A SUSTAINABLE WORLD – AN ECOLOGICAL FOOTPRINT AND I=PAT PERSPECTIVE

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Abstract
This paper identifies two approaches to how humanity might go about living sustainably – a Reformist approach and a Transformational approach. Reformism, as the current dominant approach, is critiqued using Ecological Footprint Analysis and I=PAT, to assess its merits in seeing humanity undertake an orderly transition to a sustainable world. The results suggest that the pathway Reformism offers is challenging to believe as credible. Further, some of the key strategies the Reformist approach advocates are shown to work against the very outcomes it otherwise sets out to achieve.

Key words:
Sustainable world framework, carbon footprint analysis, I=PAT.

1. Introduction

This paper reports on a component of a current research project (the Project) that is concerned with what it means for humans to live sustainably, that is, for there to be a sustainable world, and how this might be achieved. The Project considers three key questions namely: (a) what does it mean for there to be a sustainable world?, (b) what sustainable world approach is being pursued by a State government in Australia, the South Australian Government?, and (c) what are the implications of this government's sustainable world approach in respect of its contribution to, or detraction from, a global sustainable world goal?

The discussion and findings reported here, conducted by way of a literature review and analysis, relate *only* to an aspect of the first of these three Project question by answering a further sub-question, namely: 'of the two main approaches the Project has identified from the literature as representing what it means for there to be a sustainable world – Reformist and Transformational approaches – which is more likely to see the primary goal of a sustainable world achieved?' The Project applies two methods to exploring this question: (a) Ecological Footprint Analysis (EFA) in conjunction with I=PAT, and (b) Socio-ecological resilience theory. This paper focuses *only* on the first of these – EFA and I=PAT – by means of a critique of the Reformist approach (for a summary report of the full Project, including methodology and key findings in relation to all 3 research questions shown above, see Clifton (Forthcoming-a), and for a detailed review of the application of Socio-ecological resilience theory to a critique of the Reformist approach, see Clifton (Forthcoming-a,b) information available from the author).

In presenting the EFA and I=PAT critique of Reformism, this paper is structured as follows:

Section 2 provides an overview of what it means for there to be a sustainable world through a summary of the two main sustainable world approaches, identified from a literature review undertaken as part of the Project (see Clifton (2010)), namely the Reformist and Transformational approaches. The purpose of this review is to summarise the key feature of Reformism as compared to the Transformational approach, from which Reformism, as the current dominant sustainable world approach, is then subjected to critique.

Section 3 provides a brief overview of EFA and discusses how this concept measures a necessary, although not sufficient, condition for humanity to live sustainably. Section 4 follows with a summary of the current EFA data and discusses how these data demonstrate humanity's unsustainable way of life.

Section 5 continues the EFA review by considering what outcome, in EFA terms, humanity *should* be striving for. This is an important question to address as without clarity of this point, this paper's critique of Reformism from an EFA perspective would lack a meaningful measure against which to model the consequences of pursuing the Reformist agenda. In considering this EFA-outcomes question, a number of issues that materially impact on how the EFA data are interpreted, but that are currency poorly developed in the literature, are reviewed in some detail. Following this review, some general parameters are established on which the EFA modelling is then based.

In Section 6, I=PAT is introduced. This section: (a) provides a general overview of I=PAT ('I' – ecological impact/Ecological Footprint, is a function of 'P' – population, 'A' – affluence/consumption, and 'T' – technology), (b) displays the Reformist and Transformation approaches in I=PAT terms, (c) discusses how I=PAT can be meaningfully applied to projecting future Ecological Footprint values based on the Reformist approach, and (c) discusses key relationships between I=PAT elements to produce a meaningful set of assumptions in using I=PAT for Ecological Footprint projection purposes. Section 6 concludes with a presentation of the results from projecting the Ecological Footprint through to the year 2050, using I=PAT, and based on the Reformist agenda.

Section 6 highlights Reformism's reliance on 'T' ('technology') to bring humanity's Ecological Footprint within necessary Biocapacity limits. In Section 7, a number of these key 'T' based strategies are discussed to consider if they are likely to deliver the outcomes the Reformist approach claims they are able to do.

Section 8 concludes with a discussion of the implications of the reported findings, the key areas of knowledge contribution this paper has sought to achieve, key limitations of the findings, and areas for further research.

2. A Sustainable World

What it means for there to be a sustainable world is a pluralistic and contested concept, grounded in differing value systems, perceptions of reality, and cultural contexts (Gibbs & Krueger 2005; Osorio, Lobato & Castillo 2005). This plurality poses challenges for summarising exactly what a 'sustainable world' means and, as Dobson (1996) points out, it makes the task of constructing a meaningful sustainable world definition virtually impossible. As an alternate to a definitional approach, Dobson (1996) recommends a typology representation of complex concepts such as that of a sustainable world, and this advice of Dobson's was followed for the Project. Two main approaches to a sustainable world were identified from the typology construction exercise conducted, they being a Reformist approach and a Transformational approach (for a discussion of the research methodology and findings for the typology construction component of the Project, see Clifton (2010)).

The Reformist approach focuses the achievement of a sustainable world on reforming the current dominant socio-economic system through changes at the margin to make this system more environmentally responsible and socially just (green-and-just). This approach is characterised by: (a) an anthropocentric bias, (b) the meeting of human needs through a focus on the consumption of goods and services produced and consumed in green-and-just ways, (c) human population policies focused on stabilising population numbers, (d) maintaining of the current process of human development built around continued economic growth and technology advance, but done in green-and-just ways, (e) a

commitment to continued economic growth to overcome problems of poverty and to promote general human wellbeing, (f) continuation of the current globalisation and free-trade agenda as necessary to underpin these economic and social goals, and (g) technological advance as necessary to drive growth, improve human wellbeing, and address any negative ecological impacts harmful to human wellbeing (Clifton 2010).

A Transformational approach however claims that progressing to, and the maintaining of, a sustainable world requires fundamental and transformational socio-economic system change. This approach is characterised by: (a) an ecocentric bias, (b) meeting human needs through consumptive sufficiency and a focus on non-material satisfiers, (c) a strategy for the long term reduction in human population numbers and an increase in the population numbers of most non-human species, (d) continued consumptive growth viewed as unsustainable and a primary cause of both ecological problems and of poverty, (e) poverty as best resolved through resource reallocation not more global resource-through-put growth, with a key role for the politically and economically powerful, especially the industrialised North, to cease the exploitation of resources from the politically and economically weak, and (f) quantitative constraints placed on natural resource use and waste discharge into the Earth's ecosystems, such that they remain well within ecosystem limits (Clifton 2010).

The Reformist approach is the current dominant approach to a sustainable world (Handmer & Dovers 1996; Gould & Lewis 2009), and is consistent with mainstream sustainable development narratives at the international and national political levels, and within business circles (Castro 2004; Robinson 2004). Although the term 'sustainable development' is not used exclusively in the Reformist context, it nonetheless has strong historical links to Reformism (Orton 1990; Escobar 1995) and as such, the more neutral 'sustainable world' term is used in this paper as a general term for humanity's 'living sustainably' goal.

Although the Reformist and Transformational approaches summarised above have connections to other viewpoints of alternate sustainable world approaches – the weak vs strong sustainability differentiation being perhaps the most prominent – caution needs to be exercised in equating such alternate narratives to the Reformist and Transformational approaches. The weak vs strong sustainability concepts for example, although used in inconsistent ways in the literature, are mostly linked to economic concepts of capital maintenance, namely, for weak sustainability, the need to maintain the aggregate of human forms of capital (K_{HF}) and natural capital (K_N), and for strong sustainability, the need to maintain the K_{HF} and K_N bases independently (Goodland 1995; Common & Stagl 2005). These weak and strong sustainability concepts are, however, mostly economic concepts (Hediger 1999; Dovers 2005) grounded in an anthropocentric paradigm (Wackernagel & Rees 1997), and form only a part of the broader suite of issues of importance in the Reformist and Transformational narratives (for a further discussion on this issue, see Clifton (2010)).

The concept of a sustainable world is also a multi-dimensional social construct. Aspects of what it means for there to be a sustainable world can be found in many academic and professional disciplines including sociology (Bell 2009), environmental ethics (Light & Rolston 2003), justice studies, especially environmental justice (Schlosberg 2007), accounting (Schaltegger, Bennett & Burritt 2006), business strategy and management (Dunphy, Griffiths & Benn 2003) and economics, notably the sub-fields of environmental economics (Field & Field 2006), ecological economics (Daly & Farley 2004), and green economics (Cato 2009). The Reformist and Transformational narratives are, in this sense, multi-disciplinary concepts and need to be considered and interpreted in this way.

But returning to the point of Reformism being the current dominant sustainable world approach, why is Reformism dominant? Three main (non mutually exclusive) explanations are evident in the literature namely: (a) Reformism is a superior sustainable world pathway than the Transformational approach (see Hart (2007) as an example of this view), (b) Reformism is the only viable approach within the current political and economic space (authors suggesting this may be of importance include Robinson (2004) and Barry (2007)), and (c) the sustainability narrative has been captured by the political and economically powerful elite and modelled into the Reformist mode to suit their own interests and ideology (for support of this view see Castro (2004) and Kempf (2008)). This paper explores the first of these three explanations.

3. Ecological Footprint Analysis

The characteristics of EFA are well documented in the literature (for examples see Wackernagel et al. (2004), Kitzes et al. (2007), and Footprint Network (2008a), however, in brief, EFA seeks to answer a specific two-part research question namely:

> "*how much of the biological capacity of the planet is demanded by a given human activity or population… [and] how much of the planet's capacity do we use compared to how much is available?*" (Footprint Network 2008b).

EFA seeks to answer this research question by:

(a) Calculating an Ecological Footprint measure, which represents the biologically productive land and water area that a unit of focus (say, a city, nation, or all of humanity) uses to produce the resources it consumes and the wastes it generates or, in other words, the rate of use of the Earth's renewable natural capital (K_{NR}) flows. The Ecological Footprint is usually expressed in standardised units of global hectares, and most commonly in per capita terms (global hectares per capita – ghpc).

(b) Calculating a measure of available Biocapacity (i.e. available K_{NR} flows), also expressed as ghpc.

(c) Comparing the Ecological Footprint and Biocapacity measures to determine a measure of ecological credit or deficit.

EFA does not capture every aspect of what it means to live sustainably (Kitzes 2007; Footprint Network 2008b). Instead, it measures what is claimed to be a necessary, although insufficient, condition for there to be a sustainable world, that being a requirement for humanity to live within the Earth's Biocapacity limits (Footprint Network 2006; Giljum et al. 2007).

EFA has its critics, and a number of claimed deficiencies have been identified and examined in detail in the literature (see for example van den Bergh & Verbruggen (1999), Venetoulis & Talberth (2005), and Kitzes et al. (2009)). Despite this, EFA is seen as the most comprehensive and widely accepted measure of humanity's use of the K_{NR}, with demonstrated consistency with other environmental impact indicators (York, Rosa & Dietz 2004; White 2007; Bagliani et al. 2008). In addition, Footprint Analysis has been accepted as a valid metric by many government, private, and NGO bodies (see Footprint Network at http://www.footprintnetwork.org/).

This paper follows the position of EFA supporters by proceeding on the basis that, although it has recognised areas of data inaccuracy and presents approximations as opposed to exact measures, the concept is sufficiently robust to provide a meaningful picture of humanity's use of the Earth's Biocapacity as compared to its availability (Wackernagel 2009). In addition, the EFA data used in this paper is that produced by the Footprint Network (http://www.footprintnetwork.org/) which is the most broadly recognised EFA data and methodology (Footprint Network 2008b).

4. Ecological Footprint Analysis and the current state of the world

Figure 1 sets out the most recent global-level EFA data. The key points to note are:

(a) Humanity's collective Ecological Footprint of 2.6 ghpc is running at 144% of available Biocapacity of 1.8 ghpc, meaning that a position of ecological overshoot exists.

(b) This overshoot position means that available Biocapacity is insufficient to meet current human demands. Instead, the K_{NR} base is being depleted and wastes (in this case, CO_2) are accumulating in the Earth's ecosystems rather than being fully assimilated.

(c) The consequences of this K_{NR} depletion and waste accumulation are carried mostly by: (i) the economically and politically weak who suffer a disproportionately low level of access to K_{NR} use as compared to the economically and politically powerful, (ii) future generations who will inherit a depleted K_{NR} base, threatening their ability to meet their own needs, and (iii) other species, in particular through a continued and escalating rate of extinction (Andersson & Lindroth 2001; Westra 2006).

In short, from a global perspective, humanity is not living within the Earth's available Biocapacity and is, in this respect, not living sustainably.

Figure 1: Current EFA data

Item	Value
Note: EF = Ecological Footprint; BioC = Biocapacity	
EF – average per person for all of humanity. [#1]	2.6 ghpc
BioC – average global BioC per person. [#1]	1.8 ghpc
Ecological deficit/overshoot – average per person for all of humanity. [#1]	-0.8 ghpc
EF as a percentage of BioC. [#2]	144%

Data sources:

#1: Footprint Network (2009): 2009 release based on 2006 data.

#2: Author calculation.

5. Ecological Footprint vs Biocapacity targets

But what Ecological Footprint vs Biocapacity measure should humanity be striving for? In the EFA literature, a minimum condition for humans to live sustainably in a global context is talked of in terms of humanity needing "*[its] global Footprint [to] be less than or equal to the global biocapacity* (Footprint Network 2006, para 15A) and *"at a global level the minimum requirement for sustainability is that humanity's footprint be smaller than the biosphere's biological capacity"* (Nijkamp, Rossi & Vindigni 2004, p. 753). The claim of "*equal to*" in the first quote is troublesome as to live sustainably, humanity's global-level Ecological Footprint needs to be less than available Biocapacity. Being equal to it will not do, as this fails to account for: (a) the Biocapacity requirements of other species, (b) the need to maintain ecosystem resilience, and (c) the conservative nature of EFA data. Gaining clarity on this issue, to which this section turns its attention, is of high importance as reliance on the raw published EFA data can paint an otherwise distorted picture of humanity's current unsustainable ways of life.

5.1. Other species

The Biocapacity measure used in EFA does not account for the needs of other species that require access to the same Biocapacity as humans (Wackernagel et al. 2004; Footprint Network 2006). The claim by EFA promoters is that the question of meeting the needs of non-human species sits outside of the research question EFA seeks to answer. Instead, the amount of Biocapacity to be set aside for other species is seen as a values-based, scientific and political decision that should be made at these levels and not automatically factored into the EFA data (Footprint Network 2006).

The Reformist and Transformational approaches however both call for the protection of biodiversity for many reasons including: (a) the maintaining of ecosystem integrity to provide the life supporting services humans need to live flourishing lives (Diesendorf 1997; UNEP 2007), (b) meeting various human instrumental needs such as recreation, spirituality, aesthetic pleasure, pharmaceutical production, support of cultural values, and agricultural purposes (UNEP 2007; Bell 2009), (c) meeting inter-generational justice obligations (WCED

1987; Brown-Weiss 1990), and (d) especially in respect of the Transformational view, meeting certain ethical obligations humans have towards nature (Naess 2005; UNEP 2007; Bell 2009). So although taking the point made by EFA advocates concerning the exclusion of non-human species Biocapacity needs from the Biocapacity measure, the question of 'how much Biocapacity should be set aside for non-human species?' still needs to be answered. Without some guidance on this matter, setting a target for sustainable human use of Biocapacity becomes impossible.

This 'how much for other species' question is poorly addressed in the literature. Most estimates talk of how much of the Earth's surface should be set aside as protected areas, with low estimates in the 10%-12% range through to higher estimates of 40%-60%+ (Soulé & Sanjayan 1998; Wackernagel et al. 1999; Wilson 2002; CABS 2003; Stokstad 2005). But there is a difference between claiming how much of the Earth's surface should be set aside as protected areas, and how much of the Earth's Biocapacity should be left for other species. An example of this difference is evident in the World Commission on Environment and Development's report 'Our Common Future' (the Brundtland Report) (WCED 1987). Some authors claim that this Report calls for about 12% of the Earth's surface to be set aside in protected areas (e.g. see Wackernagel & Yount (1998)). This 12% number does not however appear in the Brundtland Report but is rather an extrapolation of the Report's proposal that, based on the state of affairs at the time the Report was written, "*the total expanse of protected areas needs to be at least tripled if it is to constitute a representative sample of Earth's ecosystems*" (p. 156). The Report however never claims this is adequate to protect biodiversity and instead sees protected areas as part of a broader approach to biodiversity protection framed within a general change in land use patterns and approaches to development. It is misleading to represent the 12% value implied in the Brundtland Report as equating to the setting aside of 12% of available Biocapacity for the benefit of non-human species.

A general view in the literature however is that the low-end 10%-12% estimate is inadequate to protect the Earth's biodiversity (Soulé & Sanjayan 1998; CABS 2003; Stokstad 2005), with a 10% value seen by some as likely to put up to half of the Earth's species at risk of human caused extinction (Soulé & Sanjayan 1998). Values in the order of 40%-60% of the Earth's surface, whether quoted in reference to protected areas or, more generally, as needing protection from intrusive human actions in a broader landscape sense, are often cited as necessary to offer an adequate basis for biodiversity protection (Soulé & Sanjayan 1998; Wilson 2002; Mackey 2004; Stokstad 2005). The claimed biodiversity protection outcomes of these 40%-60% values are consistent with both the Reformist and Transformational biodiversity protection narratives, although the Transformational view tends to the higher end (or beyond) of this value range (Clifton 2010)).

Further, the Biocapacity that needs to be set aside for non-human species is not just any space, but needs to focus on biological criteria (UN 1992; Foreman 1995), as opposed to continuing past strategies of protecting areas of the Earth's surface that are of little or no value to humans, or areas suited only to human recreational actives (Callicott 2003; Ehrlich & Ehrlich 2008). This is important when considering the Biocapacity measure used in EFA calculations, as Biocapacity is based on biologically productive areas of land and water that support significant photosynthetic activity and biomass accumulation that can be used by humans. The Biocapacity measure excludes non-productive and marginal areas such as arid regions, open oceans, the cryosphere, other low-productive surfaces, and areas producing biomass that are not of use to humans (Kitzes et al. 2007). As such, vast areas of the Earth's surface – deserts, polar regions, very mountainous areas, open ocean space, and so on – can be set aside in protected areas that have little or

no relevance to areas incorporated in the Biocapacity measure and the survival of species in these areas.

So in answer to the question of how much Biocapacity should be set aside for non-human species, the literature offers no clear answer. It suggests however that a figure in the 10%-12% range is not credible and higher estimates in the order of 40%-60%+ are more likely to be required to deliver an outcome consistent with sustainable world principles.

5.2. Socio-ecological resilience

The next point concerns the maintaining of ecosystem resilience. Two main forms of resilience are identified in the literature, namely engineering resilience and ecological (or socio-ecological) resilience (Peterson, Allen & Holling 1998; Walker & Salt 2006) (socio-ecological resilience is the term used in this paper for this second form of resilience). Engineering resilience refers to the ability of a system to bounce back to its pre-disturbance state following some from of disturbance – such as a global financial crisis and the ability of the economic system to return to an upward growth path. Socio-ecological resilience on the other hand refers to the ability of a system to continue to function effectively despite exposure to disturbance. A number of factors enhance socio-ecological resilience including (a) diversity within a system, (b) maintaining of spare capacity and keeping well away from system tipping points, and (c) the ability of a system to adapt to change, evolve, and to self organise (Meadows, Randers & Meadows 2004; Walker & Salt 2006). In the sustainable world context, it is socio-ecological resilience that is of key importance through the continued meeting of the sustainable world goals of human and ecological wellbeing, regardless of what disturbance and change might occur to ecological and social systems over time. In this sense, the concepts of a sustainable world and socio-ecological resilience are inseparable (Holling 1996; Walker & Salt 2006).

The key point to be made here is that human use of Biocapacity that is close to total available Biocapacity is not only biodiversity eroding but is also limiting in the extent to which spare systems capacity is maintained and tipping points are kept at a distance. The EFA literature does not confront in any material way this issue of socio-ecological resilience in its consideration of human use of available Biocapacity. As such, no guidance is available from the literature on what Ecological Footprint vs Biocapacity gap is needed to address the full scope of resilience issues, although the need for such a gap is clear.

5.3. Conservative values

EFA data tends to underestimate the Ecological Footprint value and overestimate available Biocapacity. The reasons for this are grounded in a preference for the conservative use of data where uncertainty exists, and exclusion from the calculations of factors where no reliable data are available (Kitzes et al. 2007; Wackernagel 2009).

An indication of the possible extent of the disparity between humanity's actual overshoot position and that presented by the EFA data is evident in a study by Venetoulis & Talberth (2005; 2006). These authors undertook an alternate calculation to incorporate many, but not all, of the factors the standard EFA figures exclude. Compared against the EFA 2005 data release, the findings showed an ecological overshoot of 39%, (that is, humanity's global Ecological Footprint was 139% of available Biocapacity), about double that of the 18% overshoot value reported in the standard EFA figures.

The point here is that basing decision making on the actual EFA data risks interpreting the true state of affairs of human appropriation of available Biocapacity in an overly optimistic way. Based on the Venetoulis & Talberth study, the disparity between the actual and the reported may be substantial. So although this issue of conservative data relates to calculated EFA values as opposed to actual Biocapacity and Ecological Footprint, it is nonetheless of importance in setting, measuring, and interpreting,

Biocapacity and Ecological Footprint targets based on EFA data.

5.4. Summary

In summary, the amount of Biocapacity that can be safely appropriated for human use within the sustainable world context remains unclear. What is clear however is that: (a) humans utilising 100% of available Biocapacity is inconsistent with a sustainable world, (b) allowing say, 10%-12% of available Biocapacity for meeting the needs of non-human species is also inconsistent with a sustainable world as it breaches biodiversity preservation objectives, and values in the 40%-60%+ range may well be required to be set aside, (c) in addition, Biocapacity needs to be set aside for socio-ecological resilience purposes, and (d) a further allowance needs to be made for the conservative nature of the EFA data.

For the purpose of the analysis presented in this paper, two values – 20% and 50% – are used for the amount of Biocapacity, as measured in the EFA data that is unavailable for human use. Although somewhat arbitrary, the 20% value takes a minimalist approach by moving a short distance beyond the 10%-12% for biodiversity purposes that has been shown above to be inadequate. The 50% value sits comfortably in the higher end ranges for biodiversity protection. An argument can of course be made that the 20% value is totally inadequate purely from a biodiversity protection perspective, and even the 50% value may be inadequate as it fails properly to factor in the conservative nature of EFA data and does not consider issues of socio-ecological resilience. But to get lost in a 'should it be 20% or 50% or something else' discussion can in some ways distract from the bigger picture. As shown in Figure 2, the setting aside of 20% of Biocapacity sees the current Ecological Footprint value running at about 180% of the resulting Biocapacity available for human use. At a 50% of Biocapacity value, the Ecological Footprint is some 289% of human available Biocapacity. Either way, the numbers are significant and the challenges humanity faces in moving to a sustainable world are considerable.

Figure 2: Current EFA data with modified Biocapacity vales

Item	Value
Note: EF = Ecological Footprint; BioC = Biocapacity	
1. Base EFA data [#1]	
EF – average per person for all of humanity.	2.6 ghpc
BioC – average global BioC per person.	1.8 ghpc
Ecological deficit – average per person for all of humanity.	-0.8 ghpc
EF as a percentage of BioC.	144%
2. BioC – 20% unavailable for human use [#2]	
BioC available for human use.	1.4 ghpc
Ecological deficit – average per person for all of humanity.	-1.2 ghpc
EF as a percentage of available BioC.	181%
3. BioC – 50% unavailable for human use [#2]	
BioC available for human use.	0.9 ghpc
Ecological deficit – average per person for all of humanity.	-1.7 ghpc
EF as a percentage of available BioC.	289%

Data sources

#1: From Figure 1.

#2: Author calculation applying the factors detailed in Section 5.4. to the base EFA data in this Figure 2.

Note: Figures subject to rounding. Detailed calculations are available from this paper's author.

6. Projecting the Ecological Footprint

6.1. Introduction

The discussion so far has considered what it means for there to be a sustainable world, and has used EFA to show that humanity is, at a global level, not living sustainably in the sense of living within the limits of available Biocapacity. In this section, the Reformist and Transformational sustainable world approaches are presented in I=PAT terms. In addition, I=PAT is used to project the current Ecological Footprint forward based on the Reformist view, with a purpose of considering the implications of pursuing the Reformist narrative in bringing humanity's Ecological Footprint within Biocapacity limits.

6.2. I=PAT

I=PAT presents human impact on the environment 'I', as a function of.

'P': Population.

'A': Consumption-production per capita (or affluence), with GDP per capita often used as a proxy measure.

'T': The environmental impact per unit of consumption/production which, although referred to as 'technology', is really a catch-all for the collective ecological impact of production and consumption activities.

(For an overview of I=PAT, see Holdren et al. (1995), Chertow (2000) and York et al. (2003b)).

Figure 3 sets out the Reformist and Transformational approaches in I=PAT terms. In brief, the Reformist approach is relatively benign on population ('P') issues, seeks strong global economic growth ('A'), and relies on technology ('T') to offset the impacts of 'P+A' to keep 'I' within ecological limits. The Transformational view however seeks to specifically restrict 'I' such that humans live within ecological limits, and all of 'PAT' are addressed to ensure these limits on 'I' are not breached.

Figure 3: I=PAT and the Reformist and Transformational approaches

IPAT element	Reformist approach	Transformational approach
'I'	Reduce Biocapacity use to sustainable levels by focusing on 'T' and using (mostly) market pricing systems that internalise all social and ecological externalities. [#1]	Set limits on Biocapacity use to be well within available Biocapacity levels. All of 'PAT' are addressed to ensure these limits are not breached.
'P'	Orientation to maximising the human population that can be supported within sustainable world criteria. Contain very high population growth rates in some (mostly developing) countries. Prevent population decline in some (mostly developed) countries. Otherwise allow population to settle to a 'natural' level.	Current human population is too high and unsustainable, and is an issue for all countries to address. A long term population reduction strategy is required through collective non-coercive and non-discriminatory choice. This population reduction strategy will enhance the wellbeing of both humans and other species.
'A'	Continued global GDP growth is necessary to progress human wellbeing and overcome problems of poverty. Reducing consumption is, for the most, not a viable option and will harm society and fail to help the poor.	Increased consumption is needed for some where basic needs are not being met but this is achieved through more equitable distribution, not more global GDP growth. Overall, and especially in the developed world and for the wealthy in developing nations, resource consumption needs to be reduced.
'T'	Technological progress to overcome the impacts of 'P+A' is the key to living sustainably and to reducing 'I' to be within ecologically sustainable limits.	Technology is an important part of the overall sustainability solution but on its own it will not achieve the needed change. Technology needs to be progressed with caution.

Source: Clifton (2010).

Note #1: This does not mean that Reformism ignores Biocapacity use limit-based policies – cap and trade systems (e.g. for carbon emissions) or quota limits (e.g. for fisheries) are examples of such policies. The focus for Reformism however is more towards market pricing mechanisms than the strong scale-limiting approaches incorporated in the Transformational approach.

6.3. I=PAT and projecting the Ecological Footprint

EFA data is specific in time as it shows 'what was' by way of human demands on the Earth's ecosystems as compared to available Biocapacity (Kitzes 2007; Footprint Network 2008b). From a sustainable world perspective however, the consequences of human behaviour need to be looked at not only in terms of the present, but also in terms of the future. Although EFA is not a forward looking or predictive measure it does not exclude its application in considering possible futures based on a set of assumptions as to how EFA components may change over time (Footprint Network 2006). It is this forward looking objective to which I=PAT can offer some valuable insights.

The Ecological Footprint is a measure of human impact on the Earth's ecosystems by way of humanity's consumption of available Biocapacity. In this sense, 'I' in the I=PAT formulation can be considered in terms of the Ecological Footprint, with all of 'PAT' as drivers of humanity's Footprint (Wackernagel et al. 1999; York, Rosa & Dietz 2007). In its basic form however, I=PAT gives no indication of the relationships between the 'PAT' elements, that is, does a change in one element (say, 'P'), produce a straight multiplicative change in 'I', or are the relationships more complex? This is a poorly researched area with no reliable I=PAT component relationship data readily available (Kitzes 2007; York 2008). However, some general guidance on possible relationships is evident in the literature as follows:

First, York et al (York, Rosa & Dietz 2003a; 2003b; 2004; 2005; 2007) conducted a cross-national analysis of Ecological Footprint in relation to 'P' and 'A' (as GDP), with results indicating (a) a strong, but slightly less than, 1-to-1 relationship between population size and Ecological Footprint meaning that a 1% increase in national population produced an almost 1% trend-line increase in a national Ecological Footprint, and (b) a monotonic upward curving relationship between 'A' and Ecological Footprint indicating that as 'A' increased, the Ecological Footprint trend-line consistently increased by a greater than a 1-to-1 factor (also see Bagliani et al. (2008) for a similar study to that of York et al, and WWF (2006) and Moran et al. (2008) for a cross-nation study of the relationship between Ecological Footprint and the Human Development Index – all of these three studies show results similar to those of York et al).

Next, efforts have also been made to identify within-nation Ecological Footprint, 'P', and 'A' relationships. In particular, some time series data comparing Ecological Footprint, GDP, and population change in the European Union (EU) for the period 1971 to 2008 appears in WWF (2007). These data show that, at an aggregate level, the EU's Ecological Footprint increased at about 75% of the collective population plus GDP per capita growth rate. EU nation-specific data however showed significant variation, examples being Germany which managed to keep its aggregate and per capita Ecological Footprint relatively stable over the 1971-2003 period (due mainly to a shift from fossil fuel to renewable energy generation), and France and Spain both showing significant increases in aggregate and per capita Ecological Footprint.

A third possible source of data is research conducted on the links between economic growth and environmental quality represented as the environmental Kuznets curve (EKC). The EKC presents human impact on the environment as an inverted 'U' shaped curve. The argument is that in the early stages of societal change towards industrialisation, increasing environmental degradation is experienced but the point is reached where further industrialisation sees a change to decreasing environmental impact and improved environmental quality (Stern 2004; Bagliani, Bravo & Dalmazzone 2008). Although this EKC phenomenon has been observed for some local environmental

quality factors such as sulphur emission and domestic water quality, it has been shown not to hold from a broader based consumption perspective, that is, the overall impact of economic growth increases human ecological impact when all impact factors are accounted for wherever those impacts may occur on the planet (Stern 2004; York, Rosa & Dietz 2007; Bagliani, Bravo & Dalmazzone 2008).

Finally, some insights can be gained by looking at historic population, GDP and Ecological Footprint data. The most recent set of EFA accounts show that, over the period 1961 to 2006, humanity's collective Ecological Footprint grew at an annual average rate of about 2.0%, global population grew at about 1.7% pa, and global GDP per capita at about 1.9% pa (raw data source: Footprint Network 2009; WRI 2010). Based on these data, humanity's collective Footprint grew by about 55% of 'P+A' although there is significant year by year variation. The last 6 years to 2006 for example show the Ecological Footprint having grown at about 70% of 'P+A'.

What these comments on the relationships between the I=PAT elements show is a lack of decoupling between 'P+A' upward pressures and the needed reductions in 'I'. Jackson (2009) identifies two types of decoupling between economic growth ('A') and ecological impact ('I') namely: (a) relative decoupling, which is a reduction in resource input per unit of production, and (b) absolute decoupling, which is an absolute reduction in resource input despite increased production output. The point Jackson makes is that although some degree of relative decoupling may be evident between continued economic growth and ecological harm, there is no evidence supporting absolute decoupling in the global context.

This lack of absolute decoupling between population and economic growth, and of continued ecological damage, is well documented (for examples, see OECD (2008), UN (2005), and Jackson (2009)). From an economic growth perspective, reasons offered for this failure to decouple include: (a) accumulated capital is applied by industry to replace labour with new technologies that drive greater production and consumption (Gould, Pellow & Schnaiberg 2008), (b) efficiency gains are pursued for the specific purpose of driving further economic growth (Princen 2005), (c) increased wealth results in changes in behaviour towards more energy intensive and environmentally demanding production and consumption patterns, including dietary changes towards a higher proportion of meat (Dauvergne 2008), and larger houses with fewer occupants per dwelling (Ho 2007; Ehrlich & Ehrlich 2008), (d) advances in 'T' are not happening quickly enough to counter 'P+A' increases (Speth 2008; Victor 2008), (e) some technological developments, including those intended to reduce human environmental impact, can result in unintended environmental harm (Dauvergne 2008; Victor 2008), and (f) resources to meet increasing population and economic growth demands need to be met from less efficient and more marginal primary sources as the most efficient sources have been utilised first, increasing financial costs, energy costs, and environmental costs to extract and process these resources (Farley, Erickson & Daly 2005).

Some of these reasons for decoupling failure will be considered in more detail below. The key point to be taken from the discussion in this section however, is that growth in 'P+A' has clear links to an increasing 'I'. Similar to the problem of identifying the amount of Biocapacity that humans can safely utilise within a sustainable world context, there is no clear data on the extent to which changes in 'P+A' flow through to 'I' despite these links being well known and reported. But for the sake of the analysis in this paper, two figures are used: (a) a collective decoupling of 'P+A' from changes in 'I' of 25%, that is, a 1% change in 'P+A' equals a 0.75% change in 'I' (consistent with the EU findings), and (b) a 50% decoupling where a 1% change in 'P+A' equals a 0.50% change in 'I' (an optimistic

view beyond what current evidence suggests is occurring).

6.4. Projecting Biocapacity

The final issue to consider in projecting the EFA data from a Reformist perspective is that of Biocapacity. Future trends in available Biocapacity remain uncertain in that it is subject to many forces including: (a) the negative impacts of current resource depletion (Daily & Ehrlich 1992), (b) the potentially positive impacts of improvements in technology that may increase K_{NR} productivity (Lenzen et al. 2007), and (c) human caused global warming, where impacts are expected to vary from region to region, and also vary depending on the magnitude of the temperature change experienced (Lenzen et al. 2007; Speth 2008). Some attempts to model future Biocapacity and K_{NR} stocks have been attempted including those of Meadows, Randers & Meadows (2004), WWF (2006), and Lenzen et al. (2007). All in all, the results are mixed and there is little to work with to present a meaningful Biocapacity projection other than assume that current total Biocapacity will remain about the same, with forward adjustments made only in respect of per capita Biocapacity changes resulting from population movements. This is the approach used in this paper.

6.5. Ecological Footprint Analysis projection results

Figure 4 presents the various inputs used to forward model humanity's per capita Ecological Footprint based on the Reformist approach. Figure 5 shows the summary data. The modelling projects through to 2050 which, although somewhat arbitrary, provides a view of the possible longer term consequences of Reformist strategies and the challenges they create.

In short, based on the most reserved set of assumptions (Ecological Footprint rises at 50% of 'P+A' growth rates, and 20% of Biocapacity is set aside as not available for human use), by 2050 the 'P+A' growth pressures that are captured in the Reformist view see the global-level Ecological Footprint rise to about 3.1 ghpc against available Biocapacity of about 1.1 ghpc. What this means is that 'T' in I=PAT needs to offset the impacts of population and GDP growth so as to reduce the collective human Ecological Footprint from 3.1 ghpc down to about 1.1 ghpc in addition to the 50% decoupling rate already factored into the calculation. At the other end of the spectrum, based on a decoupling rate of 25%, and 50% of Biocapacity set aside as unavailable for human use, the 2050 Ecological Footprint becomes about 3.9 ghpc against a Biocapacity of 0.7 ghpc.

The problem here however is that the magnitude of the task 'T' based strategies need to accomplish is well beyond anything that is evident as currently being achieved despite the idea of sustainability, in the form of Reformist based sustainable development, having been prominent on the international stage for over 20 years since the release of the 1987 Brundtland Report. To put the magnitude of the task into further perspective, of the 124 nations included in the most recent set of EFA accounts (Footprint Network 2009), only 23 have a current Ecological Footprint of 1.1 ghpc or less, and of these, only 3 have a Footprint of 0.7 ghpc or less. All of these 23 nations fit comfortably within a low or least developed nation descriptive. On the other hand, the average Ecological Footprint for the roughly 1 billion people living in the world's high income countries is currently about 6.1 ghpc, which is as much as 6 times what humanity needs to reduce its collective Ecological Footprint measure to by 2050 in order to be living sustainably in EFA terms by that date.

These figures pose some serious challenges to the believability of the Reformist agenda. Although not denying the benefits of having a positive outlook on human ingenuity and problem solving capabilities, surely we must question the Reformist view of pinning the future wellbeing of humanity, and of all life on the planet, on yet to be developed 'T' solutions to the negative impacts of Reformist population and economic growth strategies.

But despite these concerns, does a focus on 'T' offer a meaningful pathway to a sustainable world regardless of the magnitude of the challenge? The discussion will now turn to exploring this question.

Figure 4: Projecting the Ecological Footprint – I=PAT inputs

Factor	Reformist modelling inputs
Note: EF = Ecological Footprint; BioC = Biocapacity	
I=PAT element: 'I' (Ecological Footprint)	• Current global average EF is approximately 2.6 ghpc. [#1] • Projected 2050 BioC based on projected 2050 population and holding all else constant = approximately 1.3 ghpc. [#2]
I=PAT element: 'P'	• Human population is currently about 6.5 billion. [#3] • Mid-range UN projection to 2050 is about 9 billion (equates to a growth rate to 2050 of approx 0.71% pa). [#4]
I=PAT element: 'A'	• Assume real global average per capita GDP growth of 1.5% pa. • Note: (i) The global GDP per capita growth rate from 1961-2006 was about 1.9% pa. [#5] (ii) The Brundtland Report calls for annual economic growth of 3%-4% in the North and 5%-6% in the South. [#6]
Decoupling rates	• Decoupling rate between 'P+A' and changes in 'I': [#7] (i) Scenario 1: 25% (i.e., 'I' increases at 75% of the increase in 'P+A'). (ii) Scenario 2: 50% (i.e., 'I' increases at 50% of the increase in 'P+A').
BioC available for human use	• BioC set aside for other species, resilience purposes, and conservative EFA calculations: [#8] (i) Scenario 1: 20% set aside leaving 80% for human use. (ii) Scenario 2: 50% set aside leaving 50% for human use.

Data sources:

#1: See Figure 1.

#2: Author calculation: [Current BioC per capita] x [global population on which current BioC value is based (6,592m)] / [projected 2050 total human population].

#3: Footprint Network (2009).

#4: UN (2007).

#5: WRI (2010).

#6: WCED (1987).

#7: As detailed in Section 6.3.

#8: As detailed in Section 5.4.

7. Decoupling 'I' from 'A' - Unpacking 'T'

There are a number of factors that comprise 'T's component parts, however this discussion will focus on two of the more prominent of these. The first, which was identified in the list of reasons for a lack of decoupling between 'P+A' and 'I' shown in section 6.3, relates to efficiency. The second concerns the adoption of less harmful behaviours in the production and consumption process.

7.1. Efficiency

Efficiency gains are a key strategy expressed in business and political circles for addressing sustainability problems. Such gains are often touted as a win for all: a win for the producer though bottom-line profit gains, a win for the consumer in reduced costs, and a win for the environment by way of reduced resource use (Hargroves & Smith 2006; Jackson 2009). Efficiency, in the context of a 'T' based strategy to counter the negative impacts on 'I' from increases in 'P+A', has two main facets which will be considered here, they being: (a) efficiency in renewable natural capital (**K_{NR}**) productivity, and (b) efficiency of use of resources in the production and consumption process.

7.1.1. Efficiency in K_{NR} productivity

The application of new technologies to increase the productivity of the Earth's K_{NR} base is an important part of the Reformist agenda. Strategies to achieve this increased

Figure 5: EFA data projected to 2050

Item	Value
Note: EF = Ecological Footprint; BioC = Biocapacity	
1. Base EFA data	
EF – current average per person for all of humanity. #1	2.6 ghpc
Projected BioC in 2050 based on population change only. #2	1.3 ghpc
BioC at 80% of 2050 value. #3	1.1 ghpc
BioC at 50% of 2050 value. #3	0.7 ghpc
2. Decoupling at 25%: EF increases at 75% of 'P+A'	
2050 EF. #4	3.9 ghpc
BioC - at 80% of 2050 value. #5	1.1 ghpc
Ecological deficit. #5	-2.9 ghpc
EF as a % of available BioC. #5	370%
BioC - at 50% of 2050 value. #5	0.7 ghpc
Ecological deficit. #5	-3.3 ghpc
EF as a % of available BioC. #5	592%
3. Decoupling at 50%: EF increases at 50% of 'P+A'	
2050 EF. #4	3.1 ghpc
BioC - at 80% of 2050 value. #5	1.1 ghpc
Ecological deficit. #5	-2.0 ghpc
EF as a % of available BioC. #5	291%
BioC - at 50% of 2050 value. #5	0.7 ghpc
Ecological deficit. #5	-2.4 ghpc
EF as a % of available BioC. #5	466%

Data sources:

#1: From Figure 1.

#2: From Figure 4.

#3: Author calculation.

#4: Future value calculation:

PV = Current aggregate EF = [Current EF per capita] x [global population on which current EF value is based (6,592m)].

n = 44 years (from year of latest EFA data to 2050).

i = 2.21% pa (i.e., population growth rate to 2050 of 0.71% + assumed per capita GDP growth rate of 1.50%, as per Figure 4), reduced by the 25% and 50% decoupling rates as per sections 2 and 3 in this Figure 5.

FV = calculated FV divided by 2050 population to produce a per capita 2050 EF value.

#5: Author calculation based on data in this Figure 5.

Note: Figures subject to rounding. Detailed calculations are available from this paper's author.

productivity include the use of modern industrialised agricultural practices, genetic engineering of plant and animal species, intensive livestock farming, and so on (Clifton 2010). Debates continue as to whether these technologies have genuinely increased resource productivity in a way that can be sustained in the longer term. Some claim that this is certainly true while others remain unconvinced and propose that when negative externalities (use of fossil fuels, chemical and fertiliser pollution, long term soil degradation, biodiversity loss, displacement of people from their lands, destruction of cultures, etc) are accounted for, these current practices are far from being sustainable (Shiva (2005) is an example of this alternate view).

But of more importance for this current discussion is the question of socio-ecological resilience. An approach that seeks to maximise the productivity of K_{NR} as envisaged in the Reformist view undermines the resilience of the very ecosystems on which human wellbeing is dependent (and similarly for the wellbeing of all other species). This undermining of resilience comes about for a number of reasons including the removal of spare systems capacity as increasing amounts of K_{NR} are pulled into the production process, the imposition of change at a rate faster than feedback mechanism can provide data on the consequences of actions taken, and a general pushing of ecosystems towards tipping points allowing for little in the way of safety buffers to cope with the unexpected (Meadows, Randers & Meadows 2004; Walker & Salt 2006).

From an I=PAT perspective, the strategy to improve K_{NR} productivity has a key objective of increasing overall Biocapacity. If successful, this makes the needed level of 'I' (i.e., the Ecological Footprint) higher than it might otherwise be in order for humans to live sustainably by way of Biocapacity use, hence reducing the size of the overall sustainability challenge. The problem is that the undermining of ecosystem resilience that flows from this productivity maximisation strategy risks the exact opposite occurring.

7.1.2. Efficiency of use of resources in the production and consumption process

Efficiency gains at the production level are well recognised as a means by which firms improve productivity, reduce costs, and increase wealth (Princen 2005; Gould, Pellow & Schnaiberg 2008). But production efficiency does not necessarily equate to overall resource use reduction. Termed the 'Jevons Paradox', pursuing production based resource efficiency can, and does, result in increased production and consumption that negates some or all of the resource efficiency gains that were otherwise expected. This effect is also apparent at the consumption end where through say, initiatives within households to reduce energy costs through power saving activities, the money saved is simply spent on alternate consumption (Princen 2005; Gould, Pellow & Schnaiberg 2008; Polimeni et al. 2009). In this respect, relative decoupling of economic growth from K_{NR} consumption, in the absence of some alternate mechanism for containing increased production and consumption, can decrease the likelihood that absolute decoupling can be achieved. In I=PAT terms, this means that the production and consumption efficiency component of 'T' has the effect of increasing 'A' such that 'T' simply cannot keep up with 'A' based pressures (York & Rosa 2003; Jackson 2009).

7.2. Less harmful behaviours in the production and consumption process

Less harmful production and consumption behaviours incorporate many factors including the use of less polluting substances, manufacturing products that can be easily recycled, extracting K_{NR} in less harmful ways (such as the harvesting of fish with less by-catch impact), and so on. But the question remains as to whether these actions have unintended consequences of increasing consumption and hence negating some of the apparent gains achieved as occurs in the efficiency context discussed above. To explore this question, two aspects of the less-harmful-behaviours issue will be considered namely: (a) green consumerism, and (b) restructuring of the economy.

7.2.1. Green consumerism

Green consumerism refers to the development, packaging, and marketing of products in a way that is claimed to be 'environmentally friendly'. The marketing message is that people can save the world through consumption choices, and can consume with a clear conscience. For business the message is improved profits. The complete package is a claimed win for business, for the consumer, and for the environment (Beder 2002; Bell 2009).

Critics argue however that green consumerism fails to address the underlying problem of resource consumption and instead, promotes further consumption under the misguided view that society can somehow consume its way out of its unsustainable state (Beder 2002). In addition, green consumerism is seen to continue the business-as-usual marketing strategies of need creation through the deliberate engineering of feelings of dissatisfaction and deprivation in people's lives, offering the solution to this dissatisfaction through consuming a particular product (in this case, a 'green' product). This marketing strategy drives continued consumption and economic growth with flow-through implications of increasing K_{NR} use (Raiklin & Uyar 1996; Hamilton & Denniss 2005).

7.2.2. Restructuring of the economy

Restructuring-of-the-economy relates to the claimed shift in production and consumption activities within economies as they continue to industrialise. The claim is that the further down the industrialisation path a nation moves, the greater the proportion of its economy that is dedicated to less resource intensive service and information industries. In this respect, increased economic growth results in a transformation to a less environmentally damaging economy, consistent with the EKC proposition discussed in section 6.3.

Counter arguments to this claim include: (a) the apparent switch to service industries is not as great as it seems, as much of the recorded change results from businesses

outsourcing activities they might have otherwise done internally, or people paying for things (meals in restaurants, home cleaning, gardening services, and so on) that they would otherwise have done themselves (Victor 2008), (b) industrialised nations tend to export their manufacturing industries, especially the 'dirtier' industries, to the developing world which gives a misleading picture of the composition of the industry mix needed to meet local consumptive demands for both industrialised and developing nations (Douthwaite 1999), and (c) other changes also go on in consumption behaviours as income grows and nations industrialise that place growing, not reducing, pressures on resource consumption (examples are shown in section 6.3).

An alternate way of considering the restructuring-of-the-economy issue is by use of the EFA data. The Ecological Footprint calculation is consumption, not production, based, where what matters in the calculation is a person's Ecological Footprint, or collectively a nation's overall Ecological Footprint, based on what is consumed regardless of where in the world those goods or services are produced (Kitzes 2007; Footprint Network 2008b). Figure 6 shows the Ecological Footprint measure for national groupings based on income. What is evident from these data is that high income countries (i.e., countries of the industrialised West, plus Japan and some other highly industrialised nations) run by far the highest Ecological Footprint and one that is well above the global average. In this sense, the restructuring-of-the-economy argument is unconvincing. The industrialised countries that presumably have transitioned to a higher portion of service industries in their economic mix have per capita Ecological Footprint measures well above what is sustainable on a global level.

8. Discussion and conclusion

8.1. Purpose and findings

This paper has presented, by way of a literature review and analysis, a critique of the merits of the current dominant approach to a sustainable world – the Reformist

Figure 6: Ecological Footprint by national income

	Population (millions)	**Ecological Footprint (ghpc)**
World	6,593	2.6
High Income Countries	1,022	6.1
Middle Income Countries	4,281	1.8
Low Income Countries	1,277	1.0

Source: Footprint Network (2009)

approach, which is an approach consistent with current mainstream sustainable development narratives evident in political and business domains – by way of the application of Ecological Footprint Analysis (EFA) in conjunction with I=PAT. This critique suggests that Reformism is challenging to believe as credible. The reliance on technology solutions (i.e., 'T' in I=PAT) requires these solutions to achieve two things: (a) a 100% decoupling of population and economic growth pressures from the Ecological Footprint, and (b) a reduction in humanity's existing aggregate Ecological Footprint from its current unsustainable level. The extent of 'T' based reductions needed to achieve these outcomes is both substantial and well beyond what is evident as occurring in practice. The enormity of the Reformist challenge is further evidenced by noting that the average Ecological Footprint value needed to be met by all of humanity is currently being achieved by only a handful of countries, all of which are very low on the scale of national development. In other words, the Reformist approach proposes a solution that continues the current focus on economic growth for progressing human wellbeing, whilst concurrently reducing the global average human Biocapacity consumption level to that of the citizens of the least developed nations on the Earth.

The magnitude of this required impact from 'T' strategies becomes even more challenging to accept as credible when considering the options 'T' offers. A number of these 'T' strategies, rather than achieving the needed absolute decoupling of economic growth from ecological impact, can instead drive increases in production and consumption, hence negating some or all of the apparent gains that were intended to be delivered. In this respect, one of the reasons put forward for the lack of absolute decoupling of economic growth from ecological impact – that changes in 'T' are not occurring fast enough (see section 6.3) – may instead be better interpreted as changes in 'T' can drive increased resource consumption such that 'T' strategies are possibly never able to occur fast enough to counter the ecological impacts of the continued economic growth they help create.

The core message presented in this paper of the highly questionable ability of the Reformist approach to deliver a sustainable world outcome is not new, but rather adds to the weight of existing evidence. Arguments rejecting the possibility of continued economic growth, demonstrating the ineffectiveness of efficiency solutions to achieve needed reductions in human impacts on the Earth's ecosystems, and affirming the increasing rather than decreasing impact humanity is having on the Earth's ecosystems, are well rehearsed. These arguments appear in the literature in a number of areas including the sustainability literature in general (e.g., Meadows, Randers & Meadows (2004), Princen (2005), Shiva (2005), Victor (2008), and Jackson (2009)), and within various academic disciplines including ecological economics (e.g., Daly, H & Farley (2004), and Common & Stagl (2005)), the emerging field of green economics (e.g., Cato (2009)), and environmental sociology (e.g., Gould, Pellow & Schnaiberg (2008), and Bell MM (2009)).

None of this is to say that all aspects of the Reformist narrative should be rejected. Clearly the need for increased efficiency in production and consumption activities is important (section 7.1), as are efforts to make these activities less ecologically harmful (section 7.2). The point however is that without some way to address the flow-though implications of these strategies in driving further Biocapacity use, these strategies can work against the sustainable world goals they otherwise seek to achieve. In this respect, pursuing the Reformist agenda may simply be a means of aggravating humanity's unsustainable ways of life under the misguided belief that a sustainable world outcome will materialise at some point in the not too distant future if we 'just work hard enough at it'.

So is the Transformational approach the solution? It is beyond the scope of this paper to explore the Transformational approach in detail, however the key points to note are these. First, the Transformational approach seeks to act directly on all of the I=PAT elements as opposed to the Reformist approach that is mostly 'T' focused (see Figure 3). In this respect, the Transformational approach offers a greater range of solutions than the Reformist approach is willing to tolerate. Next, the Transformational approach specifically seeks a socio-ecological resilience approach to how humanity goes about conducting itself, as compared to the Reformist approach that is focused on maximisation and optimisation strategies within both social and ecological systems (Clifton 2010). In both of these respects – direct action on all I=PAT elements, and a socio-ecological resilience focus – the Transformational view seems to present a pathway forward that is more likely to see a sustainable world achieved than the Reformist approach can otherwise offer.

Earlier in this paper it was noted that Reformism is the current dominant approach to a sustainable world. Reformism however, not only dominates, but it does so to the exclusion of the Transformational narrative in political and business circles. To be heard politically and by business, any proposals to progress the achievement of a sustainable world need to fit the Reformist view (Handmer & Dovers 1996; Gould, Pellow &

Schnaiberg 2008). If, as this paper, and as other authors propose, Reformism is challenging to believe as a credible pathway to a sustainable world, then why does Reformism dominate to the exclusion of the Transformational view? One answer is that the third of the reasons for Reformism's dominance set out in section 2 – the sustainability agenda has been captured by the politically and economically powerful elite – is in fact true. If this is the case, then even if further research on the various issues detailed in this paper, plus other efforts to interrogate the Reformist and Transformational approaches, result in an increasing weight of evidence against Reformism, the challenges of embracing an alternate narrative take on a whole new dimension. Hurdles in progressing to a sustainable world cannot in this setting be overcome by simply presenting a convincing argument. The current wrestle over the reality, cause, and severity, of global warming, and embarking on a path of needed action, is an example of this dilemma (Hamilton 2007; Hoggan 2009). The point to be made here is that although further work on considering the merits of the Reformist and Transformational views is worthwhile, and to which this paper has hopefully made a valuable contribution, such research needs to be paralleled with efforts to address the economic and political power obstacles that might be standing in the way of needed change.

8.2. Contribution, limitations, and further research

This paper has sought to contribute to efforts to help progress humanity to the orderly and peaceful achievement of a sustainable world by: (a) adding to the body of literature that expands consideration of approaches to a sustainable world beyond mere adherence to the current dominate Reformist view, (b) adding to an understanding of how EFA demonstrates humanity's current unsustainable use of the Earth's renewable natural resources, particularly by way of consideration of the Biocapacity needs of other species, and introducing to EFA discussions the need to consider socio-ecological resilience requirements in Biocapacity allowances, and (c) adding to the weight of evidence in considering the merits of the Reformist view as a credible pathway forward for humanity.

In the process of reviewing the I=PAT and EFA concepts and their application to critiquing the Reformist approach, a number of challenges emerged where further research may be beneficial. The key areas evident in the above discussion are: (a) the conservative nature of the EFA data, (b) the amount of Biocapacity that is available for human use, (c) the drivers of change in Biocapacity and how this might unfold in the future, and (d) the drivers of future Ecological Footprint values and in particular, the relationships between I=PAT components.

8.2.1. Conservative nature of the Ecological Footprint Analysis data

The conservative nature of the EFA data is, to some degree at least, resolvable through improvements in data gathering and analysis, and through improvements in the EFA calculation methodology, all of which are the subject of an ongoing research programme (Kitzes et al. 2009). Some inaccuracy can however be expected to remain if for no other reason than a full understanding of humanity's impact on the K_{NR} base may simply not be knowable. A more realistic expectation may be to couple improvements in EFA data accuracy with error estimates as to the possible extent of its under-reporting of the true state of affairs.

8.2.2. Biocapacity for human use

Although further research can help improve our understanding of the amount of Biocapacity that can be safely utilised by humanity, science alone will not answer the question. As an example, underlying the question of how much Biocapacity should be set aside for non-human species are basic value issues as to the extent to which non-human species should simply be managed to meet human needs (an anthropocentric orientation), as compared to flourishing for their own sake (an ecocentric orientation)

(Clifton 2010). In addition, and as discussed in section 5.1, the question of 'how much Biocapacity for other species' needs to be matched with a 'how is this to be set aside' question. But despite this, both the Reformist and Transformational approaches place a high level of importance on biodiversity maintenance, and some further research is needed to consider possible ranges of Biocapacity that should be set aside for biodiversity protection. In addition, greater effort needs to be made in presenting the EFA data to make it clear that living at, or just below, the Biocapacity number quoted is not consistent with a sustainable world.

Finally, the issue of socio-ecological resilience is poorly explored in the EFA setting. Much more needs to be done to develop this stream of thought including gaining increased understanding of the interactions between the Biocapacity allowance and the resilience allowance (for example, does a greater focus on biodiversity protection address at least some resilience issues, such that biodiversity and resilience allowances in the Biocapacity measure may not be merely additive?).

8.2.3. Drivers of change in Biocapacity

The forward looking Biocapacity measure used in the modelling described in this paper assumes a zero net outcome from enhancement strategies and degradation consequences (see section 6.4). Gaining a better understanding of the likely trends in future Biocapacity, although of value in the type of modelling undertaken here, also confronts some significant challenges. For example, the impacts of human caused global warming, including its biodiversity loss implications, remain highly uncertain as do the implications of the current continued degradation of the Earth's ecosystems (UN 2005; Brown 2008). Further, the arguments presented in this paper suggest that a continued focus on the Reformist approach to progressing a sustainable world will most likely see an escalation in K_{NR} depletion hence reducing the very Biocapacity it seeks to preserve. So although further exploration of this issue can be helpful in considering possible future Biocapacity states, it is likely to remain an issue of significant uncertainty.

8.2.4. Drivers of Ecological Footprint and I=PAT.

As discussed in section 6.3, the relationships between the various I=PAT components is not well understood. These issues are more than simply attempting to determine coefficients so as to understand what an X% increase in 'A' or 'P' might translate to in terms of movement in 'I'. The reason for this is that the 'PAT' elements also interact, where change in one can drive change in another (Holdren, Daily & Ehrlich 1995; Victor 2008). This is evident from the discussion in section 7, where the instigation of certain 'T' strategies are shown to have flow-on impacts on 'A'. Further research on the nature of these interactions may offer not only opportunities for better forward looking modelling, but also better decision making by governments, businesses, and households, when acting to progress sustainable world outcomes.

8.3. Limitations and their implications

The data accuracy issues discussed above clearly result in limitations on the extent to which the numbers quoted in the I=PAT calculations can be seen as an accurate reflection of humanity's current and future Ecological Footprint, and of the current and future available Biocapacity that is available for human use.

The calculations can also, in some respects, be seen as likely to underestimate the true state of humanity's overshoot position from following the Reformist approach. One reason is that certain assumptions in the I=PAT projections have erred on the cautious, in particular, the per capita GDP growth rate of 1.5% pa used in the calculations is less than has been the experience over the last 40 years or so, and may under-represent actual growth rates. The 1.5% figure is also well below the rates of growth that are called for by Reformist advocates (see Figure 4). It remains to be seen of course whether continuation of

current K_{NR} depletion will, as a number of authors propose, become a constraint on economic growth making the 1.5% assumption overly optimistic (Meadows, Randers & Meadows 2004; Brown 2008). Next, even the most conservative Biocapacity value used in the I=PAT projections as being available for human use – 50% of the total available –does not make any additional allowance for socio-ecological resilience needs, or accommodate the conservative nature of the EFA data.

But does all of this uncertainty in the data used in this paper to construct an argument as to the merits of the Reformist approach really matter? Well, in some respects the answer is no. Wackernagel (2009), in discussing the accuracy of the EFA data, makes the point that the EFA output, as with the output of any model, will never be entirely accurate – it will always be an approximation. For Wackernagel, what is important to ask is whether "*[the] results [are] accurate enough to be useful*" (p. 1925), with this usefulness dependent on the question the output is intended to address. Although improvements in data accuracy would be nice to have in conducting the review set out in this paper, the core issue being considered is whether the Reformist approach is a credible pathway to achieving a sustainable world. To do this, Reformism needs to deliver continued human and ecological wellbeing, a necessary condition of which is for humanity to live within Biocapacity limits. In this respect, improving the accuracy of the data may help firm up the detail, but is unlikely to change the high level conclusions this paper makes.

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