Sustainability and the SDGs: a systems perspective

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ABSTRACT

The UN Sustainable Development Goals (SDGs) released in 2015, set out 17 goal statements that respond to key global social, economic and environmental challenges. The agenda unfortunately misses an opportunity to explain exactly what is meant by the term 'sustainability' by explicitly linking the term to the Brundtland Commission's widely known definition "meeting the needs of the present without compromising the ability of future generations to meet their own needs". More importantly, the strategy involves separate agendas for each goal domain, without any explicit recognition of the interdependence between them, or reflect the fact that they are dimensions of a complex socio-ecological system (SES) that exhibits multiple feedbacks. This paper sets out how each of the SDG domains can be conceptualised as an SES with 'enduring human wellbeing' as the central goal. System dynamics modelling of the global SES indicates that policy interventions involving a rapid transition from fossil fuels to renewable energy, reduced resource intensity and materials recycling are necessary to prevent 'overshoot and collapse' behavior in the later stages of the 21st century, and facilitate ongoing improvements in global average living standards. The contribution (and limitations) of the circular economy concept to this transition are discussed. The importance of 'social quality' in achieving levels of human wellbeing beyond material living conditions is identified, involving policy objectives such as social cohesion, social justice and equity

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1. INTRODUCTION

The U.N. *Transforming our world* initiative lists 17 Sustainable Development Goals (SDGs) in a manner that suggests 17 separate agendas need to be pursued in parallel to achieve a sustainable world. The SDG authors missed two major opportunities in the development of the SDGs: establishing a simple, central goal that builds on the momentum achieved since the Brundtland report of 1987, and linking the goals together as dimensions of a complex socio-ecological system within which there is interdependence and feedback. I set out an alternative systems-based perspective of the global socio-ecological system (SES) in this article, comprising the interactions and feedback between its social, economic and environmental dimensions.

Modelling of the global population – economy – resource system by myself and others, suggests that a business-as-usual approach will lead to serious ecological damage and resource scarcity during the latter part of this century, ultimately causing reductions in population and living standards. I discuss the major transitions in energy and resource use required to avoid this outcome, including the attractions and limitations of the circular economy concept.

I also discuss the purely social dimension of sustainability in systems terms, including the nexus between material living standards and the broader concept of human wellbeing and its importance in moving the global socio-ecological system towards equilibrium.

Each of the 17 sustainable development goals is placed within the socio-ecological system configuration described in the article.

2. THE UN SUSTAINABLE DEVELOPMENT GOALS

In 2015, the UN General Assembly adopted '*Transforming our world : the 2030 Agenda for Sustainable Development*' (United Nations, 2015). The 17 SDGs cover off the many facets of policy that, we are invited to believe, will deliver sustainable development. Unfortunately, like many such initiatives, the goals read as a wish-list for progressing separate initiatives, inviting a continuation of the 'silos' approach to development policy.

Most disappointing of all is the failure to provide a clear statement that articulates the central goal of sustainable development. The word 'sustainability' is used throughout the goal statements, in respect of agriculture, economic growth (![1]), industrialisation, water, energy, consumption and production, cities and communities, and management of forests and oceans. What do these adjectives mean? Does the achievement of these objectives in aggregate produce a 'sustainable' world?

It is instructive to recall where all this started, which was the report of the World Commission on Environment and Development '*Our Common Future*', chaired by Gro Harlem Brundtland (1987). It was this report that coined the much referred to definition of sustainable development[2]:

"meeting the needs of the present without compromising the ability of future generations to meet their own needs"[3].

Although there have been many variations developed since, as governments and others have parsed the Bruntland definition, for most this remains the essence of the term. Despite what many people think, this definition identifies sustainability as a social aspiration, not an environmental one. It, somewhat clumsily, speaks to the need to ensure all the resources that give rise to achieving wellbeing remain available to future generations. I have suggested therefore that a simple goal statement for sustainability is '*enduring wellbeing'*. This is in fact very similar to Goal 3 of the SDGs, which is:

Good Health and Well-being - Ensure healthy lives and promote well-being for all at all ages

An opportunity was missed to make this or a similar sentiment the centrepiece of the SDGs, creating continuity from Brundtland to the present. If wellbeing is not the central focus of sustainability policy, what is? All of the other goals are components of this central goal[4]. Why do we want 'no poverty'; 'clean water'; 'reduced inequality'; 'economic growth;' and 'climate action' if not to advance human wellbeing?

3. SEEING THE WORLD AS A SOCIO-ECOLOGICAL SYSTEM

More important even than creating a central focus for the SDGs is the failure to articulate them as interdependent domains within a complex socio-ecological system (Berkes & Folke, 1998). For example, it is obviously not possible to make advances in poverty and hunger in any nation without addressing its existing and future economic conditions. Addressing this deficiency has fallen to organisations such as the Millennium Institute who have developed the iSDG system dynamics model[5] that builds in the required interrelationships and feedback in order to facilitate a better understanding of how an overarching national plan will influence each of the goals.

The first dimension of the sustainability problem relates to the interactions between the human world and the biosphere which we inhabit with all other life on earth, and which provides the material necessities required for a decent standard of living. This dimension is represented in the causal loop diagram[6] in Figure 1.

Although all the loops act simultaneously it is helpful to consider them one at a time. The polarity

[1] 'Sustainable growth' is an oxymoron, as pointed out by the World Bank economist Herman Daly thirty years ago (Daly, 1990). "*Since the human economy is a subsystem of a finite global ecosystem which does not grow, even though it does develop, it is clear that growth of the economy cannot be sustainable over long periods of time.*"

[2] In fact the term 'sustainable development' was probably first used as the sub-title for the 'World Conservation Strategy: Living Resource Conservation for Sustainable Development' (1980)

[3] In fact, the report itself does not use these words in a definitional sense but as part of an opening clause under the heading of Sustainable Development. The full sentence reads: "*Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs*."

[4] Of course, there are still problems with the statement as drafted. Do we only want to 'promote wellbeing for all'? Surely, we want to 'achieve wellbeing for all'.

[5] https://www.millennium-institute.org/isdg

[6] An explanation of causal loop diagrams is available at http://www.public.asu.edu/~kirkwood/sysdyn/SDIntro/ch-1.pdf.

of the arrows indicates the effect of one variable on another[7]. As examples, in the above:

- An increase in living standards leads to higher levels of economic production (all other things being constant) so the causation is positive.
- An increase in economic production leads to lower levels of natural resources (all other things being constant) so the causation is negative.

3.1. The Economy (blue loops)

These two loops essentially dominate the story of human history since the beginning of the agricultural age some 10,000 years ago. Rising living standards lead to higher population levels, which lead to higher levels of economic production which lead to higher living standards and so on (Loop R1). Compounding the growth rate of R1 is that rising living standards have also led to more economic production on a per capita basis (Loop R2).
The behaviour over time of such a loop is either exponential growth or exponential decline. Exponential growth is reflected in the data from the modern era (Figures 2 and 3).

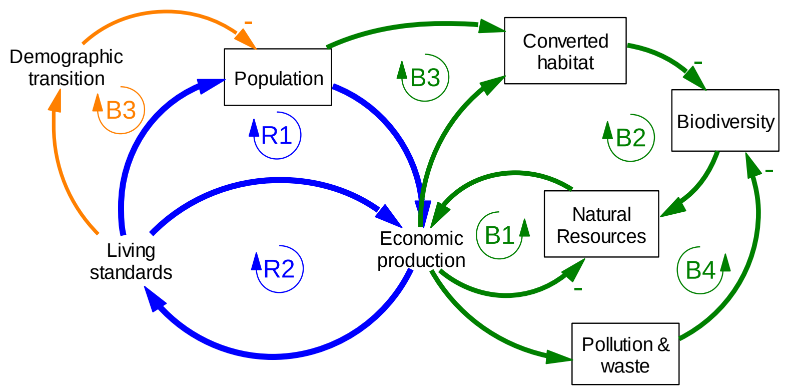

Figure 1 Causal loop diagram of the global socio-ecological system

3.2. Environment and natural resources (the green loops)

Material living standards are dependent on the non-human world, through the provision of so-called ecosystem services (Gómez-Baggethun, De Groot, Lomas, & Montes, 2010) which we derive from natural resources. Economic production depletes natural resources. The conversion of habitat (Loop B2) and the creation of pollution (including carbon) and waste (Loop B4) both limit nature's ability to provide ecosystem services into the future (Reid et al., 2005). Those that are finite (e.g. fossil fuels) will eventually run out completely (Maggio & Cacciola, 2012), and those that are renewable are being depleted at faster rates than they are regenerated (Grooten & Almond, 2018). If limits are reached, this scarcity creates feedback in the system that will reduce economic production, living standards and population (Loop B1).

3.3. Society (the orange loop)

From the rise of civilisation, up to the present time we have seen, in average global terms, an increase in human health and wellbeing on the foundation of higher living standards (Easterlin, 2000). Of course, there is huge variability across the world and setbacks at various times, but this scenario more or less describes human progress to date.

The effect of living standards on global population is changing. Over human history, rising living standards have increased birth rates and reduced death rates, and have accordingly led to higher population levels. That would indicate a positive relationship between living standards and population, and that has been the case in the past (Loop R1). As living standards rise in developing

[7] For clarity I have only labelled the negative causations. All unlabelled arrows indicate positive causation.

countries the net population growth rate (births minus deaths) is dropping, as it already has in much of the developed world - the so-called demographic transition (Lesthaeghe, 2011). This is significantly a function of increasing gender equality, essentially the ability of women to control their own fertility (McNay, 2005). Accordingly, in the modern era, the relationship between living standards and population is reversed – higher living standards will tend to reduce population, hence the negative sign in Loop B3. Evidence for the demographic transition can be seen in the reduced rate of population growth since the 1970s (Figure 2).

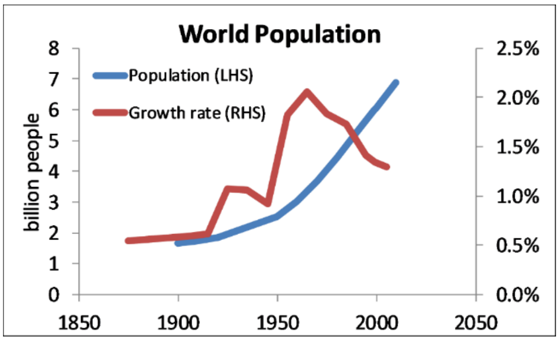

Figure 2 World population (Source: UN Population Division)

4. A GLOBAL MODEL

This highly simplified depiction provides the basis for understanding cause and effect in the global socio-ecological system. However, there are many different trajectories (behaviour over time) for this system. You cannot tell what the future state of the system may be by looking at this picture (bearing in mind that no model can accurately predict the future). Clearly, growth to date due to the reinforcing loops R1 and R2 have dominated the balancing loops, as shown by the exponential growth in real-world data on population (Figure 2), economic growth (Figure 3) and living standards.

The sustainability question is therefore what will happen in the future as the world population grows towards 9 billion or more, poorer nations become richer, the effects of pollution (particularly carbon) grow, and resources become depleted. To investigate plausible scenarios for the future requires a full global systems model.

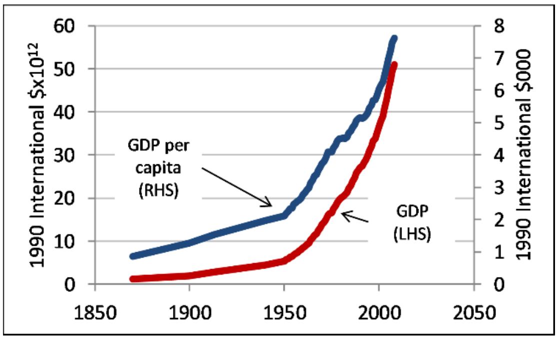

Figure 3 Global GDP Source: Maddison Historical Statistics[8]

The technique of system dynamics has long been used to model the links between economy, environment and well-being at the global scale, most famously in the Limits to Growth (LtG) studies first published in the early 70s (Donella H. Meadows, Meadows, Randers, & Behrens, 1972), updated in the 1990s (Donella .H Meadows, Meadows, & Randers, 1992) and early 2000s (Donella H. Meadows, Meadows, & Randers, 2004). The models establish a causal structure linking living standards (the basic constituent of wellbeing) to production and consumption of renewable and non-renewable resources and pollution absorption capacity. My own more recent work is a simplified global population – economy - resource model that explores the future impact of declining resource availability on the world economy (Grace, 2015). The model tracks the likely future consumption of renewable resources, fossil fuels and non-renewable materials and the economic impact of availability to 2300[9]. The model was calibrated against data from 1960 to 2010.

The simulations produce similar findings to the LtG studies, namely that business as usual will lead to resource scarcity, which will likely become evident during the latter part of this century and constrain economic production, reducing income per capita, living standards and ultimately population. Put simply, the present exploitation of natural resources (renewable and non-renewable) is *unsustainable* in the common language use of the term, i.e. that it cannot continue indefinitely. The findings indicate that policy interventions involving a rapid transition from fossil fuels to renewable energy, reduced resource intensity and materials recycling are

8 https://www.rug.nl/ggdc/historicaldevelopment/maddison/original-maddison

9 An open source online version of this model is available at https://forio.com/simulate/williamrgrace/sustainable-world

necessary to correct this trajectory and facilitate ongoing improvements in global average living standards. Delivering this transition is the central challenge for economic reform in the 21st century, but judging its feasibility requires a more detailed consideration of the nexus between the economy and resource consumption.

The economy and resources

Economists generally depict the means of production as comprising labour and capital (in the form of raw materials, tools, machinery and facilities). In fact, the final product and all intermediate items embedded in it or used to make it, derive ultimately from natural resources, solar energy and human labour (including fossil fuels that derive from the decomposition of organic matter). Although the material and energy intensity usually involved in the provision of 'services' is a fraction of that used in manufacturing 'goods', they are still produced in engineered buildings containing a myriad of engineered components and parts. Production is essentially about the transformation of natural resources (directly or indirectly) by human effort into the goods and services used in the economy –Figure 4.

It is the extraction, processing and transformation of these resources that provide the goods and services that underpin modern society. It is also these same activities that give rise to the loss of habitat and biodiversity, greenhouse gas emissions and other pollution that now threaten the living standards of people everywhere.

The former World Bank economist and founding member of the school of ecological economics Herman Daly introduced the concept of a steady-state economy more than forty years ago (Daly, 1974).

A steady-state economy is defined by constant stocks of physical wealth (artifacts) and a constant population, each maintained at some chosen, desirable level by a low rate of throughput-i.e., by low birth rates equal to low death rates and by low physical production rates equal to low physical depreciation rates, so that longevity of people and durability of physical stocks are high.

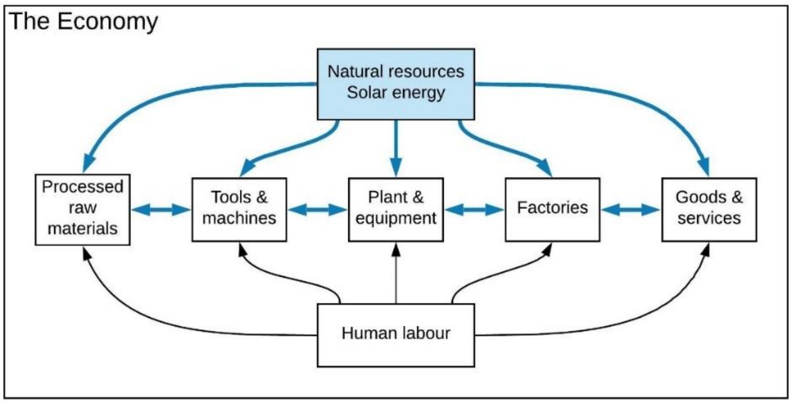

Figure 4 Flows of materials and energy in the economy

This is a description of a system in equilibrium, where rates of inflow and outflow vary over time but are approximately equal. In respect of natural resource exploitation this means (Daly, 1990):

- The rate of harvest of renewable resources should not exceed the rate of regeneration (e.g. sustainable forestry);
- The generation of economic by-products (which we call waste) should not exceed the assimilative capacity of the environment; and
- The depletion of non-renewable resources should require comparable development of renewable substitutes for that resource.

This thinking has given rise to the concept of the circular economy (Stahel, 2016) in which a lifecycle approach is taken to the exploitation of natural resources. The key components of this approach are to reduce the rate of natural resources exploitation through:

- extending service life, i.e. improved durability of products and structures and reduced built in obsolescence;

- re-using, repairing, retrofitting rather than replacing them; and
- recycling the product or its components.

To explore the potential of the circular economy concept it is necessary once again to consider the dynamics (behaviour over time) of the energy / resources system (see Figure 5). The driver for this system is economic demand, which gives rise to the exploitation of mineral (non-renewable) resources, renewable (biological) resources and energy resources.

4.1. Mineral resources

As mineral resources are essentially non-renewable (in the temporal scale of interest to humanity) exploitation of these resources necessarily reduces the available remaining stocks. And of course, there are losses involved in the exploitation of these resources. As stocks decline, the economic and environmental cost of exploitation inevitably increases. Materials, products and machines made from such resources will deteriorate over time. The modern throwaway culture means that many products are unlikely to be retained for even their designed life cycle. Both factors mean more resources must be exploited just because of obsolescence, let alone new demand.

4.2. Renewable resources

Ecological systems underpin all life on earth. The ecological footprint (Wackernagel & Rees, 1998) is a ratio measure of the rate of natural resource exploitation to the rate of regeneration of those resources (biocapacity). If the footprint ratio is greater than one, that means resources are being exploited faster than they are regenerating. Further, as stocks of renewable resources decline, the rate of regeneration also (generally) decreases (Arrow, Bolin, Costanza, & Dasgupta, 1995). Accordingly, we need to be concerned with both the rate of exploitation and the level of stocks (e.g. tropical forest coverage, fish stocks). Currently the ecological footprint is 1.7[10], i.e. we are using these resources at 1.7 times the rate that they are being replenished.

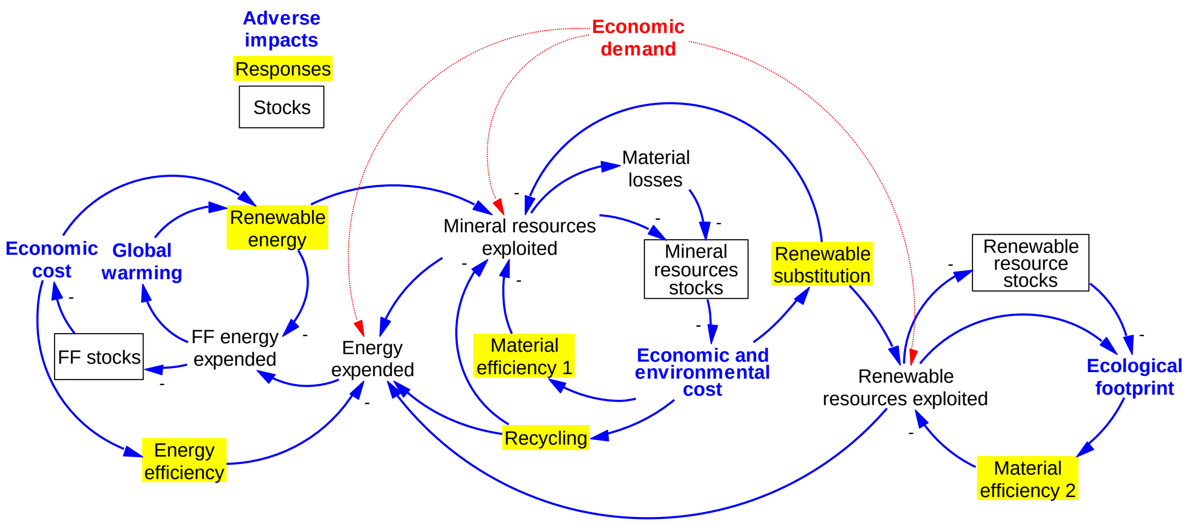

Figure 5 Causal loop diagram of the resource-energy subsystem

4.3. Energy

The exploitation of raw resources of all kinds requires the input of energy, as does their transformation into machines, products and structures, and the operation of those machines, products and structures. Measures that seek to reduce the material throughput of the economy such as reuse and recycling also require energy to be expended. The traditional use of fossil fuels for the

[10] https://www.footprintnetwork.org/our-work/ecological-footprint/

production of this energy is responsible for global warming (Bruckner et al., 2014). As fossil fuels are also a non-renewable resource (again at the temporal scale relevant to humanity), their exploitation inevitably reduces remaining stocks. As stocks decline, their ongoing exploitation involves higher economic and environmental costs irrespective of greenhouse gas emissions. The only long-term solution is a transition to a purely renewable energy powered economy. While the energy sources of wind and solar are inexhaustible (at least for the next few billion years) the machines that exploit them are not, including batteries that require material inputs, which are all currently mineral resources (iron, cadmium, titanium, lithium etc). And of course, more energy.

It is important to understand that this is a single system with interdependencies and feedback throughout. Policies that deal with one specific sub-system without understanding the implications for the rest of the system are flawed and will ultimately fail.

This system picture sets out the key objectives and challenges to address in support of the sustainable development goals.

Objectives

- to minimise the environmental impacts of resource exploitation in the economy to stabilise key ecological stocks at an acceptable level to support life on earth (i.e. the rate of exploitation is approximately equal to the rate of regeneration);
- to minimise the economic costs of resource exploitation which are a (necessary) overhead in seeking to retain high levels of human well-being for those that have them, and to obtain them for those who don't; and
- to minimise and eventually eliminate greenhouse gas emissions, while reducing the economic costs of energy.

The challenges

Achieving the objectives requires simultaneous action to manage those variables that affect them, with a minimisation of trade-offs (highlighted in yellow in Figure 5):

- efficiency measures of one kind or the other (including high levels of durability and longer life cycle products);
- re-purposing, reusing, or recycling the components themselves or the materials embodied in the products, machines and structures;
- substituting mineral resources with renewable resources where this is possible (e.g. substituting hydrocarbon-based plastics with natural polymers);
- reducing the energy intensity of production in, and operation of the economy; and
- transitioning to renewable energy.

It is important to remember the second law of thermodynamics in all of this. The adoption of these measures reduces the rate of exploitation of non-renewable resources and the associated environmental costs, but not to zero. Improving the rate of non-renewable resource exploitation through recycling requires more energy input. The substitution of non-renewable resources with renewable resources increases the ecological footprint. The exploitation of renewable energy requires mineral resources to build the machines. Because of this, there can be no completely circular economy, unless or until the world operates on purely renewable energy and renewable resources, and the ecological footprint is reduced below unity[11]. Although that may not be realised for many decades or even centuries to come, if at all, recognising that ultimate aim identifies the direction in which we must travel.

5. THE SOCIAL DIMENSION

Human well-being is not just a function of material living standards, although those are its foundation. There are many factors influencing an individual's sense of wellbeing. According to the OECD's *Framework for Measuring Well-being and Progress* (OECD, 2011, 2013a), overall wellbeing at the individual level comprises two high level dimensions: material conditions and quality of life (Figure 6).

[11] As it did in pre-industrial times

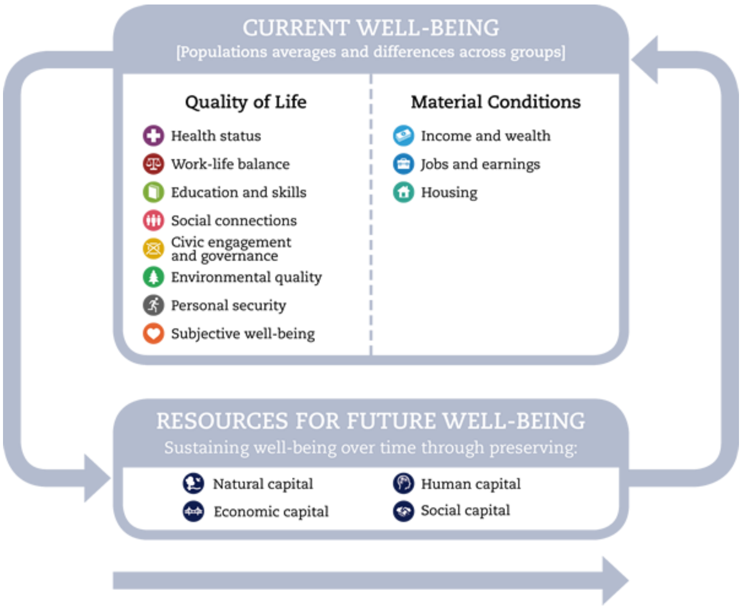

Figure 6 OECD Framework for measuring well-being and progress[12]

This framework attempts to reflect dynamics in that it identifies that the retention of various forms of capital are required in order to support well-being. The previous sections in this article relate to the *material conditions* component of this picture (referred to in this paper as living standards). However, the *quality of life* component is presented as a list (as are the SDG's) which is problematical in respect of understanding causation, interdependence and feedback. Inherent in this characterisation is that an individual's quality of life is significantly determined by the nature of the society in which they live, e.g. civic engagement and governance, health status, personal security). This understanding gives rise to the concept of *social quality*.

The International Association on Social Quality[13] (IASQ) defines social quality as

"the extent to which people are able to participate in social relationships under conditions which enhance their well-being, capacity and individual potential."

IASQ propose three conditions that influence social quality:

1. *the objective conditions of daily life, including the socio-economic conditions people are living in, the social cohesion they experience in their communities, social inclusion to realise their civil rights and the extent of their social empowerment to enable them to play responsible roles in society and in the processes of societal change.*
2. *the subjective conditions of life, as the degrees of personal security and social recognition, social responsibility and their personal capacities to combat situations and feelings of alienation, exploitation, discrimination and degradation.*
3. *the normative conditions of life: social justice and equity; solidarity at community, national and international level; to promote the equal value of all people and to defend and enhance their human dignity. These also form the basic orientation to judge the outcomes of the linking of the objective and the subjective conditions.*

In their book *The Spirit Level*, Wilkinson and Pickett (2010) establish a strong correlation between equality and wellbeing. A multitude of studies described in the book provide compelling evidence that wellbeing as measured by a range of factors is related not to absolute material living standards but to relative levels of inequality within the community, and disparities in social status (see Figure 7). Although the direct causation between

[12] Source: http://www.oecd.org/statistics/measuring-well-being-and-progress.htm

[13] https://socialquality.org/

inequality and wellbeing is contested (Nolan & Whelan, 2014; Pinker, 2018), the underlying IASQ social conditions that are associated with inequality, e.g. social inclusion, social recognition, social empowerment, social justice, probably explain Wilkinson and Pickett's impressive correlations.

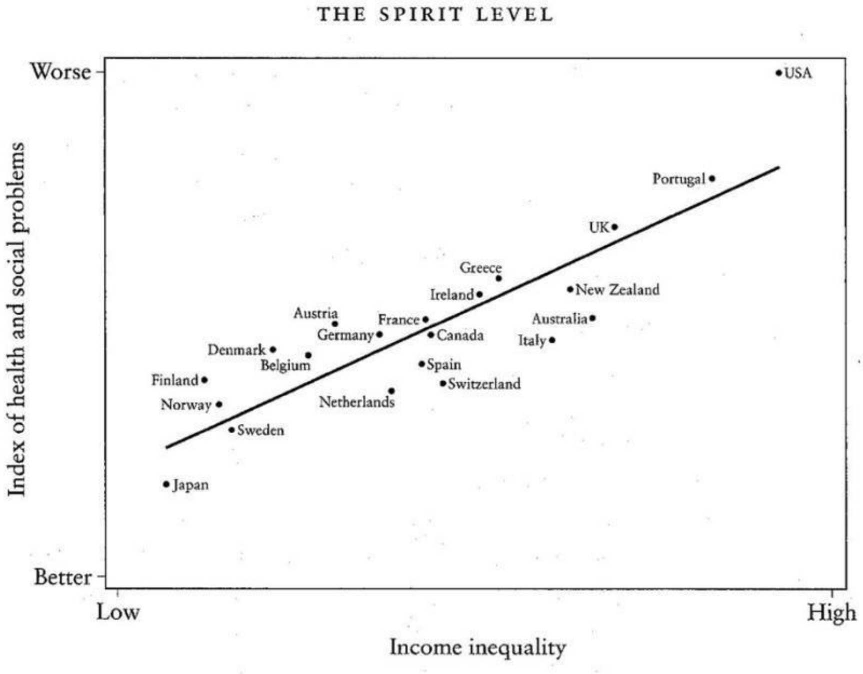

Figure 7 Inequality and social problems (Source: The Spirit Level)

Significant improvements in the levels of equality between nations will be needed to realise the full global demographic transition. In recent decades the rise in living standards has resulted in greater levels of inequality, as identified in the book by the French economist Thomas Piketty; Capital in the Twenty First Century (2013). His work shows that wealth inequality has been trending upwards in the developed world since the 1800s save for a period in the first part of the twentieth century due to wars and the depression.

The incorporation of the social subsystem in our systems conceptualisation results in the expanded causal loop diagram set out in Figure 8.

This additional structure has the following components.

Higher living standards contribute to human wellbeing, which in turn increases social quality and reduces inequality, reinforcing improvements in wellbeing (Loop R4). Improvements in equality promote the demographic transition (Loop B4), enhancing the effect of Loop B3.

However, these tendencies are offset by Loop R3. If higher living standards in the more rapidly growing developing world increase average global inequality, they will also suppress the demographic transition, which is a prerequisite for stabilising population. This results in a reinforcing loop in which living standards, inequality and population all rise together (Loop R3).

This highly simplified depiction provides the basis for understanding cause and effect in the global socio-ecological system. However, it is possible to place all 17 of the sustainable development goals within this simple picture (see Figure 8).

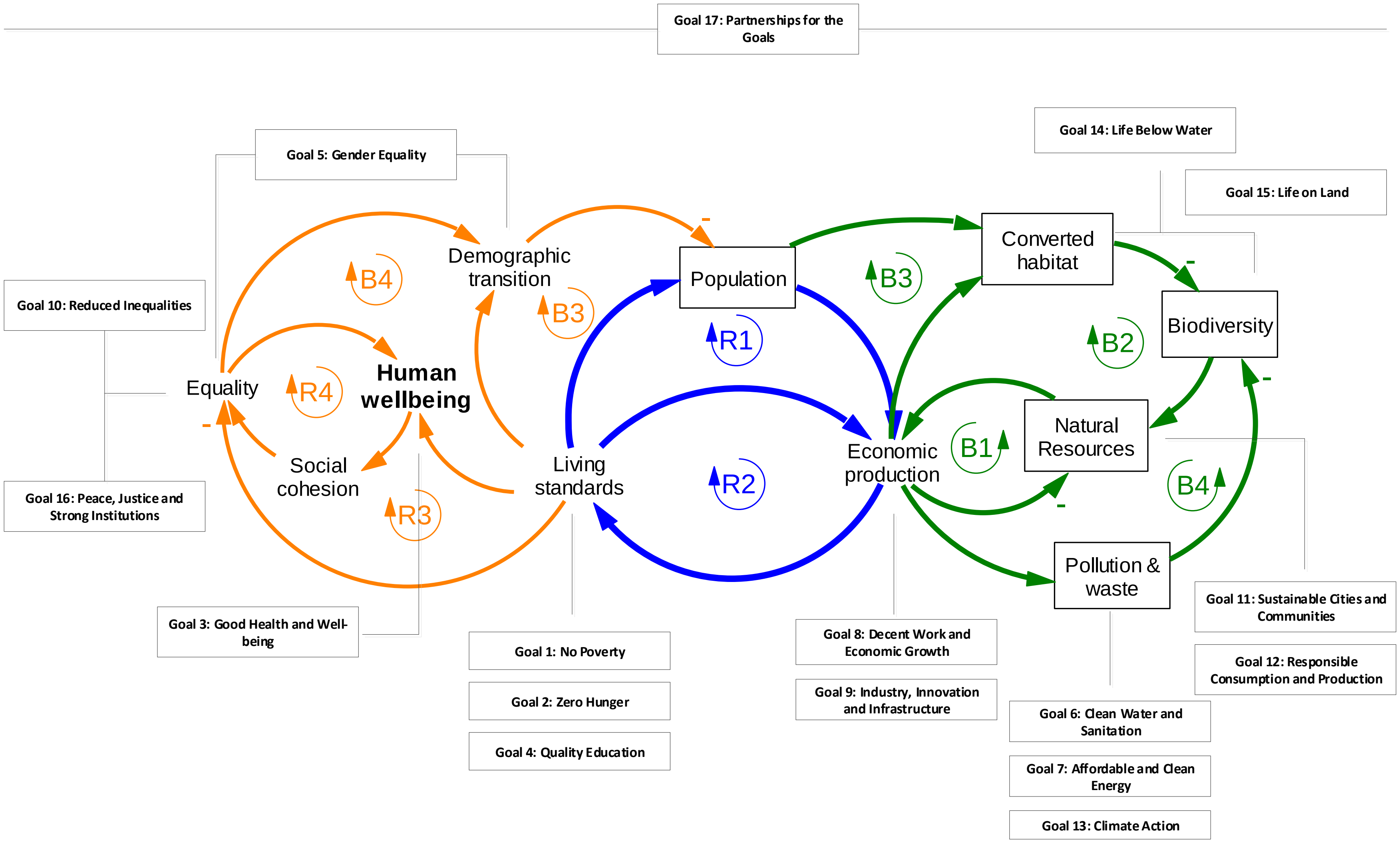

Figure 8 Causal loop diagram of the complete socio-ecological system including a depiction of the SDGs

6. CONCLUSIONS

The 1987 Brundtland Report produced a definition of sustainable development that established its central focus as the attainment and retention of a decent quality of life (meeting peoples' 'needs'). Although governments, businesses and the community have struggled with this definition, it has been helpful in many ways, as it has forced a debate about what underpins quality of life, with an increased emphasis placed on threats to ecological integrity. The SDGs have replaced this central focus of sustainability with 17 separate goals, many of which contain the word 'sustainable' as an adjective, without clarifying exactly what that term means. The opportunity to create continuity from Brundtland to the present has therefore, unfortunately been lost. More importantly, the SDGs goal domains are not presented as interconnected and interdependent dimensions of a socio-ecological system, missing the opportunity to identify how and where strategies most need to be integrated to guide policy and investment, and monitor progress.

There are two dimensions to the sustainability problem:

- the interactions between the human world and the biosphere which provides our material necessities; and
- the purely social interactions that affect human wellbeing more broadly.

In respect of the former, population must be stabilised through sufficient improvements in living standards to complete the demographic transition and reduce inequality between the developing and developed countries, while the ecological footprint must be reduced through measures to create (as closely as possible) a global circular economy during the 21st century. Pursuing human wellbeing beyond living standards requires a focus on social quality rather than economic growth, including reducing income and wealth inequality within nations.

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