A Critique of the Decoupling Strategy: A 'Limits to Growth' Perspective

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Abstract

This paper presents a critique of the decoupling strategy which underpins the dominant 'green growth' paradigm within sustainability discourse and which shapes both national and international political and economic policies. The decoupling strategy assumes that all nations on the planet can and should pursue economic growth in terms of Gross Domestic Product (GDP) and that this is consistent with sustainability because GDP can be sufficiently 'decoupled' from environmental impact through a range of technological and market-based innovations. This decoupling thesis will be critically analysed by way of a detailed case study of the 2015 Australian National Outlook Report published by the CSIRO, which attempts to make the case for 'sustainable prosperity' via economic growth and decoupling. We show that the report contains a series of highly questionable and problematic assumptions that together undermine its case for decoupling as a plausible pathway to sustainability. Furthermore, even if the report's most ambitious scenario were to be achieved, we show that it would still not provide a long-term sustainable and just solution beyond 2050, which further undermines the decoupling strategy. Our analysis then steps back from the specific case study to briefly unpack the key implications of the analysis and explain why the limits of decoupling support the case for an alternative 'degrowth' strategy of planned economic contraction. To conclude, some broader reflections on the debate over sustainability are offered, hoping to make clear the magnitude of the task for those who want to make the case for 'green growth' via decoupling.

A critique of the decoupling strategy: a 'limits to growth' perspective

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1. Introduction

In recent years several high profile and influential reports have attempted to make the case for 'green growth' – the idea that continuous economic growth in Gross Domestic Product (GDP) is compatible with, and is even necessary to achieve, 'sustainable prosperity' (see Hatfield-Dodds et al., 2015a: 4; see also UNEP, 2011; Grantham Institute, 2013; Blomqvist et al, 2015). Today, green growth remains the dominant sustainability paradigm within government, academia, and most environmental agencies, as well as in international institutions like the United Nations, the OECD, the International Monetary Fund, and the World Bank (see generally, Green Growth, 2016; Purdey, 2010). Central to this paradigm is the view that economic growth, no matter how environmentally damaging it has been historically, can be 'decoupled' from environmental impacts by way of technological innovation, resource efficiency improvements, pricing mechanisms, and conservation efforts. Through such methods, it is widely assumed that GDP growth can be separated from generating further ecological damage and can actually help regenerate ecosystems. Decoupling therefore holds out the promise of allowing the pursuit of growth to continue while, at the same time, defusing the ecological crisis and advancing social justice. To the extent this decoupling strategy is considered plausible, the growth paradigm is not questioned.

For decades this seductive line of reasoning has been challenged by a range of alternative 'limits to growth' (LtG) perspectives (Meadows et al., 1972; Jackson, 2009; Bardi, 2011; Turner, 2011). According to this broad-ranging critique, the pursuit of economic growth cannot be sustained indefinitely within a finite biosphere, nor can affluent, Western-style living standards, currently enjoyed by a minority of humanity, be globalised to all 7+ billion people, let alone the 9+ billion people expected to be living on Earth in 2050 (Gerland et al., 2014; Turner, 2008). This critical school of thought contends that the extent of decoupling required to make the green growth vision 'sustainable' is too great (see Ward et al., 2016). Ultimately, the LtG paradigm warns that if the drive for global economic growth and universal affluence continues, the consequences of ecological overshoot will lead to the collapse of global civilisation sometime in the 21st century, with some arguing that the turning point may currently be underway (Turner, 2014).

The stakes in this debate, therefore, could not be higher. Whether or not the decoupling strategy is seen as convincing will help determine how governments, communities, and individuals around the world respond to the sustainability challenge. If 'green growth' is deemed plausible and attractive, it will remain the dominant approach to addressing environmental and social justice issues. After all, it is non-confronting to governments, businesses, and consumerist cultures. But if the strategy is flawed – that is, if green growth via decoupling cannot achieve a just and sustainable global economy – then the most developed or over-developed regions of the world should immediately begin moving 'beyond growth' and arguably initiate a process of planned economic contraction – or 'degrowth' – with the aim of moving toward a steady state economy that operates within the sustainable carrying capacity of the planet (D'Alisa, Demaria, and Kallis, 2015). This would provide some necessary ecological room for the poorest nations to develop their economic capacities in order to achieve a dignified living standard, but eventually those nations would also need to transition to a steady state or post-growth economy.

This paper critically evaluates the decoupling strategy at the heart of the green growth paradigm. We do this through a case study of the high profile Australian National Outlook (ANO) Report, published in late 2015 by Australia's Commonwealth Scientific and Industry Research Organisation (CSIRO) (Hatfield-Dodds et al., 2015a). The results were also published in the prestigious, peer-reviewed journal *Nature* (Hatfield-Dodds et al., 2015c), suggesting that the conclusions are robust and should be accepted at face value. The report argues that with collective effort and sound policy, Australia can 'achieve economic growth and improved living standards while also protecting or even improving our natural assets' (Hatfield-Dodds et al., 2015a: 12).[1] The findings of the report are underpinned by several scientific papers that will also be considered throughout our critique (Schandl et al., 2015; Hatfield-Dodds et al., 2015b; Hatfield-Dodds et al., 2015c; Baynes, 2015). We maintain that the ANO Report has not established a convincing case for the decoupling strategy, a conclusion that has implications beyond the Australian context.

The report's modeling assumes that green growth for Australia is only possible if ambitious policies are enacted by governments worldwide, particularly in the OECD nations (Hatfield-Dodds et al., 2015c). The resource efficiency assumptions of the report are also based heavily on the findings of a global study on worldwide decoupling potential (Schandl et al., 2015). As such we evaluate the report in the context of the global sustainability challenge, focusing mainly, though not exclusively, on issues of climate change, resource use, and social justice. In order to offer a balanced critique, our attention is dedicated to the report's most ambitious sustainability scenario (the '*Stretch*' scenario), which we have chosen in order to evaluate the CSIRO's best case for decoupling. If the *Stretch* scenario can be shown to fail from a sustainability and justice perspective, then obviously the less ambitious scenarios, which involve progressively more modest reductions in environmental impact, fail as well.

After summarising the ANO Report, we begin our critique by emphasising that the report, like much of the green growth literature, assumes that significant global inequality and poverty persists through to 2050. At a fundamental level, then, we argue that the ANO Report lacks ambition as it is predicated on continued injustice. This weak ambition also has the effect of reducing the long-term magnitude of the 'decoupling' challenge. In other words, decoupling toward sustainability is easier if most of the world remains in conditions of poverty or extreme inequality, but we will argue that this is an

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[1] In the supplementary material the authors note that 'environmental pressures' do not factor in the potential for critical resource scarcities. This is potentially a key oversight given emerging concerns about resource scarcity generally (Bardi, 2014), and specifically the peaking of production rates for fossil fuels in the foreseeable future (e.g. Mohr et al, 2015). As the ANO authors write: 'in most cases the modelling accounts for environmental pressures but not the state of underlying environmental assets or natural capital, and so we are not able to provide a detailed stock-based assessment of sustainability (defined as non-declining stocks of human, built and natural capital)' (Hatfield-Dodds et al, 2015c, Supplementary Methods SM-7, page 8.
See: http://www.nature.com/nature/journal/v527/n7576/extref/nature16065-s1.pdf).

unacceptable compromise. If the decoupling strategy is to succeed, it must address both the sustainability and the social justice dimensions of the global predicament.

After making this preliminary but critical point, we outline a series of additional criticisms regarding major problematic assumptions contained within the *Stretch* scenario. If any of these assumptions can be shown to be implausible or invalid, let alone several of them or all of them, then the projected decoupling gains and the vision of green growth again break down. Furthermore, we argue that even if the scenario somehow turns out to be achievable, it will have failed to put Australia or the world on a sustainable path beyond 2050, when the scenario timeframe ends. We conclude by briefly restating the limits to growth perspective in light of our critique, and briefly defend the emerging degrowth strategy, at least with reference to the most developed regions of the world. Drawing out the implications of our analysis for the poorest regions of the world must be left for another occasion.

2. Overview of the ANO Report

The ANO Report includes 20 different scenarios for Australia's future development for the period 2010-2050, intended to provide guidance for Australian policy makers on the achievement of long-term 'sustainable prosperity.'[2] Each scenario is characterised in terms of multiple interrelated variables at both the national and global level, which together impact on sustainability outcomes. At the national level these variables include: energy and resource efficiency; agricultural productivity; individual consumption; working hours; and new land markets related to energy and ecosystem services. These national variables are then combined with four different levels of global greenhouse gas emission abatement effort (from 'no abatement' through to 'strong abatement'), to produce 20 future scenarios for Australia through to 2050.[3] Each scenario has different environmental outcomes with respect to five main variables: greenhouse gas emissions, resource use, water stress, native habitat and biodiversity. Depending on the scenario, environmental impacts for each of these variables more than double, stabilise, or fall.

In order to analyse this report, it is important to highlight the distinction between 'absolute decoupling' and 'relative decoupling' that is regularly drawn in the decoupling literature (e.g. Jackson, 2009: Ch. 4). Absolute decoupling refers to when GDP increases while overall environmental impacts stabilise or fall, whereas relative decoupling refers to when growth in environmental impact is slower than growth in GDP (i.e. reduced impacts per unit of GDP). The distinction is needed because in a growing economy it is possible, and often empirically the case, that relative decoupling occurs but absolute environmental impact continues to increase because over time growth in the economy

[2] The report defines 'sustainable prosperity' as 'economic development that improves human wellbeing and social resilience, while significantly reducing environmental risks and damage to scarce natural resources and ecosystem services' (Hatfield-Dodds et al, 2015a: 4). This definition leaves open the possibility that environmental risks and damage could be 'significantly reduced' while environmental stocks on which the economy depends continue to deplete, only at a reduced rate. The study findings are presented as positively supporting the case that Australia is 'free to choose' sustainability and economic growth (Hatfield-Dodds et al, 2015c), but this is so only if the authors' weak definition of sustainability is accepted and the assumptions of the modelling are sound, neither of which withstand critical scrutiny.

[3] The most ambitious sustainability outcomes for Australia depend on immediate and universal global action on climate change – below we accept the assumption without criticism, but note here that other commentators have pointed out this level of uniform global action seems highly optimistic within the current political context (Lenzen and Foran, 2016).

overwhelms the efficiency gains achieved. As is widely agreed, for long-term sustainability large scale absolute decoupling is needed across a range of environmental indices (UNEP, 2016; Giljum, 2014).

In the *Stretch* scenario, which will be the focus of our critique, the input assumptions result in Australian GDP increasing by 2.6 times by 2050, compared with the 2015 baseline, while at the same time, dramatic absolute decoupling in carbon and resource use occurs (Hatfield-Dodds et al., 2015c: 14). From 2040 onwards Australia's net greenhouse gas (GHG) emissions fall below zero, mainly due to carbon sequestration, making Australia a 'net emissions sink, withdrawing more GHG emissions than it emits' (Hatfield-Dodds et al., 2015b: 76). This huge reduction in emissions occurs despite a continuous rise in energy demand and ongoing fossil fuel use, albeit at a lower rate than in other scenarios, but still reaching approximately double current energy supply by 2050 (Hatfield-Dodds et al., 2015c: 25). The scenario also projects a 36% reduction in Australian domestic material extractions by 2050 (Hatfield-Dodds et al., 2015c: 50). Given the economy is forecast to multiply 2.6 times by 2050 this implies almost a 70% reduction in resource use per unit of GDP.

These are very ambitious claims and a recent critique of the ANO Report has already called the plausibility of the claims into question. Lenzen and Foran (2016) have shown that with respect to the carbon intensity of the Australian economy, both the medium and high abatement scenarios require a ten-fold acceleration in technologically driven emission intensity improvement compared to the trend rate over the last three decades. As Lenzen and Foran point out, so far no country in the world has achieved anywhere near such a rate. The same historically unprecedented gains are required with respect to resource efficiency, with *Stretch* projecting a 4.5% p.a. improvement for the global economy through to 2050. By comparison, a review of the evidence found that resource efficiency improvement from 1980-2009 averaged 0.9% p.a. (Giljum et al, 2009).[4] Furthermore, as that review, as well as a more recent UNEP (2016) report found, this average efficiency improvement rate masks a more recent efficiency *decline* since the turn of the century. That is, today the global economy uses *more* resources per unit of GDP than in the year 2000. This means that, far from decoupling – even in relative terms – over the last decade and a half the global economy has undergone a process of material 'recoupling'. This justifies a deep skepticism in relation to the green growth school, because it is founded upon a decoupling strategy that has been failing for decades as environmental problems have worsened.

Even so, the ANO Report claims that their decoupling strategy is feasible, but only if dramatic government policy interventions, both in Australia and globally, are implemented urgently (see also, Hatfield-Dodds et al., 2015c: 12). This is mainly in the form of carbon markets which act to give individuals and businesses strong financial incentives to change their consumption and investment choices. The scenario assumes a global carbon price of $50/tonne is implemented from 2015-2020, which then increases by 4.5% per annum to reach $236/tonne by 2050. At the same time, landholders are given a financial incentive to plant fast-growing trees on previously cleared land, in order to biosequester carbon, with payment per tonne of carbon sequestered starting at

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[4] According to figures given in Giljum et al (2009: 328) this represented a per annum efficiency improvement that was less than one third of the rate that would have been needed for 'absolute' decoupling, i.e., growth of GDP without any increase in materials use. As such, despite the efficiency gains, between 1970 and 2010 annual global material use trebled, reaching 70.1 billion tonnes in 2010, up from 23.7 billion tonnes in 1970 (UNEP, 2016: 31).

15% below the carbon price. Reference is also made, with little detail provided, to the need for further government investment in resource productivity if decoupling, on the scale assumed, is to be achieved (Schandl, 2015). These policies act to incentivise five main processes that it is claimed will together achieve the decoupling outcomes reviewed above:

1. *Carbon-sequestration* in the form of carbon and environmental plantings[5] covering up to two-thirds of Australian land within Australia's agricultural 'intensive use zone' (i.e. the most productive Australian agricultural land, totalling 85 million ha, 'stretching from central eastern Queensland to the wheat belt of southern western Australia' (Grundy et al. 2016: 71));
2. *Carbon Capture & Storage (CCS)* technology applied to the coal and gas stationary energy sectors;
3. *Energy and resource efficiency* improvements across the economy;
4. *Uptake of renewable energy*, for proportions of electricity and transport;
5. *Changes in individual work and consumption patterns*, such as a projected 11% reduction in average working hours by 2050 due to greater take up of part time work and a shift towards 'experiential' consumption choices (i.e. travel, eating out) that are assumed to be less energy and materially intensive.[6]

In the ANO Report the reliance on carbon capture in the form of both CCS and land, sequestration is crucial to the overall achievement of net zero or even negative emissions by 2050. Without these two strategies, the projected carbon reductions would not be possible given that all scenarios assume continued burning of significant amounts of fossil fuels through to 2050. The *Stretch* scenario, for example, still depends on over 1000 PJ in non-CCS fossil fuel use for the transport sector alone, which is only a small reduction on current fossil fuel use for transport (Hatfield-Dodds et al., 2015c: 55). The viability of these practices is thus critical to the CSIRO's decoupling strategy, as it significantly reduces the costs and problems associated with the transition away from fossil fuels and toward alternative, low-carbon energy sources.

The authors of the ANO Report argue that the above changes 'will not require a shift in societal values' (Hatfield-Dodds et al., 2015c: 52), let alone a challenge to growth-based global capitalism. Most of the changes in individual behaviour, for example, are said to result from financial incentives brought about through collective government policy. The report's lead author has acknowledged that Australians would need to find the political will to enact these policies, however he argues that this would not require a shift in current cultural values, as strong action on climate change already enjoys strong majority support within the Australian electorate (Hatfield-Dodds, 2015). As he states: 'none of the scenarios we modelled assume change in values or a new social or environmental ethic' and it does not require 'rejecting consumerism' (Hatfield-Dodds, 2015).

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[5] Carbon plantings are defined as fast growing monocultures designed to rapidly absorb carbon i.e. Eucalyptus monocultures. Environmental plantings, by contrast, are typically mixed, local native species, designed to provide maximum biodiversity services in a given area (Bryan et al, 2015: 10).

[6] It should be noted that these changes to work and consumption patterns, which have already been underway for some time in rich countries have not led to much, if any, overall dematerialisation especially when the resources embedded within imports are taken into account (see e.g. Trentman, 2016; Wiedmann et al, 2014). That said, we agree that such changes will be important elements in the transition towards a sustainable economy. However, the analysis in this paper suggests that they will be insufficient if the commitment to ongoing growth in GDP, rising affluence and population etc. remains in place, as is taken for granted in all ANO scenarios.

Below we outline a range of reasons why the conclusions of the ANO Report are certainly not established and, moreover, that the approach is so problematic that the chances of achieving genuinely green growth are slim to non-existent. To the extent this is accepted, alternatives to the growth economy ought to be taken more seriously.

3. A Critique of the ANO Report

3.1 Global inequality and poverty assumptions

We begin our critique of the ANO Report by making a fundamental point about its deep inadequacies from a social justice perspective, a point that applies to much of the green growth literature that typically depicts 'sustainable pathways' while silently assuming that billions of people remain in destitution. 'Sustainability for whom?' we might fairly ask.

From the point of view of justice and ethics, it would seem difficult or impossible to justify a level of affluence that only a privileged portion of the global population were permitted to enjoy. In other words, if a section of the global population is entitled to a particular way of life (e.g. Australians, North Americans, and Western Europeans), it would seem unjust to deny the rest of humanity the right to that way of life too. This is why major international reports on sustainability assume that all nations can and should continue growing their economies and that in coming decades all people will be lifted out of poverty and rise to roughly the same level of 'development' as those in the richest nations (e.g. UNEP, 2016). This is essentially the mainstream vision of 'sustainable development'.

Accordingly, unless advocates of decoupling wish to defend a grossly unequal world, they need to be able to show that their 'green growth' development agenda is viable for a world in which the global population in 2050 – expected to be 9+ billion people (UN, 2015) – has achieved similar levels of development to OECD nations. Obviously, the decoupling challenge becomes all the greater (and we would argue impossible) if by 2100 Earth is home to 10 or 11 billion humans all living affluent lifestyles in growing economies. As we will show, within a growth paradigm the degree of decoupling required to sustainably realise this vision becomes utterly implausible. If this is so, we contend that the green growth decoupling strategy must be rejected in favour of an economic vision that allows the entire community of life to flourish within the sustainable limits of the planet.

The ANO Report under consideration does not include a robust assessment of global justice concerns. The authors proceed on the assumption that by 2050 three billion people will form part of the global 'consumer class' (Hatfield-Dodds, 2015a: 8), defined as that class of people with annual incomes of at least US$12,000. But this amounts to less than one fifth of the ANO's 2050 Australian per capita income, meaning that even many of those in the consumer class will be 80% poorer than Australians. Furthermore, in the S*tretch* scenario, by 2050 global population is projected to reach 8 billion people, meaning that a further five billion would be excluded from the consumer class. These figures make it clear that the ANO Report, in line with many other decoupling statements (e.g. UNEP, 2011; Grattan Institute, 2013; Green Growth, 2016), has set itself an inadequate and unjust development goal, presumably in an attempt to make the decoupling task more manageable and avoid redistributive policies. Accordingly, even if the *Stretch* scenario were achieved, it ought to be rejected on social justice grounds.

It might be objected that it is unrealistic to expect the global population to achieve Australian development levels by 2050. While that may be the case, decoupling advocates must then make clear that beyond 2050, a huge amount of further green growth must take place to eliminate poverty and lift the global population to 'developed' living standards – a point to which we will return. The decoupling task obviously becomes far more difficult when this mainstream development goal is adopted. Consider the following multiples, based on the ANO Report's most ambitious scenario:[7]

- Australia's material footprint in 2050 is projected to be 25 tonnes per capita (Hatfield-Dodds et al., 2015b: 67). But if 8 billion people had this same footprint it would require 200 billion tonnes of natural resources per annum. This would be almost three times the 70 billion tonnes consumed by the world economy in 2010 (Wiedmann et al., 2014; UNEP, 2016). Yet, even the current rates are causing many severe environmental problems and raising concerns about future resource scarcity (Bardi, 2014), to say nothing of the increased geopolitical conflict that would likely arise over access to those increasingly scarce resources (Klare, 2012).
- Australia's energy footprint is projected to be about 6 tonnes of oil equivalent per capita by 2050 (Hatfield-Dodds et al., 2015b: 53). But to provide that amount of energy for the assumed 8 billion people would require approximately 54 billion tonnes of oil equivalent, or 2260 EJ. That is more than double the ANO Report's world energy forecast of 1100 EJ by 2050 (2015b: 53) – which is itself nearly double current energy supply.
- Australia's carbon footprint is forecast to decline to 7 tonnes CO_2 per capita under a strong global abatement scenario. But if that carbon footprint were shared by all 8 billion people it would result in the release of 56 billion tonnes of CO_2 each year – a substantial *increase* on the already grossly unsustainable 39.7 billion tonnes released in 2015 (Global Carbon Project, 2016).
- Note also that the above analysis assumes a population of 8 billion in 2050 whereas the mid-range estimates of recent population studies expect the global population to be approximately 9.7 billion, perhaps as high as 10 billion (UN, 2015). If these expectations eventuate, there will be 1.7 billion people or more that the ANO Report has not accounted for in terms of resource and energy demands. Population increase in line with UN projections would further undermine the feasibility of the green growth strategy advanced in the report.

Accordingly, even the report's most ambitious decoupling scenario would be inadequate in a world in which all 8+ billion lived like Australians. The magnitude of the required reductions in resource use and pollution intensity would be extreme. Tim Jackson (2009) calculates that the global economy would be 15 times larger in terms of GDP if OECD nations grow by 2% per year to 2050 with the poorest having caught up by that time. On similar growth assumptions, Alexander (2016) shows that the global economy could be 60 times larger by 2100. Taking into account these multiples, plus accounting for the fact that the global economy is *already* in ecological overshoot (WWF, 2014),

[7] It should be noted that these multiples are based on the most optimistic 2050 Australian footprint numbers provided in the ANO report. If those optimistic assumptions do not eventuate, the Australian per capita footprint will be far higher in 2050, and thus the decoupling task for 'universal affluence' is even greater.

Trainer (2016) estimates that several key environmental indices would need to be reduced to less than one twentieth of current levels per unit of GDP if the entire global population was to rise to expected Australian 2050 living standards. Making such a large economy fit within the sustainable carrying capacity of the planet would, we argue, require a degree of decoupling that is in the realm of fantasy (Fletcher & Rammelt, 2016; Ward et al., 2016). Of course, the implications of aiming for that level of decoupling and failing would not be a fantasy, but would imply great suffering to a great many people. Accordingly, it is imperative to assess the plausibility or likelihood of achieving such decoupling, given how much is at stake.

We contend that this point is reason enough to reject the vision of 'sustainable prosperity' presented in the ANO Report. In what follows, however, we will show that even if we were to set aside its embedded assumptions of global inequality, the ANO Report's more limited scenario is highly questionable. Nevertheless, it is important to keep in mind that, even if it could be achieved in that limited context, the report would not have shown that the decoupling strategy is a viable long-term path to a sustainable or just world order.

3.2 Carbon budget assumptions

Another fundamental critique of the ANO Report can be made in terms of its carbon budget assumptions, which risk dangerous levels of climate change, even in its *Stretch* scenario. The carbon budget used in the ANO Report is derived from the IPCC's RCP2.6 scenario that is estimated to give the world a 66% chance of staying within the 2-degree C target. For this level of risk, the IPCC (2013) calculates the mean remaining global carbon budget for 2012-2100 to be 990 $GtC0_2$. However, many scientists have grave concerns about adopting a carbon budget that may give humanity a one-in-three chance of exceeding safe warming levels (e.g. Anderson and Bows, 2011). This arguably contravenes the United Nations Framework Convention on Climate Change's own adoption of the precautionary principle (IPCC, 2001; Kriebel et al., 2001). If we were to opt for a lower level of risk, the budget would be greatly reduced. The Australian Climate Council, for example, has found that for a 75% chance of achieving the 2-degree target, the budget needs to be lowered to 672 $GtCO_2$. At the current rate of global emissions, humanity will exceed this budget by about 2030 (Climate Council, 2015). Adopting this budget would therefore require a rapid and unprecedented reduction in global emissions, at an even faster rate than the *Stretch* scenario, which, as noted, already requires an increase of ten times the emissions efficiency improvement rate, compared to recent trends in Australia (Lenzen and Foran, 2016).

It should also be pointed out that, since the Paris Agreement on climate change, it is now internationally accepted that the 2-degree target is too risky, and that the world should be aiming to stay within the safer target of 1.5 degrees above pre-industrial levels. Again, this would reduce the available carbon budget considerably, and while the ANO Report was published in advance of the Paris summit, and therefore cannot be expected to have anticipated its outcome, it remains the case that the assumptions upon which the ANO Report are based are no longer in accordance with the stated objectives of the international consensus post-Paris. Accordingly, the most fundamental goal of the report is now not aligned with accepted international objectives. Adopting a goal of remaining within a 1.5-degree increase would reduce the available carbon budget used in the ANO study and hence increase the level of decoupling required to achieve the economic and environmental performance levels associated with the *Stretch* scenario.

In adopting the 2-degree threshold and 66% chance of avoiding that temperature rise, it can reasonably be argued that the ANO study was merely conforming with the global discourse at the time of publication. We do wonder, though, where the balance may have rested between sober scientific appraisal and political expediency in deciding on this particular modelling assumption. We suspect that untangling the influence of these respective factors may be a significant challenge in a situation like this, even for those directly involved in the decision itself. Anderson (2015) has argued that many in the international climate science community are essentially 'self-censoring' when it comes to presenting the nature of the climate challenge, conforming to the dominant growth paradigm in order to make their work politically palatable. We think there is value in reflecting on the extent to which influences of this nature may also be at play with studies such as the ANO Report. Anderson argues that if a more scientifically defensible goal of 1.5-degree were adopted, it would become clearer that we are facing a climate emergency, requiring decarbonisation trajectories so deep and swift that achieving them would be inconsistent with continued growth in developed nations (Anderson and Bows, 2011; Anderson, 2015).

3.3 Carbon sequestration assumptions

Despite the reservations above, for present purposes we will assume the validity of the carbon budget stipulated in the ANO Report, as even that budget presents extremely thorny problems for the green growth vision. One of the defining elements in the ANO Report is its biosequestration assumptions, which, in *Stretch*, requires Australia to grow new forests on up to 59 million hectares (Mha) of land in order to reach net zero or even negative emissions by 2050, despite still burning significant amounts of fossil fuels. These carbon plantings are projected to cumulatively sequester up to 13.2 $GtCO_2$ over the period to 2050 (Bryan et al., 2015: 2) which accounts for up to half of Australia's emissions reductions (Hatfield-Dodds et al., 2015c: 50).

The scale of that biosequestration task demands critical scrutiny. This assumption is essential to the ANO approach because obviously a modest transition toward renewable energy is easier and cheaper if biosequestration allows for a significant portion of energy supply to remain in the form of fossil fuels. The assumption, however, is extremely problematic.

A major concern with carbon planting on the scale envisioned is the potential for competition with other sustainable land-use practices. In *Stretch*, a variable combination of carbon and environmental plantings, depending on the level of biodiversity funding,[8] is projected to cover between 45 and 59 Mha of Australia's agricultural land within the 'intensive use zone' (Hatfield-Dodds et al., 2015b: 36). To put this in context, there is currently 85 Mha within the intensive-use agricultural zone in Australia, so carbon and environmental plantings would need to occupy between 54 and 70% of Australia's *best agricultural land* (Bryan, 2015: 17-19). On top of this, an additional unstated amount of land, albeit relatively small, is required to provide the projected 10% of transport fuel from biomass, leaving between 20 and 35 Mha for crop and livestock production (Bryan,

[8] The variation in planting area is due to three different planting pathways modelled within the ANO report including: 1) 'carbon focussed,' 2) 'balanced focus,' and 3) 'biodiversity focus' – each with varying combinations of carbon and environmental plantings. The inherent trade-offs between these strategies are discussed below.

2015: 35). This is the type of response required to defend green growth (and even more land would need to be converted to biosequestration for a smaller carbon budget).

A report by the Australian Climate Council, summarising the recent literature on land based carbon sequestration points out the major risk of 'displacing land for food production, energy generation or conservation' (2016: 29). With regard to food, the ANO Report claims that, despite the greatly diminished land base, crop production, if not livestock,[9] can be increased from present rates as long as trend agricultural productivity rates are maintained on the remaining one-third of land that currently produces over two-thirds of output (Hatfield-Dodds et al., 2015b: 37). There are strong reasons to doubt this claim, given, especially, that it appears the report may underestimate the potential impact that climate change and expensive oil could have on agricultural productivity in coming decades.[10] If trend productivity agricultural rates are not achieved, then food production costs are likely to rise much higher than the ANO forecasts, with problematic social and economic flow-on effects. The authors also note that the projected provision in *Stretch* of 10% of transport energy supplied by biofuels is critically dependent on this productivity assumption, otherwise 'potential biofuel supplies are very limited' (Hatfield-Dodds et al., 2015b: 50).

Even if we assume that carbon plantings, on the scale envisaged, will not lead to problematic trade-offs with food and energy provision, the report seems to overlook other risks and trade-offs that might undermine the net carbon sequestration benefits. For example, the Climate Council (2016: 30) points out that large scale carbon plantings risk causing 'carbon leakage' whereby, for example, grazing land set aside for carbon forests in one location only results in the clearing of forests to make grazing land available elsewhere, reducing or eliminating carbon sequestration gains.

Another major problem with relying so heavily on carbon planting is the risk of severe weather events or unanticipated climatic excursions reducing or even eliminating carbon gains. The ANO Report has deducted fire and drought losses from its overall carbon accounting (Bryan et al., 2015), but the indeterminacy of the occurrence and effect of extreme drought or fire events makes it impossible to apply conventional risk management techniques to compensate for carbon leakage from plantations back to the atmosphere (Lohmann, 2006). As such, the size of the deductions in the ANO Report cannot be regarded as better than a guess. If their guess is wrong, once again the vision of green growth turns brown. It should also be noted that the ANO modelling implicitly recognises there will be unavoidable trade-offs between carbon plantings, which have minimal biodiversity benefits, and environmental plantations designed to achieve

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[9] The technical report (Bryan, 2015: 25) shows that in both the 'biodiversity' and 'balanced' planting scenarios, beef and sheep livestock production drops dramatically over the modelled timeframe. Indeed Figure 3 of the technical report (Hatefield-Dodds, 2015b; 43) shows that the *Stretch* scenario results in a *doubling* of livestock prices by 2050. This will surely have major social and political implications, none of which are discussed.

[10] With regard to climate change the authors acknowledge that future impacts have only been modelled 'in a limited way' (2015b: 48). Given understandable uncertainties they have not factored in, for example, the potential impact of increasing severe weather events (droughts, floods, storms etc.) or temperature change on crop yields, both of which could have major negative impacts on productivity. The report contains no discussion of the potential problems caused by the end of cheap oil and the increasing reliance on expensive unconventional sources of oil, the effects of which are already being felt today and which is arguably a major factor behind the slowdown in productivity performance over recent decades (see e.g. Tversberg, 2016). Oil is an essential input throughout the entire supply-chain in modern agriculture (Church, 2005). Thus if oil becomes increasingly unaffordable this is likely to have major negative ramifications on agricultural productivity rates.

maximum biodiversity gains but at reduced carbon sequestration rates. For example, the planting strategy which aims for the maximum amount of environmental plantings, and therefore biodiversity gains, 'results in an estimated 11% reduction in potential carbon sequestration' (Bryan et al., 2015:23).

One deep uncertainty associated with the ANO's biosequestration strategy is how, exactly, to convert up to 59Mha of land to biosequestration as envisaged by the ANO Report. The strategy presented in the report is to use financial incentives: reward landowners for planting up their land with fast growing, carbon-sequestering plants at a rate 15% below the carbon price. The strategic assumption here is that landowners, in this new policy context, will make economically rational decisions to plant carbon-sequestering plants, rather than continue with conventional, carbon intensive agricultural practices, such as producing beef. While that strategy accords with the tenets of neoclassical economic theory, the practical transition is far less certain and it simply cannot be taken for granted that this proposed policy context will achieve the ambitious biosequestration goals. What if farmers do not act as rational, self-interested, utility maximisers? What if beef for export remains profitable? What if farmers are content to make decisions on the basis of satisficing and simply do not want to plant up their farmland with trees? (Grubb, Hourcade, and Neuhoff, 2014). In the absence of confident policy foresight (a very reasonable concern, especially in Australia), farmers may be nervous about beginning such a transition in case a later government changes the policy context. Granted, a financial incentive is likely to facilitate the uptake of biosequestration to a significant extent, but the confidence with which it is assumed that 59 Mha of land will be converted to carbon planting cannot be supported in a situation such as this in which the decision environment is characterised by both irreducible uncertainty and indeterminacy (Lohmann, 2006). It is possible, but the ANO modelling has not adequately addressed the *likelihood* of this transition occurring in reality – it has just assumed it will occur.

Of course, if the modelling assumptions do not bear out in reality, the vision of green growth breaks down. Remember, achieving such ambitious biosequestration goals is required in order to allow Australia, in the vision outlined in the ANO Report, to continue burning significant amounts of fossil fuels. But this will obviously delay a more urgent transition beyond fossil fuels, and if the biosequestration goals are not achieved, which is possible and indeed likely, then such a delay could be disastrous from a climate perspective. Just like with the roll out of CSS and anticipated efficiency improvements (critically examined below), the ANO study must make a range of highly speculative assumptions in order to defend its vision of green growth, only one of which needs to fail for the vision to break down.

Even if the modelling assumptions do prove to be achievable, the strategy is, at best, a short-term 'fix'. This is because after a certain period of time fast-growing plantations reach full maturity, at which point they will be satiated and no longer able to absorb carbon. Due to this 'saturation effect', after about 50 years, as the authors acknowledge the 'flow of carbon sequestration will peak and eventually decline to zero, drawing attention to challenges and opportunities, which we have not fully modelled beyond 2050' (Hatfield-Dodds et al., 2015c; Smith & Torn, 2012).[11] Indeed, the 'challenges'

[11] By 'opportunities' the authors refer to the possibility of using the mature plantations as biofuel combined with carbon capture and storage (BECCS), but this solution, which relies on the viability of highly speculative future technology development including CCS, 'involves large risks and uncertain feasibility' (see Hansen et al, 2016: 1).

would be immense. It would mean that in the years after 2050 less carbon will be absorbed by plantations, even while the economy continues to grow and remains heavily dependent on fossil fuels. The report and its supporting papers give very little space to this problem but acknowledges that the scheme is 'transitional', designed to buy time until 'longer term changes in technologies and processes in energy, transport and broader economy' are achieved (Hatfield-Dodds, 2015: 76). We believe that this significantly understates the problems that would face policy makers beyond 2050 and, ultimately involves simply pushing the emissions challenge down the road, to be dealt with by future generations. The ANO Report claims that its strategy is sustainable, but this requires that the implicit 35-year time horizon for the authors' definition of sustainability is accepted. There is no objective basis for agreeing on what 'sustainability' means. But we contend that the concept surely extends beyond a mere three and a half decades and must be analysed as such.

Finally, at a global scale, it must be recognised that most nations have far less afforestation and reforestation potential than Australia. This is especially the case when realistic allowance is made for projected growth in land use for food, bio-energy, urban expansion and conservation. Already it has been observed that afforestation programs in rich countries have, to some extent, been made possible by importing food and wood products from developing nations 'leading to reduced forest cover and carbon sinks there' (Canadell et al., 2013: 4). Literature reviews suggest the maximum land use for carbon planting is in the range of 300-940 Mha, with several studies pointing out that the lower end of this range is more realistic when easily overlooked political, social and ecological constraints are factored in (Canadell et al., 2013; Smith & Torn, 2012; Nilsson and Schopfhauser, 1995). One study taking into account ecological limits to productivity, as well as net carbon gains, found that this land allocation could save an estimated 1 billion tonnes of carbon p.a. but this would 'imply important opportunity costs and impacts on biodiversity and food, fuel and fiber production' (Smith & Torn, 2012: 98). By comparison, as the Australian Climate Council points out (2016), global carbon emissions from fossil fuel combustion are currently 10 billion tonnes p.a. In other words, each year fossil fuel combustion transfers 10 times more carbon to the atmosphere from geologically stable deposits than can realistically be absorbed through carbon planting. To make the same point another way, if 900 Mha of additional forest land were planted it would provide 0.11 ha per person on average for 8 billion people. By comparison, the *Stretch* scenario contains an additional 1.3 ha of forestland per capita for Australia – i.e. almost 12 times the viable land-allocation available for all people. This means, for most countries if not Australia, the vast majority of reduction will have to come from reducing emissions from fossil fuel combustion.

3.4 CCS assumptions

The ANO Report places great faith in carbon capture and storage technology (CCS) as a means of extensively reducing carbon emissions. CCS involves three core processes: 1) the capturing of CO_2 from power plants (using either pre- or post-combustion methods); 2) transportation through pipelines and; 3) storage in geological formations at depths greater than 800 metres. The technology is obviously attractive, in theory, because it holds out the hope of prolonging the consumption of coal and gas in power stations – while capturing most of the emissions – and therefore delaying the need for a transition to 100% renewable energy.

The *Stretch* scenario is heavily dependent on a large-scale rollout of CCS, with 50% of Australia's 2050 electricity supplied by coal and gas power plants that rely on CCS. The ANO Report states, 'the successful implementation of CCS is central to meeting global aspirations to limit global warming' and it notes that without CCS abatement, global emissions are projected to be 21% higher (Hatfield-Dodds et al., 2015b: 54). There is, however, no discussion of the many unresolved problems with the technology and, even if it proves technically feasible at scale, future CCS costs are subject to such great uncertainty that it is impossible, at this stage, to assess economic feasibility in any definitive way. Again, the confident claims about sustainability made in the ANO Report seem wholly unjustified given the range of highly uncertain premises upon which those claims are based.

The report acknowledges that despite two decades of research and pilot projects, CCS has 'not yet been demonstrated at commercial scale'[12] (Hatfield-Dodds et al., 2015b: 50; Anderson, 2016). This is not just with respect to the capturing of carbon from power plants, but also transportation via pipelines and storage in permanently safe geological sites (Scott et al., 2015; Hamilton, 2016). To date, most storage pilot projects have been abandoned because they ran into technical problems and cost blowouts (Hamilton, 2016).[13] There are also doubts about whether there are enough suitable geological sites capable of preventing leakage for an indefinite period, especially if fossil fuel consumption continues to rise beyond current levels (Scott et al., 2015).

With regard specifically to capturing CO_2 from power stations, recent research suggests that the energy penalty involved has been widely underestimated. Common estimates for CCS energy use are in the range of 3060% for coal plants capturing 90% of their CO_2 emissions. However, Supekar and Skerlos (2015) found that careful study of data from small-scale and pilot CCS plants indicates that fuel cost compared to a plant of the same gross electricity output without CCS is likely to be up to 136% higher i.e. more than double the fuel cost. They found that previous fuel cost estimates had failed to factor in a 'feedback loop' process whereby capturing $C0_2$ requires the burning of additional coal, which generates additional CO_2 that also needs to be captured, which, in turn, requires more fuel, and so on.[14] It is unclear whether the ANO study has factored this research into its carbon price assumptions.

Even leaving all those concerns aside, at a global level, Smil (2011) points to the magnitude of the task involved if CCS were to be used to bury just one-fifth of today's carbon dioxide emissions. He argues that it would require 'an entirely new worldwide industry whose annual throughput was…70% larger than the annual volume now handled by the global crude oil industry whose immense infrastructure of wells, pipelines, compressor stations and storages took generations to build' (Smil, 2011: 219).[15] Aside from the huge financial costs likely to be involved to make all this viable, the energy impost of such a project has not yet been estimated but will be very large meaning the energy return on energy investment (EROI) will be far lower than ordinary

[12] Defined as more than 500 MW rated power.
[13] Ironically, the only time carbon storage has proved commercially viable has been when 'pressurized gas is used to help recover yet more crude oil from heavily depleted wells' (Quiggin, 2015).
[14] If correct, not only will it greatly increase the final delivered energy cost of CCS electricity, it will also be a major negative contribution to the material efficiency of the Australian economy – an important consideration given the optimistic resource efficiency projections discussed below.
[15] Smil also points out that, unlike the fossil-fuel industry which was built mostly at the expense of private for-profit companies, CCS would have to be funded almost entirely at taxpayer expense.

coal-fired generation. Furthermore, before long that vast infrastructure would become redundant as fossil energy resources decline over the course of this century.

There is a final long-term problem with reliance on CCS. Typically proposed CCS techniques are estimated to be capable of capturing 80-90% of carbon from the burning of coal and gas (IPCC, 2005). However, the IPCC's carbon budget for a 66% chance of remaining below 2-degree temperature increase requires a complete cessation of net carbon emissions by 2050 (Anderson 2015; Cias et al., 2013). It is true that this problem is considered in *Stretch* via carbon planting which can temporarily absorb excess emissions. However, as we argued above, carbon planting is not a long-term solution given that in the second half of the 21st century it is likely to peak and decline as a source of carbon sequestration. This means that if, after 2050, mature plantations were used as bioenergy with carbon capture and storage (BECCS), as the authors suggest (i.e. Hatfield-Dodds et al., 2015c: 52), there would still be a net release of carbon into the atmosphere,[16] even if we assume the rest of the ANO *Stretch* scenario could be implemented successfully.

3.5 Efficiency assumptions

The ANO Report's third major decarbonisation strategy is to massively increase energy and resource use efficiency and hence productivity across the Australian economy. In *Stretch*, efficiency gains result in Australian energy demand growing at 0.6% p.a i.e. half current trend rates (Hatfield-Dodds, 2015a: 34) while, as noted earlier, global resource productivity is expected to improve at the historically unprecedented rate of 4.5% p.a through to 2050 (Schandl et al., 2015: 45).[17] This figure appears to be derived from the well-known 'factor-five' literature (Von Weizaecker, 2009) but with no indication of how it has been applied, or original substantiation of the plausibility of the case for factor-five reductions.

There are several reasons why efficiency gains, in the real world, are likely to be far less than factor-five. First, optimistic claims tend to overlook the implications of ongoing depletion of non-renewable resources. As the most easily accessible resource deposits are produced first, later deposits tend to require increasing time, energy and money to discover and extract. Whereas, for example, only 2% of new oil discoveries in 1990 were located in ultra-deep-water locations, by 2005 this had risen to 60% (Murphy & Hall, 2011). With respect to fossil fuels, this trend is reflected in the declining energy return on energy invested (EROI). Between 1995 and 2006 the global average EROI for oil and gas declined from an estimated 30:1 to 18:1 (Hall et al., 2014; Murphy, 2010), with average EROI of US oil production falling to 11:1 (Murphy, 2014). Further decline in EROI is expected in coming decades, given the increasing reliance of the global economy on non-conventional, low EROI, sources of oil and gas supply (Hall et al., 2014).[18] What

[16] This is especially the case when carbon losses through the entire process are factored in. Smith and Torn (2012:95) note that the final carbon sequestered via BECCS is likely to be less than half the amount of carbon originally fixed by plantations, due to losses 'from farm and transport fossil fuel use, pre-capture storage and processing and C02 capture and injection'.
[17] Once again key assumptions and derivations have not been clearly stated. No disaggregated data is provided about assumed efficiency gains for each individual sector of the economy. Neither is it made clear whether estimates are derived from full life-cycle analysis, and therefore represent net gains, rather than simply gross gains.
[18] Hall et al. note that the recent rapid development of tight oil production in the United States via hydraulic fracturing technology is not likely to reverse this trend (Hall et al., 2014; 146).

this means is that even if there are efficiency gains in, say, manufacturing processes, to some extent they will be taken back by efficiency loses in resource extraction. This situation evokes the challenge faced by the Red Queen in Lewis Carroll's *Through the Looking Glass*, who has to run faster and faster simply to stay in the same place (Likvern, 2012).

The impact of depletion is also evident in the mining sector with declining mineral ore grades and increasing mining waste rock and tailings evident, both in Australia and globally, resulting in higher energy, water and emission costs for mining and ore separation (Mudd, 2009; Deideren, 2015). Often overlooked is the fact, as Deideren notes, that fossil-fuel and mineral depletion will compound each other in a self-reinforcing feedback loop i.e. more energy is required to extract lower grade mineral ores which will exacerbate energy depletion, and this, in turn, will exacerbate minerals depletion given the 'huge amounts of main and ancillary equipment and consumables needed for mining' (Deideren, 2015, 9). These *geological* trends, which are essentially beyond the control of policy-makers, are likely to result in reduced resource efficiency in the extractive sector – which will function to offset at least part of the efficiency gains made across the rest of the economy.

Furthermore, optimistic efficiency projections often fail to factor in the likelihood of diminishing returns over time. For any given technology, it is often quite easy to make dramatic efficiency improvements initially. However, once the low hanging fruit, so to speak, has been picked, technical improvement becomes more difficult and delivers diminishing marginal returns. Ayres (2009) notes that for many decades there have been plateaus for the efficiency of production of electricity and fuels, electric motors, ammonia, iron and steel production. Given this, while large increases are no doubt possible in certain areas, this does not imply that rapid, large and continuous technical gains can easily be made across all sectors of the economy.

Finally, potential efficiency gains often overlook the impact of rebound effects whereby efficiency improvements are partially or wholly negated by consumption growth enabled by the efficiency improvements themselves (Herring et al., 2009; Sorrell; 2007). For example, a 5% increase in car fuel efficiency may only reduce net fuel consumption by 2%, if the efficiency improvements incentivise people, either directly or indirectly, to act in more energy intensive ways. Directly, this occurs if fuel efficiency reduces the running costs of a car and those reduced costs result in more frequent driving or greater driving distances. Indirectly, it occurs via the savings from improved fuel efficiency being spent on alternative high-consumption activities. Backfire effects, where efficiency improvements lead to increase rather than decrease in overall resource or energy use, can have even more profound implications (Alcott, 2005).

Some of these confounding factors may be mitigated by the financial incentives induced by the high carbon price in *Stretch*, but the efficiency improvements that might be realised in practice are nonetheless subject to high levels of uncertainty. While the study *asserts* that efficiency improvements of 4.5% are achievable, it does not *demonstrate* that this is the case. The ANO study has shown that *if* certain conditions are met, positive environmental outcomes may result, but this is quite distinct from establishing a plausible case that those conditions *can* be met. We argue that the uncertainties entailed here are such that the likelihood of such an outcome *cannot* be established, and that this should be reflected in the conclusions drawn from the modelling exercise.

The ANO authors conclude by stating: 'we find that substantial economic and physical decoupling is possible' (2015a; 49). Such a conclusion, though, does not appear to us to be consistent with the nature of the study. On our interpretation, what the study finds is the model outcome that results when certain assumptions about resource use efficiency improvement, carbon price, CCS, etc. are extrapolated out to 2050. In other words, the study finds the consequences of those assumptions, not that those assumptions are necessarily or definitively realistic or achievable. As such, the authors clearly have not found that sustainability and growth are compatible *in practice* – that is, outside the context of the 'model world' that they have constructed. It is very important to bear this in mind in understanding the study's significance.[19]

3.6 Sustainability beyond 2050

We conclude now with a point the ANO Report avoids. What happens after 2050? Even if the *Stretch* scenario turns out to be achievable, there are several reasons why the world as a whole would not be on a long-term sustainable path. Consider the following points:

- A major study on global decoupling potential (Schandl, 2015), which was a key source for the ANO study, and used the same carbon price assumptions, found that even the high abatement scenario (equivalent to *Stretch*), would not achieve absolute decoupling in critical domains. The study found that 'while relative decoupling can be achieved in some scenarios, none would lead to an absolute reduction in energy or materials footprint' (2015: 49).
- And yet, beyond 2050, Australia (and the world) would still have a growth economy. Ward et al. (2016) have shown that, if you extrapolate the economic growth rate in *Stretch* out to 2100 the Australian economy would by then be 7.7 times its 2015 level. Given a very generous assumption that a further 50% efficiency improvement can be achieved beyond 2050, they calculate that 'material extractions and final energy demand are up 29% and 256% respectively on 2015 levels' (Ward et al., 2016). In other words, the environmental reductions made over the scenario timeframe would by 2100 be eliminated. They conclude that this demonstrates 'categorically that GDP growth cannot be sustained indefinitely' (Ward et al., 2016: 10)
- After 2050 the carbon-planting scheme will be declining in effectiveness, every year, as a carbon sink. Combined with the fact that by 2050, if not well before, fossil fuel supply will be in decline (Mohr et al., 2015), this will necessitate a difficult and costly transition to mostly, if not entirely, renewable energy supply (Stram, 2016; Trainer; 2014; Mediavilla et al., 2013). As discussed above, this difficulty would be compounded by severely limited bio-fuel potential, given competing land demands (Canadell et al., 2013).
- Globally, by 2050 world energy consumption would have risen to double present levels, inevitably placing more pressure on dwindling resource supplies and the

[19] It is worth noting here that the most recent update of the original Limits to Growth study (Meadows, Randers and Meadows, 2005) explores what would happen in the authors' own 'model world' if high levels of technology-driven decoupling were in fact achieved. In the best-case Scenario 9, over the course of a century the inputs to the Limits to Growth model result in non-renewable resource use reducing by 80 percent per unit of industrial output, and pollution reducing by 90 percent per unit of output. As a result, in that particular model run economic collapse is averted and a high level of human welfare is converged upon globally. Like the ANO study though, the decoupling rate in the Limits to Growth study is assumed as a model input. It is the consequences of this assumption that the authors demonstrate, not the feasibility of achieving such a decoupling rate in practice.

planet's already stressed ecological systems. By then biodiversity loss, soil degradation, ocean acidification, fish depletion, chemical pollution, among other already existing problems would most likely be exacerbated as a result of the decades of economic expansion and extraction (WWF, 2016; Rockström et al., 2009).
- And yet, according to the ANO Report, in 2050 there would be at least 5+ billion people still to be integrated into the ever expanding 'consumer class.'

Jorgan Randers (2012), one of the original authors of the *Limits to Growth* report (Meadows et al., 1972), does not think humanity will run into critical limits by 2050. But by about 2070 he thinks the situation will have become catastrophic. The point is that the exact timing of *when* we hit ecological limits is not critical. What is critical is that *at some point* in the foreseeable future they *will* be hit, if the world's economies remain driven by the endless pursuit of growth. At best the ANO Report provides some reason to think that limits will be felt later rather than sooner, but it does not give us any good reason to think we will not eventually hit them. To the extent the decoupling strategy fails, it is this growth paradigm itself that is the ultimate cause of the ecological crisis. Our argument is not that the attempt to decouple economic activity from environmental impact is misplaced. Our argument is simply that the decoupling strategy cannot make the global growth paradigm sustainable. Given the fundamental nature of any transition 'beyond growth', this needs immediate, dedicated attention.

4. Conclusion

The ANO Report, published by Australia's most prestigious scientific body, the CSIRO, claims Australia can continue to grow its economy in terms of GDP, and that it can do this without degrading the environment in unsustainable ways. Similarly, in the *Nature* article based on the ANO Report, the authors claim that Australia is 'free to choose' economic growth and sustainability. They even insist that achieving sustainable outcomes does not require questioning consumerist social values. Given the status and credibility that typically attach to CSIRO and peer-reviewed *Nature* publications, most people, including politicians, can be expected to take the 'pro-growth' CSIRO conclusions at face value as sound.

In this paper we have provided a variety of reasons why the ANO Report, and by implication the *Nature* article, have drawn key conclusions that have not been established by the modelling study on which they are based. Our lines of critique have focussed on the unacceptable social justice implications of the work; its misconceived carbon budget assumptions; its extraordinary proposal to plant up two thirds of Australia's best agriculture land with carbon sequestering plants, without presenting a convincing case for how to achieve this; its deep reliance on CCS technology which to date is not commercially viable; its highly optimistic assumptions about resource efficiency improvements; and the fact that its claims about 'sustainability' only extend to 2050. We note also that the report assumes that there will be no resource scarcity challenges that interfere with this long-term vision of economic growth. If any one of these assumptions turns out to be misconceived or unachievable, the vision of 'sustainable prosperity' defended in the report will not eventuate. Our paper has presented grounds for doubting *all* of their assumptions, such that cumulatively the report's conclusions must be considered, at best, not established, and, on balance, mostly likely false. Indeed, even if the report's most ambitious *Stretch* scenario were somehow achieved by 2050, we have shown that by no means would a growth-orientated Australia or a growth-orientated world be on a sustainable path.

If this broad critique is correct, the implications are profound: humanity must face up to the fact that the dominant macroeconomics of growth are unsustainable. With specific reference to the most developed regions of the world, acknowledging that there are environmental limits to growth would be the first step in making the fundamental transition 'beyond growth'. Indeed, given the extent of ecological overshoot, the likelihood of future population growth, and the need for the poorest nations to develop their economic capacities in some form, it would seem that any coherent transition to a 'one planet' global economy will require the developed or overdeveloped nations not just moving to a non-growing economy but actively initiating a policy of planned economic contraction, or degrowth.

Obviously a degrowth policy framework raises enormous problems and issues which are beyond the scope of this paper, but which are beginning to be addressed by critical scholars and activist communities across the globe (see generally, D'Alisa, Demaria, and Kallis, 2015). To summarise briefly, it would involve a planned economic contraction and reorganisation of developed economies, so as to achieve the long-term reductions needed, as well as provide space for development of the poorest nations and room for biodiversity to flourish, whilst also meeting the needs of all people for meaningful, healthy and productive livelihoods. While the main focus of a degrowth strategy would be to reduce environmental impact to sustainable levels, the above analysis suggests this cannot be done without a contraction of wealth and income for global rich and middle class – that is, such a goal would not be compatible with ever-increasing GDP or consumerist values or lifestyles, as is taken for granted by the decoupling strategy. We realise that such a solution is far outside the scope of real-world politics today, but that only sets the challenge for civil-society groups across the planet. In our view, no other large-scale sustainability vision and strategy adequately responds to the true nature of the global predicament. It is imperative that sustainability scholars and activists give more attention to the need for such a radical shift in vision and policy agenda.

The long-term goal – the final destination of a degrowth process – would be a society characterised by much less materialistic lifestyles, highly self-sufficient, zero-growth economies at all levels, especially the local level, and a new social ethos based on increased cooperation and sharing (Trainer, 2010). It is our view that only societies that have these general characteristics hold out the hope of making the long-term reductions needed for sustainability on a full planet.

By way of conclusion, we would like to draw attention to two key implications of this study, which are relevant to future attempts to defend green growth by way the decoupling strategy.

- The first is the social justice dimension. What does any particular green growth vision assume re inequality / global poverty? Defenders of green growth ought to make these assumptions explicit.

- The second is that green growth advocates must explain how the growth paradigm can put humanity on a long-term path towards sustainability. Even if growth could be green until 2050 – which we doubt – can it remain green if growth continues through to 2100 and beyond? If not, then the deep transformation beyond growth ought to be initiated without delay.

We believe that when these two aspects are brought to the surface, it becomes clear that the decoupling strategy cannot lead to a growing global economy that is just and sustainable.

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