradition of official UN reports, which have all failed to call for the required emergency, WWII-scale mobilisation of investment to phase out FF as rapidly as technically possible (Spratt, 2019).

Since the cost of energy transition varies considerably between nations, and there are also incentives for national governments to 'free-ride' or rely on mitigation by others, strong international agreements for cost sharing and meaningful sanctions are essential to accelerate the process. Such agreements would have to go far beyond the ineffective United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement, or the badly designed EU emissions Trading System, neither of which have had much success in facilitating energy transition. Ironically, Swedish schoolgirl Greta Thunberg's Fridays for Future, school strike campaign and other movements such as Extinction Rebellion, have done much more to focus public opinion on the climate emergency in many countries, with a widespread upsurge in Green Party votes and a first commitment by new EU Commission President Ursula von der Leyen to attain carbon neutrality by 2050.

To avoid widespread collapse of water supplies and agriculture in populous regions, which is most likely to be the first major climate related disaster if emergency policies are not rapidly implemented, other measures are also needed. Reducing food waste, deforestation and meat consumption, and transition from industrial factory farming to sustainable eco-agriculture, are all urgently required for food security, which includes halting the parallel emergency of accelerating biodiversity loss (SDG, 2019).[2]

The 1.5°C target is arbitrary, and evolving temperatures cannot be predicted at all precisely from actual emissions paths and policy measures. The target is likely to be exceeded, at least temporarily, even if all emissions were suddenly stopped, due to the thermal inertia of the large ocean mass, which takes a long time to reach equilibrium temperature with relatively slow circulation from the surface down to the depths. Eliminating aerosol air pollution from biomass and FF burning, which has a substantial cooling effect, would actually accelerate warming in the short run, and require further drawdown of atmospheric CO_2. Much faster warming of the critical Arctic region also reduces the relevance of mean global temperatures.

A CO_2 concentration of 350 ppm is considered to be the maximum 'safe' level and is thus a much more relevant target (though the pre-industrial level was only 280 ppm), since the current warming trend began at about this level in the 1970s. Nearly half of current emissions are sequestered by natural sinks. However, ending deforestation, and additional carbon sequestration through reforestation and a switch from industrial monocultures, which promote soil carbon loss, to regenerative eco-agriculture and agro-forestry will be needed, in addition to rapid transition from FF to RE, to reduce the atmospheric carbon concentration to 350 ppm by 2050. Industrial hemp can sequester 10 tonnes of carbon per hectare per year, in poor soil with little water and no need for fertilizers, so is much more effective than slow growing tree plantation. (Hawken, 2018; Rumpel et al, 2018). These policies have already been shown to be highly cost-effective at local levels, and are much more promising than carbon capture and storage (CCS), which has proved to be very costly and ineffective in several discontinued tri-

[2] Whether political response will be rapid enough to avert disaster remains an open question, with plenty of grounds for pessimistic scepticism in spite of a surge of 'green votes' in the 2019 European Parliament elections, but with strong right wing populist support forclimate science denial as well.

als in the US (Grandia, 2018). Sgouridis et al (2019) show in detail that RE investment is much more cost-effective that any likely development of CCS, though of course technological breakthroughs cannot be ruled out.

It is ironic that the dangers of climate change had already been clearly identified by 1989, when pioneering scientist James Hansen testified before the US Congress, and the first IPCC had been constituted, with little progress over the intervening 30 years, or indeed at the latest, December 2018 COP24 conference at Katowice (Revkin, 2018). New research by Yu et al (2018) provides strong evidence that 1.5°C of average warming will be reached by about 2030 on present trends or 'business as usual' (BAU), 10 years earlier than predicted by the 2018 IPCC *Special Report*. One estimated global carbon budget of cumulative emissions for not exceeding 1.5°C will exhausted by 2020 under BAU, underlining the urgency of radical mitigation and 'drawdown' policies for which only the political will is lacking (Hawken, 2018; Hickel, 2017).

The good news is that solar and wind power costs have been declining much faster than only recently predicted, to reach or fall below parity with FF generation costs in favourable locations, but this development is rather overwhelmed by the still limited share of wind and solar (WS) in global primary energy consumption (only about 1.5%, though estimates vary), and totally inadequate investment. Nuclear remains the most expensive new power source, but closing down existing nuclear power for purely party-political reasons, while only planning to phase out heavily subsidised coal by 2038, as in Germany's expensive but ineffective 'Energiewende', will remain one of Chancellor Angela Merkel's worst legacies (*Der Spiegel,* 2019).

Estimated WS capacity is just over 1 trillion watts (TW), currently growing at about 17% p.a. with investment under $300 billion pa (and recently declining in monetary terms). Jacobson et al (2017) estimate about 50 TW of new wind, water and solar (WWS) capacity would be needed by mid-century for a zero carbon economy, which would thus require an average expansion of about 1.6 TW p.a. over the next 30 years to attain, more than 10 times the current annual WS[3] addition! Of course, this could only be achievable with initially still higher growth rates, underlining the catastrophic inadequacy of current 'business as usual' climate and energy policy (BAU), which will generate only a slow decline of the FF primary energy share of about 80%, as well as a rapid overrun of the 'safe' global carbon budget, and a probable 'hothouse earth'. Sgouridis et al (2016) investigated the dynamics of a complete transition to renewable energy including storage from a net energy perspective while staying within the carbon budget. To achieve this, installation rates would peak at around 8TW p.a. in 2035, and emissions could be cut by more than half by 2030 with major energy savings and parallel 'drawdown' of atmospheric carbon through eco-agriculture and industrial hemp plantation.

Jacobson et al (2017, 2018, 2019) analyse several technically feasible models of decarbonisation. One estimate gives a total gross investment cost for transition by 2050, at about $125 trillion or an average annual cost of just over $4 trillion,[4] which, as we argue below, represents a less demanding policy shift for the rich countries that will have to bear most of the cost than the WWII mobilisation which finally ended the Great Depression in the US (McKibben, 2015; Tooze, 2019). This estimate is quite conservative, neglecting likely major further improvements in WS or any other, new RE technologies, but does assume large scale efficiency gains and savings through electrification. These numbers are of course only a rough guide to gross costs, and neglect the extensive co-benefits of transition discussed below. Hawken (2018) provides detailed discussion of many different technologies to 'drawdown' carbon and transition to RE, with similar overall conclusions. A comprehensive new report by Ram et al (2019) estimates a much lower cost of global transition to 100% RE by 2050.

Behavioural changes such as much higher cycle and public transport shares in urban areas, less flying, meat consumption, deforestation and material use in an economy based on repair and recycling rather than obsolescence and disposal, will also be necessary to ensure rapid enough transition and avoid shortages of crucial materials.

In the next section 2, we offer a brief account of traditional neglect and fundamental misunderstanding of the climate emergency by prominent economists. In section 3 we then summarise the evidence that mobilising society for energy transition would yield enormous medium term financial, health and employment 'co-benefits' that would more than pay for transition, in addition to averting catastrophic climate change as the ultimate long term '*bonus*'. Section 4 explains the macroeconomic and distributional benefits of the 'Green New Deal' (GND) or mobilisation for energy transition, all the more urgent after decades of neoliberal austerity. A detailed discussion of the main policies for a GND follows in section 5, while section 6 relates these policies to the 'growth or de-growth' debate. Conclusions are summarised in a final section 7.

[3] Most of the new capacity would be WS, since there is only limited scope for expanding (mainly small scale) hydro power.

[4] Presumably in constant, current dollars, roughly 5% of current global GDP.

2. TRADITIONAL ECONOMICS OF CLIMATE CHANGE AND ENERGY TRANSITION

Long after the threats of unmitigated climate change, pollution and environmental destruction had been recognised by environmentalists and scientists, these issues were ignored by most economists. The 2018 Nobel laureate economist, William Nordhaus, was an exception who did make early attempts to quantify the 'optimal' carbon tax with the help of long-term models of GDP growth and possible climate damage known as 'integrated assessment models' (IAMs), but nevertheless assumed growth to be much more important than climate damage and essentially unlimited.[5] Future damages are reduced to trivial present values using unreasonably high discount rates, and future generations are assumed to be so much richer that they can easily cope with climate change! His latest attempt (Nordhaus, 2017), estimates the welfare maximising 'social cost of carbon' or optimal tax rate at $31 per ton, rising by about 3% p.a., which would only slightly reduce the BAU emissions path. He predicts 'mean warming of 3.1°C for an equilibrium CO_2 doubling' by 2100, without considering the methane and other feedbacks which would almost certainly generate much higher temperatures and a largely uninhabitable 'hothouse earth' under such a policy. With average annual real per capita growth predicted to be about 2%, mainly due to exogenous technological change, climate damage is claimed to be only about 2% of GDP by 2100, though much of the world's population might not survive this BAU programme!

All these model predictions are decisively contradicted by the climate science which is never mentioned by Nordhaus. It is now clear, as Steffen et al (2018) and others have shown, that even the old 'political' target of 2°C average warming, let alone 3.1°C, would decimate global food production, and trigger irreversible methane and other feedbacks to leave much of the world uninhabitable in the long run, with warming ultimately far beyond 3.1°C. *'What is more, Nordhaus reasons that the sectors most vulnerable to global warming—agricultural, forestry, and fishing—contribute relatively little to global GDP, only about 4 percent. So even if the entire global agricultural system were to collapse in the future, the costs, in terms of world GDP, would be minimal'* (Hickel, 2018). On this logic, billions of the world's poorest inhabitants contribute relatively little to Global GDP, so their death from starvation would also hardly matter. Furthermore, water and products of the vulnerable sectors are universally under-priced, neglecting externalities and sustainability, and encouraging overuse and exploitation.

In addition to the moral repugnance of these conclusions, they are also based on elementary economic errors. If agriculture was devastated by climate change, most of the rest of the global economy would collapse, and food prices would explode, so while billions of the poorest inhabitants would starve, what was left of the agricultural sector would actually *dominate* global GDP because inflated spending on food would exhaust most budgets even in rich countries! This is likely to be the first really major global impact of climate change, long before rising sea levels have flooded many of the world's biggest cities, because modern industrial agriculture in general and many of the most important food growing areas in China, India, and Africa, as well as the wheat belt of the North American Great Plains are particularly vulnerable to increasing aridity, falling water tables, rising temperature and extreme weather events as climate change progresses.

A major reduction of meat consumption and food waste could feed the current population with a much smaller total output, as well as greatly reducing FF use and emissions, and providing healthier diets, but in addition, large - scale conversion to regenerative eco-agriculture, and ending deforestation are necessary for long term sustainability. This incorporates mixed farming, low-till cover-cropping and controlled animal grazing, to reverse accelerating soil carbon loss, degradation and desertification under current destructive and unhealthy industrial agriculture, with its reliance on intensive factory farming and large-scale, vulnerable monocultures, to sequester a substantial share of carbon emissions (Holt-Jimenez, 2019; Hawken, 2018; Rumpel et al, 2018; FitzRoy and Papyrakis, 2016; Montgomery, 2016).

While Nordhaus's ideas seem to have provided academic respectability for policy makers' obsession with growth and neglect of food security and climate mitigation measures, other prominent economists,[6] never cited by Nordhaus (2017), have clearly recognised the possibility of catastrophic climate change and the impossibility of any meaningful cost-benefit analysis of, for example, the destruction of much of human and other terres-

[5] Bardi (2018, 2011) discusses Nordhaus's repeated failure to understand 'complex systems' of ecology and economy, as modelled in the Club of Rome's Limits to Growth and various updates (Meadows and Randers, 2004).

[6] See Stern (2015), and Wagner and Weitzman (2016). These studies as well as the latest climate and environmental science and the threat to global food production are all ignored by Nordhaus (2017), although they clearly show that all his central assumptions are completely unrealistic. However these and most other economists have neglected the co-benefits of transition discussed below.

trial life, so that policy priority should just be the fastest politically 'feasible' transition to zero carbon. Such a policy will minimise the expected cost of ongoing climate change as well as the risk of more distant disastrous outcomes. In this respect, these economists follow the lead of climate scientists, but like Nordhaus, neglect the much earlier, pioneering work of ecological economists such as Daly (1973, 1992) and environmentalists such as McKibben (1989), who have long recognised that drastic reduction of emissions with a mobilisation of resources almost comparable to that of WWII (but lasting for decades), represents the only safe and viable climate policy, which would also provide many co-benefits. Indeed, full employment after the Great Depression was only restored by war time mobilisation in the US.

As Gilding (2018) remarks, '*The only rational response …is to do whatever it takes*', which must again mean the fastest 'feasible' transition, where the constraint is how rapidly behavioural changes such as less driving, flying and meat-eating can be implemented in the wider population with help of 'nudges' and persuasion in a democratic framework. What is not widely realised, due to the well-funded efforts of the FF lobby to exaggerate the costs of transition to RE, as well as denying the costs of climate change, is just how small – actually *negative* – the real overall *net* costs of transition are likely to be, though of course the FF sector will be the main loser with all their 'stranded assets' left in the ground.[7]

3. THE COST-REDUCING AND HEALTH-IMPROVING CO-BENEFITS OF ENERGY TRANSITION

In addition to the obvious benefit of saving the natural world and human civilization from irreversible and catastrophic climate change in the long run, transition to RE offers three additional major co-benefits in the medium term (Hawken, 2018; FitzRoy and Papyrakis, 2016; Smith, 2013). The most obvious is perhaps the reduction of expenditure on FFs as they are replaced by RE, thus reducing the net cost of transition. The IEA (2019) estimates world FF energy investment of about $1.5 trillion in 2018, about 2% of global GDP, so the average annual total direct cost of BAU could be nearly half of the average annual $4 trillion cost of complete transition in the next 30 years, following Jacobson et al (2017). They also estimate that nearly 13% of total end-use energy world-wide is used to *produce* the refined FF and uranium that provide most of the current energy supply. All FF costs are likely to rise substantially as the most easily exploited resources are declining and reliance on unconventional, 'tight' oil and gas and costly fracking increases. Total FF cost savings will depend on the precise path of RE expansion, but should be substantial, at least in the later stages, though rapidly expanding RE and efficiency investment will initially raise FF demand which is a necessary component of what was termed the Sower's Way – the use of FF for building the RE infrastructure (Bardi, et al, 2016).

The second co-benefit or cost saving has recently been highlighted by the IMF, where Coady et al (2017) estimate the current global costs of air pollution from FF, including about 4 million annual fatalities from outdoor air pollution, at around $4 trillion in 2015, roughly equal to the projected average cost of transition! However Burnet et al (2018) and Lelieveld et al (2019) find 9 million – twice as many – fatalities p.a. from ambient (outdoor) fine particulate, or $PM_{2.5}$, and ozone pollution, with much improved data and estimates, greater than the 7 million annual deaths from smoking found by the WHO. Indoor air pollution from cooking with solid fuels and traditional stoves are a major additional source of mortality and morbidity in developing countries, but with less quantitative data. All this obviously implies much higher costs, at least double the IMF estimate, depending on how the morbidity and mortality of poor individuals is evaluated. Over 90% of the fatalities are in poor countries, which is why the imputed value of a statistical life (VSL) of about $1 million, or less with morbidity costs included, is only a small fraction of the VSL in advanced economies. Thus following the new studies, $10 trillion or about 13% of global annual GDP would seem to be a very conservative, rough estimate of annual health and well-being costs from FF pollution.[8]

These costs have two components – the direct, financial or resource costs of lost output, disability and extra costs of care and medical services, and the intan-

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[7] See McGlade and Ekins, 2014; Rogeli et al, 2015. An alternative is compensation or a public sector buyout of FF assets in order to reduce opposition with a Pareto improvement for all (Broome, 2018; Smith, 2019), not an appealing policy after decades of deception and disinformation, a campaign which was clearly contradicted by ExxonMobil's own early research results. Smith (2019) emphasises that displaced FF-affected workers do need to be given alternative employment and training.

[8] Most of the fatalities are among vulnerable individuals with a much lower life expectancy than the average, but this is often the result of a long history of exposure. Pollution also directly reduces happiness of all who are affected, as well as the future health, life expectancy and IQ of children who suffer exposure. Huge health costs from indoor air pollution due to biomass burning for cooking in developing countries should be added, and could also be largely eliminated with cheap solar energy and clean cookers, adding substantially to the benefits from transition to renewable energy. Scovronick et al (2019) estimate that 'The global health benefits from climate policy could reach trillions of dollars annually…'.

gible, welfare costs of premature mortality and morbidity, as well as directly reduced life satisfaction for most people affected. These latter costs are usually estimated as the VSL, and the value of QALYS – quality adjusted life years – by willingness to pay for a marginal reduction in the probability of fatality or morbidity, or for a cleaner environment, which in turn implies dependence on income and hence large differences between rich and poor countries, an ethically dubious distinction. We do not have separate estimates of the intangible and tangible components, but even just the latter are likely to exceed the approximately $4 trillion estimated average annual cost of complete transition to a zero carbon economy by 2050.

Coady et al. (2017) refer to the total imputed cost as 'post-tax subsidies', which are much greater than direct or pre-tax financial FF subsidies of less than $1 trillion p.a. Economists usually refer to external costs of pollution rather than subsidies, but not accounting for these costs with an appropriate 'Pigouvian' tax on FF does amount to an implicit subsidy which has substantially increased FF consumption and consequent environmental and health damage.

Pollution costs have been steadily increasing under BAU, and some health damage from pollution will continue to emerge after the pollution is reduced or eliminated. Nevertheless, avoiding a growing share of at least $(2+10 = 12) trillion direct and indirect or external annual costs of FF as RE grows and replaces FF suggests a very approximate average annual saving of half the total, or $6 trillion.[9] This is much larger than the Jacobson et al (2017) estimate of annual average cost of transition, leaving a huge co-benefit in addition to averting irreversible and catastrophic climate change as the ultimate 'bonus'. Of course, health and other costs of pollution would increase rapidly under continued BAU, well beyond 2050, until the industrial global economy collapsed under the impact of climate change, and most of the global population died, so these 'estimates' are very conservative, rough guides to orders of magnitude. Furthermore, the health benefits from a zero carbon economy would continue *indefinitely* after 2050, so even in terms of discounted present values, the surplus of cost savings or benefits over the actual expected costs of transition to RE would be still further increased, a huge reward over and above the essentially incalculable benefit from averting catastrophic climate change.[10]

4. GREEN NEW DEAL

Various co-benefits of 'steady state economics' and energy transition have long been emphasized by environmentalists such as McKibben (2016, 2006, 1989) and progressive economists, such as Daly (1973, 1977), and recently by the Green New Deal Group and New Economics Foundation in their 'Green New Deal' proposal (NEF, 2008; Murphy and Hines, 2019).[11] After the financial crash of 2007/8, 'quantitative easing' (QE) – the purchase of government bonds by central banks – helped to fuel an asset price boom, making mainly the rich even richer and contributing to growing inequality, with little effect on employment. Austerity then inflicted huge losses on the majority, as most wages have stagnated and welfare spending cut, particularly in the UK and US, while un- and particularly under-employment remain serious problems everywhere (Storm, 2017; Blanchflower, 2019).

The Keynesian alternative would have been a major fiscal expansion to fund labour-intensive investment in infrastructure and energy transition in a Green New Deal, creating jobs for genuine full employment, and a start to averting irreversible climate change. ECB expenditure of €2.4 trillion on QE, ending in 2018, was a gigantic missed opportunity, as were similar QE programmes in the UK and US (Tooze, 2019).

The Keynesian 'multiplier' effect results as increasing employment reduces the need for welfare and unemployment benefit payments, so the formerly unemployed will start to pay taxes, while their greater spending will in turn stimulate the rest of the economy and further raise tax receipts. Thus some of the original extra public expenditure will be recouped, further reducing the net cost of RE and other public investment before the economy reaches full employment, with little danger of increasing inflation in the current environment of very low interest rates and inflation. Prospects of 'secular stagnation' advanced by prominent economists strengthen the case for further fiscal stimulus (Eggertsson et al, 2018; Tily, 2017).

Launching a programme of rapidly expanding RE and related investment will require initially increasing

[9] Summarises for simplicity a linear increase of savings from initially 0% to finally 100% of projected total FF costs of at least $14 trillion p.a. As noted above, some of the health costs and hence savings are intangible.

[10] Hawken (2018) summarises of savings from complete decarbonisation by 2050 of $74 trillion with a very different methodology, but without distinguishing between pecuniary and non-pecuniary components, and using the outdated Coady et al (2017) health cost estimates, which could explain why the total is somewhat lower than the estimates reported here. It is not clear whether the total represents final accumulated savings or a present discounted value. However the similar orders of magnitude from such disparate approaches are quite reassuring.

[11] The idea is receiving increasing attention from progressive Democrats such as Alexandria Ocasio-Cortez, the UK Labour Party and Green Party supporters in the US and Europe, though neoliberal media disinformation and neglect have so far hindered any broader public understanding or acceptance (Roberts, 2018; Klein, 2019; Rifkin, 2019).

public expenditure and funding requirements before the multiplier effect begins to generate rising revenue and reduce welfare claims. While the dysfunctional Euro system raises serious legal obstacles to such necessary policies (Mody, 2018), there are no real problems for countries with sovereign currencies such as the UK, where central banks can simply create necessary funds without causing inflation, as long there are underutilised resources, and governments can borrow or raise taxes on high earners. As Tooze (2019) puts it, *'A decade after the world bailed out finance, it's time for finance to bail out the world'.*

However, conservatives obsessed with the neoliberal ideology of smaller government, lower taxes for the rich, less welfare for the 'undeserving' poor, and 'debt fetishism', have imposed austerity in the UK and much of the EU since 2010 at enormous cost in both human and economic terms. They continue to oppose fiscal expansion, neglect infrastructure and underfund the NHS and care services, while completely failing to understand the urgency of climate change mitigation (Cooper and Whyte, 2017). And more broadly, the ad hoc Maastricht criteria for Eurozone members place all emphasis on debt and budget deficits, ignoring employment, poverty or any environmental/CC targets. The official UK Climate Change Committee (CCC, 2019) has published detailed plans for zero carbon by 2050, now also an officially legislated target, but there are currently no signs of needed policies.

Conservatives in the US including most of the Republicans in Congress and the Trump administration generally deny basic climate science[12] (as well as modern economics and even evolution), as do Vladimir Putin in Russia and Brazil's new President Jair Bolsonaro, so the political prospects for rapid implementation of serious climate policy even in Europe, let alone in other major polluters, are still extremely dim. China leads in RE investment but also in emissions and coal consumption by a wide margin, and while coal use may have peaked, appalling pollution problems remain, and the urgently needed, rapid reduction of coal powered generation has not yet been addressed, while China continues to support new coal power in many developing countries.

5. POLICIES FOR ENERGY TRANSITION

The co-benefits outlined above are all medium to long term, and so major additional initial expenditure remains necessary. Economists agree that substantial and rising carbon taxes should be part of any climate policy, but to gain public acceptance and avoid adverse distributional effects, at least some of the revenue should be returned, either as an equal per capita 'dividend' to all citizens as part of a universal basic income, or targeted to the most disadvantaged. While redistributive in aggregate because the rich generally use more FF- carbon per head than the poor,[13] there are always some low income households with a high FF consumption, e.g.in rural areas, who would need additional compensation (Boyce, 2018; Stiglitz and Stern, 2017). Subsidised electric cars for low income individuals with long commutes and lacking access to public transport would have obvious benefits to mitigate the distributional impact of a carbon tax, as would the expansion of low cost or free public transport (as recently introduced in Luxembourg). Banning most cars from cities would greatly facilitate cycling, socialising and public transport with major health and welfare benefits, and be much more effective than current plans just to replace petrol and diesel cars with still very expensive e-cars, or indeed with *any* motorised individual transport.

Extensive and sometimes violent, 'Gilet Jaunes' protests erupted in France in late 2018 in opposition to rising fuel taxes, initially announced without any compensation or redistribution of revenues, thus illustrating the importance of distributional equity, and finally forcing the Macron government into cancelling the fuel tax hike and several neoliberal policies which also reduced the incomes of low earners. As Mehling (2018) explains, subsidies for RE are also needed to accelerate development and gain broad acceptance, and higher taxes which impact low income households need to include appropriate compensation, in contrast to purely redistributive taxes on high earners, which should then be used to benefit the poorer majority of the population. Under such appropriate conditions there is actually widespread support for a global carbon tax (Carattini et al, 2019). Unfortunately some commentators such as Martin Wolf in the Financial Times (5 Nov, 2019) claim without evidence that large scale public investment in mitigation implies abandoning markets in favour of a 'planned economy' with disastrous effects. He fails to understand that it is far too late to rely exclusively on carbon taxation.

To alleviate the inevitable disruptions of transition to RE, as well as problems already being caused by the growth of non-standard and precarious employment

[12] Even those who claim to accept the evidence for climate change generally still deny the need for urgent policy measures to reduce FF use.

[13] In the US, the top 10% of the income distribution emit over 4 times as much carbon per head as the bottom 10%, and globally they are responsible for about half of total emissions. However Boyce (2018) shows that a $200 / t CO_2 US fee-and-dividend would leave 12% of the lowest income quintile, and 23% of the 2nd quintile worse off, so the need for additional compensation is clear, some of which could come from a universal basic income.

for many, a modest universal basic income for all citizens, combined with a public sector job offer or guarantee, seems to be the most effective policy to supplement existing and unco-ordinated, targeted welfare measures (FitzRoy and Jin, 2018)

A carbon tax or 'fee-and-dividend' which is not too high to be disruptive initially, but rises on a pre-announced path to ultimately capture the full external costs of FF use, and thus undo the existing implicit subsidies discussed above, should provide the appropriate incentives for the private sector to invest in energy saving and RE. However direct government and central bank intervention, 'green bonds' and subsidies will surely be required for rapid change on the required scale, less than WWII mobilization when military spending peaked at 41% of GDP, but lasting for decades (Tooze, 2019). In particular because the very fast growth of RE capacity needed to achieve largely complete decarbonisation by mid-century will impose initially rising costs, supply-side bottlenecks and shortages. Certainly to build the continental -scale smart grids and storage and back-up facilities needed to 'smooth' the natural intermittency of local RE production will require major public investment and international political coordination in Europe and elsewhere. Smith (2019) and others argue in detail that only 'eco-socialism' with public ownership of large corporations can manage rapid transition, though it is difficult to see why appropriate regulation and other policies cannot achieve the same goal.

Contrary to frequent claims, higher taxes are not necessary initially, though reducing growing inequality with more progressive, redistributive taxes on high incomes would have many political and welfare benefits, but obviously faces strong opposition. Instead, as long as there are underutilised resources in the economy, sovereign governments and their central banks can create new money, or borrow without risk of generating inflation or default, to fund the vital and productive investment of a Green New Deal. As the additional expenditure is re-spent by the initial recipients and thus raises other incomes, this Keynesian multiplier mechanism will increase government tax revenues and over time can offset much of the initial investment cost.

The first stages of a massive expansion of RE will also require additional FF energy, which may even require a temporary increase of FF production if energy saving elsewhere does not proceed fast enough. Sgouridis et al (2016) have estimated that FF supplies should be adequate for transition with the growth of unconventional or 'tight' oil and gas, in spite of the decline in easily recoverable reserves and the 'energy return on energy invested' (EROEI).

The intermittency of WS is frequently claimed to be a major obstacle to complete decarbonisation. However Jacobson et al (2017, 2018), Breyer et al (2018), Brown et al (2018) and Ram et al (2017) have shown in detail that an appropriate combination of continental-scale smart grids, feasible storage technologies and closed cycle gas turbine back- up generating capacity, using bio-gas or even natural gas, can smooth supply and solve the intermittency problem at a cost which is dwarfed by the value of the energy savings from almost complete electrification. Since the back-up will only be required during very rare, extreme weather conditions persisting over large areas, the average annual emissions from use of natural gas during such events will be negligible. In Europe, for example, the sunny Mediterranean periphery would be optimal for solar, and could be linked to the windy north for night time wind power generation by a high voltage, direct current, 'smart grid' with very low transmission losses, and additional savings potential when coupled with smart metering and household appliances.

An important but neglected point is that moving from 'low' to zero emissions is the most expensive phase of transition. Particularly since existing natural sinks would be substantially augmented by adoption of eco-agriculture and large scale reforestation, a small, remaining share of flexible natural gas for power generation, as a back- up to variable renewables, could greatly reduce storage and other costs and still allow a steady reduction in the stock of atmospheric CO_2 concentration to the target of 350 ppm. Complete decarbonisation may thus be an unnecessarily ambitious and expensive goal, though the final trade-offs will need careful calculation and monitoring. The main priority must be the initially rapid reduction of emissions through energy saving and expansion of RE while phasing out coal consumption, and cutting globaal emissions by at least half by 2030.

6. GREEN GROWTH, DE-GROWTH OR BOTH?

There is a long standing debate about the feasibility of continuing (greener) GDP growth on the transition path to a zero carbon economy and subsequently, or whether radical reduction of currently wasteful and polluting production and consumption will be required, and if so, how the costs of such de-growth should be distributed (Antal and van den Bergh, 2017; Jackson, 2018; Semieniuk et al, 2018; Schröder and Storm, 2018). There does seem to be general agreement, at least among environmental economists, that complete decoupling of GDP growth from environmental damage is an illusion (Ward et al, 2016). However, this debate sometimes diverts attention away from the crucial supply-and-demand synergy of expanding RE, replacing first coal, and then other FF power as rapidly as possible, and simultaneously reducing energy demand by investment in energy efficiency and saving. Thus there is extensive scope to retrofit buildings for greater energy efficiency, and replacing ICE vehicles with EVs, including public transport, and bicycles.[14] Much of this activity is labour intensive, and under a Green New Deal full employment should be attainable, with rising incomes for the formerly un-and-underemployed, and increasing public expenditure, so that GDP would certainly grow in the initial stage of transition. However this growth would be mainly in investment, though with some consumption growth for the newly employed and low income households who benefit from redistributive carbon fee-and-dividend payments and a universal basic income, as well as more progressive taxes on the rich.

Clearly developing countries need green growth to attain the Sustainable Development Goals, but equally obviously, the developed economies cannot continue material growth indefinitely, with ever more and ever larger cars and houses which use many other scarce resources in addition to energy. Indeed, radical conservation and savings policies will be needed, including repair and maintenance of durable goods instead of the 'throwaway culture' of planned obsolescence. In the long run the 'levelized cost of electricity' (LCOE),[15] after transition to RE is estimated to be lower than the BAU LCOE largely powered by FFs in the many studies referenced above, but it will not be zero (though the *marginal* cost of RE up to capacity limits is very low with no FF use). Thus there will continue to be limits to the recycling of non-renewable resources, and hence to sustainable material (and population) growth. On the other hand, declining IT costs facilitate the 'weightless' growth of human knowledge, though the resulting power of digital 'natural monopolies', the proliferation of 'fake news', and the potential for intrusive surveillance, abuse and addiction in digital social networks remain serious threats, still far from being effectively regulated (Zuboff, 2019).

Though ignored by policy makers and academic GDP growth proponents such as Nordhaus (2017) and Friedman (2006), but emphasised by Nobel Laureate economist Joseph Stiglitz (2009; 2019), Kubiszewski et al (2013) and many others, it has long been known that GDP is a poor measure of welfare, and that *'[c]hasing GDP growth results in lower living standards. Better indicators are needed to capture well-being and sustainability.'* (Stiglitz, 2009). Since the pioneering work of Easterlin (1974, 2013), a large and expanding body of survey evidence shows that subjective well- being, life satisfaction or happiness are unrelated to economic growth in the long run in developed economies, though short-term fluctuations are positively correlated. This is mainly because unemployment and loss of income are major causes of unhappiness, and also because *relative* income is an important determinant of happiness above the poverty level, which does not change when all incomes are growing simultaneously (Kaiser and Vendrik, 2018).

Though income is correlated with well-being in cross sections at any time, the effect is weak for income above the poverty level. The main determinants of happiness are satisfying work, health and family and social relationships, as well as environmental quality. Even worse, growing inequality in recent decades has eroded both well-being for the majority who have not benefitted from economic growth, and the basic institutions of democracy (Atkinson, 2015; Dorling, 2017; Stiglitz, 2013; Wilkinson and Pickett, 2010, 2018). In the UK, only the minority with higher education and earnings reported increasing life satisfaction over the last two decades, while in the US average happiness has declined since the 1970s, with greatest decline for the poor (FitzRoy and Nolan, 2018; Graham, 2017).

In an egalitarian society with minimal poverty and deprivation, technological progress can be used to reduce working time and improve work-life balance following practice in Social Democratic Denmark and other Nordic economies, which also regularly yield the highest life satisfaction or happiness rankings (Gustavson, 2011; Radcliff, 2013; Lakey, 2016). In addition to transition to RE, another, complementary, transition, from neoliberal obsession with GDP growth to priority for well-being and sustainability is urgently required (Laurent, 2017). As Jackson (2016) and many others have emphasised, 'prosperity without (material) growth' is then the only sustainable, long run alternative in advanced economies to currently prevailing 'growth fetishism' and environmental destruction, though of course knowledge should continue to grow, and poor countries still need to overcome poverty with aid for green growth.

7. CONCLUSIONS

Concern about climate change is increasing in populations around the world as the effects become

[14] Such policies have already dramatically improved the quality of urban air and life in cities such as Copenhagen, Freiburg, and, remarkably, in Curitiba, Brazil (FitzRoy and Papyrakis, 2016).

[15] The net present value of the unit-cost of electricity over the lifetime of a generating asset, including both investment cost and operating cost, equal to the break-even average price. Aghahosseini et al (2019) find that complete transition of power generation to RE in the Americas by 2030 would already reduce the LCOE compared to BAU

increasingly evident. However, the perception that complete transition to RE would be inordinately expensive remains widespread, a perception which is not only the result of intensive FF lobbying and disinformation efforts. Proponents of RE remain preoccupied with the undoubtedly spectacular technical progress and falling costs of RE, but have generally failed to make the economic case that rapid global energy transition under the necessary massive mobilisation with a Green New Deal would provide a financial and welfare bonanza.

Much of the world's advanced economies remain mired in 'secular stagnation' a decade after the Great Recession, with high levels of underemployment and declining labour force participation, not captured in official unemployment statistics. At the start of WWII, the US was suffering from even worse problems from the legacy of the Great Depression in the early 1930s, with over 14% unemployment, which was reduced to about 1% by 1944, while GDP doubled with military spending that peaked at 41% of GDP. A Green New Deal of similar magnitude today could also generate truly full employment to save the environment and reverse 'global heating', with immense and *immediate* benefits for the most deprived, un-and-under-employed who are currently suffering from neoliberal policies and shrinking welfare. It is these and other short to medium term co-benefits of energy transition and climate change mitigation which are most likely attract widespread political support from electorates whose immediate survival concerns tend to crowd out warnings of apparently distant climate catastrophe.

Thanks in particular to the pioneering work of Stanford's Mark Jacobson and his co-authors we now know that average annual costs of energy transition by 2050 are of similar magnitude to the financial savings from phasing out FF and averting just the local health costs of FF pollution, in addition to the welfare benefits of ultimately avoiding the more that 9 million current fatalities from outdoor air pollution alone and the associated morbidity. In addition, of course, the benefits from rapid action to avert irreversible climate change and a resulting 'hothouse earth' are essentially incalculable, the ultimate bonus to follow all the co-benefits of energy transition in the short to medium term. The crucial unanswered question for our future remains – will increasingly frequent and severe, climate-related disasters help to overcome denial, disseminate scientific understanding and mobilise public opinion and political will rapidly enough for effective action?

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